NAVAL EDUCATION AND TRAINING PROFESSIONAL DEVELOPMENT AND TECHNOLOGY CENTER

NONRESIDENT
TRAINING
COURSE

July 1997

UNITED STATES NAVY

Builder Advanced

NAVEDTRA 14045

NAVAL EDUCATION AND TRAINING
PROFESSIONAL DEVELOPMENT AND TECHNOLOGY CENTER
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

07 Dec 98

ERRATA #1

Specific Instructions and Errata for Nonresident Training Course

BUILDER ADVANCED

1. No attempt has been made to issue corrections for errors in typing, punctuation, etc., that do not affect your ability to answer the question or questions.

2. To receive credit for deleted questions, show this errata to your local course administrator (ESO/scorer). The local course administrator is directed to correct the course and answer key by indicating the questions deleted.

3. <u>Assignment Booklet</u>

Delete the following questions and write "Deleted" across all four of the boxes for that question.

Question #	Question #
2-24	4-72
4-12	5-66
4-14	6-7
4-41	6-30

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

1997 Edition Prepared by
BUCS(SCW) Brice Greenfield

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Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

CONTENTS

NONRESIDENT TRAINING COURSE follows the index

SUMMARY OF
BUILDER
RATE TRAINING MANUALS

BUILDER 3&2, VOLUME 1

Builder 3&2, Volume 1, NAVEDTRA 14043, is a basic book that should be mastered by those seeking advancement to Builder Third Class and Builder Second Class. The major topics addressed in this book include construction administration and safety; drawings and specifications; woodworking tools, materials and methods of woodworking; fiber line, wire rope, and scaffolding; leveling and grading; concrete; placing concrete; masonry; and planning, estimating, and scheduling.

BUILDER 3&2, VOLUME 2

Builder 3&2, Volume 2, NAVEDTRA 14044, continues where Volume 1 ends. The topics covered include the following: floor and wall construction; roof framing; exterior and interior finishing; plastering, stuccoing, and ceramic tile; paints and preservatives; advanced base field structures; and heavy construction.

BUILDER ADVANCED

Builder Advanced, NAVEDTRA 14045, is an advanced book containing material that should be mastered by personnel in the Builder rating preparing for advancement to Builder First Class. The topics covered in this TRAMAN include the following: technical administration; planning, estimating, and scheduling; concrete construction; masonry construction; shop organization and millworking; quality control; maintenance inspections; heavy construction; and advanced base functional components field structures.

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

COMMANDING OFFICER
NETPDTC N331
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

Answer Sheets: All courses include one “scannable” answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n314.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1826
DSN: 922-1001, Ext. 1826
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE N314)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
Comm: (850) 452-1511/1181/1859
DSN: 922-1511/1181/1859
FAX: (850) 452-1370
(Do not fax answer sheets.)
Address: COMMANDING OFFICER
NETPDTC (CODE N331)
6490 SAUFLEY FIELD ROAD
PENSACOLA FL 32559-5000

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 9 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)

COURSE OBJECTIVES

In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following:

Technical Administration

Planning, Estimating, and Scheduling

Concrete Construction

Masonry Construction

Shop Organization and Millworking

Quality Control

Maintenance Inspections

Heavy Construction

Advanced Base Functional Components Field Structures

Student Comments

Course Title: *Builder Advanced*

NAVEDTRA: 14045 **Date**: ______

We need some information about you:

Rate/Rank and Name: ______ SSN: ______ Command/Unit ______

Street Address: ______ City: ______ State/FPO: ______ Zip ______

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00)

CHAPTER 1

TECHNICAL ADMINISTRATION

LEARNING OBJECTIVE: *Identify the administrative duties and responsibilities of a Builder second and first class petty officer in relation to the Personnel Readiness Capability Program, training, construction administration, safety, and environmental protection.*

This training manual will help you meet the occupational qualifications to advance to either Builder second class or first class petty officer. The Navy and the Seabees are committed to the personnel of the Navy in terms of education, training, and advancement programs. This training manual pertains to the technical subject matter of the Builder rating; therefore, we strongly recommend that you study it methodically from time to time.

When a particular task is assigned that a group, or one individual, performs, the steps in each function must be PLANNED. Individuals who perform these tasks must be properly trained, well-organized, and supervised.

As either crew/squad leaders or project supervisors, you will be responsible for planning, training, organizing, and supervising any assigned task.

Additionally, you will be responsible for various administrative duties that require PAPERWORK. These duties will include: conducting Personnel Readiness Capability Program interviews, maintaining reports, drafting rough evaluations, planning work assignments, and identifying safety and environmental hazards.

Your assigned command determines the way you are to carry out your administrative responsibilities; however, your skills in planning, organizing, applying effective supervisory techniques, and your ability to get along well with people will determine whether you obtain your goals in the Seabee community, regardless of your assignment.

Before you assign work, be sure to give careful consideration to the qualifications of your personnel. Ask yourself this question? Are they experienced, and do they have the proper training required?

Supervision will not be covered in this TRAMAN; therefore, you will need to refer to *Military Requirements for Petty Officer Second and First Class*, NAVEDTRA 12045/12046, and the *NCF/Seabee 1 & C*, NAVEDTRA 12543, for guidance.

THE PERSONNEL READINESS CAPABILITY PROGRAM

The *Personnel Readiness Capability Program* (PRCP) provides timely personnel information to all levels of management within the Naval Construction Force (NCF). This program increases the ability of management to control, to plan, and to make decisions in determining operational readiness. The program identifies the occupational skills required for determining qualified personnel in formal training and individual skills required by the Naval Facilities Engineering Command (NAVFAC P-458).

NAVFAC P-458 has been consolidated into one volume to facilitate the use by staff personnel and PRCP interviewers. The PRCP contains standard skill definitions applicable to the NCF. Standards and Guides consists of seven separate manuals (one for each Seabee rating) and is the interviewer's primary tool in collecting and updating skill data.

SKILL

A "skill" is a specific art or trade. For PRCP purposes, a skill is either "manipulative" or "knowledge."

SKILL INVENTORY

An accurate and current skill inventory is the backbone of the PRCP. Without this inventory, the reliability of any planning based on information stored in the PRCP data bank is questionable. The PRCP is the primary management tool used to determine the readiness of the unit and the skill deficiencies of its members. It is used in conjunction with the requirements established by the Commander, Second

Naval Construction Brigade (COMSECONDNCB), and Commander, Third Naval Construction Brigade (COMTHIRDNCB), which are issued in their joint instruction COMSECOND/COMTHIRDNCBINST 1500.1 (series). This instruction identifies and defines the skills required for peacetime and contingency operations to be met and it specifies the required number of personnel to be trained in each skill. These skills are classified into the following five major categories:

1. Individual general skills (PRCP 040 - 090). These are essentially knowledge skills related to two or more ratings, such as material liaison office operation (PRCP 040), instructing (PRCP 080), and safety (PRCP 090).

2. Individual rating skills (PRCP 100 - 760). These are primarily manipulative skills associated with one of the seven Occupational Field 13 (Construction) ratings. Some examples are light-frame construction (PRCP 150), for the Builder; cable splicing (PRCP 237), for the Construction Electrician; and shore-based boiler operation (PRCP 720), for the Utilitiesman.

3. Individual special skills (PRCP 800 - 830). These are technical skills performed by personnel in several ratings, including people that are not in Occupational Field 13; for example, forklift operation (PRCP 800), ham radio operation (PRCP 840), and typing (PRCP 803).

4. Military skills (PRCP 901 - 981). These skills are further classified into the following three subcategories: mobilization, disaster recovery, and Seabee combat readiness. Examples are aircraft embarkation (PRCP 902), M-16 rifle use and familiarization (PRCP 953), disaster recovery, and heavy rescue (PRCP 979).

5. Crew experience skills (PRCP 1000A - 1010A). These skills are obtained through on-the-job training (OJT). Most projects are related to advanced base construction, such as observation tower (PRCP 1002A), fire fighting (PRCP 1009A), and bunker construction (PRCP 1008A).

A skill inventory has three principal steps. First, each skill is closely defined and divided into task elements. Second, a standard procedure for obtaining the information is developed. This procedure helps make sure the information is collected and that it meets with certain standards of acceptability. The third step is the actual collection of the skill data and it includes the procedures for submitting the data to the data bank.

PRCP STANDARDS AND GUIDES

Skill definitions alone contain insufficient information to classify people accurately, and they do not provide any cl ossification procedures. Therefore, in recognizing this fact, the Civil Engineer Support Office (CESO) conducted special Seabee workshops. As a result, the PRCP, NAVFAC P-458, *Standards and Guides,* was developed under the guidance of CESO. The interviewing procedures as set forth in the PRCP Standards and Guides allow the trained interviewer to classify people to a predetermined skill level with an acceptable degree of uniformity. With your knowledge of the tasks required, you are authorized to classify others to an appropriate skill level by observing their performance, either in training or on the job.

Skill information obtained by interview or observation is recorded on the individual's skill update record. This form is then generated by each command and may vary in format. The skill information is then forwarded to the S-7 department. This is recorded on the Seabee Automated Mobile Management System (SAMMS) and then forwarded to the appropriate Naval Construction Regiment (NCR). The information is reviewed, the skill deficiencies are determined, and training requirements are established to maintain the readiness of the unit. Complete instructions and information for the use of the PRCP skill update record and other PRCP data processing information can be obtained from the training officer (S-7), or NAVFAC P-458, *Standards and Guides for Builder,* volume 1, and COMSECONDNCB/COMTHIRDNCBINST 1500.1 (series).

As a crew leader, you are directly responsible for using the PRCP Standards and Guides to assist a designated interviewer in maintaining an accurate skill profile on your personnel. You are also responsible for providing the initial information for the PRCP data bank. Any subsequent updating of this initial information for each person is based on their performance while on the job (which you observe), completed training, and regular interviews. Newly reported personnel, regardless of previous assignment, require an interview within 30 days from reporting onboard an NCF unit.

PRCP INTERVIEWS

Two types of PRCP interviews are in use today. The first and most important is the individual rating skill interviews. The second type is simply called other interviews. Both require the use of the PRCP Standards and Guides.

Individual Rating Skill Interviews

When conducting an individual rating skill interview, the interviewer uses a discussion technique to classify Seabees in the skill levels of the various individual rating skills. This technique requires the interviewer to have a thorough understanding of the skills and tasks defined in the PRCP Standards and Guides. Few interviewers have the talent required to interview in all the skills of a rating. So interviewers must be mature enough to recognize their own limitations and then be willing to seek assistance from other qualified individuals as necessary. For example, an interviewer could use the masonry crew supervisor to assist in interviewing personnel for masonry skills.

Other Interviews

Other interviews are used to classify people into the areas of individual, general, and special skills, military skills, and crew experience. With few exceptions, these skills do not require an experienced interviewer. In many cases, skill levels can be assigned to individuals on the basis of their service or training record; this includes completed training evolutions, such as contingency construction crew training or block military training. To cut down on interviewing time, make use of skill level classification whenever possible. So when a person is scheduled for interviewing, it will be just a matter of verification or updating.

Interviewing Steps

When you interview put the interviewee at ease. A good way for you to do this is to explain the purpose of the interview. For example, explain to the interviewee that the interview will cover the following:

- What he or she is expected to know and to do.
- Determining what he or she can do so that the right job can be assigned.
- What his or her skill deficiencies are so that he or she can receive proper training.

Next, explain to the interviewee that he or she should discuss the knowledge of the skill honestly. There should be no embarrassment if an individual does not know every item covered in the guides. Then tell each interviewee what skills and the skill levels for which he or she is being interviewed. Last, read the skill definition aloud to see if the person is knowledgeable of the subject.

STANDARDS AND GUIDES FOR INDIVIDUAL RATING SKILLS

When assigned as an interviewer, you must obtain, read, understand, and use the PRCP Standards and Guides. The format is standard. After the skill title, you will find the contents, the skill definitions, and the tasks, which are divided into task elements.

Skill Title and Contents

The title identifies the skill; for example, figure 1-1 identifies the individual Builder skill No.#132, Mixing, Placing, and Finishing Concrete.

The number 132 is a numerical code for this skill. You should use the contents to make sure there are no missing pages. You must interview each candidate to see if he or she is qualified for that skill level.

Skill Definitions

The skill definitions in the PRCP Standards and Guides introduces the skill material to the interviewees. Figure 1-1 also shows an individual rating skill definition. The definition shown is for the Builder and is a statement of tasks to be performed at each skill level.

There will be either 1, 2, or 3 skill levels, depending upon the complexity and the number of tasks. Each level within a given skill is more difficult than the previous one and requires a broader knowledge in both application and theory. For example, a person having skill level 1 in Planning, Estimating, and Scheduling would perform a skill, such as determine crew size and manpower requirements. Whereas, for skill levels 2 and 3, a person would demonstrate a skill, such as developing Level IIs, a knowledge factor of a specific area and hold the Navy Enlisted Classification (NEC 5915) for skill level 2.

Task and Task Elements

A task is a specific portion of the overall skill level. For an example, refer to figure 1-2. Some tasks cover broad areas. Others may be quite specific and brief. Each task is further divided into several smaller jobs called task elements.

A task element is a basic part of each task. When interviewing, you should use the Action Statements and their related Task Elements to determine the interviewee’s qualifications. Action statements tell you the type of information you should obtain from the person being interviewed. Each action statement is

132 - Mixing, Placing, and Finishing Concrete

CONTENTS

132	**Skill Definition**
.1	Skill Level 1
	.01 Mix Concrete
	.02 Place and finish concrete
	.03 Maintain tools and equipment
.2	Skill Level 2
	.01 Operate concrete machines
	.02 Perform operator’s maintenance on concrete machines
	.03 Determine proportion of materials of standard mix by rule of thumb
.3	Skill Level 3
	.01 Operate and maintain pumping machines.

SKILL DEFINITIONS

Skill Level 1:	Individual must use and explain common concrete construction terms; use and care of tools, equipment, and materials (including those from the Mason Tool Kit) used to mix, place, compact, screed, float, trowel, and tool concrete by hand; use and care for mechanical vibrators; and grind, point, and “ sack rub” concrete surfaces.
Skill Level 2:	Skill Level 1, plus operate and perform operator’s maintenance on typical portable concrete mixers, hand-held finishing machines, and concrete saws; and designate standard mix and determine proportion of materials by “rule of thumb.”
Skill Level 3:	Individual must operate and perform operator’s maintenance before, during, and after operation on pneumatic, or piston-type concrete pump; remove, connect and disconnect tube/hoseline from pump’s manifold or nozzle; check and adjust pressure on hydraulic system; control and regulate flow of concrete; clear and clean out clogs; maintain concrete pumps (pneumatic, squeeze-crete or piston type) and associated accessories.

Figure 1-1.—Title and content of the PRCP Standards and Guides.

is identified in the guides by a capital letter **(A, B, C,** etc.). Capital letters are listed near the top, and how many are used varies from task to task. The first action statement in figure 1-2 is “Describe the sequence of steps of this procedure and explain the reasons for each.” A matrix is used to show how the statements relate to the task elements.

To become familiar with the matrix, refer to task element 132.1.02, “Methods of finishing concrete.” Under the task element subparagraph b, you find “troweling.” When you follow this line and look to the right of this statement at the matrix, you will see Xs under letters **A, B, C, D, E, F, G,** and **H.** This indicates which action statements apply to this task element.

Use a positive approach when you interview. The interviewee either “knows” or “doesn’t know” the skill and the interviewer must make this determination.

Task Interviews

You are to begin the interview by reading the task aloud. This directs the interviewee’s concentration to the right area. Then rephrase the task in your own words. For example, you could rephrase it as follows:

> “Describe the sequence of steps in ’troweling’ a concrete slab to a smooth finish, and explain the reasons for troweling. ”

132.1.02 TASK: Place and finish concrete.

Apply these ACTION STATEMENTS to the TASK ELEMENTS listed below:

A. Describe the sequence of steps of this procedure and explain the reasons for each.

B. List significant tools/equipment/machines used in this procedure.

C. Discuss the control/coordination required while performing this procedure.

D. Describe indications that would be observed during this procedure (lights, breakers, valves, meters, gauges, noise, vibrations, smoke, etc.)

E. Describe assistance required while performing this procedure.

F. Explain results if this procedure is not performed properly or if it is neglected.

G. Perform the steps of this procedure when practical.

H. Discuss safety precautions.

TASK ELEMENTS:	A	B	C	D	E	F	G	H
.01 Methods of placing concrete.	X		X					X
a. Bucket		X			X			
b. Hand tooling		X						
c. Pump		X		X	X			
d. Chute		X			X			
e. Vibrator compacting		X			X	X	X	
.02 Methods of finishing concrete.						X		X
a. Screed	X	X			X		X	
b. Troweling	X	X			X		X	
c. Floating	X	X			X		X	
d. Grinding	X	X					X	
e. Pointing	X	X					X	
f. Sack rub	X	X					X	

Figure 1-2.—Typical task analysis with task elements and related action statements.

This rephrased sentence is not a question. It is a statement that directs the interviewee to tell you what he or she knows about performing the steps required and the reasons for performing them. There are no questions in the PRCP Standards and Guides; therefore, no answers are provided. The guides point out the areas to be discussed (in terms of Action Statements and Task Elements). Then you, the interviewer, evaluate the interviewee's responses based on your knowledge and judgment.

The only way you can determine whether the interviewee knows the task element is to make sure you have full knowledge of the task yourself. If you are unfamiliar with or "rusty" in any tasks in the guides, you must study these areas thoroughly before attempting to interview anyone. Also, if you do not understand how a particular action statement is used with a task element, you must resolve this before interviewing. One way of doing this is for you to discuss the problem with others who are familiar with the skill.

You should know the task element ONLY with the applicable action statements indicated in the columns to their right by an X in the matrix. For example, in figure 1-2, only action statements B and E are used with task element .01a. In task element .02a of the same figure, only action statements A, B, E, and G are applied. As an expert in the skill, you may want to ask questions about tasks that are not covered by the guides; however, you must avoid doing this, as you would have no applicable standard against which to gauge the interviewees' responses. When you feel strongly that the guides can be improved, discuss your recommendations with the PRCP coordinator.

Scoring Interviews

When interviewees have a Navy Enlisted Classification (NEC) in the skill for which they are interviewed, they are automatically assigned to that skill level. There is no need for further interview for lower levels. All tasks must be accomplished for each skill level. Then results of the interview are introduced into the PRCP system.

TRAINING

There is no "best" training method that applies to every situation. According to the *Naval Construction Force (NCF)* Manual, NAVFAC P-315, each training program is formulated to provide personnel with the skills needed to accomplish current missions in the NCF. The *Organization and Function fir Public Works Departments*, NAVFAC P-318, does not cover training. The majority of their work is through OJT.

Any training program is developed according to the pattern, priorities, and tempo established by the commanding officer. It covers many phases from orientation courses to special technical courses.

The success of any training program depends upon operational commitments, policies, and directives from higher authorities. The experience, the previous training of assigned personnel, and the availability of training facilities will also affect the success of the training program.

TRAINING ORGANIZATION

Navy regulations state that in Naval Mobile Construction Battalions (NMCBs), the executive officer (XO) supervises and coordinates the work, exercises, training, and the education of personnel in the command. The XO supervises the training of officers, coordinates the planning and execution of training programs, and when necessary, acts to correct deficiencies. The executive officer's main assistant is the plans/training officer (S-7). However, Public Works and associated non-NCF units do not have training departments and must rely heavily on OJT and general military training (GMT).

Company commanders are directly responsible for training their company personnel and for meeting the training goals established by the commanding officer. The company commanders help formulate training programs, supervise the training of subordinate officers, and direct the technical military and general training of their companies. Company commanders also designate their own training petty officer to assist in coordinating training among company personnel and the S-7 department.

Platoon commanders monitor the training progress of personnel in their platoons. They directly supervise on-the-job training and some military training. All petty officers are responsible for training their personnel by means of lectures, discussions, project work, and so on.

The plans/training officer (S-7), normally a lieutenant, is assisted by a permanently assigned staff consisting of one chief petty officer and two to four petty officers. This group is concerned with the formulation and administration of both the formal military training program and the formal technical training program. These programs include formal schools, SCBT, advanced base construction, and disaster recovery training. Individual class assignments are administered within each company and must correspond to the guidelines established by the S-7 department.

Figure 1-3 shows a typical battalion training organizational chart.

TRAINING GUIDELINES

In general, make sure training is consistent with the following guidelines:

1. Closely integrate and coordinate training with the daily operations of the unit's mission. The adopted plan and organization for training must not interfere with essential construction functions.

2. Notwithstanding the guideline just listed, keep the construction schedule flexible to make use of opportunities for training that might even expedite the construction schedule.

3. Take maximum advantage to train everyone for the opportunities that exist, because those who simply "muster and make it" deprive themselves of becoming

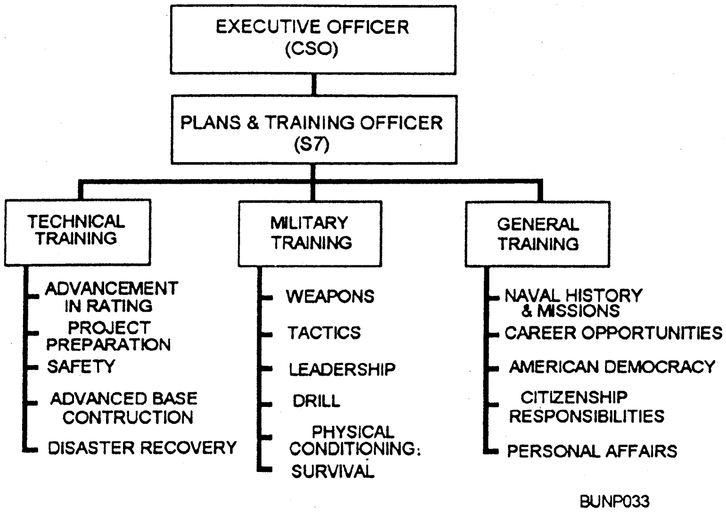


Figure 1-3.—NMCB training organizational chart.

well-trained Seabees and Builders, and makes advancement difficult to achieve.

TRAINING NEEDS

Training for advancement is an ongoing concern for all personnel at all levels. The Navy benefits by your advancing in rate. Highly trained personnel are essential to the Navy's mission. By each advancement, you become more valuable as a technical specialist and as a person who can supervise, plan, lead, and train others.

As the Navy implements training programs, so does the NCF. Training our Seabees in battalion during home-port periods becomes the primary mission. They expect to spend about 75 percent of the available man-days in formalized technical, military, and general training classes. In addition, the planning and estimating teams that plan deployment projects may be considered to be involved with OJT.

Approximately 2 months before an NMCB returns from deployment, a training team is sent back to its home-port regiment for a training conference to prepare the training schedule for the home-port stay of the battalion. This team schedules the training required for the battalion to meet its operational readiness and construction tasking for its next deployment. The team also coordinates home-port support for berthing, supplies, recreation, and billets for training support (FSB/PRE). All personnel are trained in the areas of technical, military, and general topics.

However, programs may be tailored to meet the specialized mission of the battalion's next deployment. If one of the projects scheduled is the repair of an airstrip, undoubtedly there will be a great deal of training in regard to rapid runway repair (RRR). This is when the Naval Construction Regiments (NCRs) play a vital role in training. You will need to know how many qualified personnel are available and whether you need to train more to repair the airstrip. Take advantage of any opportunities to train as many of your personnel as possible. "Muster and make-it" is NOT a training evolution.

As supervisor, you may check a member's service records, conduct PRCP interviews, and select those best suited for training given at a Navy C-1 advanced school or at a special construction battalion training course (SCBT).

ON-THE-JOB TRAINING

On-the-job training (OJT) plays a major role in the development of our Seabees. As a crew leader or project supervisor, make sure your troops are being properly trained. Remember how and when you were trained. For example, one person helps another learn the trade and that person's experience is passed on to others. That is OJT.

OJT happens around us all the time. There are as many examples of OJT as there are contacts between personnel in the Seabees. In a Seabee organization, OJT is important because of the continuous changes in equipment and personnel. It also provides continuous opportunities for new and better methods of doing construction work.

In the Seabee community, as well as in private industry, the term *on-the-job training* means helping an individual acquire the necessary knowledge, skill, and habits to perform a specific job. This definition implies that job training applies not only to the Construction man or to new personnel in an organization but also to any other person assigned to a new job. Furthermore, OJT is a continual process among Seabees. No one is completely trained; we are constantly learning new techniques (tricks of the trade) every time we work on a project.

However, remember that OJT is an active process, and it requires supervisors to be aware of the needs of the trainees and to motivate them to learn.

Use methods that add meaningful experiences to the trainee's storehouse of knowledge, listen to suggestions, and give precise direction. Then you, as a crew leader and project supervisor, will gain proficiency.

A supervisor who does a good job of training personnel benefits in many ways. For one thing, well-trained crew members brag about their supervisor, especially to their buddies in other crews. When you have a valuable skill, knowledge, or attitude and impart either of the same to ten others, you have multiplied your effectiveness considerably.

Training Methods

When conducting OJT, you must tailor the training methods around the nature of the subject, the time available, and the capabilities of the trainee.

No other method of training is as effective, as intelligent, or as interesting as coach-pupil instruction. In addition to being a quick way of fitting anew worker into the operation of a unit, it serves as one of the best methods of training, because without specific directions and guidance, a worker is likely to waste time and material and form bad work habits.

Many industries have apprenticeship programs designed to train workers in a trade or skill. Most apprentice training consists of both coach-pupil instruction with skilled worker supervision and periodic group instruction.

Self-study is important for the OJT trainee and you are to encourage the practice of it. Skilled and semiskilled jobs require a considerable amount of job knowledge and judgment ability. Even in simple jobs, there is much basic information a worker must learn. However, the more complicated technical jobs involve highly specialized technical knowledge and related skills that must be taught.

Group instruction is a practical adjunct to direct supervision and self-study. It is a time-saver when several workers need the same job-related knowledge or procedures. The supervisor or trainer can check training progress and clarify matters the trainees find difficult to understand. Group instruction, when intelligently used, speeds up production. For example, suppose you have six trainees learning the same job. Four of the trainees are having trouble with a certain job element, while the other two have learned it. The four people having trouble can be brought over to the other two, and in a short time, the difficulty will most likely be solved. In OJT, this is called group instruction. As you can see, group instruction is not the same as classroom or academic instruction.

Another type of OJT is piecemeal instruction. For instance, a crew member asks you for information and you supply it. That is piecemeal instruction. A supervisor's orders are, in a sense, a piecemeal method of instruction because they should let others know what, when, where, how, and why. Other examples of piecemeal instruction are explaining regulations, procedures, and orders; holding special meetings; indoctrinating a new person; and conducting organized meetings.

Trainee Development

In any type of effective training in which one individual is working directly under the supervision of another, the trainers and trainees must understand the objectives of the training. Factors, deserving your careful consideration as a supervisor, include determining the trainees training needs, defining the purpose of training, and explaining or discussing job training concerns with the trainees.

In determining training needs, it is often a good idea for you to interview the trainees. Through proper questioning you can get a summary of their previously acquired skills and knowledge related to the job. You should compare jobs the trainees know how to do with those they will be doing. Then determine the training needs (required knowledge and skills minus the knowledge and skills the trainees already possess). Training needs should be determined for each job pertaining to the trainee's position assignment. Next, analyze the job to be done and have all the necessary equipment and materials available before each job training situation.

When you define the purpose of training, clearly explain the purpose of the job, the duty, or the task to be performed by the trainees. Then point out to the trainees their place on the team and explain to them their role in accomplishing the mission of the unit. Stress the advantages of their doing the job well, and how the training benefits them, their organization, and the Seabees.

The trainers should also explain facts about the job to be done, principles that are proven and workable, and directions on ways to do the job safely, easily, and economically. Explain also, any technical terms or techniques that will improve the skills of the trainees. Furthermore, stress the importance of teamwork and attention to detail in each operation of a job.

The trainers and trainees are to discuss the problems that arise in doing a job, and try to clear up any questions the trainees may have concerning the job. Trainers are to point out to the trainees the similarities of different jobs. Furthermore, trainers are to cover the relationship of procedures in a particular job to things with which the trainees are already familiar. This way the trainees learn through association with past experiences. Also important, trainers are to discuss the progress of the trainees.

The most valuable end product of a peacetime military operation is well-trained personnel. Regardless of the unit's mission, you must have trained personnel to carry it out. All petty officers in the Navy are responsible for training the personnel under their immediate supervision. Do NOT take this responsibility lightly.

SYSTEMATIC TRAINING

Effective training requires a great deal of planning and directed effort. To prevent a haphazard approach to the job of training, you must organize materials into logical sequence and use an accurate method to measure the results. When any learning takes place, there will be results. When no learning takes place, you have not trained. The following four steps are provided to help you plan and carry out your training programs:

- Encourage learning by using the correct training methods.
- Measure achievement at regular intervals to assure that learning is taking place.
- Record results to document progress and to improve your training system.
- Reward or recognize those who perform.

Evaluation

Evaluations are worthwhile tools. Both you and the trainee will want an evaluation of the work accomplished. Generally, the most valid trainer evaluations are obtained by testing the trainees. When they have learned to perform in a highly satisfactory manner, this is the best indication that training has occurred. Personnel must be trained correctly. Improper training, in many cases, is worse than no training at all.

Performance Testing

Performance testing enables you to do a better job of conducting an OJT program. Use performance tests to find how well your trainees are doing their jobs. However, it is difficult to find a test that truly assists you in evaluating performance.

Performance tests should enable you to rate the work of subordinates accurately enough to carry out the following objectives:

- To help you determine the qualifications of personnel
- To aid you in rating the improvement of persons
- To help you determine whether trainees can actually perform
- To assist you in assigning new people to particular jobs
- To help you locate trainees strengths and weaknesses

Since it is a practical check on a work project, a performance test must be conducted in a sample work situation in which the trainee performs some active task that can be examined. The testis not designed to measure what a person knows about the job (a written or oral test may fill that need for you). Instead, it is intended to help you rate that person's ability to actually do the job. Do your best in organizing and administering the performance test. There will always be room for improvement in most of the testing that you do.

CONSTRUCTION ADMINISTRATION

Proper administration and planning are the backbone of any project (large or small), and they are just as important as constructing the project.

You will have personnel assigned to you whom you must employ effectively and safely. Your supervisor expects you not only to meet production requirements and to conduct training but you must also learn the process of "paperwork." Be patient. If you plan well, you will succeed. The following section contains information to assist you in planning, organizing, and coordinating work assignments. You must master these skills to meet the production schedule.

PLANNING WORK ASSIGNMENTS

Planning is the process of determining the requirements and developing the methods and schemes of action for performing a task. Proper planning saves time and money and ensures that the project is completed in a professional manner. Remember, "proper planning prevents poor performance." When planning various assignments, you must consider many factors. The following paragraphs highlight some, but not all of the factors you should consider during this planning stage.

When you are assigned a project, whether in writing or orally, one of the first things for you to do is to make sure you clearly understand just what is to be done. Study the plans and specifications carefully. When you have questions, seek and find the answers from those in a position to supply the information you need. Also, make sure you understand the priority of the project, the expected time of completion, and any special instructions to be followed.

In planning for a small or large project, you must consider the capabilities of your crew. Determine who is to do what and how long it should take to complete the assignment. Also, consider the tools and equipment you will need and arrange to have them available at the jobsite when the work is to get under way. Determine who will use the tools, and make sure the crew members to whom they are assigned know how to use them properly and safely.

To be certain a project is done properly and on time, consider the way it is to be accomplished. When there is more than one way of doing a particular task, analyze the methods and select the one most suited to the job conditions. Listen to suggestions from others. If you can simplify a method and save time and effort, by all means do it.

As a crew leader, your goal is to get others to work together to complete their assignments. Always maintain an approachable attitude toward your crew, so each crew member feels free to seek your advice when in doubt about any phase of the work. Emotional balance is especially important; you must neither panic before your crew, nor be unsure of yourself in the face of conflict.

Be tactful and courteous in dealing with your crew. Never show partiality to certain members. Keep your crew members informed on matters that affect them personally or concern their work. Also, seek to maintain a high level of morale because low morale will have a definite negative effect upon the quantity and quality of their work.

Establish goals for each workday and encourage your crew members to work together as a team to accomplish them. You should set goals to keep your crew busy, but make sure they are realistic. Discuss the project with your crew members so they know what you expect from them. During an emergency, most crew members will make an all-out effort to meet the deadline. However, people are not machines, and when there is no emergency, do not expect them to work continuously at an excessively high rate. The importance of teamwork cannot be overemphasized, and neither can the importance of daily crew briefings. Daily crew briefings provide for a vital communication link to the quality completion of the project. You do not want to keep any member of the crew "in the dark."

As the petty officer in charge of a crew, you are responsible for time management of the crew member and for yourself. You must plan constructive work for your crew. Always remember to PLAN AHEAD! A sure sign of poor planning is when crew members stand idle each morning while you plan the events of the day. At the close of each day, confirm plans for the next workday. In doing so, you may need answers on the availability and the use of manpower, equipment, and supplies. Keep the following questions in mind:

1. Manpower. Who is to do what? How is it to be done? When is it to be finished? Sins idleness may breed discontent, have you arranged for another job to start as soon as the first one is finished? Is every crew member being fully employed?

2. Equipment. Are all necessary tools and equipment on hand to do the job? Is safety equipment on hand?

3. Supplies. Are all necessary supplies on hand to start the job? If not, who should take action? What supply delivery schedules must you work around?

You must set a definite work schedule and inspection plan, and set up daily goals or quotas. Plan "personal inspection to check at intervals the work being done and the progress toward meeting the goals. This will involve a spot check for accuracy, for workmanship, and the need for training.

Organization

As a crew leader, you must ORGANIZE. This means that you analyze the requirements of a job and structure the sequence of events that will bring about the desired results.

Develop the ability to look at a job and estimate how many man-hours are required for completion. You will probably be given a completion deadline along with the job requirements. Next (or perhaps even before making your estimate of man-hours), plan the job sequences. Make sure you know the answers to the following questions. What is the size of the job? Are the materials on hand? What tools are available, and what is their condition? Is anyone scheduled for leave? Will you need to request outside support? After getting answers to these questions, you should be able to assign your crews and set up tentative schedules. When work shifts are necessary, arrange for the smooth transition from one shift to another with a minimum of work interruption. How well you do so is directly related to your ability to organize.

Delegation

In addition to organizing, you must DELEGATE. This is one of the most important attributes of a good supervisor. The failure to delegate is a common weakness of a new supervisor. It is natural for you to want to carry out the details of a job yourself, particularly when you know that you can do it better than any of your subordinates. When you try to do too much, you can quickly get bogged down in details and slow down a large operation. On some projects, you may have crews working in several different places. Obviously, you cannot be in two places at once. There will be many occasions when a Builder needs assistance or instruction on some problem that arises. When your personnel have to wait until you are available, then valuable time may be lost. So, it is important that you delegate authority to one or more of your crew members to make decisions in certain matters. Remember that although you delegate authority, you are still responsible for the job.

Coordination

As a crew leader, you must COORDINATE. When several jobs are in progress, you are to coordinate the completion times so one follows another without delay. Your coordinating skills also play a very helpful role when you work closely with other companies. Coordination is not limited to projects only. You would not want to approve a leave chit for a crew member only to find that person is scheduled for school during the same time. For example, you would not schedule a crew member for the rifle range only to find the range coach unavailable at that time.

Production

The primary responsibility of every crew leader is PRODUCTION. You and your crew will be at your best by practicing the following guidelines:

- Planning, organizing, and coordinating the work to get maximum production with minimum effort and confusion.
- Delegating as much authority as possible but remaining responsible for the final product.
- Continuously supervising and controlling to make sure the work is done properly.
- Be patient. "Seabees are flexible and resourceful."

Safety, Health, and Physical Welfare of Subordinates

Safety and production go hand in hand since the only efficient way to do anything is the safe way. Production is sure to fall when your personnel are absent because of injury, your shop equipment is down because of damage, or completed work is destroyed by accident. Therefore, you must teach and stress safety constantly, and set examples by always observing safety precautions yourself. Teach safety as part of each training unit, and plan each job with safety in mind. Safety will be covered later in this chapter.

Daily Work Assignments

The assignment of work is an important matter. On a rush job, you may have to assign the best qualified person available to meet the deadlines. When time and work load permit, rotate work assignments, so each person has an opportunity to acquire skills and experiences in the different phases of their rating. When assignments are rotated, the work becomes more interesting for the crew. Another good reason to rotate work assignments is to prevent a situation in which only one person is capable of doing a certain type of work. This specialization could be a severe disadvantage if that person were to be transferred, hospitalized, or to goon leave for a lengthy period of time.

Give special consideration to work assignments for strikers. They should be assigned to jobs of gradually increased levels of difficulty. Strikers may be useful assistants on a complicated job, but they may not fully understand the different phases of the job unless they have worked their way up from basic tasks.

In assigning work, be sure to give the worker as much information as necessary to do the job properly. An experienced worker may need only a general statement concerning the finished product. A less experienced worker is likely to require more instruction concerning the layout of the job and the procedures to be followed.

Often, you may want to put more workers on a job than it really requires. Normally, the more workers you use, the less time it will take to get the job done. Remember, there is a limit to the number of workers that can successfully work on one job at any given time. You should not overlook the advantages of assigning more crews or crew members to a project when their services are needed or when presented an opportunity to learn a unique phase of the rating. Teamwork, versatility, and new skills can be learned from a variety of work assignments.

TIMEKEEPING

In battalions, and at shore-based activities, your duties will involve the posting of working hours on time cards for military personnel. Therefore, you should know the type of information required on time cards and understand the importance of accuracy in labor reporting. You will find that the labor reporting system used primarily in Naval Mobile Construction Battalions (NMCBs) and the system used at shore-based activities are similar.

A labor accounting system is mandatory for you to record and measure the number of man-hours expended that a unit spends on various functions. In this system, labor usage data is collected daily in sufficient detail and in a way that enables the operations department to compile the data readily. This helps the operations officer manage manpower resources and prepare reports for higher authority.

Although labor accounting systems may vary slightly from one command to another, the system described here can be tailored to record labor at any command.

Any unit must account for all labor used to carry out its assignment, so management can figure the amount of labor used on the project. Labor costs are figured and actual man-hours are compared with previous estimates based on jobs of a similar nature. When completed, this information is used by unit managers and higher commands to develop planning standards.

The labor accounting system covered in this section is based upon the procedures and guidelines established by both Naval Construction Brigades (NCBs) for NMCB use.

TIME CARDS

Time cards are the basis of your situation reports (SITREPs) input; therefore, it is imperative that time cards are filled out correctly and accurately. COMSECONDNCB/COMTHIRDNCBINST 5312.1 is the instruction that governs time-keeping procedures. Figure 1-4 is an example of a time card used for the prime or lead company for keeping labor. Subcontractors also use a similar type form for accounting their time on a project. A sample of these time cards can be located and copied from the Naval Construction Force Crew Leader's Handbook.

LABOR CATEGORIES

All man-hours will be recorded under a specfic code in one of <u>three</u> labor categories. There will be no time-keeping requirements for Headquarters companies and Details (DFTs) which perform administration type functions. The categories are listed below:

- Direct Labor
- Indirect Labor
- Readiness and Training

Labor Codes

DIRECT LABOR includes all man-days expended (ME) directly on assigned construction tasks, either in the field or in the shop, which contributes to completing the project. <u>Remember, man-days are computed on the basis of an eight hour day, regardless of the length of the scheduled workday.</u>

BUNP034

PRIME TIME CARD

Crewleader	**Signature**	**Company**	**Crew Size**	**Transfers This Date**
Project Number	**Project Title**			**Date**

	Direct Labor by Construction Activity Number									**Indirect**					**Readiness and Training**				
Crew Member's Rate/Name									**Total**					**Total**					**Total**
Totals																			

Figure 1-4.—Prime Time Card.

All tasked projects are normally assigned a project number and labor expended on a specific project will be reported under that project's number (fig.1-5). Included under direct labor, besides construction, are such tasks as:

- Project and site surveying.
- Shop work that contributes directly to the completion of the project,
- Camp Maintenance when accomplished as part of the battalion direct labor tasking such as Emergency Service Requests (ESRs), Standing Job Orders, and Specific Job Orders.
- Mineral products operations for either a tasked project or as a specific or as a specific tasked project.
- Construction equipment operation when assigned to a tasked project.

INDIRECT LABOR includes all labor required to support construction operations but does not usually produce an end product itself. Therefore, this time is not reported under a project number but under an indirect labor code, as shown in figure 1-5.

READINESS and TRAINING comprises all manpower expended in actual military operations, unit embarkation, and planning and preparations necessary to ensure the military and mobile readiness of the unit. Also includes attendance at service schools, factory and industrial courses, fleet-level training, military training, and organized training conducted within the battalion or unit. Report or record these man-hours under a specific name such as MIL/OPS, Embark, or GMT.

Your report will be submitted on a typical daily time card form, like the one shown in the Naval Construction Force Crew Leader's Handbook (NCF/CLH). The form provides a breakdown by man-hours of the activities in the various labor codes for each crew member for each day on any given project. This form is reviewed at the company level by the staff and platoon commander, and then it is initialed by the company commander before it is forwarded to the operations department. It is tabulated by the management division of the operations department, along with all of the daily labor distribution reports received from each company and department in the unit.

The crew leader will prepare a daily account of all man-hours expended on a time card form, like the one shown in figure 1-4. The time cards can be submitted daily to the project manager or can be kept until the "two week" labor summuary report is due. Once you complete this two week report, this will help you in preparing your SITREPs. This report is the means by which the operations office analyzes the labor distribution of total manpower resources for each day. It also serves as feeder information for preparation of the monthly OPS/SITREP reports and any other source reports required of the unit. This information must be accurate and timely. Each level in the company organization should review the report for an analysis of its own internal construction management and performance.

SAFETY PROGRAM

As an individual and a petty officer, you must be familiar with the safety program at your activity. You cannot function effectively as a petty officer unless you are aware of how safety fits into this program. You should know who (or what group) arbitrates and establishes the safety policies and procedures you must follow. You should also know who provides

INDIRECT LABOR. This category includes all labor required to support construction operations, but which does not produce an end product itself. Indirect labor reporting codes areas follows:

X0l	Construction Equipment Repair, and Records
X02	Project and Camp Maintenance Support
X03	Project Management
X04	Location Moving
X05	Project Travel
X06	Material Support
X07	Tools
X08	Administration and Personnel
X09	Lost Time
X010	Other

Figure 1-5.—Labor Codes.

guidelines for safety training and supervision. All NCF units and shore commands are required to implement a formal safety organization.

As a Seabee EVERYONE is responsible for safety. According to the NCF *Safety Manual,* COMSECONDNCB/COMTHIRDNCBINST 5100.1 (series), the battalion safety office administers the battalion safety program and provides technical guidance. Overall guidance comes from the *Navy Occupational Safety and Health Program Manual (NAVOSH)*, OPNAVINST 5100.23 (series). If you have any questions concerning safety on the project, the safety office is the best place for you to get your questions answered.

It is not the responsibility of the safety office to prevent you from doing something you know or suspect is unsafe, but they do have the authority to stop any operation when there is impending danger of injury to personnel or damage to equipment or property. Safe construction is your responsibility, and ignorance is no excuse. It is your responsibility to find out how to do construction in a safe manner.

SAFETY TRAINING

The key to any successful safety and health program is through the application of goal-oriented techniques, past experiences, adherence to safe operating practices and procedures, and the full cooperation of personnel. This goal is reached most effectively through a well-developed and well-coordinated training program.

Formal Training

Navy Enlisted Classification (NEC) 6021, NAVOSH, 2-week class, trains you on the 29 CFR PART 1926. This document contains the occupational safety and health standards for construction as promoted by the Occupational Safety and Health Administration as of August 1991.

The NCF Supervisory Safety course is a 40-hour course taught by NCRs or the battalion safety officer. Attendees are familiarized with the safety program, the use of safety manuals, the identification of construction hazards, and the inclusion of safety in project planning. All E5-E6 personnel in line companies and details, all project safety representatives, and all crew leaders are required to attend the course.

The Hazard Recognition/Mishap Prevention course is a 16-hour course taught by the safety chief to familiarize the working level personnel with common hazards and safe work practices. Project safety representatives and crew leaders who have not attended the "NCF Supervisory Safety" course are required to attend it.

OJT is a <u>continuous</u> evolution to train crew members, and the crew leader needs to use all the references listed above, plus past experiences, knowledge, previous training, and daily stand-up safety lectures.

MISHAP PREVENTION

The goal of our safety program is to prevent mishaps. Seabees do not use the word *accident* because it implies the absence of fault (accidents happen). <u>Mishaps most commonly result from one's failure to follow safe construction practices.</u> First, let's define a **mishap** in the following way:

> A **mishap** is an unplanned event or series of events that result in death, injury, occupational illness, or damage and/or loss of equipment or

You may be appointed to assist the safety officer in administering the Mishap Prevention Program. The following is a seven step process for you to consider and practice in preventing mishaps.

Step 1: <u>**Recognize hazards**</u> — Begin by recognizing that construction is a dangerous business. The potential for death or serious injury is present daily on jobsites. Identify <u>very specifically</u> what hazards could cause death or injury.

<u>**Hazard**</u> is defined as a workplace condition that might result in injury, health impairment, illness, disease, or death to any worker who is exposed to the condition or damage or loss to property/equipment.

<u>**Serious hazard**</u> is a workplace condition of a Category I or Category II nature as defined below.

- Category I - Catastrophic: May cause death of an individual or the loss of a facility.
- Category II - Critical: May cause severe personnel injury, severe occupational illness, or major property damage.

Category III - Marginal: May cause minor personnel injury, minor occupational illness, or minor property damage.

Category IV - Negligible: Probably would not affect personnel safety or health but is nevertheless in violation of specific criteria.

Step 2: **Identify corrective action** — Our primary reference for preventive measures is the *Occupational Safety and Health Standards for the Construction Industry,* 29 CFR PART 1926 and our secondary reference being the *U.S. Army Corps of Engineers Safety and Health Requirements Manual,* EM 385.

Step 3: **Obtain equipment/material/training** — The operations department and safety department will provide assistance for setting up training and any equipment or material necessary for the mishap.

Step 4: **Ensure personnel awareness** — A key to a successful mishap prevention program is personnel awareness. The purpose of the daily **5 minute** stand-up safety lecture is to make sure everyone is properly trained to perform the task at hand. These lectures must address all hazards identified on NCF CAS sheets or any construction task performed by the Seabees.

Step 5: **Proper supervision** — The crew leader is responsible for making sure the crew members are provided with the proper training, equipment, and material to perform their task.

Step 6: **Emergency response** — To ensure that an emergency response is not delayed in the event of a mishap, you must post on the jobsite the location of the nearest phone, a map of the nearest medical facility, and emergency phone numbers.

Step 7: **Investigate and report** — Any mishap or near mishap must be documented to minimize the chance of it happening again. Crew leaders must initiate a mishap report.

Mishap Reporting

When a MISHAP occurs in your shop or office or within your crew, you must submit an accident/mishap report to the safety officer. Use the sample message format shown in figure 1-6, as described in OPNAVINST 5102.1.

When you properly use this report, it is one of your best mishap prevention tools. In many cases, the difference between a minor mishap and a major one is a matter of good fortune. Do not ignore mishaps that result in small cuts and bruises; investigate the reason for them and correct the cause. If you persist in doing this, you will have a safe and efficient jobsite, shop, or office.

Mishap Investigation

Before filling out an accident/mishap report, you must conduct a mishap investigation to get the answer to questions, such as those in the following six categories:

1. Unsafe conditions. Was the equipment improperly guarded, unguarded, or inadequately guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment, or unsafe planning? Was the proper safety apparel being worn? Were the proper respirators, goggles, and gloves provided?

2. Type of mishap. Did an object strike the person? Did the person fall at the same level or from a different level; or did the person get caught between objects or slip (not fall)?

3. Unsafe act. Was the person operating a machine without proper authorization or at an unsafe speed; that is, too fast or too slow? Was a safety device made inoperative; that is, blocked out or removed? Was a load made unsafe or were tools or equipment left in an unsafe place where they would fall? Did someone fail to wipe oil, water, grease, or paint from working surfaces? Did the injured person take an unsafe position or posture or lift with a bent back or while in an awkward position? Did the person lift jerkily or ride in an unsafe position on a vehicle or use improper means of ascending or descending? Was the injury caused by failure to wear the provided safety attire or personal protective devices, such as goggles, gloves, masks, aprons, or safety shoes?

4. Unsafe personal factor. Was the person absentminded or inattentive; unaware of safe procedures, unskilled, or unable to recognize a hazardous situation? Did the person fail to understand the instructions, regulations, or safety rules. Did this person willfully disregard instructions or safety rules; or did this person have a personal weakness, such as poor eyesight, defective hearing, or a hernia?

5. Type or injury. Did the injured person sustain a cut, sprain, strain, hernia, or fracture?

1. General:

The format and content shown below is to be used for reporting personnel injuries/death and material (property) damage mishaps. Submit as much of the information as is available. Submit supplementary reports as necessary to supply the missing information when available. OMIT ITEMS THAT DO NOT APPLY OR ARE NOT RELEVANT TO THE MISHAP.

2. Content and Format:

(Precedence–normally ROUTINE. See paragraphs 302b(3) and 402(3) when higher precedence is required).

FROM: REPORTING ACTIVITY
TO: NAVSAFECEN NORFOLK VA
INFO: (As may be directed by higher authority)

UNCLAS //N05102// FOUO (Normally UNCLAS unless classified information must be included.)

THIS IS A (LIMITED/GENERAL) USE MISHAP REPORT TO BE USED ONLY FOR SAFETY PURPOSES IN A ACCORDANCE WITH OPNAVINST 5102.1A

SUBJ: PID/MPD REPORT–(REPORT SYMBOL OPNAV 5102-1 (PID) and/or OPNAV 5102-2 (MPD))

REFERENCES: (If follow-up message, refer to prior message.)

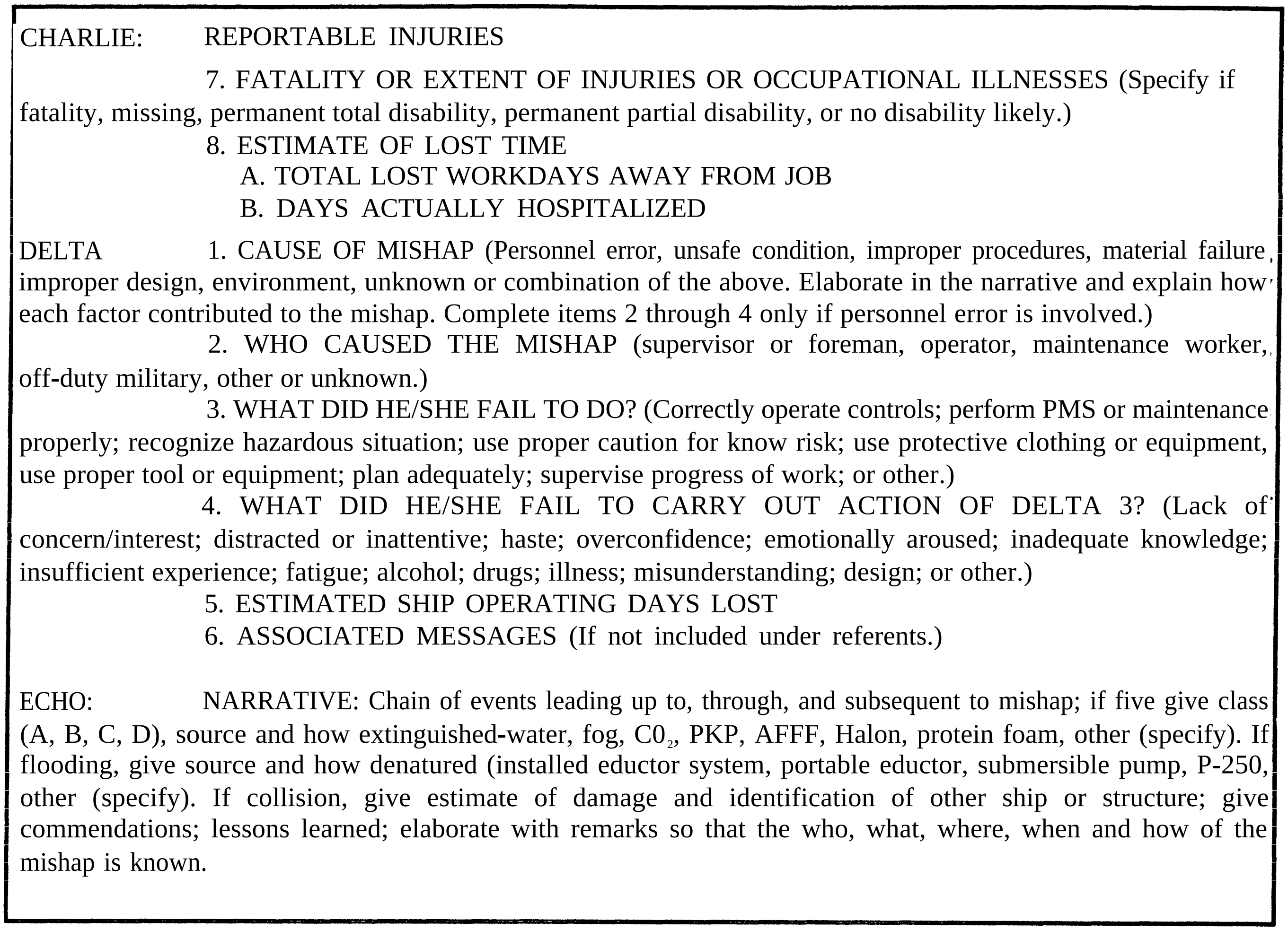
ALFA 1. UIC OF REPORTING ACTIVITY
2. TYPE OF MISHAP (Flooding, Fire, Injury/Death, Equipment Casualty, etc.)
3. LOCAL DTG OF MISHAP
4. GEOGRAPHIC LOCATION (If classified, give general area)
5. LOCATION WHERE MISHAP OCCURRED (If at duty station, give work center or description; e.g., torpedo room, main deck frame. If other, so indicated; e.g., at home, on/off base, football, etc.)
6. EVOLUTION AT TIME OF MISHAP (TYT, REFIT, ISE, MAINTENANCE , UNREP, etc.)
7. SHIP'S STATUS (Under way, anchored, submerged, dry-docked, etc. For mishaps ashore, leave blank.)

BRAVO: 1. EQUIPMENT DAMAGED OR DESTROYED BY THE MISHAP (Include EIC, TEC, or NSN if applicable; describe damage.)
2. ESTIMATED, COST TO REPAIR OR REPLACE DOD PROPERTY. (Provide a total cost including man-hours at $14 per hour plus cost of material and equipment.)
3. ESTIMATED COST OF NON-DOD PROPERTY DAMAGE

CHARLIE: REPORTABLE INJURIES

1. NAME/SSN/AGE/SEX (If more than one person involved, information in this section must be explicit as to which individual is being described. Repeat items 1-8 for each individual.)
2. RANK/DESIGNATOR/RATE/GRADE. JOB AND EMPLOYMENT STATUS (For employment status specify USN, USNR, Navy Civilian, etc.)
3. DUTY STATUS (On or off duty)
4. SPECIFIC JOB OR ACTIVITY INDIVIDUAL ENGAGED IN AT TIME OF MISHAP (PMS, watch standing, football, woodworking, etc.)
5. NUMBER OF MONTH'S EXPERIENCE AT THE JOB OR ACTIVITY (The experience the person possessed for the activity engaged in.)
6. MEDICAL DIAGNOSIS (Include parts of body and type of injury. For occupational illnesses specify the type as outlined in the Note below.)

Figure 1-6.—Mishap report format.



CHARLIE: REPORTABLE INJURIES

7. FATALITY OR EXTENT OF INJURIES OR OCCUPATIONAL ILLNESSES (Specify if fatality, missing, permanent total disability, permanent partial disability, or no disability likely.)

8. ESTIMATE OF LOST TIME

A. TOTAL LOST WORKDAYS AWAY FROM JOB

B. DAYS ACTUALLY HOSPITALIZED

DELTA 1. CAUSE OF MISHAP (Personnel error, unsafe condition, improper procedures, material failure, improper design, environment, unknown or combination of the above. Elaborate in the narrative and explain how each factor contributed to the mishap. Complete items 2 through 4 only if personnel error is involved.)

2. WHO CAUSED THE MISHAP (supervisor or foreman, operator, maintenance worker, off-duty military, other or unknown.)

3. WHAT DID HE/SHE FAIL TO DO? (Correctly operate controls; perform PMS or maintenance properly; recognize hazardous situation; use proper caution for know risk; use protective clothing or equipment, use proper tool or equipment; plan adequately; supervise progress of work; or other.)

4. WHAT DID HE/SHE FAIL TO CARRY OUT ACTION OF DELTA 3? (Lack of concern/interest; distracted or inattentive; haste; overconfidence; emotionally aroused; inadequate knowledge; insufficient experience; fatigue; alcohol; drugs; illness; misunderstanding; design; or other.)

5. ESTIMATED SHIP OPERATING DAYS LOST

6. ASSOCIATED MESSAGES (If not included under referents.)

ECHO: NARRATIVE: Chain of events leading up to, through, and subsequent to mishap; if five give class (A, B, C, D), source and how extinguished-water, fog, C0$_{2}$, PKP, AFFF, Halon, protein foam, other (specify). If flooding, give source and how denatured (installed eductor system, portable eductor, submersible pump, P-250, other (specify). If collision, give estimate of damage and identification of other ship or structure; give commendations; lessons learned; elaborate with remarks so that the who, what, where, when and how of the mishap is known.

Figure 1-6.—Mishap report format—Continued.

6. Part of body affected. Did the injury involve an arm, legs, ribs, feet, fingers, or head?

These categories suggest some of the things, but not all of those you must investigate and report when mishaps occur.

Remember, there are some questions in these categories that require medical information that can only be obtained from a doctor. Each mishap is different, and each is to be investigated and judged on its own merits. Do not jump to conclusions. Start each investigation with an open mind. The most important reason for any mishap investigation is to prevent similar ones from occurring.

HEARING AND SIGHT CONSERVATION

The Navy's goal is to prevent occupational hearing and sight loss within the workplace and to assure that the exposure of members to potential hazardous noises and eye hazards are held to a minimum. The Navy's policy is also to provide the necessary medical care, surveillance, documentation, and treatment to all personnel.

Hearing Conservation

Environments that produce potentially hazardous noise should be modified to reduce the noise level to acceptable levels whenever it is technologically and economically feasible. The reduction of noise at the source is in the best interest of the Navy and its personnel. The Navy's Hearing Conservation Program includes the following recommendations:

- Work environments are to be surveyed to identify any potentially hazardous noise levels.

- Periodical hearing examinations are to be conducted to monitor the effectiveness of the hearing conservation program.
- Education is vital to the overall success of a hearing conservation program.

The Navy's Permissible Exposure Limit (NPEL) for occupational noise is 84 decibels (unit of measure to express sound pressure levels) for an 8-hour time weighted average (TWA). When TWA exposures exceed 84 dB, then include personnel in the Navy's Hearing Conservation Program. The formulas to compute decibels are in the OPNAVINST 5100.23 .1802.2

Any work area where the TWA sound level exceeds 84 dB and where the noise level would peak at 140 dB will be designated as hazardous noise areas and labeled as per *Navy Medicine*, NAVMED 6260/2 (series). These labels should read Hazardous Noise Warning Decal, 8 inches by 10 1/2 inches (displayed on stationary equipment and all entryways) and Hazardous Noise Labels, 1 inch by 1 1/2 inch (displayed on power tools). These are approved decals and labels for marking hazardous noise areas and equipment.

Remember Builders, you work mainly with power tools and machinery with which the decibels will range from 50 dB (power saws) to 140 dB (radial saw at peak operations), so it is your responsibility to protect your hearing. If you have any further questions regarding hazardous noise areas, do not hesitate to contact your safety officer.

Sight Conservation

Navy policy requires that Navy personnel exposed to eye hazards are to be provided adequate eye protection at government expense. The following basic program requirements are to be implemented:

1. A complete survey of all activity work areas, equipment, and processes must be conducted to determine which eye hazards exist, which personnel require eye protection, and what type of eye protection is required.

2. All areas designated as eye hazards must be posted with the appropriate warning signs. Such signs should be consistent with the requirements of 29 CFR 1910.145 and are to be located at all entrances to designated areas as practical.

3. Emergency eyewash stations must be provided in all areas where the eyes of any employee may be exposed to corrosive materials.

<u>Remember Builders, your eyesight is the most valuable tool you will ever possess.</u>

For further references to SAFETY, contact your safety officer or refer to the OPNAVINST 5100.23 (series), Naval Safety Supervisor course (TRAMAN), and Army Corps of Engineers, EM-385.

POLLUTION AND HAZARDOUS WASTE

Pollution abatement is the responsibility of all Navy personnel whether military or civilian. We need to become more innovative in finding ways to reduce pollution in our environment. Land, air, and water are the three primary parts that make up this planet and are ecologically balanced. When one of the parts is severely damaged, it has an equally damaging effect on the other two parts. It is absolutely essential for us to review practices that have or may have a detrimental effect on the environment and determine whether measures can be taken to lessen or eliminate these undesirable effects further.

Historically, the most prevalent polluters have been in the fields of manufacturing, facilities maintenance, construction, and waste disposal. NCF personnel can do little to control manufacturing pollution. However, they can provide some control over the methods in which many manufactured items are used and the ways in which residues, such as construction waste and potential pollution materials, are disposed. This is particularly important when it could have an adverse effect on the immediate environment at an NCF jobsite.

POLLUTION IMPACT AREAS

Nearly all pollution is caused by substances from the following categories of materials:

<u>Hazardous</u> — any material, substance, chemical, and so forth, that is regulated as hazardous (harmful, exposing one to risk), requiring an MSDS.

<u>Nonhazardous</u> — any material, substance, chemical, and so forth, that is not regulated and does not require an MSDS.

<u>Organic</u> — a material or substance generally characterized by chains of connected carbon atoms. A

larger number of known organic chemicals have been synthesized in the laboratory, and our society is dependent on such synthetic materials as plastics, synthetic fibers, dyes, detergents, and insecticides. The vast majority of synthetic products are derived from petroleum. Ninety percent (90%) of all organic chemicals are made from materials derived from petroleum and natural gas.

Inorganic — this term describes the properties and the behavior of all elements and their compounds (brass, copper, gold, etc.), except for the majority of the carbon compounds which are the domain of organic chemistry. Exceptions to this are carbon monoxide, carbon dioxide, and calcium carbonate.

Environmental protection and hazardous waste disposal are two serious concerns in the NCF today. Cleaners, acids, mastics, sealers and even paints are just a few of the hazardous materials that may be present on a project site. As a crew leader, you are responsible for the protection of your crew and their safety. You are equally responsible for protecting the environment. Stiff fines and penalties that apply to NCF and civilian work may be charged to those who do not protect the environment. The bottom line is that you can go to jail for not providing an environmentally safe jobsite. Therefore, you should contact your environmental representative or safety office immediately in case of any environmental problem (spill, permits, planning, etc.).

WATER AND GROUND POLLUTION

There are some wastes that should never be flushed into a sewer. Sewage treatment plants and industrial waste treatment plants are not designed to, neither can they, adequately treat all wastes. Some wastes, such as those containing more than a trace of oil, cleaning fluids, gasoline or other volatile, toxic chemicals, acids or alkalies, and some solid materials cannot be handled by sewers.

Besides creating a fire hazard, oil and other petroleum-related products pose many possible pollution threats when they are spilled in the water, dumped into the storm or sanitary sewer system, or spilled on the ground. Oil products on the ground infiltrate and contaminate surface water supplies with the groundwater runoff caused by rain. Oil products dumped or carried into storm or sanitary sewers are also potential explosion hazards.

Waste oils, filters, and contaminated fuel should be collected and disposed of in a nonpolluting manner. Most naval activities collect and dispose of waste oil periodically through a contractor. The contractor may bum it in a boiler plant or in a heating system or reprocess it in an oil reclaimer unit. The naval supply fuel farms usually have the means to dispose of waste oils properly.

There will be times when you will see what could be a potential hazard, such as contaminated water running off the equipment on the washrack. It is your responsibility to check with the person in charge of the washrack to be sure this wastewater is treated and not discharged into the storm system. Provisions must be made for pretreating or separating oil products and cleaning solvents used at the washrack.

Water Pollution

Pollution results from many activities of both mankind and nature. Water becomes polluted when wastes from activities flow into a lake or stream in such quantities that the natural ability of the water to cleanse itself is lessened or completely destroyed.

These wastes have placed a serious strain on our wastewater treatment systems and our waterways. Some types of waste are difficult to remove. Other types respond to conventional treatment, but there are not enough treatment facilities to keep them out of our waters. Solving the pollution problem is not easy, but it must be solved if we are to have an adequate supply of safe, clean water for future use.

An oil slick on the surface of the water blocks the flow of oxygen from the atmosphere into the water. This is harmful to the fish and to other aquatic life. If the fish do not die from the oil coating on their gills or from eating the oil or oil-laden food, their flesh is tainted and they are no longer fit for human consumption. Besides harming aquatic life, drinking water can become contaminated by oil. Drinking water from wells and surface storage facilities is treated with chemicals to rid the water of harmful bacteria. However, no amount of treatment can rid a system of contamination from waste oil products. The system must be abandoned.

CAUTION

Always be careful of what you dispose of and where ! READ labels and MSDSs to avoid these types of mishaps.

Ground Pollution

Construction site work, repair, and maintenance of facilities have the immediate potential for becoming polluting activities. Since the majority of construction efforts take place on land, project supervisors must identify potential pollution hazards and take steps to minimize their effects. Some of the most common pollution activities that affect the ground areas and water ecosystems are grubbing and equipment repair operations.

Large-scale clearing and grubbing during the initial stages of a project often produce damaging environmental effects, such as increased soil erosion, reduction of atmospheric oxygen, and destruction of wildlife habitat. Another primary concern is the introduction of particulate matter into streams and riverbeds. Particulate matter released into waterways causes increased siltation and algae growth.

To prevent these damaging effects, you should save as much vegetation as possible such as trees, grass, and other plants that hold the soil in place. Consider allowing tree rows to be left in place until the project is completed. Replant cleared areas. Construct a shallow trench around the perimeter of a project to help contain water runoff into streams and rivers and to prevent siltation. The decision to burn scrubs and stumps should be based on atmospheric conditions. You should burn only when conditions are favorable and the material to be burned is totally dry. A burn permit is required for all burning operations! To prevent wild fires and of smog, do NOT use petroleum-based fuels to start fires! Petroleum-based fuels do not burn completely, and the residue seeps into the underground water table.

AIR POLLUTION

As a crew leader, be aware of work conditions that cause air pollution and the efforts required to minimize or connect such problems.

When incomplete combustion occurs in base boilers, space heaters, and stoves, the unburned hydrocarbons and the various other fuel components combine chemically to form by-products. Many of these by-products are harmful to people and the environment.

The by-products that have the most adverse effect on the air are carbon monoxide, particulate matter, sulfur oxides, unburned hydrocarbons, nitrogen oxides, and lead. The most effective means of controlling air pollution from incomplete fuel combustion is to maintain the equipment properly and frequently. Another means of lessening air pollution, not always under your control, is the use of only the best grade of fuel. High-grade fuel contains low particulate matter, low water and sulfur content, and few contaminants.

SOLID WASTE

The Environmental Protection Agency (EPA) defines solid waste as “any garbage, refuse, or sludge from a waste treatment plant, water supply treatment plant, air pollution control facility, or any other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial (including construction), commercial, mining, or agricultural operations or community activities.” Solid waste is a growing international concern and it has reached critical proportions in many areas.

The present practice of disposing construction waste by burying the material on site is no longer considered a viable method of disposal. All construction and demolition materials must be disposed of in a safe, logical way to prevent future damage to the ecosystems. **Recycling** is a very good alternative to disposing of certain material.

Solid wastes are best disposed of in one or more of the following ways:

- Shredding
- Baling
- Source separation
- Recycling
- Comporting
- Incineration
- Landfill disposal

The term *disposal* identifies the point at which the *Navy* relinquishes control of its solid waste or provides for its ultimate disposal in Navy-operated facilities. Presently, the most practical way to dispose of solid wastes is through the sanitary landfill method. The Navy has recycling and incineration facilities currently in operation. In Norfolk, Virginia, the Navy uses a heat reclamation unit to produce steam; however, these units are in the experimental stage and are not presently in general use. Each of the disposal methods helps to reduce the initial volume of solid waste, but each method leaves varying amounts of residuals behind that must eventually be deposited in a controlled sanitary landfill facility.

At all levels of society, we must take appropriate action to abate pollution and to preserve the environment by properly disposing of solid waste material.

Since all Navy facilities must conform to the laws and regulations of federal, state, and local environmental agencies, the Navy has produced its own instruction and guidelines. The information developed specifically for Navy use is as follows: 29 CFR 1910 (OSHA), 40 CFR 240-262 (series), OPNAVINST 5090.1 (series), *Environmental and Natural Resources Protection Manual;* NAVFAC MO-213, *Solid Waste Management;* and NAVFAC DM 5.10, *Solid Waste Disposal.*

HAZARDOUS MATERIAL CONTROL

The Hazardous Material Control Program is a Navy-wide program that enforces the correct storage, handling, usage, and disposition of hazardous material. Hazardous waste disposal is a serious concern to the NCF today. Cleaners, acids, mastics, sealers, and even paints are just a few of the hazardous materials that may be present in your shop or on your project site. As a crew leader, you are responsible for the safety and protection of your crew.

PROPERTIES OF HAZARDOUS WASTE

Few discarded materials are so compatible with the environment or so inert as to have no short- or long-term impact. Hazards that appear minor may have unexpected impacts long after disposal. When two or more hazards pertain to a material, the lesser may not receive the necessary consideration. When two discarded substances are mixed, a chemical reaction with severe and unexpected consequences may result.

Since waste is generally a mixture of many components, its physical and chemical properties cannot be defined with any degree of accuracy. Whenever possible, the approximate composition of a hazardous waste should be ascertained from the originating source or from the manifest accompanying the waste being transported. Generally, when one component predominates, the physical and chemical properties of the waste mixture are nearly those of the major component. This is not true for the hazardous properties of waste mixtures consisting of relatively harmless major components and small amounts of highly toxic, radioactive, or etiologically (disease-producing) active components. The hazard, in this case, is determined by the smaller component.

The EPA defines hazardous solid waste as any material that has the potential to produce the following results:

- Cause, or significantly contribute to, an increase in mortality or any serious, reversible, or incapacitating reversible illness.
- Pose a substantial hazard to human health or the environment when the hazardous material is improperly stored, treated, transported, or disposed of.

By EPA standards, the determining factor for a material to be classified as hazardous waste is that it must meet one or more of the conditions of being ignitable, corrosive, reactive, or toxic, as covered in the following information.

- Ignitable

It is a liquid, other than an aqueous solution, containing less than 24 percent alcohol by volume and has a closed-cup flash point of less than 60°C (140°F).

It is not a liquid, but is capable under standard temperature and pressure of causing fire through friction, absorption of moisture, or spontaneous chemical changes, and when ignited, burns so vigorously and persistently that it creates a hazard.

It is an ignitable, flammable compressed gas, which is defined as a gas that forms a flammable mixture when mixed with air at a concentration less than 13 percent (by volume) or has a flammability range with air that is greater than 12 percent, regardless of its lower flammable limit.

It is an oxidizer, such as a chlorate, permanganate, inorganic peroxide, nitrocarbo nitrate, or a nitrate that yields oxygen readily, and stimulates the combustion of organic matter.

- Corrosive

It is a watery solution with a pH less than or equal to 2 or greater than or equal to 12.5.

It is a liquid, that corrodes steel at a rate greater than 6.35 mm (0.25 inch) per year at a test temperature of 55°C (130°F).

- Reactivity

It is normally unstable and readily undergoes violent change without detonating.

It reacts violently with water.

It forms potentially explosive mixtures with water. When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or to the environment.

It is a cyanide- or sulfide-bearing waste that, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or to the environment.

It is capable of detonation or explosive reaction when it is subjected to a strong initiating source or if heated under confinement.

It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

It is a known forbidden substance or a class A or B explosive.

- Toxic

It is a material that contains or degrades into toxic components in concentrations that poses a potential hazard to the environment or to the public health and that may be fatal to humans in low doses.

HAZARDOUS WARNING MARKINGS AND LABELS

To determine specific hazards at a glance, refer to the warning markings and labels that identify hazardous materials. Hazardous warning markings and labels are necessary to show clearly the hazardous nature of the contents of packages or containers at all stages of storage, handling, use, and disposal. When unit packages (marked packages that are part of a larger container) are removed from shipping containers, the continuity of the specific hazard warning must be preserved. This is normally done by applying the appropriate identifying hazardous label to the hazardous material container or package.

The Department of Transportation (DOT) labeling system shown in figure 1-7 is a diamond-shaped symbol segmented into four parts. The upper three parts reflect hazards relative to health, fire, and reactivity. The lower part reflects the specific hazard that is peculiar to the material.

There are four specific labels that are designed to illustrate each hazard:

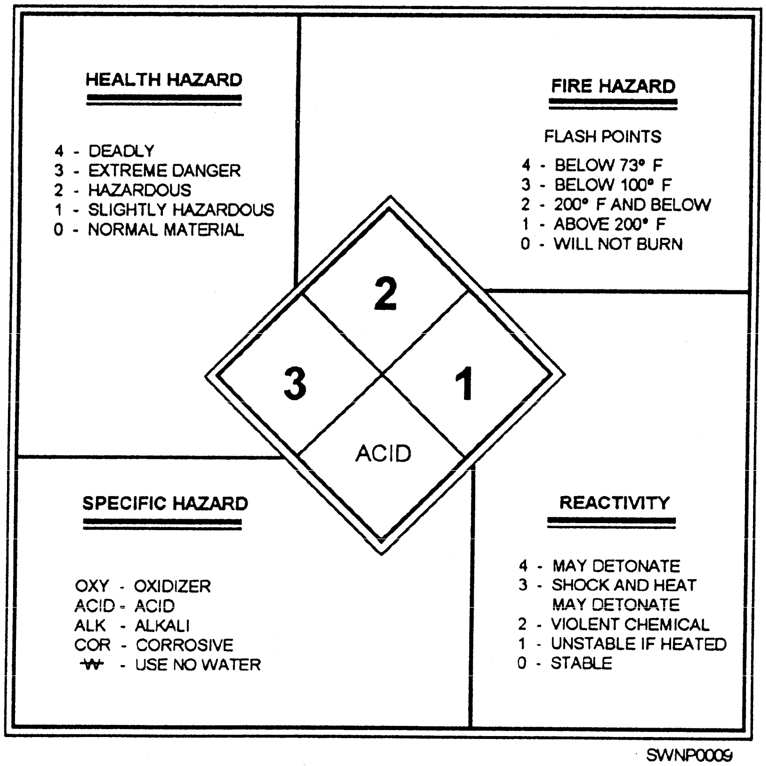


Figure 1-7.—Hazardous Code Chart.

Health Hazard — the ability of a material to either directly or indirectly cause temporary or permanent injury or incapacitation.

Fire Hazard — the ability of the material to bum when it is exposed to a heat source.

Reactivity Hazard — the ability of a material to release energy when it contacts with water. This term can be defined as the tendency of a material, when in its pure state or as a commercially produced product, to polymerize, decompose, condense vigorously, or otherwise become self-reactive and undergo violent chemical changes.

Specific Hazard — this term relates to a special hazard, concerning the particular product or chemical, which was not covered by other labeled hazard items.

The degree of hazard is expressed by a numerical code as follows:

4 = extremely dangerous material

3 = dangerous hazard

2 = moderate hazard

1 = slight hazard

0 = no hazard

The example shown in figure 1-8 describes the hazards of methyl ethyl ketone. Methyl ethyl ketone is usually found mixed with paints, oils, and greases from solvent cleaning, paint removers, adhesives, and cleaning fluid residues. The numbers on the label identify this chemical compound as follows:

- Health Hazard 2, “Hazardous”
- Fire Hazard 4, “Flash point below 73°F extremely dangerous materail”

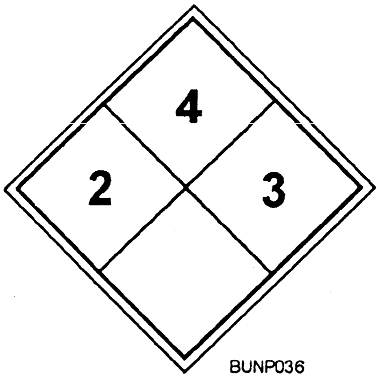


Figure 1-8.—Hazard warning label for methyl ethyl ketone.

- Reactivity 3, “Shock or heat may detonate, dangerous material”
- Specific Hazard, “None”

Other specific labeling requirements are provided in the NAVSUPINST 5100.27 (series). All supervisors are to review this instruction carefully.

HAZARDOUS MATERIAL STORAGE

The safest practice concerning hazardous material is for users to draw only the amount of material that can be used that day. On the jobsite, store hazardous materials in approved storage containers. Place the containers a minimum of 50 feet away from any ignition device or source. Plan for the delivery of proper storage equipment before hazardous materials are delivered to the jobsite. Since many hazardous materials require separate storage containers (for example, corrosives and flammables cannot be stored together), consult your safety office.

HAZARDOUS MATERIAL TURN-IN

Dispose of excess material through an authorized hazardous material disposal facility. The proper labeling of hazardous materials is critical. Properly labeled waste can be disposal of for a relatively low price. Unidentified material must first be analyzed, which is extremely expensive. Anytime you turn-in hazardous material, include a ledgeable MSDs with the material. This saves valuable time and expense and it makes the job easier for supply.

Avoid mixing unlike types of waste. Do not mix waste paint thinner in a waste oil drum. The Navy sells uncontaminated waste oil for a profit. If only minor amounts of any other substance are present in the waste oil, the Navy must pay high prices for analysis and disposal. The best disposal method is for you to properly label the materials and return them, unmixed, to the supply department. Clearly label each container, preferably with the BM line item or other supply tracking documentation. It is always best for you to check with the battalion MLO staff or safety office for proper disposal procedures.

MATERIAL SAFETY DATA SHEET

Many different materials are used in the workplace throughout the Navy, most of which are hazardous. A key to the NAVOSH program is informing workers about these hazards and the measures necessary to control hazardous materials. To track all hazardous materials, the Department of Defense (DoD) has established the Hazardous Material Information System (HMIS), OPNAVINST 5100.23 (series), which acquires, stores, and disseminates data on hazardous materials procured for use. This information is readily available through every supply department.

A Material Safety Data Sheet (MSDS) (fig. 1-9) has a variety of formats and is required for each hazardous item procured. It should be submitted to the procuring activity by the contractor/manufacturer/vendor. The MSDS contains nine sections which provides the user with the following information:

1. General information
2. Hazardous ingredients
3. Physical/chemical characteristics
4. Fire and explosion hazard data
5. Reactivity data
6. Health hazard data
7. Spill or leak procedures
8. Special protection information
9. Control measures/special precautions

Hazardous materials, purchased by the military exchange systems for resale, do NOT require Material Safety Data Sheets.

Upon drawing any hazardous material, MLO provides the crew leader with an MSDS. The MSDS identifies any hazards associated with exposure to that specific material. It also identifies any personnel protective equipment or other safety precautions required, as well as the needed first aid or medical treatment as a result of exposure. The crew leader is required by federal law to inform crew members of the risks and all safety precautions associated with any hazardous material present in the shops or on the jobsite. Do this during each daily safety lecture. Additionally, the MSDS must be posted conspicuously at the jobsite, shop spaces, and any other approved hazardous material storage area.

COMMON HAZARDOUS CONSTRUCTION WASTES

Refuse of a highly combustible nature, such as dry wastepaper, excelsior (fine wood shavings), and so forth, should be collected in metal containers and not allowed to accumulate. When stored in quantity, keep these materials away from buildings, roadways, and ignition sources by a distance of 50 feet or more. Transport materials to an incinerator or landfill on a frequent schedule to minimize a fire hazard.

Drying Oils

Rags, paper, paint rollers, brushes, and so forth, that have absorbed drying types of oils, are subject to spontaneous heating. Keep them in well-covered metal cans and thoroughly dry them before collection for transport. Consider for example, the oils listed below. When you apply these oils, the materials used are subject to spontaneous heating and could ignite if not disposed of properly.

1. Linseed oil is a very common oil made from the flaxseed plant. Researchers find this oil very combustible when it is absorbed by rags and stored improperly. The chemical methyl ethyl ketone is an ingredient of linseed oil, which is a highly flammable organic solvent used as a thinner and a drying agent.

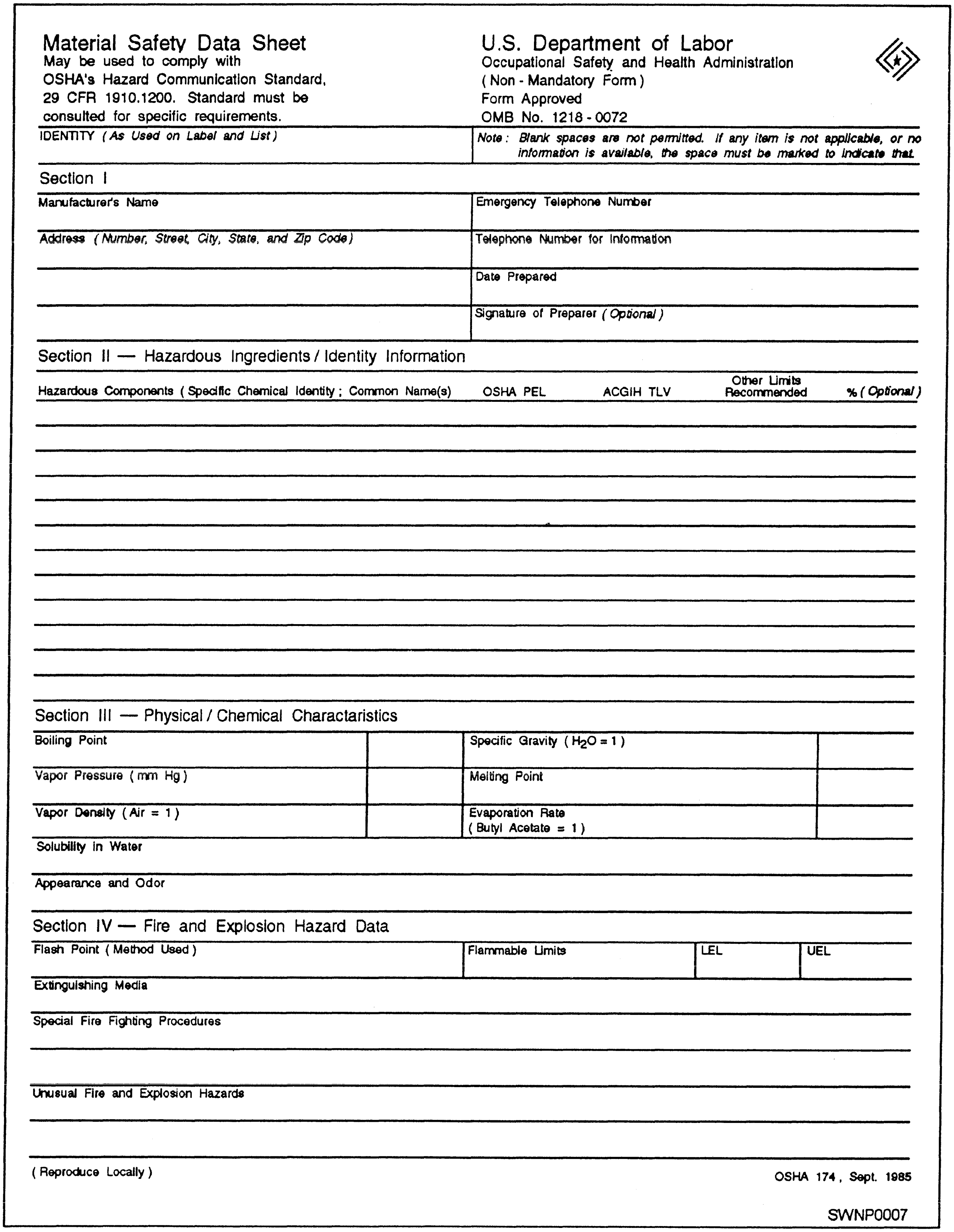
2. Tung oil is a fast-drying oil produced from the seed of a Chinese tree and contains the chemical methyl ethyl ketone. Tung oil has a relatively high flash point of 140°F, but the rags used to absorb the oil are very combustible if not disposed of properly.

3. Form oil is made up of modified polyurethane and resin-based materials. Usually applied by spray-on methods but at times applied by rubbed-on or rolled-on methods with various material. These materials are subject to spontaneous heating.

Flammable Liquids, Adhesives, and Waste Solvents

Flammable liquids, adhesives, and waste solvents have variable flash points and hence varying hazards, depending upon the composition. Some may contain solids, tars, waxes, and other combustible materials. Chlorinated solvents and water may also be present. Note the following examples:

1. Contact cement is a rubber or butane-based liquid adhesive, which is highly volatile. **Methyl ethyl ketone** is one of the chemicals in the makeup of this adhesive.



Material Safety Data Sheet
May be used to comply with
OSHA's Hazard Communication Standard,
29 CFR 1910.1200. Standard must be
consulted for specific requirements.

U.S. Department of Labor
Occupational Safety and Health Administration
(Non - Mandatory Form)
Form Approved
OMB No. 1218 - 0072

IDENTITY *(As Used on Label and List)*

Note : Blank spaces are not permitted. If any item is not applicable, or no information is available, the space must be marked to indicate that.

Section I

Manufacturer's Name	Emergency Telephone Number
Address *(Number, Street, City, State, and Zip Code)*	Telephone Number for Information
	Date Prepared
	Signature of Preparer *(Optional)*

Section II — Hazardous Ingredients / Identity Information

Hazardous Components (Specific Chemical Identity ; Common Name(s)	OSHA PEL	ACGIH TLV	Other Limits Recommended	% *(Optional)*

Section III — Physical / Chemical Charactaristics

Boiling Point		Specific Gravity (H_2O = 1)	
Vapor Pressure (mm Hg)		Melting Point	
Vapor Density (Air = 1)		Evaporation Rate (Butyl Acetate = 1)	

Solubility in Water

Appearance and Odor

Section IV — Fire and Explosion Hazard Data

Flash Point (Method Used)	Flammable Limits	LEL	UEL

Extinguishing Media

Special Fire Fighting Procedures

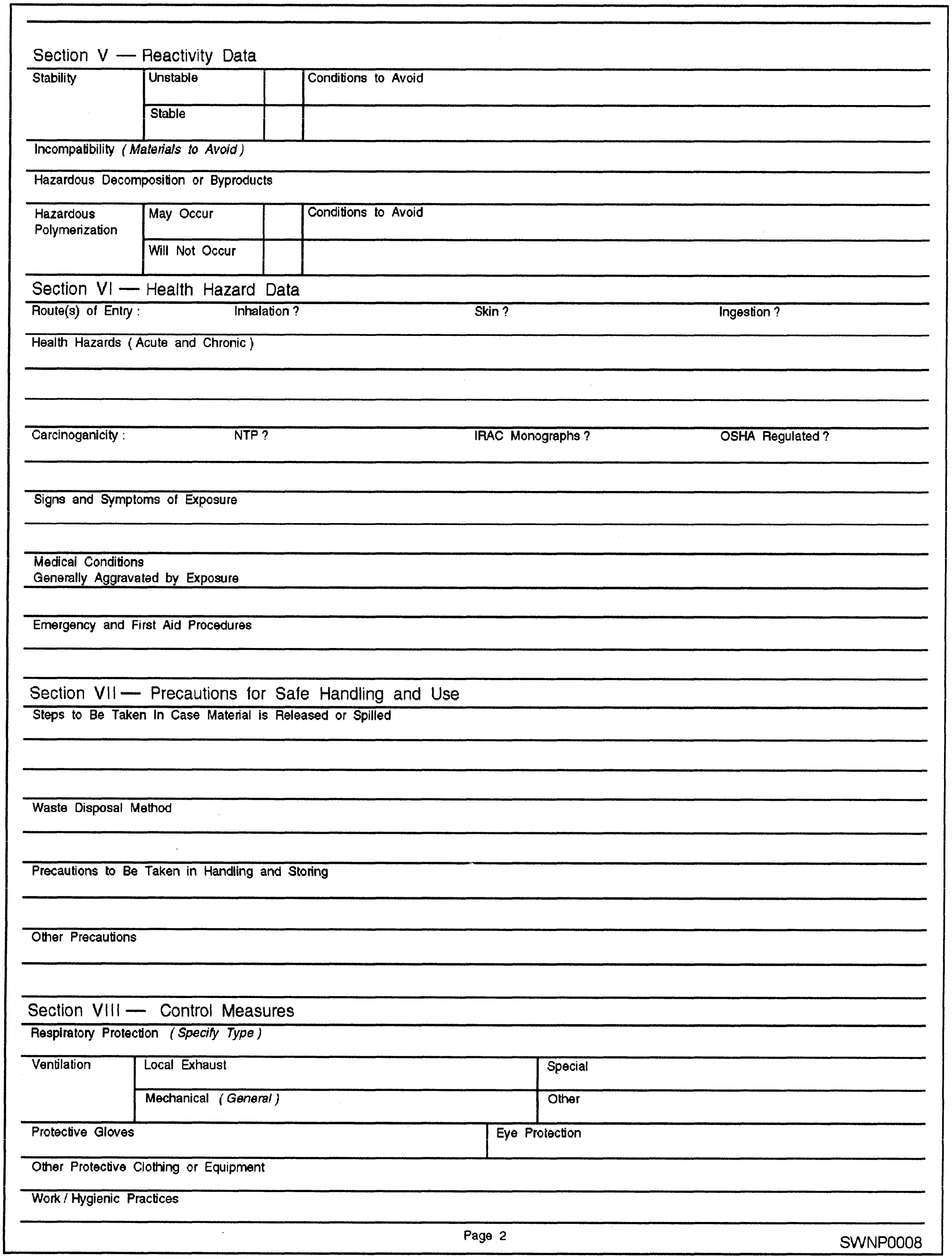
Unusual Fire and Explosion Hazards

(Reproduce Locally)

OSHA 174 , Sept. 1985

SWNP0007

Figure 1-9.—Material Safety Data Sheet, page 1.



Section V — Reactivity Data

Stability	Unstable		Conditions to Avoid
	Stable		

Incompatibility *(Materials to Avoid)*

Hazardous Decomposition or Byproducts

Hazardous Polymerization	May Occur		Conditions to Avoid
	Will Not Occur		

Section VI — Health Hazard Data

Route(s) of Entry :	Inhalation ?	Skin ?	Ingestion ?

Health Hazards (Acute and Chronic)

Carcinoganicity :	NTP ?	IRAC Monographs ?	OSHA Regulated ?

Signs and Symptoms of Exposure

Medical Conditions
Generally Aggravated by Exposure

Emergency and First Aid Procedures

Section VII — Precautions for Safe Handling and Use

Steps to Be Taken In Case Material is Released or Spilled

Waste Disposal Method

Precautions to Be Taken in Handling and Storing

Other Precautions

Section VIII — Control Measures

Respiratory Protection *(Specify Type)*

Ventilation	Local Exhaust	Special
	Mechanical *(General)*	Other

Protective Gloves	Eye Protection

Other Protective Clothing or Equipment

Work / Hygienic Practices

Page 2

SWNP0008

Figure 1-9.—Material Safety Data Sheet, page 2.

2. Roofing cement is a petroleum-based product with asphalt binders and primers mixed in, and it is NOT environmentally friendly. Disposal of these products are "nightmares" to our supply system and our landfills.

3. Curing compounds consist of waxes, chlorinated rubber, resins, and highly volatile solvents. However, these are water- based curing compounds that are environmentally friendly.

4. Oil-based paints consist mainly of a drying oil (usually linseed), and they are mixed with one or more pigments (unsoluble solids). The disposal of oil-based paints is also a "nightmare to the supply system and our landfills.

These construction products are also covered in the NAVFAC MO 110, *Paints and Protective Coatings.*

Asbestos

Another air pollutant that you must be knowledgeable of and concerned with is **asbestos dust.** Asbestos is a fibrous mineral that can be woven like wool. Through a variety of processes, asbestos can be turned into thousands of construction products. These products were used extensively from the 1930s through the 1960s. Asbestos, used by mankind for over 2,500 years, was found to be a health hazard in the early 1900s.

Then, only miners and workers in industrial manufacturing plants were believed to be affected by asbestos. However, as research continued, asbestos was discovered to be the main cause of asbestosis, a generic term for a wide range of asbestos-related disorders and mesothelioma. Mesothelioma, at one time, was a rare form of lung cancer. Now it occurs much more frequently among people exposed to asbestos dust particles.

The three terms associated with asbestos dust particle length that you need to know are *micron, nanometer,* and *angstrom.* To give you an idea of their size, realize that in 1 meter, there are 1 million microns, 1 billion nanometers, and 10 billion angstroms. Within this size range, air that appears to be dust-free can contain millions of disease-producing asbestos particles. These minuscule asbestos particles have led to many laws, regulations, and clean-up problems. These invisible particles can remain suspended in the air for months. To solve this problem, you must take air samples to ascertain the severity of the situation. To remove these particles, the air must be scrubbed with a special air filtration machine, called a High Efficient Particulate Air (HEPA) filtered vacuum. This vacuum will filter out 99.97 percent of asbestos particles from the air.

Normally, asbestos removal is not conducted by NCF personnel. See COMSECONDNCB/ COMTHIRDNCBINST 5100.1 (series) for detailed guidance on NCF asbestos policy and procedures. However, if you are stationed at an overseas Public Works Department (PWD), you might have to "abate" (contain or dispose of) this fibrous material. To remove **asbestos,** you must be qualified through the National Asbestos Training Center (NATC) or equivalent agencies. OPNAVINST 5100.23 (series) covers asbestos very thoroughly, or you may refer to the Department of Labor (DOL) or CFR 1910.1001 and 1926.58 for control of asbestos exposure. For many years, asbestos was used for the following types of applications:

- Roofing, siding, and flooring products
- Friction products, that is, brakes and clutch facings
- Reinforcing materials in cement pipe, concrete asbestos board (CAB), lagging, and thickening agents used in some paints
- Thermal and acoustical insulation

In all cases, you must constantly research the laws governing asbestos. If you continually work with or around asbestos, stay informed of current regulations and laws regulating the use of it. Asbestos laws are constantly changing and being updated. At the present time, legislation is proposed to outlaw all forms and uses of asbestos. When you doubt whether you've had contact with asbestos, consult your safety office.

This chapter provides various, but limited insight about PRCPs, construction administration, training, safety and environmental pollution. This information given you and the references listed are what you need to study to advance, hone your skills, and to become an "outstanding" Seabee.

CHAPTER 2

PLANNING, ESTIMATING, AND SCHEDULING

LEARNING OBJECTIVE: *Interpret the different types of construction drawings and specifications used within the Naval Construction Force (NCF), and identify the requirements needed to plan, estimate, and schedule using the Critical Path Method (CPM) and Engineered Performance Standards (EPS).*

Good construction planning and estimating procedures are essential for any Seabee. They provide quality construction to the customer. This chapter gives you helpful information for planning, estimating, and scheduling construction projects normally undertaken by Seabees. This information will help you understand the concepts and principles and is **NOT** intended to be a reference or to establish procedures. Planning, estimating, and scheduling can be done through various techniques. This chapter describes suggested, proven methods that result in effective planning and estimating. Your responsibilities are to decide how and when to apply these techniques.

To plan any project, you must first be familiar with the construction drawings and specifications. The construction of any structure or facility is described by a set of related drawings that gives the Seabees a complete sequential graphic description of each phase of the construction process. In most cases, a set of drawings shows the location of the project, the boundaries, the contours, and the outstanding physical features of the construction site and its adjoining areas. Succeeding drawings give further graphic and printed instructions for each phase of construction.

TYPES OF CONSTRUCTION DRAWINGS

Drawings are generally categorized according to their intended purposes. Some of the types of drawings commonly used in military construction are covered in this section.

MASTER PLAN DRAWINGS

MASTER PLAN DRAWINGS are commonly used in the architectural, the topographical, and the construction fields. They show sufficient features to be used as guides in long-range area development. They usually contain section boundary ‘lines, horizontal and vertical control data, acreage, locations and descriptions of existing and proposed structures, existing and proposed surfaced and unsurfaced roads and sidewalks, streams, rights-of-way and appurtenances, existing utilities, north point indicator (arrow), contour lines, and profiles. Master plan and general development drawings on existing and proposed Navy installations are maintained and constantly upgraded by the Resident Officer in Charge of Construction (ROICC) and by the Public Works Department (PWD).

PRESENTATION DRAWINGS

PRESENTATIONS DRAWINGS present the proposed building or facility in an attractive setting in its natural surroundings at the proposed site. These often consist of perspective views complete with colors and shading. Presentation drawings are actually used to “sell” an idea or a design concept.

SHOP DRAWINGS

SHOP DRAWINGS are drawings, schedules, diagrams, and other related data used to illustrate a material, a product, or a system for some portion of the work prepared by the construction contractor, subcontractor, manufacturer, distributor, or supplier. Product data include brochures, illustrations, performance charts, and other information by which the work will be judged. As a BU, you may be required to draft shop drawings for minor shop and field projects, but, on the other hand, let the EAs do these drawings.

WORKING DRAWINGS

A WORKING DRAWING (also called project drawing) is any drawing that furnishes the information the craftsmen requires to manufacture a machine part or a builder crew requires to erect a structure; it is prepared from a freehand sketch or a design drawing. Complete information is presented in a set of working drawings that are complete enough for the user to require no further information. Project drawings include all of the drawings necessary for the different Seabee ratings to complete the project. These are the drawings that show the size, quantity, location, and relationship of the building components.

A complete set of project drawings consists of general drawings, detail drawings, and assembly drawings. General drawings consist of “plans” (views from above) and elevations (side or front views) drawn on a relatively small defined scale, such as 1/8 in. = 1 ft. Most of the general drawings are drawn in orthographic projections, although sometimes details may be shown in isometric or cavalier projections. Detail drawings show a particular item on a larger scale than that of the general drawing in which the item appears, or it may show an item too small to appear at all on a general drawing. Assembly drawings are either an exterior or a sectional view of an object showing the details in the proper relationship to one another. Usually, assembly drawings are drawn to a smaller scale than are detail drawings. This procedure provides a check on the accuracy of the design of detail drawings and often discloses errors.

Construction drawings are reviewed and evaluated for design and technical accuracy by NAVFACENGCOM to ensure good quality, consistency, and cost effectiveness of the design. Special terms covered in the following paragraphs describe these procedures from the initial development of the project to the final phase of construction.

PRELIMINARY DRAWINGS

PRELIMINARY DRAWINGS are the initial plans for projects prepared by the designer or architect’s and engineer’s (A/E) firm during the early planning or promotional stage of the building development. They provide a means of communication between the designer and the user (customer). These drawings are NOT intended to be used for construction, but they are used for exploring design concepts, material selection, preliminary cost estimates, approval by the customer, and a basis for the preparation of finished working drawings.

Notice that most of the design work incorporated into the preliminary drawings at the 35 percent stage of completion contain, as a minimum, the following information: site plans, architectural floor plans, elevations, building sections, preliminary finish schedule and furniture layouts, interior and exterior mechanical and electrical data, and civil and structural details. All of the preliminary project drawings scheduled for use by the Seabees are reviewed by the COMSECONDNCB or COMTHIRDNCB, as appropriate e, for construction methods or procedures, whereas preliminary contract drawings are reviewed by the ROICC.

FINAL DRAWINGS

FINAL DRAWINGS are 100 percent complete, signed by the contracting officer, and are used for bidding purposes. This set of plans becomes the official contract drawings once the contract is awarded. Final drawings are often revised to show changes made by a scope change or by a change order with the concurrence of both the contractor and the contracting officer. At this stage of completion, no further functional input may be introduced into the final drawings because of time constraints. In general, final drawings, together with project specifications, cost estimates, and all of the calculations, comprise the final stages of design requirements.

RED-LINED DRAWINGS

RED-LINED DRAWINGS are the official contract drawings that you will mark up during construction to show as-built conditions. They are marked in the color “red” to indicate either a minor design change or a field adjustment.

AS-BUILT DRAWINGS

AS-BUILT DRAWINGS are the original contract drawings (or sepia copies) that you will change to show the conditions from the red-lined drawings. When the facilities have been completed, the construction contractor or the military construction force (NMCB) is required to provide the ROICC with as-built drawings, indicating construction deviations from the contract drawings. All of the as-built marked-up prints must reflect the exact conditions on all features of the project as constructed. After the project is completed, the ROICC transmits the as-built marked-up prints to the engineering field division (EFD).

RECORD DRAWINGS

The original contract drawings, corrected according to the marked prints, provide a permanent record of as-built conditions when the construction work on a project is completed. The original RECORD DRAWINGS may be retained in the custody of the

EFD, or they may be transferred to the station commanding officer in a current status by such commands.

PROJECT DRAWINGS PREPARATION

All Naval Facilities Engineering Command (NAVFACENGCOM) project drawings are prepared according to DoD-STD-100. The policy and procedures for preparing and developing these drawings are outlined in the Military *Handbook,* MIL-HDBK 1006/1. Project drawings must be complete, accurate, and explicit since they (together with the design specifications) form the basic ingredients used in contracts for the construction of naval facilities.

POLICY AND STANDARDS

The design criteria for project drawings are set by NAVFACENGCOM. These criteria also applv to definitive designs and standard drawings and to project specifications. EFDs and A&Es are allowed latitude in new concepts, creative thinking, and the use of new materials; however, when deviations from mandatory criteria are considered, EFD and A&E need to obtain prior clearance from NAVFACENGCOM headquarters.

For dimensions on project drawings, you may use customary U.S. dimensions unless the project is in an area in which System International (S1) is normally used. The International System of Units is the international y accepted “metric” system. For details of the proper use of S1 units, see appendix I. Refer to ASTM E380-82, *Standard for Metric Practice,* for generic conversions and ASTM E621-79, *Recommended Practice for the Use of Metric (SI) Units in Building Design and Construction,* for conversions in engineering and design.

ORDER OF DRAWINGS

Project drawings for buildings and structures are arranged in the following order:

1. TITLE SHEET and INDEX—Contains specific project title and an index of drawings. (Used only for projects containing 60 or more drawings).

2. SITE or PLOT PLANS—Contains either site or plot plans or both, as well as civil and utility plans. For small projects, this sheet should include an index of the drawings.

3. LANDSCAPE and IRRIGATION—(if applicable).

4. ARCHITECTURAL—(including interior design as applicable).

5. STRUCTURAL.

6. MECHANICAL—(heating. ventilation. and air conditioning).

7. PLUMBING.

8. ELECTRICAL.

9. FIRE PROTECTION.

DRAWING SHEET SIZES

Standard drawing sheet sizes are used to facilitate readability, reproduction, handling, and uniform filing. Blueprints, produced from standard-size drawing sheets, are easily assembled insets for project stick files. The NCF uses two format sizes. These are flat and roll sizes according to ANSI Y14.1, and they are approved for use by DoD-STD 100. **Flat** size refers to drawings that are relatively small in size and should be stored or filed flat. **Roll** size refers to drawings that are filed in rolls due to their length.

TYPE	SIZE (IN INCHES)
Flat	17 x 22 (C size)—when small sheets are required
Flat	22 x 34 (D size)—for project and other drawings
Flat	28 x 40 (F size)—option to 22 x 34

TITLE BLOCK

The title block identifies each sheet in a set of drawings (fig. 2-1). Generally, the title block is located at the bottom right corner of the drawing, regardless of the size of the drawing (except for vertical title block). For further information on the layout of title blocks, refer to the *Military Handbook,* MIL-HDBK 1006/1, or the *Engineering Aid Basic,* NAVEDTRA 12535.

The information provided in the title block is very important information that you, the Builder, MUST understand. In addition to the size of the drawing,

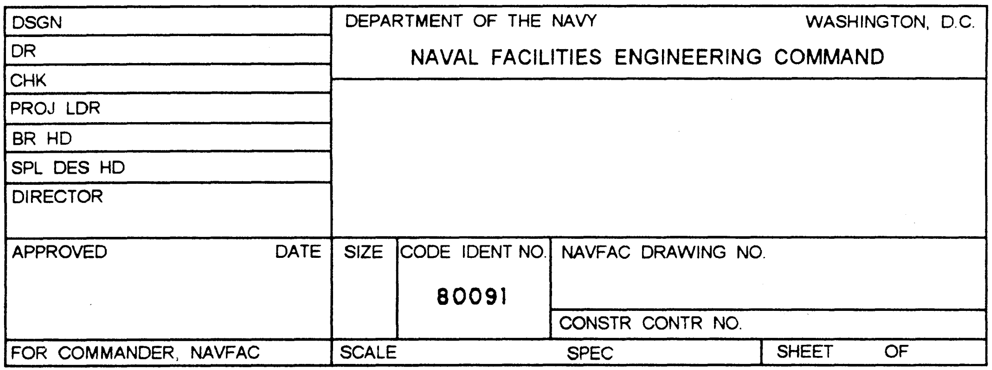


Figure 2-1.—Title block.

other information provided in the title block is as follows:

- Architect's name
- Architect's seal
- Drawing title
- Date prepared
- Revisions
- Designed by
- Checked by
- Drawing numbers
- Name of local activity
- Code ID number (80091 NAVFAC)
- Letter designation
- Size of drawing
- Scale of drawing
- ABFC drawing number (if applicable)
- Approved by

There are many variations to title blocks. Depending on the preparing activity (NAVFAC, NCR, NMCB, A&E, etc.), all title blocks should contain the same information listed previously. The code ID number of the Federal Supply Code of Manufacturers (FSCM) "80091" is required in the title block of all NAVFAC drawings. The layout and title blocks are also shown in the *American National Standard Institute* (ANSI Y14.1-1980) manual.

DRAWING NUMBERS

NAVFACENGCOM drawing numbers issued to individual engineering field division are within the following limits:

NORTHERN DIVISION.	2 000 000	to	2 999 999
CHESAPEAKE DIVISION.	3 000 000	to	3 999 999
ATLANTIC DIVISION	4 000 000	to	4 999 999
SOUTHERN DIVISION	5 000 000	to	5 999 999
WESTERN DIVISION.	6 000 000	to	6 999 999
PACIFIC DIVISION.	7 000 000	to	7 999 999

NAVFACENGCOM headquarters retains custody of all of the numbers up to and including 1 999999 and all other drawing numbers not assigned. Each cognizant EFD is responsible for the control of assigned numbers and for issuing, assigning, and recording these numbers for its own use or the use of activities within its geographical area. Each activity maintains an assignment record including locations and drawing titles of drawing numbers assigned to it. Figure 2-2 is an example of a local activity, such as the Civil Engineering Support Office (CESO), using a drawing number assigned by the Western Division (WESTDIV). This title block is from the *Facilities Planning Guide,* NAVFAC P-437.

You may not use a NAVFACENGCOM assigned number for any other drawing, even though the drawing to which it has been assigned is not being used. Sometimes, because of extensive revision on a particular drawing, it becomes necessary to prepare a new drawing and to assign a new NAVFACENGCOM drawing number.

If you find major problems within a drawing, you can identify "who" prepared the drawing by these drawing numbers. However, make sure you communicate through your chain of command before contacting these divisions.

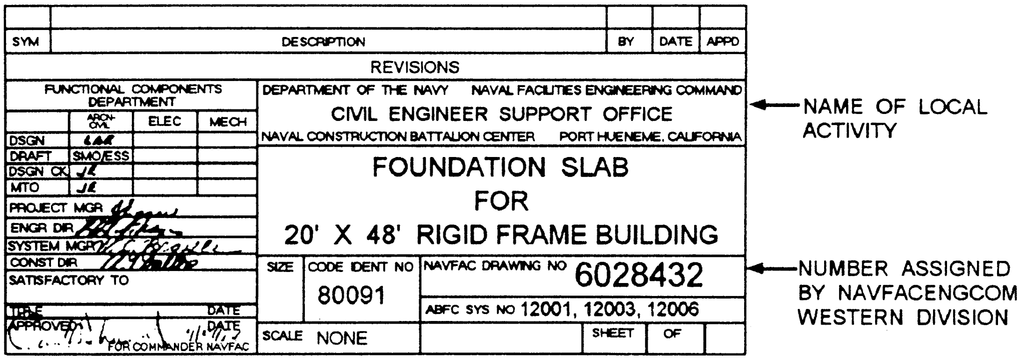


Figure 2-2.—CESO drawing number.

DRAWING REVISIONS

A Revision block contains a list of revisions made to a drawing. The Revision block is in the upper right-hand corner. Drawing revisions to NAVFACENGCOM project drawings are to be made according to DoD-STD-100C. The Revision block may include a separate "PREPARED BY" column to indicate the organization, such as an A/E firm, that prepared the revision. Like title blocks, revision blocks may vary in format with each command.

GRAPHIC SCALES

Graphic scales are in the lower right-hand corner of each drawing sheet with the words *Graphic Scales* directly over them. The correct graphic scales must be shown prominently on each drawing, because as drawings are reduced in size, the reductions are often NOT to scaled proportions. <u>Remember, scaling a drawing should be a done as a "last resort."</u>

DRAWING SYMBOLS

Because of the small scale used in most drawings, standard graphic symbols are used to present complete information concerning construction items and materials. These typical symbols are used so frequently in construction drawings that their meaning must be familiar not only to the preparer, but to the user as well. The main information sources for a particular symbol are the Military (Drawing) Standards (MIL-STD) and the American National Standards Institute (ANSI). Refer to these standards before you use other references. The following is a list of the most commonly used military standards.

Standard	Description
MIL-STD-14	*Architectural Symbols*
MIL-STD-17-1	*Mechanical Symbols*
MIL-STD-18	*Structural Symbols*
ANSI Y32.9-1972	*Graphic Symbols for Electrical Wiring and Layout Diagrams Used in Architecture and Building Construction*
ANSI Y32.4-1977	*Graphic Symbols for Plumbing Fixtures for Diagrams Used in Architecture and Building Construction*
NSI/AWS A2.4-1986	A *Symbols for Welding*

As a Builder, you will find that your knowledge of the applicable symbols will assist you greatly in doing the job correctly and promptly, and above all, with confidence. In figure 2-3, symbols are used to identify sections, elevations, and details that are commonly misinterpreted. Some of the basic architectural symbols, as shown in figure 2-4, are commonly found on site or plot plans. Structural symbols are shown in the NAVFAC P-405, the *Steelworker*, vol. 1, and the *Engineering Aid Basic.*

DRAWING NOTES

NOTES are brief, clear, and explicit statements regarding material use and finish and construction methods. Notes in a construction drawing are classified as specific and general.

SPECIFIC NOTES are used either to reflect dimensioning information on the drawing or to be explanatory. As a means of saving space, many of the terms used in these notes are often expressed as abbreviations.

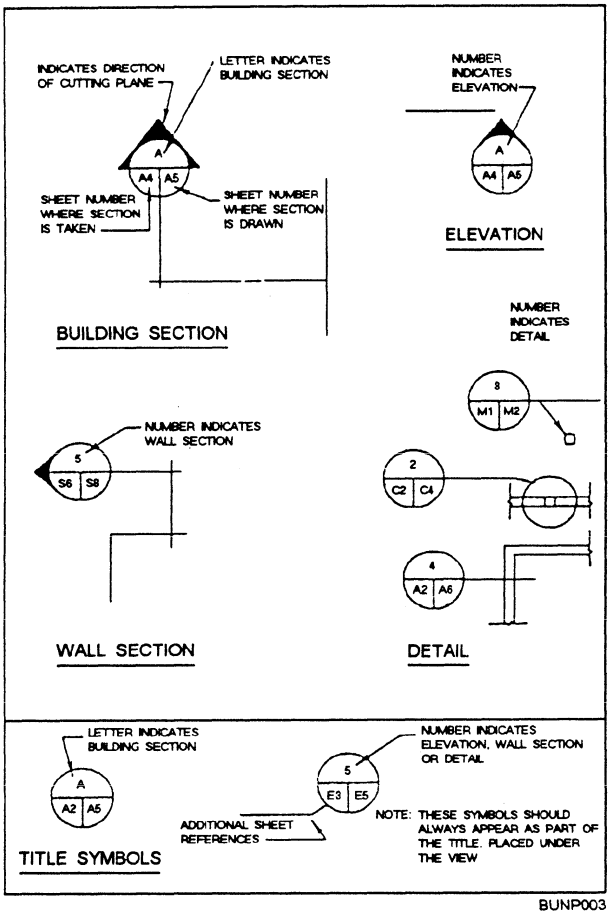


Figure 2-3.—Symbols used to identify sections, elevations, and details.

GENERAL NOTES refer to all of the notes on the drawing not accompanied by a leader and an arrowhead. As used in this TRAMAN, general notes for a set of drawings that cover one particular type of work are placed on the first sheet of the set. General notes are usually placed a minimum of 3 inches below the Revision block. General notes for architectural and structural drawings may include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable unit stresses of all the construction materials used in the design. General notes for civil, mechanical, electrical, sanitary, plumbing, and similar drawings of a set may include, when applicable, references for vertical and horizontal control (including sounding) and basic specific design data.

General notes may also refer to all of the notes grouped according to materials of construction in a tabular form, called a SCHEDULE. Schedules for items, like doors, windows, rooms, and footings, are somewhat more detailed. Formats for these are covered later in this chapter.

MAIN DIVISIONS OF PROJECT DRAWINGS

Generally, working or project drawings are divided into the following major divisions: civil, architectural, structural, mechanical, electrical, HVAC, and fire protection. In Seabee construction, however, the major divisions most commonly used are as follows: civil, architectural, structural, mechanical, and electrical. As Builders, you will deal mainly with civil, architectural, and structural divisions. For the electrical division, you can refer to the *Construction Electrician (CE) Advanced* along with the fire protection division. For information pertaining to the mechanical division, along with heating, venting, and air-conditioning (HVAC), you can refer to the *Utilitiesmen Advanced.*

Regardless of the category, working drawings serve the following functions:

- They provide a basis for making material, labor, and equipment estimates before construction begins.
- They give instructions for construction, showing the sizes and locations of the various parts.
- They provide a means of coordination between the different ratings.
- They complement the specifications; one source of information is incomplete without the others.

CIVIL DRAWINGS

CIVIL WORKING DRAWINGS encompass a variety of plans and information to include the following:

- Site preparation and site development
- Fencing
- Rigid and flexible pavements for roads and walkways
- Environmental pollution control
- Water supply units (that is, pumps and wells)

Depending on the size of the construction project, the number of sheets in a set of civil drawings may vary from a bare minimum to several sheets of related drawings. Generally, on an average-size project, the first sheet has a location map, soil boring log, legends, and sometimes site plans and small civil detail

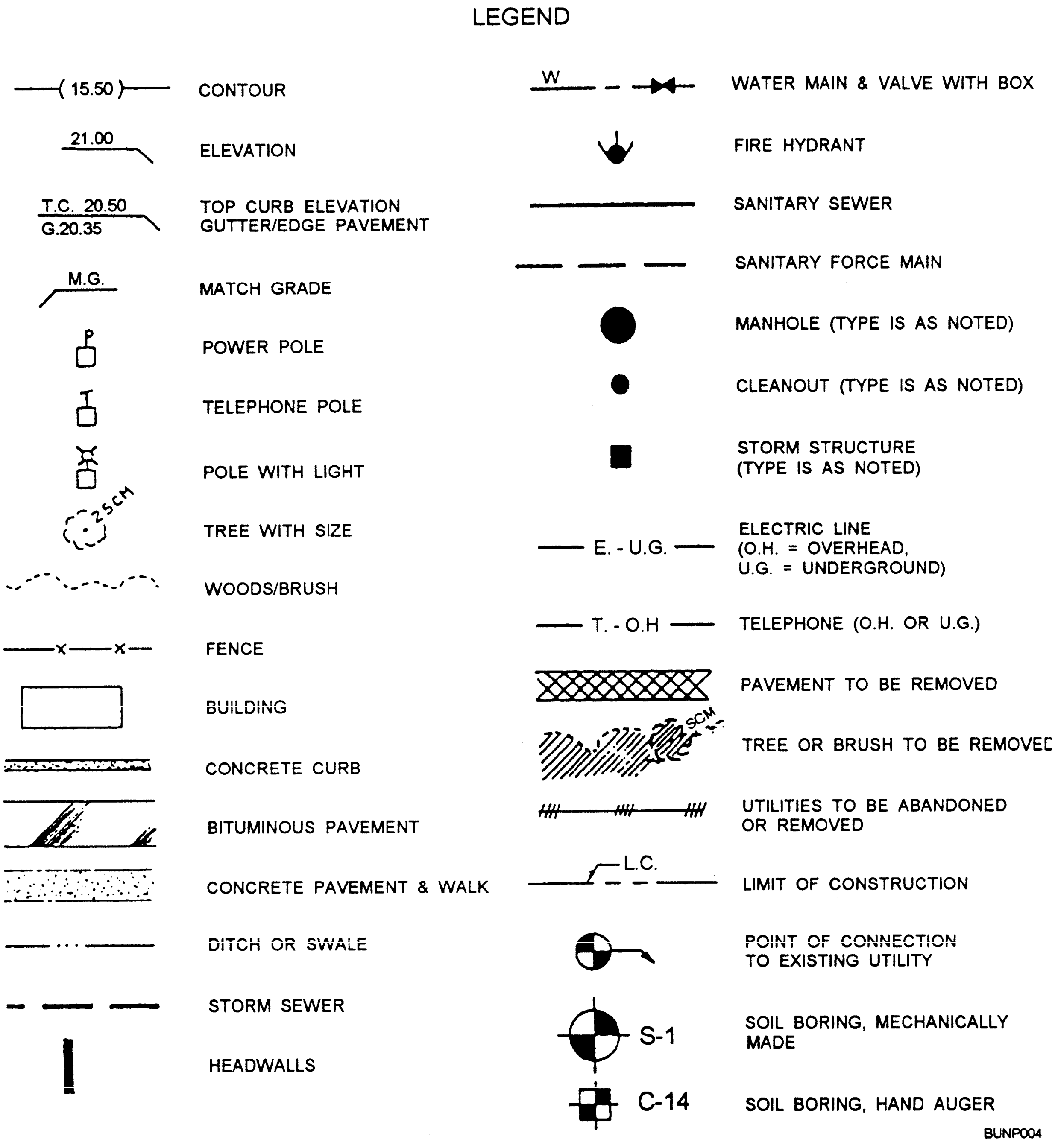


Figure 2-4.—Sample legend of symbols.

drawings. (Soil boring tests are conducted to determine the water table of the construction site and classify the existing soil.) Civil drawings are often identified with the designating letter C on their title blocks.

A SITE PLAN (fig. 2-5) furnishes the essential data for laying out the proposed building lines. It is drawn from notes and sketches based upon a survey. It shows the contours, boundaries, roads, utilities, trees, structures, references, and other significant physical features on or near the construction site. By showing both existing and finished contours, the field crews (Equipment Operators) are able to estimate and prepare the site for construction and to finish the site (including landscaping) upon completion of construction. As a BU, you should be familiar with the methods and symbols used on maps and topographic drawings. Site plans are drawn to scale. In most

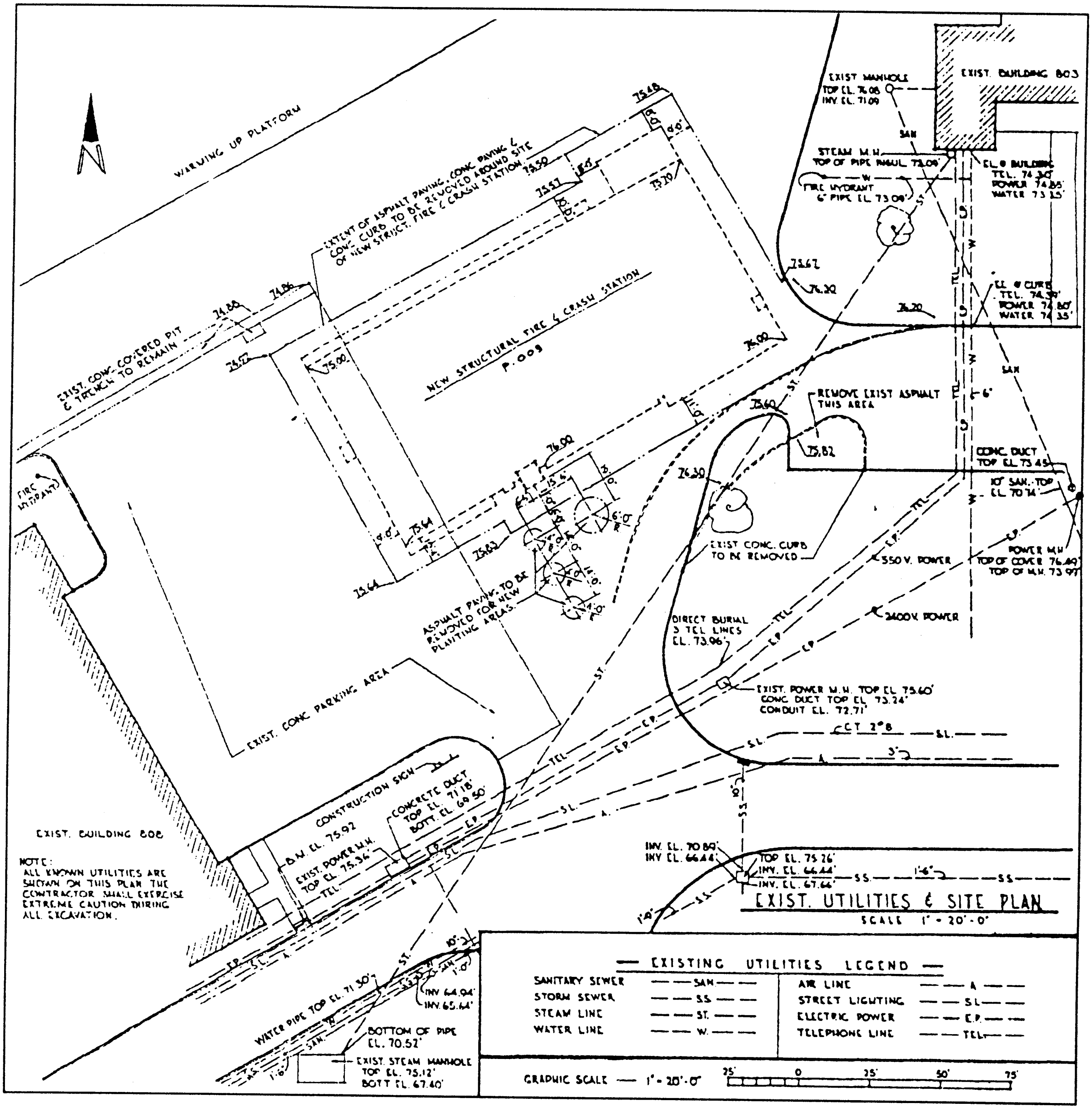


Figure 2-5.—Site plan.

instances, the engineer’s scale is used, rather than the architect’s scale. Refer to the *Engineering Aid Basic* and the *Engineering Aid Intermediate/Advanced* for more information.

ARCHITECTURAL DRAWINGS

ARCHITECTURAL DRAWINGS are identified with the designating letter *A* on their title blocks. These drawings consist of all the architectural design and composition of the building. A set of architectural drawings includes floor plans, building sections, exterior and interior elevations, millwork, door and window details and schedules, interior and exterior finish schedules, and special architectural treatments. For small, uncomplicated buildings, the architectural drawings might also include foundation and framing plans, which are generally included as part of the structural drawings.

Floor Plan

The FLOOR PLAN is the key drawing in a set of project drawings—the drawing that all of the construction personnel look at. Hence the purpose of the floor plan is to show information about the location and type of construction, location of doors, windows, built-in fireplaces, stairs, rooms, and exterior and interior features. Ideally, drawings of floor plans should be drawn to 1/4 in. = 1 ft scale for easy readability. Figure 2-6 represents a drawing of a first floor plan and first floor framing plan.

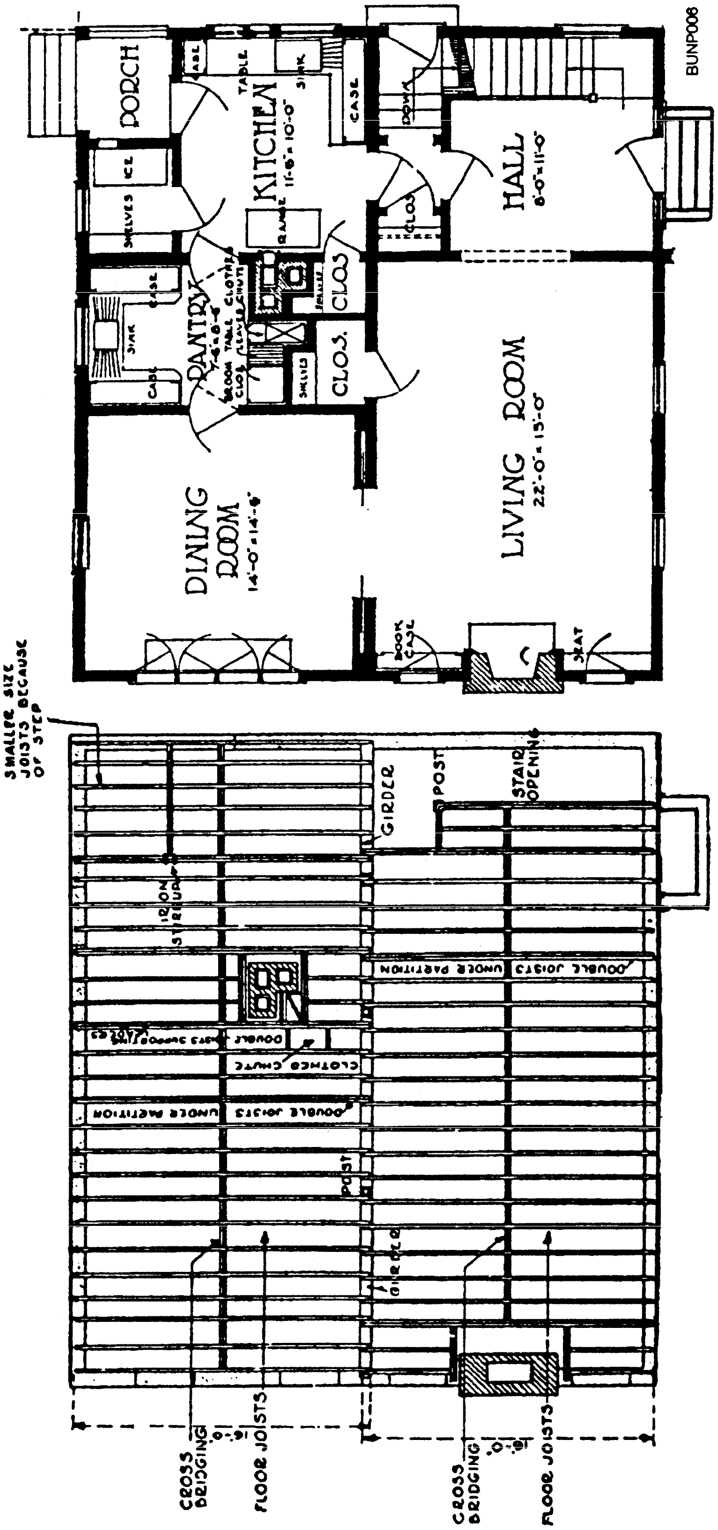


Figure 2-6.—A first floor plan and first floor framing plan.

Elevations

ELEVATIONS are orthographic projections, showing the finished interior and exterior appearance of the structure. Interior elevations are required for important features, such as built-in cabinets and shelves, but it is not uncommon for elevations to be drawn for all interior walls in each room of a building. Cabinet elevations show the cabinet lengths and heights, distance between base cabinets and wall cabinets, shelf arrangements, doors and direction of door swings, and materials used. Interior wall elevations show wall lengths, finished floor-to-ceiling heights, doors, windows, other openings, and the types of finish materials used.

Exterior elevations show the types of materials used on the exterior, the finished grade around the structure, the roof slope, the basement or foundation walls, footings, and all of the vertical dimensions.

Basically, the following four elevations are needed in a set of drawings to complete the exterior description: the front, the rear, and two sides of a structure, as they would appear projected on vertical planes. A typical elevation is drawn at the same scale as the floor plan, either 1/4 in. = 1 ft or 1/8 in. = 1 ft; however, occasionally a smaller scale may be used because of space limitations, or a larger scale maybe used to show more detail.

Several methods are used to identify each elevation, as it relates to the floor plan. The method Seabees most commonly use is labeling the elevations with the same terminology used in multiview and orthographic projection; that is, FRONT, REAR, RIGHT-SIDE, and LEFT-SIDE ELEVATIONS or sometimes NORTH, SOUTH, EAST, and WEST.

STRUCTURAL DRAWINGS

The STRUCTURAL DRAWINGS (usually identified with the designating letter *S* on the title block) consist of all of the drawings that describe the structural members of the building and their relationship to each other. A set of structural drawings includes foundation plans and details, framing plans and details, wall sections, column and beam details, and other plans, sections, details, and schedules necessary to describe the structural components of the building or structure. The general notes in the structural drawings should also include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable stresses of all material used in the design.

Foundation Plan

A FOUNDATION PLAN is a top view of the footings or foundation walls, showing their area and their location by distances between centerlines and by distances from reference lines or boundary lines. Actually, it is a horizontal section view cut through the walls of the foundation showing beams, girders, piers or columns, and openings, along with dimensions and internal composition.

Primarily the building crew uses the foundation plan to construct the foundation of the proposed structure. In most Seabee construction, foundations are built with concrete-masonry units (CMU) or cast-in-place concrete. Figure 2-7 shows a plan view of a 20’ x 48’ PEB, as it would look if projected into a horizontal plane that passes through the structure. In this typical drawing, notice that only the placement of the anchor bolts are shown, along with a typical detailed drawing of the footing, the column, and the slab.

Framing Plan

The FRAMING PLANS show the size, the number, and the location of the structural members constituting the building framework. Separate framing plans are drawn for the floors and roofs. Occasionally, the Draftsman will draw a wall framing plan; however, wall framing plans are generally viewed in the sectional views or detail drawings.

The FLOOR FRAMING PLAN must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings must be added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings.

The floor framing plan is basically a plan view, showing the layout of the girders and joists. Figure 2-8 shows the manner of presenting floor framing plans. The unbroken double-line symbol indicates joists. Joist symbols are drawn in the position they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used. Bridging is also shown by a double-line symbol that runs perpendicularly to the joist. In figure 2-8, the number of rows of cross bridging is controlled by the span of the joist; place the rows no more than 8 feet apart. Hence a 14-foot

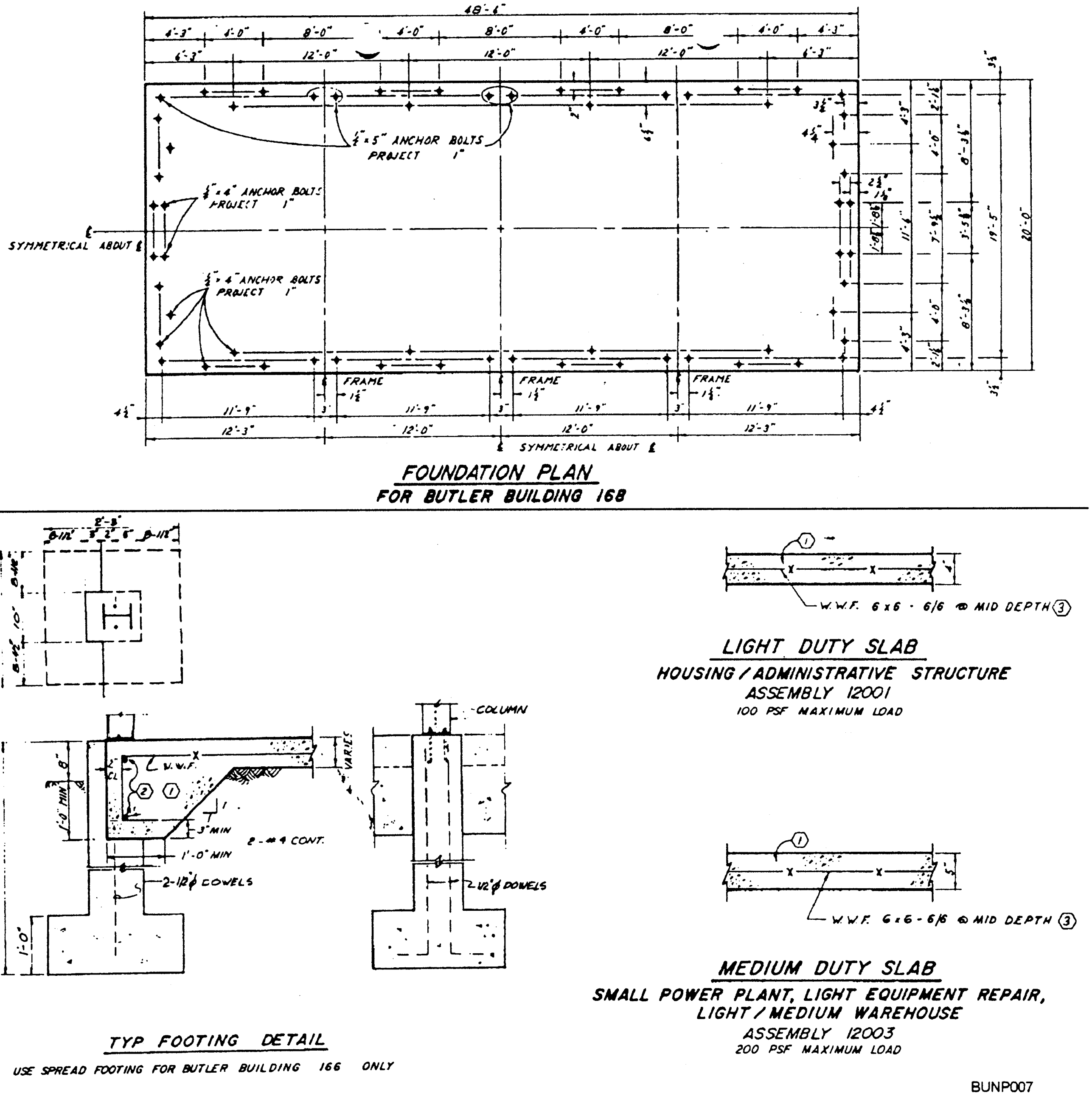


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Figure 2-7.—Foundation plan with detail drawings.

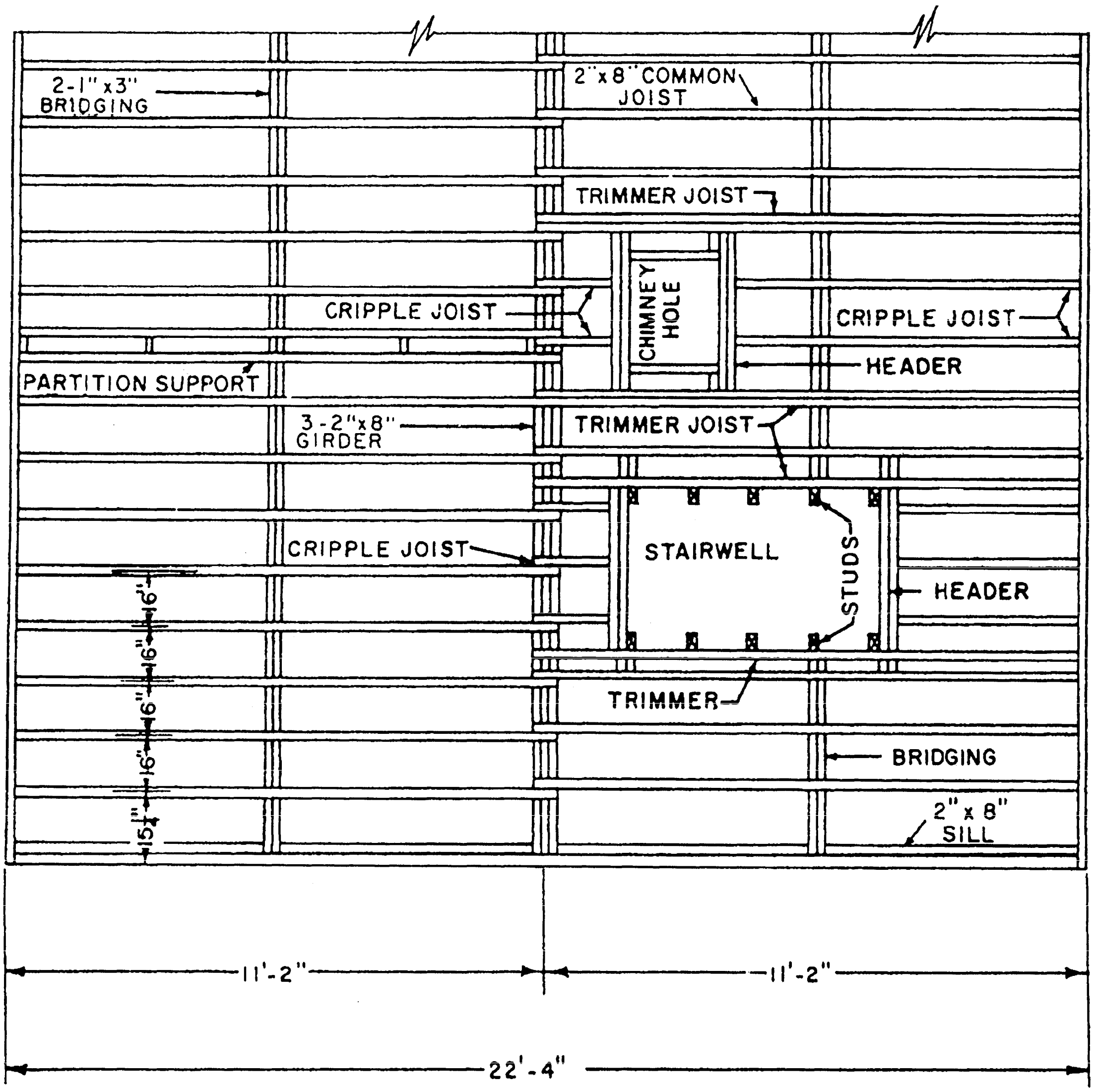


Figure 2-8.—Floor framing plan.

span may need only one row of bridging, but a 16-foot span needs two rows.

Dimensions need not be given between joists. Such information is given along with the notes. For example, 2" x 8" joists @ 2 ft - 0 in. OC indicates that the joists are to be spaced at intervals of 2 ft 0 in. on center (OC). Lengths may not be indicated in framing plans; the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such data. Notes also identify floor openings, bridging, girts, or plates.

The ROOF FRAMING PLANS show the construction of the railers used to span the building and support the roof. The size, the spacing, the roof slope, and all of the details are also shown in the plan. The roof framing plan is drawn in the same manner as the floor framing plan; rafters are shown in the same manner as joists. Figure 2-9 is an example of a roof framing plan for a wood-framed roof. Roof framing plans in the construction world today are very technical and highly engineered (wind resistance, load-bearing capacity, etc.), and in most “stick frame” construction, pre-fab yards or truss manufacturers (civilian sector) provides your roof system.

Sections

As necessary, SECTIONS are used in each of the main divisions of construction drawings to show the types of construction required, the types of materials used, their locations, and the method of assembling the building parts. Although they may be used in each of

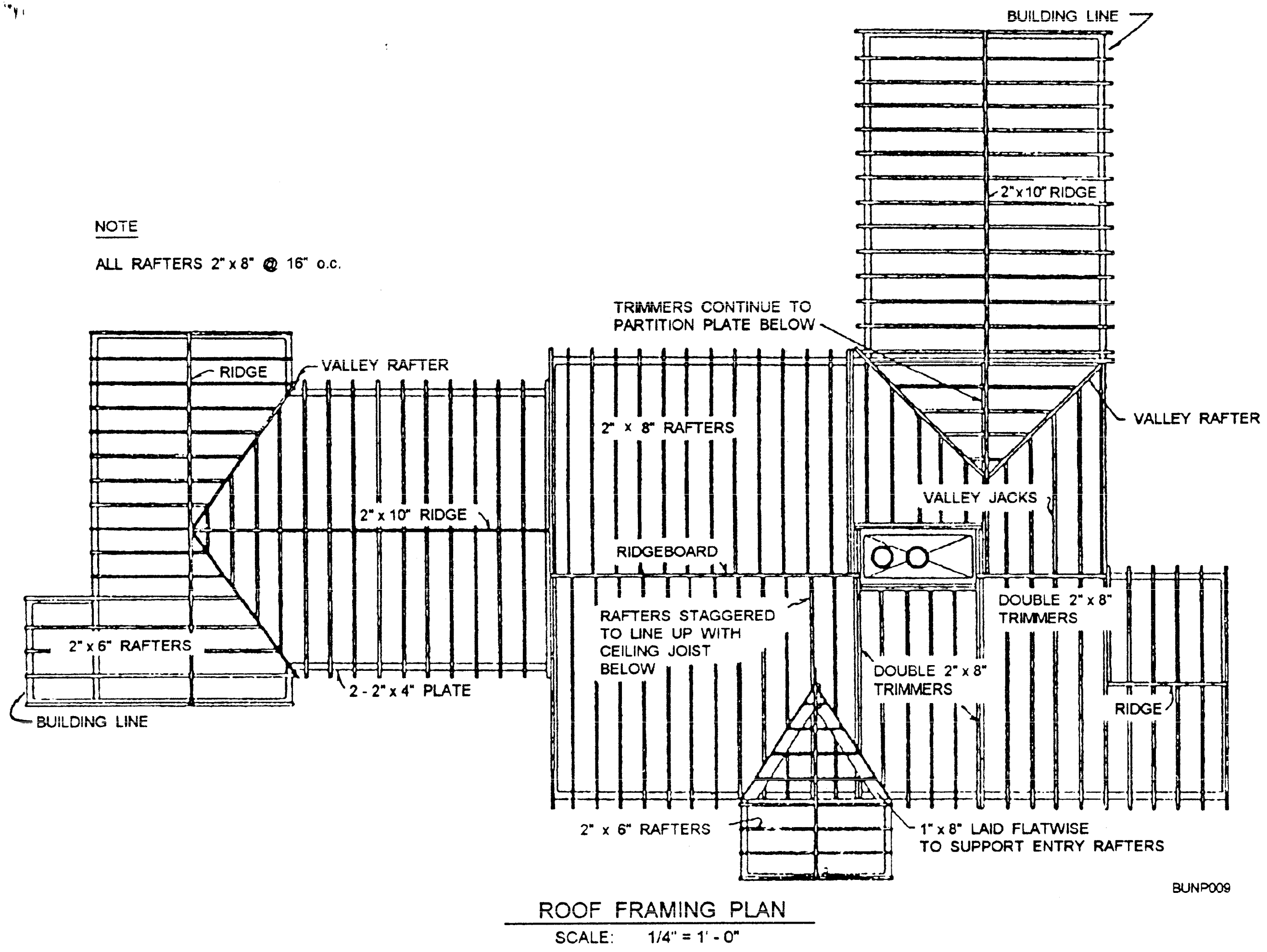


Figure 2-9.—Roof framing plan.

the divisions, the most common sections are generally located in the architectural and structural divisions.

All properly prepared sections are important to those responsible for constructing a building. To Builders, the most important sectional drawings are the wall sections, such as those shown in figure 2-10. These sections, commonly drawn at a scale of 3/4 in. = 1 ft and normally located in the structural division, provide a wealth of information that is necessary to understand structural arrangement, construction methods, and material composition of the walls of the building.

Details

DETAILS are large-scale drawings of the construction assemblies and installation that were not clearly shown in the sections. These enlarged drawings show the Builder **how** the various parts of the structure are to be connected and placed. The construction of specific types of foundations, doors, windows, insulation, cornices, and so forth, is customarily shown in the detail drawings located within their appropriate main division of the construction drawings. Details are usually grouped together so that references may be made readily available. Figure 2-7 shows a detail of a typical concrete footing.

The scale selected for details depends on how large it needs to be drawn to explain the necessary information clearly. Details are usually drawn at a larger scale than sections, generally 3/4 in., 1 1/2 in.,

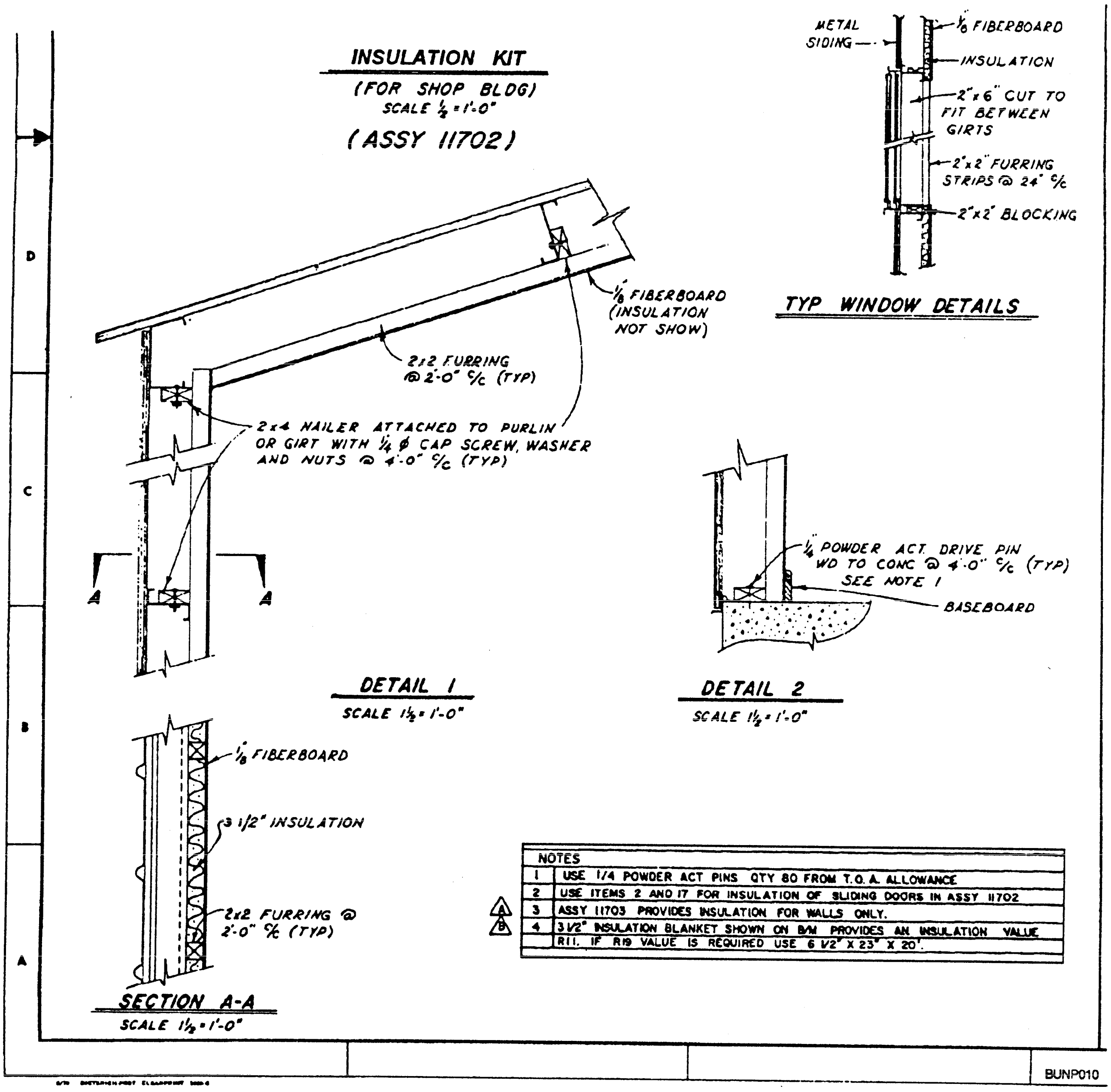


Figure 2-10.—Sectional view.

or 3 in. 1 ft. Details commonly used are readily available in the Architectural Graphics Standards (AGS).

Schedules

SCHEDULES are tabular or graphic arrangements of extensive information or notes related to construction materials. The use of schedules presents a quick and easy way for planners, estimators, contractors, and suppliers to share similar data, hence reducing construction errors and saving time. In the Seabees, the success of the planners and estimators (P&E) in accurately preparing takeoff of the supply department (S-4) in properly ordering construction materials, and of the construction crew (line companies and detachments) in installing the materials in their proper locations depends greatly upon the efficiency with which the relative information is conveyed on the drawing (plans).

The material information most commonly placed in schedules relates to doors, windows, room finishes, lintels, and other structural elements. A DOOR SCHEDULE varies from being a bare minimum (for small jobs) to being extensive (for large projects). A door schedule may include the following: door number, quantity, mark or code number, type, size, material description, lintel, and remarks.

An example of a tabular door schedule is shown in table 2-1. Doors are commonly marked with a number or numbers and letters. Letter *D* is a common designation used for doors (sometimes enclosed in a circle or other shape).

A WINDOW SCHEDULE (table 2-2) provides an organized presentation of the significant window characteristics. Information often includes the following: mark, window type, size, required opening size, material type, lintel, and remarks. Windows are often marked with letters or letters with numbers. The letter *W* is used most commonly for window schedules.

A MATERIAL FINISH SCHEDULE (table 2-3) may include the following: room number, material finish for floors, walls, base, and remarks. Where several rooms in a row have an identical finish, a common practice is for the ditto mark(") or the initials DO is used. It is essential that you take care when making changes in the material finish used in a

Table 2-1.—Door Schedule

Mark	SIZE	DESCRIPTION	REMARKS
1	3′-0" × 6′-8" × 1 3/4"	EXT. Metal Insul	Decor
2	2-3′-0" × 6′-8" × 1 3/4"	EXT. S/C OAK/ 4 lite	French
3	2′-8" × 6′-8" × 1 3/8"	INT. H/C S/PINE	Flush

Table 2-2.—Window schedule

Mark	SIZE	DESCRIPTION	REMARKS
	3′-0" × 3′-0"	Alum. frame DSB	Dbl/hung
	4′-5 1/8" × 4′-2 5/8"	Metal frame DSB	Jalouise

Table 2-3.—Material Finish Schedule

ROOM	FLOOR	WALLS	CEILING	BASEBOARD	TRIM
Dining and living	1" × 4" Oak	1/2" Drywall paint white	1/2" Drywall paint white	Wood	Wood
Bedroom	Carpet w/foam pad	1/2" Drywall paint Beige	1/2" Drywall paint white	Wood	Wood
Bathroom	Linoleum-tan	1/2" Drywall paint white	1/2" Drywall paint white	Lino-cove	Wood
Kitchen	Linoleum-tan	1/2" Drywall paint white	1/2" Drywall paint white	Lino-cove	Wood
Utility room	Linoleum-tan	1/2" Drywall paint white	1/2" Drywall paint white	Lino-cove	Viny l

particular room, because the changes you make will greatly affect other rooms below it. Errors are less likely to occur and revisions will be easier to handle when each space in the schedule is lettered individually. Remember, whenever possible, place all of the schedules on the same sheet as their respective drawings on the building.

WRITTEN SPECIFICATIONS

Because many aspects of construction cannot be shown graphically, even the best prepared construction drawings often inadequately show some portions of a project. For example, on a drawing can anyone show the quality of workmanship required for the installation of doors and windows, or who is responsible for supplying the materials? These are things that can be conveyed only by hand-lettered notes. The standard procedure is to supplement construction drawings with detailed written instructions. These written instructions, called specifications (or more commonly specs), define and limit materials and fabrication to the intent of the engineer or designer.

Usually, it is the design engineer's responsibility y to prepare project specifications. As a Builder, you will be required to read, interpret, and use these in your work as a crew leader or supervisor. You must be familiar with the various types of federal, military, and nongovernmental reference specifications used in preparing project specs. When assisting the engineer in preparing or using specifications, you also need to be familiar with the general format and terminology used,

NAVFAC SPECIFICATIONS

The Naval Facilities Engineering Command (NAVFACENGCOM) prepares NAVFAC specifications and sets standards for all construction work performed under its jurisdiction. This includes work performed by the Seabees. The three types of NAVFAC specifications are covered in the following information.

NAVFACENGCOM Guide Specifications

NAVFACENGCOM guide specifications (NFGS) are the primary basis for preparing specifications for construction projects. These specifications define and establish the minimum criteria for construction, materials, and workmanship and must be used as guidance in the preparation of project specifications. Each of these guide specifications (of which there are more than 300) encompass a wide variety of different materials, construction methods, and circumstances. Therefore, they must be tailored to suit the work actually required by the specific project.

To better explain this, let's look at figure 2-11 which is a page taken from a NAVFACENGCOM guide specification. In this figure, you can see that there are two paragraphs numbered 3.2.1. This indicates that the spec writer must choose the paragraph that best suits the particular project for which he or she is writing the specification. The capital letters *I* and *J* in the right-hand margin next to those paragraphs refer to footnotes (contained elsewhere in the same guide specification) that the spec writer must follow when selecting the best paragraph. Additionally, you can see that some of the information in figure 2-11 indicates other choices that the spec writer must make. Guide specifications should be modified and edited to reflect the latest proven technology, materials, and methods.

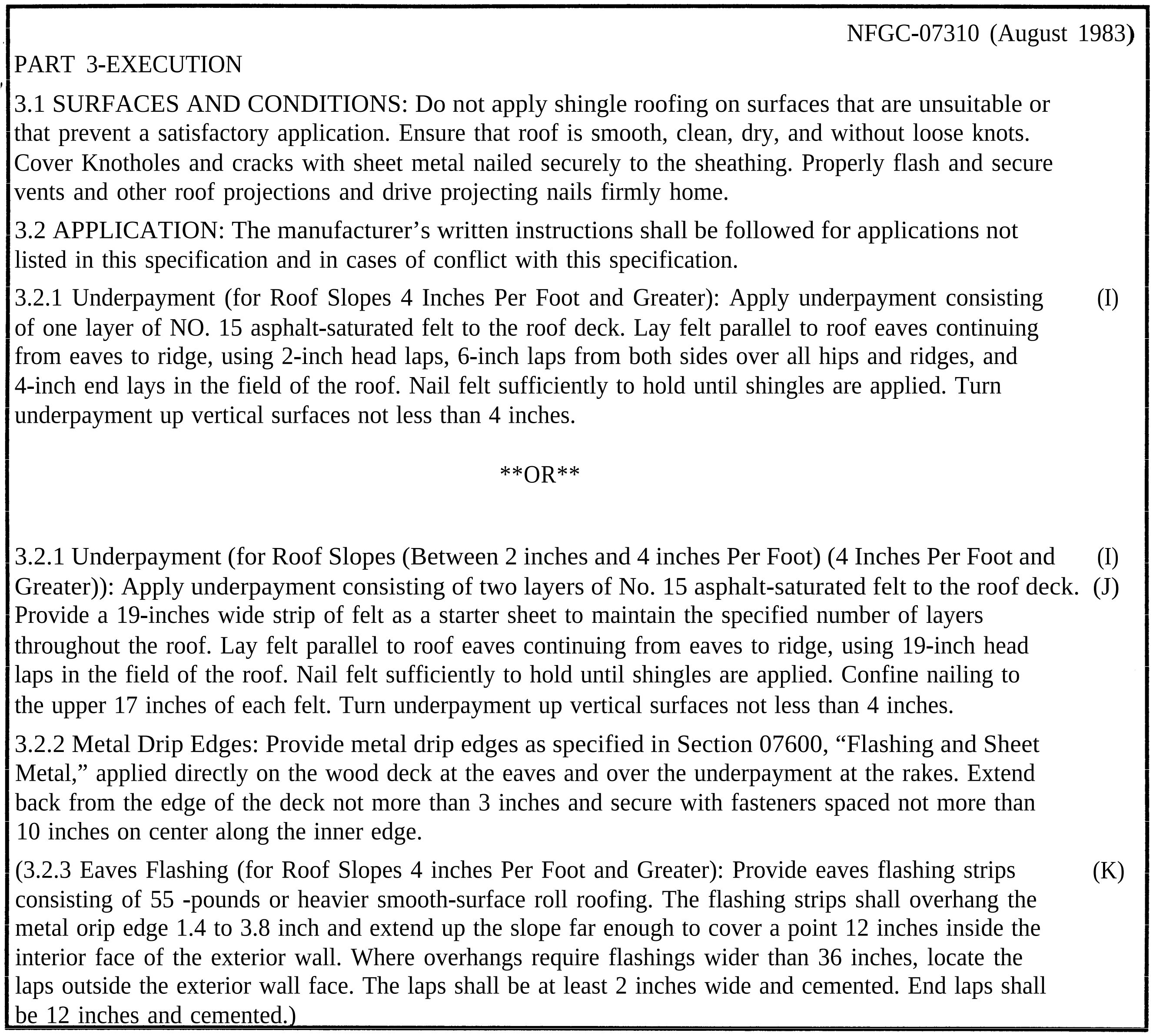
EFD Regional Guide Specifications

Engineering Field Division (EFD) regional guide specifications are used in the same way as the NAVFACENGCOM guide specifications but only in areas under the jurisdiction of an EFD of the Naval Facilities Engineering Field Command. When the spec writer is given a choice between using an EFD regional guide specification or a NAVFACENGCOM guide specification with the same identification number, the writer must use the one with the most recent date. This is because there can only be one valid guide specification for a particular area at any one time.

Standard Specifications

Standard specifications are written for a small group of specialized structures that must have uniform construction to meet rigid operational requirements. NAVFAC standard specifications contain references to federal, military, other command and bureau, and association specifications. NAVFAC standard specifications are referenced or copied in project specifications and can be modified with the modification noted and referenced. An example of a standard specification with modification is shown below.

> "The magazine shall be Arch, Type I, conforming to specifications S-M8E, except that all concrete shall be class F- 1."



NFGC-07310 (August 1983)

PART 3-EXECUTION

3.1 SURFACES AND CONDITIONS: Do not apply shingle roofing on surfaces that are unsuitable or that prevent a satisfactory application. Ensure that roof is smooth, clean, dry, and without loose knots. Cover Knotholes and cracks with sheet metal nailed securely to the sheathing. Properly flash and secure vents and other roof projections and drive projecting nails firmly home.

3.2 APPLICATION: The manufacturer's written instructions shall be followed for applications not listed in this specification and in cases of conflict with this specification.

3.2.1 Underpayment (for Roof Slopes 4 Inches Per Foot and Greater): Apply underpayment consisting of one layer of NO. 15 asphalt-saturated felt to the roof deck. Lay felt parallel to roof eaves continuing from eaves to ridge, using 2-inch head laps, 6-inch laps from both sides over all hips and ridges, and 4-inch end lays in the field of the roof. Nail felt sufficiently to hold until shingles are applied. Turn underpayment up vertical surfaces not less than 4 inches. (I)

OR

3.2.1 Underpayment (for Roof Slopes (Between 2 inches and 4 inches Per Foot) (4 Inches Per Foot and Greater)): Apply underpayment consisting of two layers of No. 15 asphalt-saturated felt to the roof deck. Provide a 19-inches wide strip of felt as a starter sheet to maintain the specified number of layers throughout the roof. Lay felt parallel to roof eaves continuing from eaves to ridge, using 19-inch head laps in the field of the roof. Nail felt sufficiently to hold until shingles are applied. Confine nailing to the upper 17 inches of each felt. Turn underpayment up vertical surfaces not less than 4 inches. (I) (J)

3.2.2 Metal Drip Edges: Provide metal drip edges as specified in Section 07600, "Flashing and Sheet Metal," applied directly on the wood deck at the eaves and over the underpayment at the rakes. Extend back from the edge of the deck not more than 3 inches and secure with fasteners spaced not more than 10 inches on center along the inner edge.

(3.2.3 Eaves Flashing (for Roof Slopes 4 inches Per Foot and Greater): Provide eaves flashing strips consisting of 55 -pounds or heavier smooth-surface roll roofing. The flashing strips shall overhang the metal orip edge 1.4 to 3.8 inch and extend up the slope far enough to cover a point 12 inches inside the interior face of the exterior wall. Where overhangs require flashings wider than 36 inches, locate the laps outside the exterior wall face. The laps shall be at least 2 inches wide and cemented. End laps shall be 12 inches and cemented.) (K)

Figure 2-11.—Sample page from a NAVFACENGCOM guide specification.

OTHER SPECIFICATIONS

The following specifications establish requirements mainly in terms of performance. Referencing these documents in project specifications assures the procurement of economical facility components and services while considerably reducing the number of words required to state such requirements.

Federal and Military Specifications

Federal specifications cover the characteristics of materials and supplies used jointly by the Navy and other government agencies. These specifications do not cover installation or workmanship for a particular project, but specify the technical requirements and tests for materials, products, or services. The engineering technical library should have all the commonly used federal specifications that are pertinent to Seabee construction.

Military specifications are those that have been developed by the Department of Defense (DoD). Like federal specifications, they also cover the characteristics of materials. They are identified by DoD or MIL preceding the first letter and serial number.

Technical Society and Trade Association Specifications

Technical society specifications should be referenced in project specifications when applicable.

The organizations publishing these specifications include, but are not limited to, the American National Standards Institute (ANSI), the American Society for Testing and Materials (ASTM), the Underwriters Laboratories (UL), and the American Iron and Steel Institute (AISI). Trade association specifications contain requirements common to many companies within a given industry.

Manufacturer's Specifications

Manufacturer's specifications contain the precise description for the manner and process for making, constructing, compounding, and using any items the manufacturer produces. They should not be referenced or copied verbatim in project specifications but may be used to aid in the preparation of them.

PROJECT SPECIFICATIONS

Construction drawings are supplemented by written project specifications. Project specifications give detailed information regarding materials and methods of work for a particular construction project. They cover various factors relating to the project, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work. Usually, drawings are accompanied by a set of project specifications. The drawings and project specifications are inseparable. Drawings indicate what the project specifications do not cover. Project specifications indicate what the drawings do not portray and clarify details that are not covered amply by the drawings. When you are preparing project specifications, it is important that the specifications and drawings be closely coordinated so that discrepancies and ambiguities are minimized. Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

ORGANIZATION OF SPECIFICATIONS

For consistency, the Construction Specifications Institute (CSI) has organized the format of specifications into 16 construction divisions. These divisions, used throughout the military and civilian construction industry, are listed in order as follows:

1. General Requirements include information that is of a general nature to the project, such as inspection requirements and environmental protection.

2. **Site Work** includes work performed on the site, such as grading, excavation, compaction, drainage, site utilities, and paving.

3. **Concrete** includes precast and cast-in-place concrete, formwork, and concrete reinforcing.

4. **Masonry** includes concrete masonry units, brick, stone, and mortar.

5. **Metals** include such items as structural steel, open-web steel joists, metal stud and joist systems, ornamental metal work, grills, and louvers. (Sheet-metal work is usually included in Division 7.)

6. **Wood** and **Plastics** include wood and wood framing, rough and finish carpentry, foamed plastics, fiber glass-reinforced plastics, and laminated plastics.

7. **Thermal** and **Moisture Protection** includes such items as waterproofing, dampproofing, insulation, roofing materials, sheet metal and flashing, caulking, and sealants.

8. **Doors** and **Windows** include doors, windows, finish hardware, glass and glazing, storefront systems, and similar items.

9. **Finishes** include such items as floor and wall coverings, painting, lathe, plaster, and tile.

10. **Specialties** include prefabricated products and devices, such as chalkboards, moveable partitions, fire-fighting devices, flagpoles, signs, and toilet accessories.

11. **Equipment** includes such items as medical equipment, laboratory equipment, food service equipment, kitchen and bath cabinetwork, and countertops.

12. **Furnishings** include prefabricated cabinets, blinds, drapery, carpeting, furniture, and seating.

13. **Special Construction** includes such items as pre-engineered structures, integrated ceiling systems, solar energy systems, aquatic facilities, and air supported structures.

14. **Conveying Systems** include dumbwaiters, elevators, moving stairs, material-handling systems, scaffolding, and other similar conveying systems.

15. **Mechanical Systems** include plumbing, heating, air conditioning, fire-protection systems, and refrigeration systems.

16. **Electrical Systems** include electrical service and distribution systems, electrical power equipment, electric heating and cooling systems, lighting, and other electrical items.

Each of the previous divisions is further divided into sections. You can find information on the required sections of Division 1 in the MIL-HDBK-1006/1, *Policy and Procedures for Project Drawing and Specification Preparation.* The Division 1 section is generally common to all projects done under a construction contract. Divisions 2 through 16 contain the technical sections that pertain to the specific project for which the spec writer has prepared the specification. These technical sections follow the CSI-recommended three-part section format. The first part, General, includes requirements of a general nature. Part 2, Products, addresses the products or quality of materials and equipment to be included in the work. The third part, Execution, provides detailed requirements for performance of the work.

Some construction industries have developed a division 17 or 18 to the CSI due to the changing technology of construction. Even NAVFAC has developed a division 17, called the **"Expeditionary Structures,"** which includes K-SPAN and High Tension Fabric buildings. Refer to chapter 9 for more information on Division 17 or the P-405.

GUIDANCE

Usually, the engineer or spec writer prepares each section of a specification based on the appropriate guide specification listed in the *Engineering and Design Criteria for Navy Facilities, MIL-BUL-34.* This military bulletin (issued quarterly by the Naval Construction Battalion Center, Port Hueneme, California) lists current NAVFACENGCOM guide specifications, standard specifications and drawings, definitive drawings, NAVFAC design manuals, and military handbooks that are used as design criteria.

The preceding material provides only a brief overview of construction specifications. For additional guidance regarding specification preparation, refer to *Policy and Procedures for Project Drawing and Specification Preparation,* MIL-HDBK-1006/1, and *EA Intermediate/Advanced.*

PLANNING

PLANNING is the process the Builders use to determine requirements and to devise and develop methods and actions for constructing a project. Good construction planning is a combination of the following elements: understanding the plans and specifications and understanding and analyzing the available resources, such as material, equipment, and manpower. PLANNING is also the process of determining the working environment, quality control, and safety procedures/precautions. All of these elements depend upon each other and must be considered in any well-planned project.

In the late 1950s, a new system of project planning, scheduling, and control came into widespread use in the construction industry. The critical path analysis (CPA), critical path method (CPM), and project evaluation and review technique (PERT) are three examples of about 50 different approaches. The basis for each of these approaches is the analysis of a network of events and activities. The generic title of the various networks is **network analysis.**

NETWORK ANALYSIS

The NETWORK ANALYSIS approach is now the accepted method of construction planning in many organizations. Network analysis forms the core of project planning and control systems. Network analysis separates the planning of the sequence of jobs from the scheduling of times for the jobs, thus overcoming simultaneous, and less effective, planning and scheduling.

All projects consist of separate but interrelated operations. In network analysis, these interrelated operations are called "activities." Activities are broken down into two phases: master activities (Level IIs) and construction or detailed activities (Level IIIs). Master and construction activities will be covered throughout this section.

The first stage in applying this technique is the preparation of a list of all activities that constitute the project to be scheduled. This list can be obtained in the following ways:

- Study of the plans and the specifications (fig. 2-1 2)
- Study of the manufacturer's specifications
- Bill of materials (BMs)

REDICHECK Plan and Specification Review

1. Preliminary Review
   - a) Quickly make an overview of all sheets spending no more than on e minute/sheet to become familiar with the project.
2. Specification Check
   - a) Check spec fro bid items. Are they coordinated with the drawings?
   - b) Check spec for phasing of construction. Are phases clear?
   - c) Compare architectural finish schedule to specification index. Ensure all finish materials are specified.
   - d) Check major items of equipment and verify they are coordinated with contract drawings. Pay particular attention to horsepower ratings and voltage requirements.
   - e) Verify that items specified "as indicated" or "where indicated" are in fact indicated on contract drawings.
   - f) Verify that cross reference specification sections exist.
   - g) Try not to indicate thickness of materials or quantities of materials in the specifications.
3. Plan Check Structural
   - a) Verify property line dimensions ion site plan against architectural.
   - b) Verify building is located behind set back lines.
   - c) Verify column lines on structural and architectural.
   - d) Verify all column locations are same on structural and architectural.
   - e) Verify perimeter slab on structural matches architectural.
   - f) Verify all depressed or raised slabs are indicated.
   - g) Verify slab elevations.
   - h) Verify all foundation piers are identified.
   - i) Verify all foundation beams are identified.
   - j) Verify roof framing plan column lines and columns against foundation plan column lines and columns.
   - k) Verify perimeter roof line against architectural roof plan.
   - l) Verify all columns and beams are listed in column and beam schedules.
   - m) Verify lengths of all columns in column schedule.
   - n) Verify all sections are properly labeled.
   - o) Verify all expression joint locations against architectural.
   - p) Verify dimensions.
4. Plan Check Architectural
   - a) Verify all concrete columns and walls against structural.
   - b) Verify on site plans that all existing and new work is clearly identified.
   - c) Verify building elevations against floor plans. Check in particular roof lines, window and door openings, and expansion joints.
   - d) Verify building sections against elevations and plans. Check roof lines, windows, and door locations.
   - e) Verify wall sections against architectural building sections and structural.
   - f) Verify masonry openings for windows and doors.
   - g) Verify expansion joints through building.
   - h) Verify partial floor plans against small scale floor plans.
   - j) Verify all room finish schedule information including room numbers, names of rooms, finishes and ceiling heights. Look for omissions, duplications and inconsistencies.
   - k) Verify all door schedules information including sizes, types, labels, etc. Look for omissions, duplications and inconsistencies.
   - l) Verify all rated walls.
   - m) Verify all cabinets will fit.
   - n) Verify dimensions.
5. Plan Check Mechanical and Plumbing
   - a) Verify all new electrical, gas, water, sewer, etc. lines connect to existing.
   - b) Verify all plumbing fixture locations against architectural. Verify all plumbing fixtures against fix
   - c) Verify storm drain system against architectural roof plan. Verify size of all pipes and that al drains are connected. Verify wall chases are provided on architectural t conceal vertical piping.
   - d) Verify sanitary drain system pipe sizes and that all fixtures are connected.
   - e) Verify HCAC floor plans against structural.
   - f) Verify sprinkler heads in all rooms.
   - g) Verify that all sections are identical to architectural/structural.
   - h) Verify that adequate ceiling height exists at worst case duct intersection.
   - i) Verify dampers indicated at smoke and dire walls.
   - j) Verify diffusers against architectural reflected ceiling plan.
   - k) Verify diffusers against architectural reflected ceiling plan.
   - l) Verify all roof penetrations (ducts, fans, etc.) are indicated on roof plans.
   - m) Verify all ductwork is sized.
   - n) Verify all notes.
   - o) Verify all A?C units, heaters, and exhaust fans against architectural roof plans and mechanical schedules.
   - p) Verify all mechanical equipment will fit in spaces allocated.
6. Plan Check Electrical
   - a) Verify all plans are identical to architectural.
   - b) Verify all light fixtures against architectural reflected ceiling plan.
   - c) Verify all major pieces of equipment have electrical connections.
   - d) Verify location of all panel boards and that they are indicated on the electrical riser diagram.
   - e) Verify all notes.
   - f) Verify that there is sufficient space for all electrical panels.
7. Plan Check Kitchen/Dietary
   - a) Verify equipment layout against architectural plans.
   - b) Verify all equipment is connected to utility systems.

Figure 2-12.—Redicheck plan and specification review.

- Modifications to previous projects
- Work sheets from previous projects
- Work element checklist (NAVFAC P-405)
- Project turnover files
- NCBs/NCRs

There are no specific definitions as to what constitutes an “activity,” and it is largely a matter of individual interpretation according to the requirements of a particular project. A good rule is, DO NOT plan a project in any more detail than is necessary to manage the scheduling of the work properly. For most NCF projects, construction activities should not be less than 1 day in duration (preferably not less than 3 days). Refer to the *Planner’s and Estimator’s Handbook*, NAVFAC P-405 and the *Seabee Crewleader’s Handbook* for more information on network analysis.

PROJECT PLANNING

Two basic ground rules are involved in analyzing a project. First, planning and scheduling are separate operations. Second, planning must always precede scheduling. If you do not plan sequentially, you will end up with steps out of sequence which may delay the project substantially. Each NCF project from the initial planning phase through the execution phase to the closeout phase is documented in a standard five-section package. This section focuses on the planning phase of a project.

The project folder, or package, consists of five individual project files. These files represent not only the project in a paper format but they also give you, as the project crew leader, project manager, or crew member, exposure to the fundamentals of construction management. This package will be presented to OPS in phases; refer to the *Seabee Crewleader’s Handbook* for more information pertaining to project management.

Listed below are the instructions needed to complete a typical NCF project package. **The forms marked with an asterisk are mandatory on all projects.** Small projects of short duration or ABFC projects may require only the mandatory forms. Other forms are used as needed. Forms may be computer generated but must be the same content as shown.

A. **NCF Project Package Contents:** To be placed at the beginning of the project package 3-ring binder.

B. **Section #1 - General Information and Correspondence.**

1. **1A Cover Sheet:** Recommend using tabbed dividers for all section cover sheets.

   a. ***Tasking Letter/Correspondence:** Distributed by S3 early in home port.

   b. ***Outgoing Messages and Correspondence:** File in chronological order, oldest on bottom to newest on top.

   c. ***Incoming Messages and Correspondence:** File in chronological order, oldest on bottom to newest on top.

2. **1B Cover Sheet**

   a. **Project Scope Sheet**

   b. **Project Organization:** In addition to this, include a compete list of all prime and sub personnel assigned to the project.

   c. **Project Planning Milestones:** This list can be added to if necessary. Ops should be contacted when assigning dates.

   d. **Project Package Sign-Off Sheet:** To be signed off prior to the RDE.

   e. **Deployment Calendar**

   f. **Preconstruction Conference Summary**

   g. **Predeployment Site Visit Summary**

   h. **Joint Turnover Memorandum:** This will be completed jointly by personnel from both battalions for turnover projects.

   i. **Pre-BOD Inspection Request:** This will be completed by the crew leader two working days prior to the requested date of inspection.

C. **Section #2 Activities and Network**

1. **2A Cover Sheet**

   a ***Level II Bar Chart:** Particular care should be taken in man-day totals recorded on this form. All numbers will match Level III calculations. Horizontal and vertical totals will match exactly.

   b. ***Two Week Schedule:** This will be completed each week by the crew leader. The Company will present it to Ops at the weekly Ops meeting. The crew leader will brief the crew on this and post on the jobsite.

c. ***Master Activity Listing:** List each master activity and describe exactly what is included in it. This will make clear to all personnel where one master activity stops and another begins.

d. ***Master Activity Summary Sheets:** This will be completed after the Level III bar chart and CAS sheets are finalized.

e. ***Level III Precedence Diagram**

2. **2B Cover Sheet**

a. **Level III Bar Chart**

b. **Construction Activity Summary Sheets:** This is one of the most important forms in the project package. Almost all the rest of the project package and project execution are driven by the CAS Sheet. Be sure all entries are as accurate as possible. Be specific (but use plain language) on the Safety, QC, and Environmental blocks. Your Safety, QC, and Environmental Plans will match this.

c. **Completed Activities CAS Sheets:** File in numerical order as construction activities are completed. Be sure to record actual man-days and duration.

d. **Two Week Labor Summary:** Completed by crew leader daily prior to submitting time cards to company.

e. **SITREP Feeders:** Forward to Ops on the 15th and 30th of each month.

f. **Other Computer Printouts/Reports**

D. **Section ##3 Resources:**

1. **3A Cover Sheet**

a. ***30/60/90-Day Material List:** Forward a copy to MLO upon completion. MLO will enter material status from PCR/PSR and forward to Ops for action. A separate form for each 30/60/90-day requirement will be submitted.

b. ***30/60/90-Day Material List Letter:** Ops will supply to the Company after receiving material status from MLO. One form may be used as long as 30/60/90-day requirements are separated.

c. ***Typical Bill of Materials:** Ops will supply to the Company after the detailed MTO is completed. Transfer information from this to the BM/MTO Comparison Worksheet.

d. ***Tool Requirement Summary:** Submit Add-on BM for special tools if not already on the BM.

e. ***Equipment Requirement Summary:** Ensure a copy is routed to ALFA Company after completion.

2. **3b Cover Sheet**

a. **List of Possible Long Lead Items:** This does not need to be kept in the project package. It is provided for planning purposes only.

b. **List of Long Lead Items:** Forward a copy to MLO after completion. Crew leader and MLO will track through home port.

c. **Material Take Off Worksheet:** Use this form when doing a detailed MTO. Transfer information to the BM/MTO Comparison Worksheet.

d. **BM/MTO Comparison Worksheet:** For any shortage of material, forward an Add-on/Reorder BM to MLO.

e. **Material Transfer Request:** Forward to MLO for project to project transfer only. Do not use for excess material.

f. **Add-on/Reorder Justification:** Attach this to all Add-on/Reorder BMs.

g. **Add-on/Reorder BM:** Use this along with the Justification Form. When adding or reordering material, circle Add-on or Reorder. For excess material forward this as an Add-on BM along with a 1250-1 signed by S-3. Remember, an Add-on is adding another line item to the BM. A Reorder is ordering more of the same materials already on the BM.

h. **Borrow Log:** Crew leader will log all project to project transfers. This is used to keep track of transfers because MLO keeps the Material Transfer Request until replacement material is received.

E. **Section #4 - Plans**

1. **4A Cover Sheet**

a. ***Quality Control Plan Cover Sheet.** First sheet of the QC Plan.

b. ***Quality Control Plan.** The project QC Plan will come directly from the CAS sheets. QC will produce a separate plan. Project and QC will compare plans and resolve any differences.

c. ***Safety Plan Cover Sheet.** First sheet of the project Safety Plan.

d. ***General Safety Plan.** Second sheet of the project Safety Plan. These are general items that apply to almost all Construction Activities. Specific items will be included on the Safety Plan.

e. ***Safety Plan** The project Safety Plan will come directly from the CAS Sheets. Include all safety items not covered on the General Safety Plan.

f. **Environmental Plan.** The project Environmental Plan will come directly from the CAS sheets

2. **4B Cover Sheet.**

a. **Daily Quality Control Inspection Report.** Completed daily by the QC representative.

b. **Field Adjustment Request (FAR) Submittal Log.** Use this to record all FARs whether approved or disapproved.

c. **FAR.** Use for all changes to the project. Keep these to a minimum. Construct project according to plans and specifications if possible. Be clear and concise when completing this. Attach drawings and extra items as needed.

d. **Request for Information (RFI) Submittal Log.**

e. **RFI.** Used for clarification of plans or specifications only. All requests for changes on the project will be submitted on a FAR.

f. **Design Change Directives (DCD).** Include all ROICC directed changes to the project.

g. **Concrete Placement Clearance Form.** Must be completed 24 hours in advance of concrete placement.

h. **Pre-placement Photos for Concrete Placement.** Include views of forms, RST and anchor bolts.

i. **Asphalt Placement Clearance Form.** Must be completed 24 hours in advance of required asphalt placement.

j. **Utility Interruption Request.** This is a typical form. Each deployment site may be different. Submit to Ops at least 2 weeks in advance of required outage.

k. **Excavation Request.** This is a typical form. Each deployment site may be different. Submit to Ops at least 2 weeks in advance of excavation.

1. **Road Closure Request.** This is a typical form. Each deployment site may be different. Submit to Ops at least 2 weeks in advance of required closure.

m. **Engineering Service Request.** Submit to Ops at least 5 days in advance of required service.

n. **Mineral Products Request.** Submit to MLO at least 2 weeks in advance of required delivery date.

o. **Other QC Forms.**

p. **Daily Safety Inspection Report.** Will be completed daily by the Battalion’s Safety Inspector.

q. **Emergency Phone Numbers.** Will be removed from the project package and posted at the jobsite.

r. **Navy Employee Report of Unsafe or Unhealthful Working Conditions.** Will be removed from the project package and posted at the jobsite.

s. **Required Safety Equipment.**

t. **Daily Safety Lecture Log.** Record daily and forward a copy to Safety as required.

u. **Accident/Near Mishap/Mishap Reports.** In the event of a mishap, this will be submitted to Safety within 24 hours on workdays. If during off duty hours, by close of business the next workday. This does NOT take the place of medical reports or other reports that may be required by Safety.

v. **Highlighted 29 CFR 1926.**

w. **Hazardous Materials Inventory Sheet.** Submit a copy to Environmental/Safety as required.

x. Other Safety Forms.

F. **Section #5 - Drawings/Specifications.**

1. **1A Cover Sheet.**
   - a ***Project Plans**
   - b. ***Highlighted Specifications**
2. **1B Cover Sheet**
   - a. **Site Layout**
   - b. **Shop Drawings**
   - c. **Detailed Slab Layout Drawings**
   - d. **Forming Plans**
   - e. **Rebar Bending Schedule**
   - f. **Other Sketches/Drawings**
   - g. **Technical Data**

The OPS Department should also assign a project planning milestones checklist (fig. 2-13) at the beginning of the home port for each project.

ESTIMATING

ESTIMATING is the process of determining the amount and type of work to be performed and the quantities of material, equipment, and labor required. Lists of these quantities and types of work are called estimates.

PRELIMINARY ESTIMATES

PRELIMINARY ESTIMATES are made from limited information, such as the general description of projects or the preliminary plans and specifications, having little or no detail. Preliminary estimates are prepared to establish costs for the budget and to program general manpower requirements.

DETAILED ESTIMATES

DETAILED ESTIMATES are the precise statements of quantities of material, equipment, and manpower required to construct a given project. The underestimating of quantities can cause serious delays in construction and even result in unfinished projects. A detailed estimate must be accurate to the smallest detail to quantify requirements correctly.

PROJECT PLANNING MILESTONES PROJECT: ____________

MILESTONES	DATE: REQUIRED	COMPLETED
1. Designate Project Supervisor	____________	____________
2. Preplanning Conference	____________	____________
3. Review Plans and Specs	____________	____________
4. Identify Long Lead Time Items	____________	____________
5. Identify Required Skills and Training	____________	____________
6. Complete project Scope Sheet	____________	____________
7. Complete Master Activity Summary Sheets	____________	____________
8. Develop Level II Network	____________	____________
9. Develop BM/MTO Discrepancy List	____________	____________
10. Complete Construction Activity Summary Sheets	____________	____________
11. Develop Level III Network	____________	____________
12. Input Network into Computer	____________	____________
13. Resource Level Project	____________	____________
14. Develop Level II Barchart	____________	____________
15. Develop Level II Barchart	____________	____________
16. Consolidate NCFSU and TOA Tool Requirements	____________	____________
17. Consolidate NCFSU and TOA Equipment Requirements	____________	____________
18. Consolidate Safety Plan	____________	____________
19. Consolidate Quality Control Plan	____________	____________
20. Prepare Readiness to Deploy Inspection Briefing	____________	____________

Figure 2-13.—Project planning milestones checklist.

MATERIAL ESTIMATES

MATERIAL ESTIMATES consist of a listing and description of the various materials and the quantities required to construct a given project. Obtain the information you will need to prepare material estimates from the activity estimates, drawings, and specifications. A material estimate is sometimes referred to as a “Bill of Material (BM)” or a “Material Takeoff (MTO)” sheet. (We will cover the BM and the MTO a little later in this chapter.)

EQUIPMENT ESTIMATES

EQUIPMENT ESTIMATES are listings of the various types of equipment, the amount of time, and the number of pieces of equipment required for you to construct a given project. Information, such as that obtained from activity estimates, drawings, specifications, and an inspection of the site, provides the basis for preparing the equipment estimates.

LABOR ESTIMATES

The LABOR ESTIMATES consist of a listing of the number of direct labor man-days required to complete the various activities of a specific project. These estimates may show only the man-days for each activity, or they may be in sufficient detail to list the number of man-days for each rating in each activity—Builder (BU), Construction Electrician (CE), Equipment Operator (EO), Steelworker (SW), and Utilitiesman (UT). Man-day estimates are used for determining the number of personnel and the ratings required on a deployment. They also provide the basis for scheduling labor in relation to construction progress.

When the *Seabee Planner’s and Estimator’s Handbook,* NAVFAC P-405, is used, a man-day is a unit of work performed by one person in one 8-hour day.

Battalions set their own schedules, as needed, to complete their assigned tasks. In general, the work schedule of the battalions based on an average of 55 hours per person per week The duration of the workday is 10 hours per day, which starts and ends at the jobsite.

Direct labor includes all labor expended directly on assigned construction tasks (either in the field or in the shop) that contributes directly to the completion of the end product. Direct labor must be reported separately for each assigned construction item. In addition to direct labor, the estimator must also consider indirect labor and readiness and training. Indirect labor includes labor required to support construction operations but does not, in itself, produce an end product. Refer to the COMSECONDNCB/COMTHIRDNCBINST 5312.1 for more information on labor.

ESTIMATOR

An ESTIMATOR is a person who evaluates the requirements of a task. A construction estimator must be able to picture the separate operations of the job mentally, as the work progresses through the various stages of construction and be able to read and obtain accurate measurements from drawings. The estimator must have an understanding of math, previous construction experience, and a working knowledge of all branches of construction. The estimator must use good judgment to determine what effect numerous factors and conditions have on project construction and what allowances should be made for each of them. The estimator must be able to do careful and accurate work. A Seabee estimator must have ready access to information about the material, equipment, and labor required to perform various types of work under conditions encountered in Seabee deployments. The collection of such information on construction performance is part of estimating. Since this kind of reference information may change from time to time, the estimator should review it frequently.

The tables and diagrams in the *Seabee Planner 3 and Estimator’s Handbook,* NAVFAC P-405, will save you time in preparing estimates, and when understood and used properly, provide you with accurate results. Whenever possible, the tables and the diagrams used were based on Seabee experience. Where suitable information was not available, construction experience was adjusted to represent production under the range of conditions encountered in Seabee construction. A thorough knowledge of the project drawings and specifications makes you alert to the various areas in which errors may occur.

Need for Accuracy

QUANTITY ESTIMATES are the basis for purchasing materials, determining equipment, and determining manpower requirements. They are also the basis for scheduling in terms of material deliveries, equipment, and manpower. Accuracy in preparing quantity estimates is extremely important since these estimates have widespread uses, and errors can be multiplied many times. Say, for example, a concrete slab is to measure 100 feet by 800 feet. If you misread the dimension for the 800-foot side as 300 feet, the computed area of the slab will be 30,000 square feet, when it should actually be 80,000 square feet. Since area is the basis for ordering materials, there will be shortages. For example, concrete ingredients, lumber, reinforcing materials, and everything else involved in mixing and placing the concrete, including equipment time, manpower, and man-hours, will be seriously underestimated and ordered.

Checking Estimates

The need for accuracy in checking estimates is vital. Check quantity estimates to eliminate as many errors as possible. One of the best ways for you to check a quantity estimate is to have another person make an independent estimate and then to compare the two. Any differences should be noted to determine which is right. A less effective way of checking is for another person to take your quantity estimate and check all measurements, recordings, computations, extensions, and copy work, keeping in mind the most common error sources (listed in the next section).

Error Sources

Your failure to read all of the notes on a drawing or failure to examine reference drawings results in many omissions. For example, you may overlook a note that states "symmetrical about the center line" and thus compute only half the required quantity.

Errors in scaling obviously mean erroneous quantities. Great care should be taken in scaling drawings so that correct measurements are recorded. Common scaling errors include using the wrong scale, reading the wrong side of a scale, and failing to note that a detail being scaled is drawn to a scale different from that of the rest of the drawing. Remember that some drawings are not drawn to scale. Since these cannot be scaled for dimensions, you must obtain dimensions from other sources.

Sometimes wrongly interpreting a section of the specifications causes errors in the estimate. If there is any doubt concerning the meaning of any part of the specification, you should request an explanation of that particular part.

Omissions are usually the result of careless examination of the drawings. Thoroughness in examining drawings and specifications usually eliminates errors of omission. Use checklists to assure that all activities or materials have been included in the estimate. When drawings are revised after material takeoff, compare new issues with the copy used for takeoff and make the appropriate revisions in the estimate.

Construction materials are subject to waste and loss through handling, cutting to fit, theft, normal breakage, and storage loss. A person's failure to make proper allowance for waste and loss results in erroneous estimates.

Other error sources are inadvertent figure transpositions, copying errors, and math errors.

ACTIVITY ESTIMATES

The crew leader is responsible for making sure all required resources are identified. The crew leader must estimate materials, equipment, and labor required to complete each construction activity. All required resources are listed on CAS sheets. The scheduled start and finish dates for each activity are taken from the Level III bar chart and shown on the CAS sheet. The resources are then tied to the schedule, and any action required to track or request resources can be monitored on the CAS sheet.

Master Activities

The Naval Construction Regiments (NCRs) usually assign master activities to the projects. The master activities can be broken into at least five construction activities. Most commonly, master activities number between eight and ten. These activities identify functional parts of the facility and are often tied to a particular company or rating. It must be clear to all personnel involved in the planning process exactly what work is included in each master activity. That is the purpose of the master activity listing. By providing a good narrative description of each master activity, it will be clear to all where each work element falls. A good narrative description reduces the chance of omitting any work items from the estimate. Master activities for a typical building might look like the following list of items:

01XX	General
02XX	Site Work
03XX	Concrete Construction
04XX	Masonry
05XX	Metals
06XX	Carpentry
07XX	Moisture Protection
08XX	Door, Windows, and Glass
09XX	Finishes
10XX	Specialties
11XX	Architectural
12XX	Furnishings
13XX	Special Construction
14XX	Conveying Systems
15XX	Mechanical Systems
16XX	Electrical Systems
17XX	Expenditionary Structures

Construction Activities

As the crew leader, you must break the master activities into construction activities. The work element checklist, contained in appendix A in the NAVFAC P-405 and the *Seabee Crewleader's Handbook*, are an excellent reference for the development of the construction activity list. A typical Naval Mobile Construction Battalion (NMCB) project might contain between 15 and 50 construction activities. Construction activity numbers are usually four digits. The first two digits identify the master activity and the second two digits show a specific construction activity within a master activity. The number also includes a prefix assigned by OPS that identifies the specific project. Looking at the list of master activities example, this project could have a construction activity for "pre-fab forms" numbered 0312. The number 03 represents master activity "concrete construction" and the "1X" distinguishes "concrete formwork" and the "2" represents "pre-fab forms" from the order of precedence in that master activity. Refer to the *Seabee Crewleader's Handbook* for the construction activities listing.

MAN-DAY ESTIMATES AND DURATIONS.— You need to know how to calculate man-days and duration days for each construction activity. The P-405 is the primary reference for Seabee man-day estimates. The P-405 lists how many man-hours it takes to do one unit of work. The size of the unit is also given. The quantity of work is divided by the unit size and multiplied by the man-hours required to do one unit. You then divide by 8 man-hours per man-day and multiply by a delay factor (DF). Tasking, estimating, and reporting are always done in 8-hour man-days, regardless of the length of the workday. Note the following formula:

MDs = QTY Of WORK ÷ UNIT SIZE X MHRS PER UNIT ÷ 8 x DF

For example, to install 16,000 sf of 1/2-inch drywall over wall studs would require how many man-days? The equation should be as follows:

MDs = 16,000 SF ÷ 1000 SF x 33 MHRS ÷ 8 = 66 x DF

PRODUCTION EFFICIENCY FACTORS.— Production efficiency factors are the first step in adjusting man-day estimates based on your unique circumstances. The intent of a production efficiency factor is to adjust for factors that will make you more or less productive than the average Seabee. In calculating a production efficiency factor, consider only those factors that affect the crew while on the job. Table 2-4 lists eight production elements in the far-left column. You need to consider the impact of each of these production elements on each activity given a specific crew, location, equipment condition, and so on. Then assign a production factor between 25 (low production) and 100 (high production) for each element. A production factor of 67 is considered average. Average these eight factors to figure your production efficiency factor (PEF).

DELAY FACTORS.— Before you can adjust the man-day estimate, you must convert the production efficiency factor to a delay factor according to the graph shown in figure 2-14. You can find the delay factor by dividing 67 (the average production factor) by the production efficiency factor (DF = 67/63.6 = 1.05). (See table 2-4.) Using the delay factor of 1.05 you now can adjust the original man-day estimate as shown in the following equation:

66 x 1.05 = 69.3 or 70 MD

This mathematical procedure has limitations. If, for example, you were working outside in extremely bad weather and all other factors were considered average (weather = 25, all others = 67), you would obtain a production efficiency factor of 62 and a delay factor of 1.08. This 8 percent increase in the man-day estimate would not adequately compensate for working in extreme weather. You are not limited to the method of delay factors in the P-405. Use common sense when impacted by extreme circumstances. Come up with what you feel is a reasonable delay factor and discuss it with your chain of command. You are not bound by either the delay factors or the production rates in the P-405. To figure man-day estimates, you can use your experience to determine the logical production rates to use. Keep in mind that the delay factor is only used to determine the man-day estimate for a particular construction activity. Each activity will have a different delay factor. All other calculations use the availability factor.

AVAILABILITY FACTORS. —Availability factors take into account that Seabees assigned as direct labor are not available 100 percent of the time. Each Naval Construction Brigade provides the availability y factors for planning purposes. Availability y factors are sometimes still referred to as site efficiency factors. These factors vary between 0.75 for main body sites to 0.85 for detail sites. Using the following equation, you can determine the man-day capability (MC) for the main body and each detail.

Table 2-4.—Production Efficiency Guide Factor Chart

PRODUCTION EFFICIENCY GUIDE FACTOR CHART

	LOW PRODUCTION 25 35 45	AVG PRODUCTION 55 65 75	HIGH PRODUCTION 85 95
1. WORK LOAD	CONSTRUCTION REQ'T HIGH, MISC. OVERHEAD HIGH	CONSTRUCTION REQ'T AVG, MISC. OVERHEAD AVG	CONSTRUCTION REQ'T LOW, MISC. OVERHEAD LOW
2. SITE AREA	CRAMPED WORK AREA, POOR LAYDOWN/ACCESS	WORK AREA LIMITED, AVG LAYDOWN/ACCESS	LARGE WORK AREA, GOOD LAYDOWN/ACCESS
3. LABOR	POORLY TRAINED/MOTIVATED CREW	ADEQUATELY TRAINED/MOTIVATED CREW	HIGHLY TRAINED/MOTIVATED CREW
4. SUPERVISION	POORLY TRAINED/MOTIVATED OR INEXPERIENCED	ADEQUATELY TRAINED/MOTIVATED EXPERIENCED	HIGHLY TRAINED, MOTIVATED, AND EXPERIENCED
5. JOB CONDITION	HIGH-QUALITY WORK REQ'D, SHORT FUSE	AVG QUALITY WORK REQ'D, ADEQUATE TIME	ROUGH/UNFINISHED WORK REQ'D, WELL PLANNED
6 WEATHER	ABNORMAL HEAT, RAIN, OR COLD	MODERATE RAIN, HEAT, OR COLD	FAVORABLE RAIN, HEAT, OR COLD
7. EQUIPMENT	POOR COND., MAINT., REPAIR, OR APPLICATION	FAIR COND., MAINT., REPAIR, OR APPLICATION	GOOD COND., MAINT., REPAIR, OR APPLICATION
8. TACTICAL/ LOGISTICAL	SLOW SUPPLY, FREQUENT TACTICAL DELAYS	NORMAL SUPPLY, FEW TACTICAL DELAYS	GOOD SUPPLY, NO TACTICAL DELAYS

Let's calculate a production efficiency factor for our 16,000 SF of drywall. Let's say we are going to do this drywall work as part of a project to rehab the station CO's admin spaces. We must evaluate each production element from the table and assign a factor:

Production element	Percentage	Remarks
Work load	67	No specific impact
Site Area	75	Good access, work area
Labor	35	Crew inexperienced, OJT required
Supervisor	75	Good supervisor
Job Condition	45	High quality work required
Weather	67	No impact
Equipment	70	sufficient tools in adequate condition
Tactical/Logistical	75	Materials on-hand believed sufficient

PEF = 509/8 = 63.6

MC = DL x **WD** x **ME** x **AF**

Use DL to represent the number of direct labor assigned, WD for the number of available workdays, Man-Day Equivalent (ME) is the number of man-days expended (actual man-hours swinging hammers) in a typical workday, and AF is the availability y factor. Availability Factor takes into account that Seabees assigned as direct labor are not available 100% of the time. Multiply these four factors to figure the man-day capability (MC). You can use this same equation to determine the direct labor manning for a detail if you substitute tasked man-days for MC and plug in AF, ME, and WD. The number of workdays is taken from the deployment calendar.

ME = WD - Lunch - Travel - Breaks-
Actual MHRS/work day

CONSTRUCTION ACTIVITY DURATIONS.— The man-day capability (MC) equation also can be used to determine construction activity durations expressed in the following equation:

Duration = MD estimated (CS x **AF** x **ME)**

or

Duration = MD estimated ÷ CS ÷ AF ÷ ME

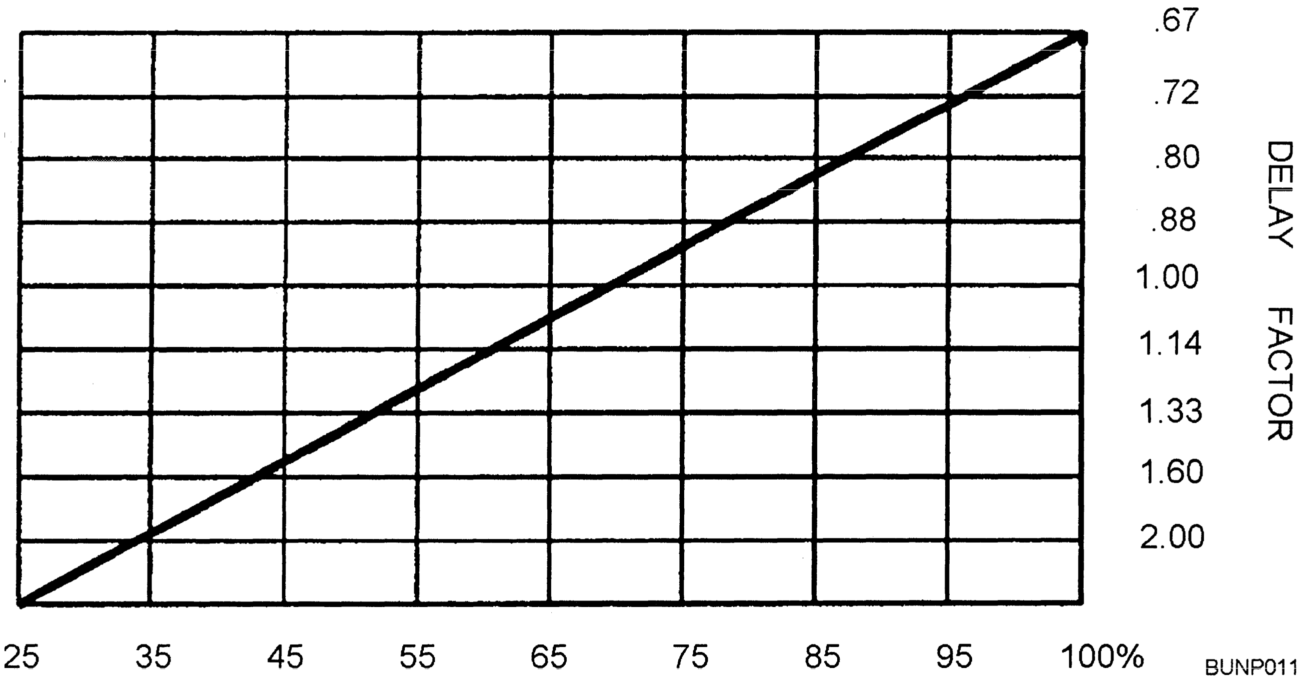


Figure 2-14.—Production efficiency graph.

The activity duration is increased by including the availability factor to account for time lost from the project site. The actual crew you would expect to see on the jobsite on the average day would be the assigned crew multiplied by the availability factor. Always use the availability factor.

If in the drywall example, you had a crew of 12 assigned, 1 hour for lunch each day, total travel to and from jobsite is 1 hour, and a total of 30 minutes for breaks each day, how long would it take to complete this task (if the availability factor 0.75, and the man-day equivalent is .9375)? Remember to use the revised man-day estimate, which includes the delay factor. The equation would be written as follows:

Duration = 70 ÷ 12 ÷ 0.75 ÷ .9375 = 8.3 or 9 workdays.

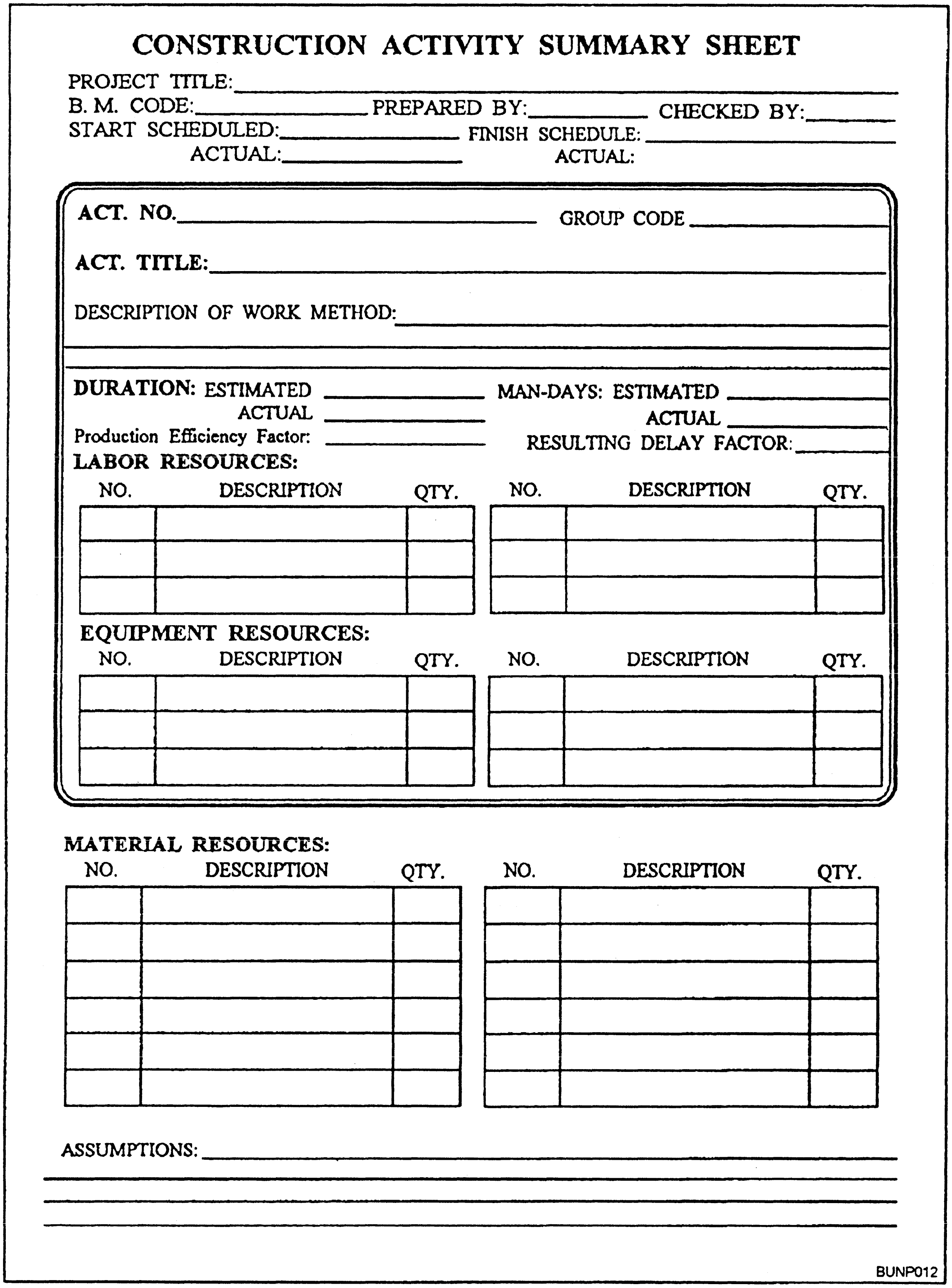
Construction Activity Summary (CAS) Sheets

Once the master activities have been broken into construction activities, you will need to use a CAS sheet (figs. 2-15 and 2-16) for each activity. In addition to the activity description and the scheduled dates, all the required resources are shown on the front. Safety and QC requirements are on the back. The space at the bottom of the back page should be used for man-day and duration calculations.

The CAS sheets should be able to stand alone. The CAS sheets should contain all of your notes, information, and calculations pertaining to man-days, durations, tools, and equipment. In this way, if you are not available, someone else can use this information and the project can continue. It is very important that CAS sheets be filled out correctly. Almost all of your remaining planning is driven from the CAS sheets. Always use a pencil to fill them out, because they change constantly.

MATERIAL ESTIMATES

MATERIAL ESTIMATES are also used to procure construction material for a given project, to determine whether sufficient material is available to construct a given project, and to determine the labor involved to install the material. The following is a suggested procedure for preparation of a material estimate. First, obtain a work element checklist by referring to the P-405, then estimate the quantity of material needed for each activity by using the P-405 and any previous experience. Use the conversion chart from table 2-5, whenever possible, for estimating waste factors and the conversion of material. This conversion should be done on a work sheet when the estimator records how each quantity of material was obtained. A typical material estimate work sheet is shown in figure 2-17. Each step can readily be understood when the work sheets are reviewed.



CONSTRUCTION ACTIVITY SUMMARY SHEET

PROJECT TITLE:
B. M. CODE: PREPARED BY: CHECKED BY:
START SCHEDULED: FINISH SCHEDULE:
ACTUAL: ACTUAL:

ACT. NO. GROUP CODE

ACT. TITLE:

DESCRIPTION OF WORK METHOD:

DURATION: ESTIMATED MAN-DAYS: ESTIMATED
ACTUAL ACTUAL
Production Efficiency Factor: RESULTING DELAY FACTOR:

LABOR RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

EQUIPMENT RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

MATERIAL RESOURCES:

NO.	DESCRIPTION	QTY.	NO.	DESCRIPTION	QTY.

ASSUMPTIONS:

BUNP012

Figure 2-15.—Construction Activity Summary Sheet (front).

ACTIVITY NUMBER:__________ .ACTIVITY DESCRIPTION: ______________________________

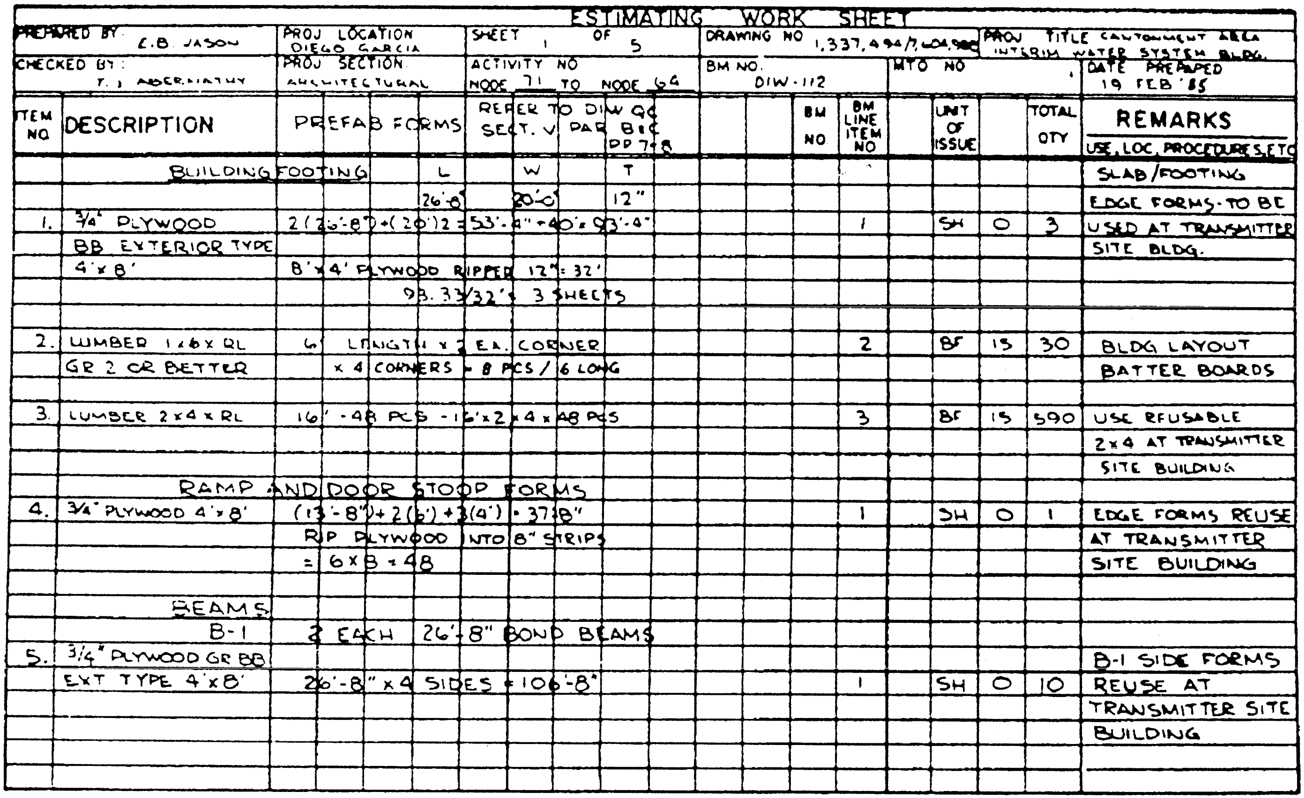
SAFETY HAZARD	SPEC. REF	REQUIRED ACTION

QUALITY CONTROL REQUIREMENT	SPEC. REF.	REMARKS/RESULTS

ENVIRONMENTAL HAZARDS	SPEC. REF.	ACTION REQUIRED

CONSTRUCTION COMMENTS:

Figure 2-16.—Construction Activity Summary Sheet (back).



ESTIMATING WORK SHEET

PREPARED BY: C.B. JASON
PROJ LOCATION: DIEGO GARCIA
SHEET 1 OF 5
DRAWING NO: 1,337,494/1,404,980
PROJ TITLE: CANTONMENT AREA INTERIM WATER SYSTEM BLDG.
CHECKED BY: T. J. ABERNATHY
PROJ SECTION: ARCHITECTURAL
ACTIVITY NO: NODE 71 TO NODE 64
BM NO.: DIW-112
MTO NO:
DATE PREPARED: 19 FEB '85

ITEM NO	DESCRIPTION	PREFAB FORMS	REFER TO DWG QC SECT. V PAR B&C PP 7-8	BM NO	BM LINE ITEM NO	UNIT OF ISSUE		TOTAL QTY	REMARKS USE, LOC, PROCEDURES, ETC
	BUILDING FOOTING	L	W T						SLAB/FOOTING
		26'-8"	20'-0" 12"						EDGE FORMS-TO BE
1.	3/4" PLYWOOD	2(26'-8")+(20')2 = 53'-4" + 40' = 93'-4"			1	SH	0	3	USED AT TRANSMITTER
	BB EXTERIOR TYPE								SITE BLDG.
	4'x8'	8'x4' PLYWOOD RIPPED 12" = 32'							
		93.33/32' = 3 SHEETS							
2.	LUMBER 1x6x RL	6' LENGTH x 2 EA. CORNER			2	BF	15	30	BLDG LAYOUT
	GR 2 OR BETTER	x 4 CORNERS = 8 PCS / 6 LONG							BATTER BOARDS
3.	LUMBER 2x4xRL	16' - 48 PCS - 16'x2x4x48 PCS			3	BF	15	590	USE REUSABLE
									2x4 AT TRANSMITTER
									SITE BUILDING
	RAMP AND DOOR STOOP FORMS								
4.	3/4" PLYWOOD 4'x8'	(13'-8")+2(6')+3(4') = 37'-8"			1	SH	0	1	EDGE FORMS REUSE
		RIP PLYWOOD INTO 8" STRIPS							AT TRANSMITTER
		= 6x8 = 48							SITE BUILDING
	BEAMS								
	B-1	2 EACH 26'-8" BOND BEAMS							
5.	3/4" PLYWOOD GR BB								B-1 SIDE FORMS
	EXT TYPE 4'x8'	26'-8" x 4 SIDES = 106'-8"			1	SH	0	10	REUSE AT
									TRANSMITTER SITE
									BUILDING

BUNP013

Figure 2-17.—Typical estimating work sheet.

Estimating Work Sheet

The estimating work sheet shown in figure 2-17, when completed, shows the various individual activities for a project with a listing of the required material. Material scheduled for several activities or uses is normally shown in the Remarks section. The work sheet should also contain an activity description, the item number, the material description, the cost, the unit of issue, the waste factors, the total quantities, and the remarks. The estimating work sheets should be kept by the field supervisor during construction to ensure the use of the material as planned.

Material Takeoff Sheet

The material takeoff sheet (MTO) is shown in figure 2-18. In addition to containing some of the information on the estimating work sheet, the MTO also contains the suggested vendors or sources, supply status, and the required delivery date.

Bill of Material

The bill of material (BM) sheet (fig. 2-19) is similar in content to the material takeoff sheet. However, the information is presented in a format suitable for data processing. Use this form for requests of supply status, issue, or location of material and for preparing purchase documents. When funding data is added, use these sheets for drawing against existing supply stocks.

Between procurement and final installation, construction material is subject to loss and waste. This loss may occur during shipping, handling, storage, or from the weather. Waste is inevitable where material is subject to cutting or final fitting before installation. Frequently, material, such as lumber, conduit, or pipe, has a standard issue length longer than required. More often than not, however, the excess is too short for use and ends up as waste. Waste and loss factors vary depending on the individual item and should be checked against the conversion and waste factors found in NAVFAC P-405.

Table 2-5.—Conversion and Waste Factors

Material	Conversion	% Waste
Concrete Construction		
Concrete (1:2:4)		
Cement	6.0 sk/cy	10
Fine aggregate	0.6 cy/cy	10
Coarse aggregate	1.0 cy/cy	10
Curing compound	0.5 gal/100 sf	10
Forms		
Footings and piers	1.5 lf/sfcs	20
2 x 4	0.2 lf/sfcs	10
2 x 8	0.7 lf/sfcs	5
Ground slabs		
1 x 4	0.1 lf/sf area	20
2 x 4	0.1 lf/sf area	5
Walls and columns 2 x 4	1.3 lf/sfcs	20
Plywood (50% reuse)	0.5 sf/sfcs	5
Beams and susp slabs		
1 x 6	0.3 lf/sfcs	5
2 x 4	0.5 lf/sfcs	20
2 x 10	0.1 lf/sfcs	10
4 x 4	0.4 lf/sfcs	5
4 x 6	0.1 lf/sfcs	5
Plywood	0.5 sf/sfcs	5
Form oil	0.5 gal/100 sf	10
Tie wire	12.0 lb/ton	10
Snap tie wedges	0.1 EA/sfcs	5
Snap ties	0.1 EA/sfcs	5
She bolts	0.1 set/sfcs	5
Nails (bf lumber + sf ply-wood, ordered as mfbm)		
6d box	6 lb/mfbm10	
8d common	4 lb/mfbm	10
16d common	6 lb/mfbm	10
20d common	2 lb/mfbm	10
6d duplex	4 lb/mfbm	10
8d duplex	9 lb/mfbm	10
16d duplex	9 lb/mfbm	10
Reinforcing steel		
#3	0.4 lb/lf	10
#4	0.7 lb/lf	10
#5	1.0 lb/lf	10
#6	1.5 lb/lf	10
#7	2.0 lb/lf	10
#8	2.7 lb/lf	10
Constr joint (bitumen)	3.0 gal/100 sf	10
Floor hardener	3.0 lb/100 sf	10
Non-slip floor finish	25.0 lb/100 sf	10
Masonry construction		
Block (8 x 16)	112.5 EA/100sf .89sf/EA	10

Table 2-5.—Conversion and Waste Factors—Continued

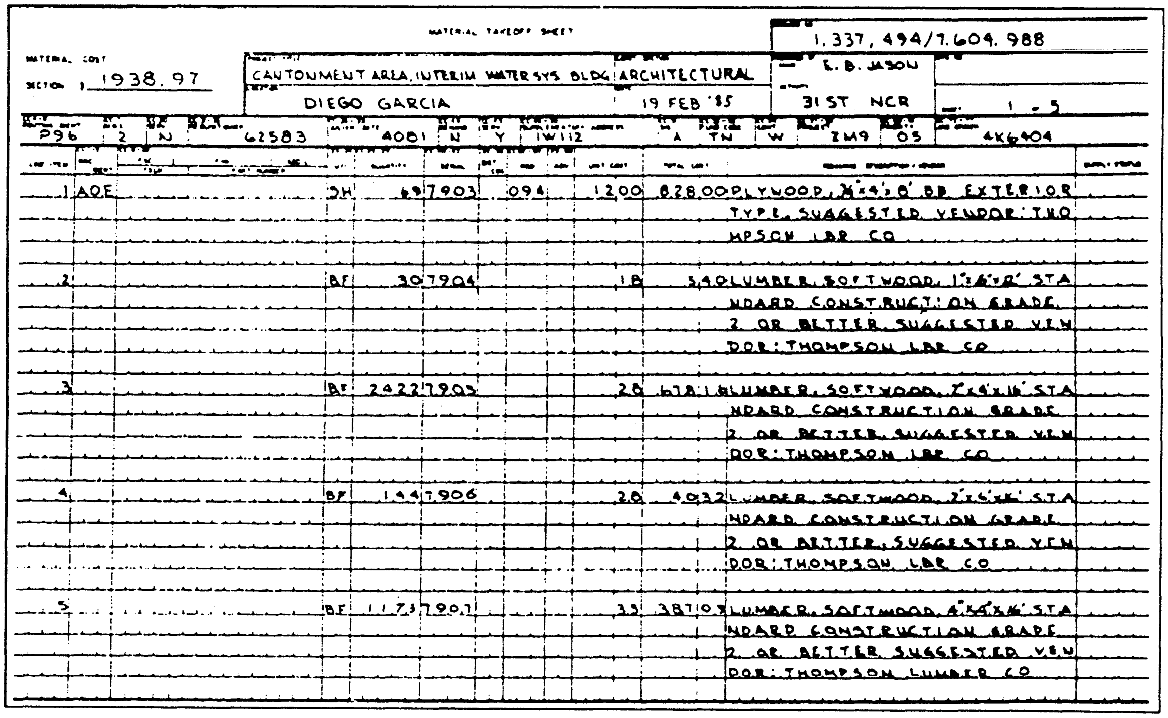
Material	Conversion	% Waste
Brick (2 1/4 x 8) - 3/8 joint		
4" Wall	6.6 EA/sf	10
8" Wall	13.1 EA/sf	10
12" Wall	19.6 EA/sf	10
Glazed structural tile		
5 1/3 x 8	3.3 EA/sf	
4 x 123.0 EA/sf		10
5 1/3 x 12	2.2 ea/sf	10
Ceramic and quarry tile		
6 x 6	4.0 ea/sf	10
9 x 9	1.7 ea/sf	10
Mortar		
Block (8 x 16) - 3/8 joint		
4" Wall	0.1 cy/100 blocks	20
8" Wall	0.2 cy/100 blocks	20
12" Wall	0.3 cy/100 blocks	20
Brick (2 1/4 x 8) - 3/8 joint		
4" Wall	0.3 cy/1000 brick	20
8" Wall	0.4 cy/1000 brick	20
12" Wall	0.4 cy/1000 brick	20
Structure tile (12 x 12) - 3/8 joint		
4" Wall	0.2 cy/100 tile	20
8" Wall	0.3 cy/100 tile	20
12" Wall	0.5 cy/100 tile	20
Tile grout	20.0 lb/100 sf	10
Plastering		
Lath		
Channel (3/4")	0.3 lb/lf	10
Lath3.4 lb/sy 5		
Nails (4d)	0.1 lb/sy	10
Tie wire	0.8 lb/sy	10
Plaster (3/4")		
Scratch coat	15 cf/100 sy	10
Brown coat	20 cf/100 sy	10
Finish coat	10 cf/100 sy	10
Carpentry		
Nails		
Framing		
8d common	5 lb/mfbm	10
10d common	15 lb/mfbm	10
16d common	10 lb/mfbm	10
Sheathing (8d common)	30 lb/mfbm	10
Flooring (8d common)	30 lb/mfbm	10
Roofing (8d common)	30 lb/mfbm	15
Wallboard (6d common)	15 lb/1000 sf	10
Trim		
4d finish	3 lb/1000 lf	10
6d finish	7 lb/1000 lf	10

Table 2-5.—Conversion and Waste Factors—Continued

Material	Conversion	% Waste
8d finish	14 lb/1000 lf	10
Lumber		
Framing	-	15
Sheathing	-	25
Flooring	-	25
Roofing	-	25
Wallboard	-	15
Trim	-	10
Steel erection		
Rivets (field)	25 ea/ton	10
Bolts (field)		
Temporary	5 ea/ton	5
Permanent	25 ea/ton	5
Sheet metal10		
Roofing		
Corrugated steel (6" end lap)		
26" width	115 sf/sq	10
27.5" width	122 sf/sq	15
Wood shingles		
16" (4" exposure)	900 ea/sq	15
18" (6" exposure)	600 ea/sq	15
24" (8" exposure)	450 ea/sq	15
Nails (4d)	4 lb/1000 shingles	15
Built-up roofing (four-ply)		
Sheathing paper	1 sq/sq	20
Felt	4 sq/sq	20
Pitch	125 lb/sq	10
Gravel	400 lb/sq	10
Tiling		
Floor tile		
Asphalt vinyl asbestos		10
Primer	5 gal/1000 sf	20
Adhesive	10 gal/1000 sf	20
Cleaner	5 gal/1000 sf	20
Wax	5 gal/1000 sf	20
Acoustic tile		
Tile		10
Cement	25 gal/1000 sf	20
Glass and glazing		
Glass		
8 x 12	75 panes/box	10
10 x 16	45 panes/box	10
12 x 20	30 panes/box	10
14 x 24	22 panes/box	10
16 x 28	16 panes/box	10

Table 2-5.—Conversion and Waste Factors—Continued

Material	Conversion	% Waste
Glazing clips-		10
Putty		
8 x 12	0.6 lb/pane	20
10 x 16	0.8 lb/pane	20
12 x 20	0.9 lb/pane	20
14 x 24	1.1 lb/pane	20
16 x 28	1.4 lb/pane	20
Caulking		
Primer2 gal/1000 lf	10	
Compound (1/2 x 1/2)	13 gal/1000 lf	10
Painting		
Metal		
Enamel	0.2 gal/100 sf	10
Zinc white	0.2 gal/100 sf	10
White lead	0.2 gal/100 sf	10
Wood		
Enamel	0.2 gal/100 sf	10
Zinc white	0.2 gal/100 sf	10
White lead	0.3 gal/100 sf	10
Varnish	0.2 gal/100 sf	10
Flat	0.2 gal/100 sf	10
Gloss	0.3 gal/100 sf	10



MATERIAL TAKEOFF SHEET

1.337, 494/7.604. 988

MATERIAL COST SECTION $ 1938.97

CANTONMENT AREA, INTERIM WATER SYS BLDG | ARCHITECTURAL | E. B. JASON

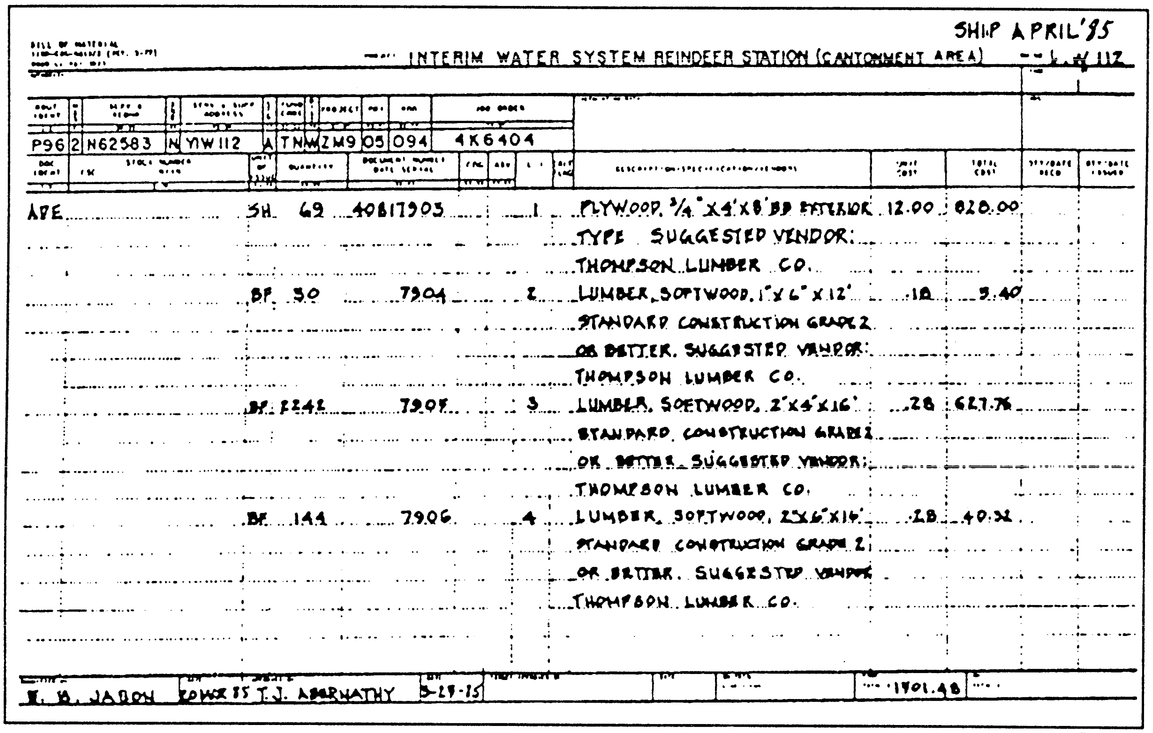
DIEGO GARCIA | 19 FEB '85 | 31 ST NCR | 1 - 5

P96 | 2 | N | 62583 | 4001 | N | Y | 1W112 | A | TN | W | ZM9 | 05 | 4K6404

1	AOE	SH	697903	094	1200	82800	PLYWOOD, ¾"×4'×8' BD EXTERIOR TYPE, SUGGESTED VENDOR: THOMPSON LBR CO
2		BF	307904		18	540	LUMBER, SOFTWOOD, 1"×6"×8' STANDARD CONSTRUCTION GRADE 2 OR BETTER SUGGESTED VENDOR: THOMPSON LBR CO
3		BF	24227903		28	67814	LUMBER, SOFTWOOD, 2"×4"×16' STANDARD CONSTRUCTION GRADE 2 OR BETTER SUGGESTED VENDOR: THOMPSON LBR CO
4		BF	1447906		28	4032	LUMBER, SOFTWOOD, 2"×6"×16' STANDARD CONSTRUCTION GRADE 2 OR BETTER, SUGGESTED VENDOR: THOMPSON LBR CO
5		BF	11737901		33	38710	LUMBER, SOFTWOOD, 4"×4"×16' STANDARD CONSTRUCTION GRADE 2 OR BETTER SUGGESTED VENDOR: THOMPSON LUMBER CO

BUNP014

Figure 2-18.—Typical material takeoff (MTO) sheet.



SHIP APRIL '95

INTERIM WATER SYSTEM REINDEER STATION (CANTONMENT AREA) L. # 112

P96	2	N62583	N	Y1W112	A	TNW	ZM9	05	094	4K6404	

APE	SH	69	40817903	1	PLYWOOD, 3/4" X 4' X 8' BD EXTERIOR TYPE SUGGESTED VENDOR: THOMPSON LUMBER CO.	12.00	828.00
	BF	30	7904	2	LUMBER, SOFTWOOD, 1" X 6" X 12' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.18	5.40
	BF	2242	7905	3	LUMBER, SOFTWOOD, 2" X 4' X 16' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR: THOMPSON LUMBER CO.	.28	627.76
	BF	144	7906	4	LUMBER, SOFTWOOD, 2" X 6" X 16' STANDARD CONSTRUCTION GRADE 2 OR BETTER. SUGGESTED VENDOR THOMPSON LUMBER CO.	.28	40.32

K. B. JARON | T. J. ABERNATHY | 5-29-95 | 1501.48

BUNP015

Figure 2-19.—Sample of a bill of material (BM) sheet.

Long Lead Items

Long lead items are not readily available through the normal supply system. They require your special attention to ensure timely delivery. Items requiring a long lead time are non-shelf items, such as steam boilers, special door and window frames, or items larger than the standard issue. Figure 2-20 shows some of the long lead items. Identify and order these items early. Make periodic status checks of the orders to avoid delays in completing the project.

EQUIPMENT ESTIMATES

Equipment estimates are used with production schedules to determine the construction equipment requirements and constraints for Seabee deployment. Of these constraints, the movement of material over roadways is frequently miscalculated. Factors, such as road conditions, the number of intersections, the amount of traffic, the hauling distances, and the speed limits, are all variables that play into your estimate. You must consider the types of material hauled, safety (machine limitations and personnel), operator experience, condition of the equipment, work hours, and the local climate are other major factors to consider in your estimate.

Equipment production must be determined so that the amount and type of equipment can be selected. Equipment production rates are available in the *Seabee Planner's and Estimator's Handbook.* The tables in this handbook provide information about the type of equipment required. Estimate the production rate per day for each piece of equipment. You should consider the factors previously covered, along with information obtained from NAVFAC P-405 and your experience. The quantity of work divided by the production rate per day produces the number of days required to perform the project. After determining the number of days of required equipment operation, consult the project schedule to find the time allotted to complete the activities. Prepare the schedule for the total deployment. Use the project schedule to determine when the work will be performed. The schedule should also indicate peak usage. It may have to be revised for more even distribution of equipment loading, thereby reducing the amount of equipment required during the deployment.

After the review of the project and material estimate are complete, prepare a list of equipment required. This list must include anticipated downtime and sufficient reserve pieces must be added to cover any downtime.

To aid you in preparing the equipment estimate schedule, use such forms as those shown in figures 2-21 and 2-22. The important information on the forms includes the sheet number, the name of the

POSSIBLE LONG LEAD ITEMS

1. Pre-Engineered Buildings
2. Marine Piles
3. Telephone Poles
4. Doors
5. Windows
6. Screens
7. Transformers
8. Circuit Breakers
9. Switch Stations
10. Fire Alarm Systems
11. Intrusion Alarm Systems
12. Air Conditioning Systems
13. Specialty Electrical Items
14. Partitions
15. Water Heaters
16. Timber (especially large sizes)
17. Lumber, Plywood (large orders)
18. Roof Systems
19. Pre-Fab Joists
20. Structural Steel Members
21. Louvers
22. Treated Wood Products
23. Specialty Coatings
24. Structural Pipe
25. Marine Hardware
26. Carpet
27. Rubber Fender Systems
28. Bolted Steel Tanks
29. Epoxy Mortars/Grouts
30. Galvanized Metal Products
31. Chain Link Fence Fabric
32. HVAC Components
33. Fire Protection Systems
34. Large Quantities/Odd Sizes of Pipe/Fittings
35. Fire Pumps
36. Control/Feedback Systems
37. Enunciator Panels
38. Power Panels
39. Explosion Proof Systems
40. Large Quantity or Specialty Cable
41. Cathodic Protection Systems
42. High Intensity Discharge Light Fixtures/Lamps
43. High Voltage Specialty Switchgear
44. Silver Solder
45. Cabinets (wood and metal)
46. Hardware/locks/cipher locks

Finish items such as decorative brick, clay tiles, unusual carpeting may require time to locate.

Large purchases of any item (over $20k or 25K depending on local purchase authority) require time to competitively bid.

Electrical items tend to be unique to each installation and require additional time.

Figure 2-20.—Possible long lead items.

estimator, the name of the checker, date checked, battalion and detachment number, location of deployment, year of deployment, project number, and a brief description of the project.

The Table of Allowance (TOA) for the NMCBs contain specific information on the quantities and characteristics of construction equipment available to the NMCBs. The TOA-01 contains equipment and tool kit descriptions. Kit descriptions are presented by their section and numerical sequence as listed in the NMCB TOA-01 followed by assembly numbers, as shown in figure 2-23. Also, refer to appendix B of the P405 for the complete listing of tool kits and equipment.

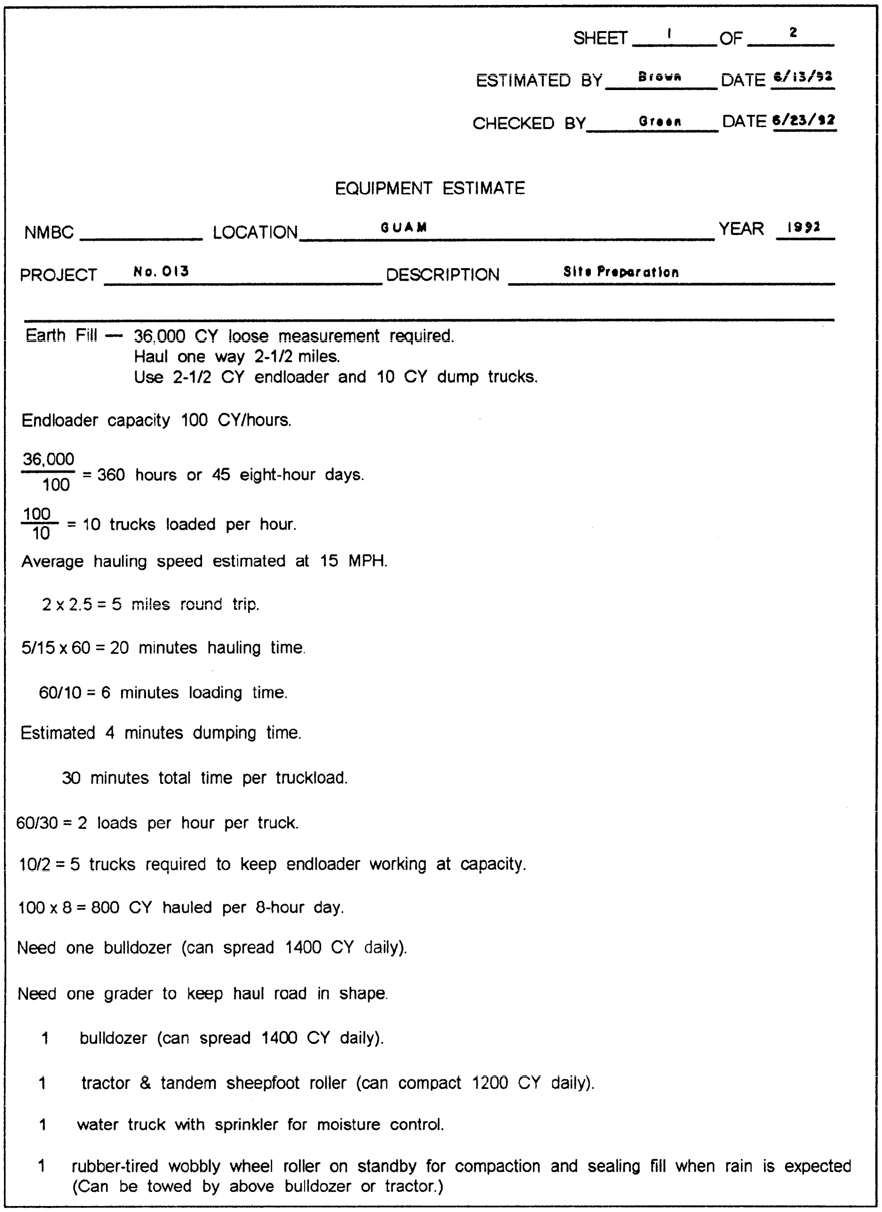
LABOR ESTIMATES

Preliminary labor estimates and detailed labor estimates are the two types covered in the following sections.

Preliminary Estimates

Use preliminary labor estimates to establish budget costs and to project labor requirements for succeeding projects and deployments. The estimates are prepared from limited information, such as general descriptions or preliminary plans and specifications, that contain little or no detailed information. In some eases, you can make a comparison with similar facilities of the same basic design, size, and type of construction. A good preliminary estimate varies less than 15 percent from the detailed estimate.

The NAVFAC P-437, *Facilities Planning Guide,* volume 1 (drawings on CD ROM) and volume 2 (materials list on diskette) is an excellent source for preliminary estimates. This manual can be used to find estimates for a wide range of facilities and assemblies most commonly constructed by the NCF. The NAVFAC,



SHEET 1 OF 2

ESTIMATED BY Brown DATE 6/13/92

CHECKED BY Green DATE 6/23/92

EQUIPMENT ESTIMATE

NMBC ____ LOCATION GUAM YEAR 1992

PROJECT No. 013 DESCRIPTION Site Preparation

Earth Fill — 36,000 CY loose measurement required.
Haul one way 2-1/2 miles.
Use 2-1/2 CY endloader and 10 CY dump trucks.

Endloader capacity 100 CY/hours.

$\frac{36,000}{100}$ = 360 hours or 45 eight-hour days.

$\frac{100}{10}$ = 10 trucks loaded per hour.

Average hauling speed estimated at 15 MPH.

2 x 2.5 = 5 miles round trip.

5/15 x 60 = 20 minutes hauling time.

60/10 = 6 minutes loading time.

Estimated 4 minutes dumping time.

30 minutes total time per truckload.

60/30 = 2 loads per hour per truck.

10/2 = 5 trucks required to keep endloader working at capacity.

100 x 8 = 800 CY hauled per 8-hour day.

Need one bulldozer (can spread 1400 CY daily).

Need one grader to keep haul road in shape.

1 bulldozer (can spread 1400 CY daily).

1 tractor & tandem sheepfoot roller (can compact 1200 CY daily).

1 water truck with sprinkler for moisture control.

1 rubber-tired wobbly wheel roller on standby for compaction and sealing fill when rain is expected
(Can be towed by above bulldozer or tractor.)

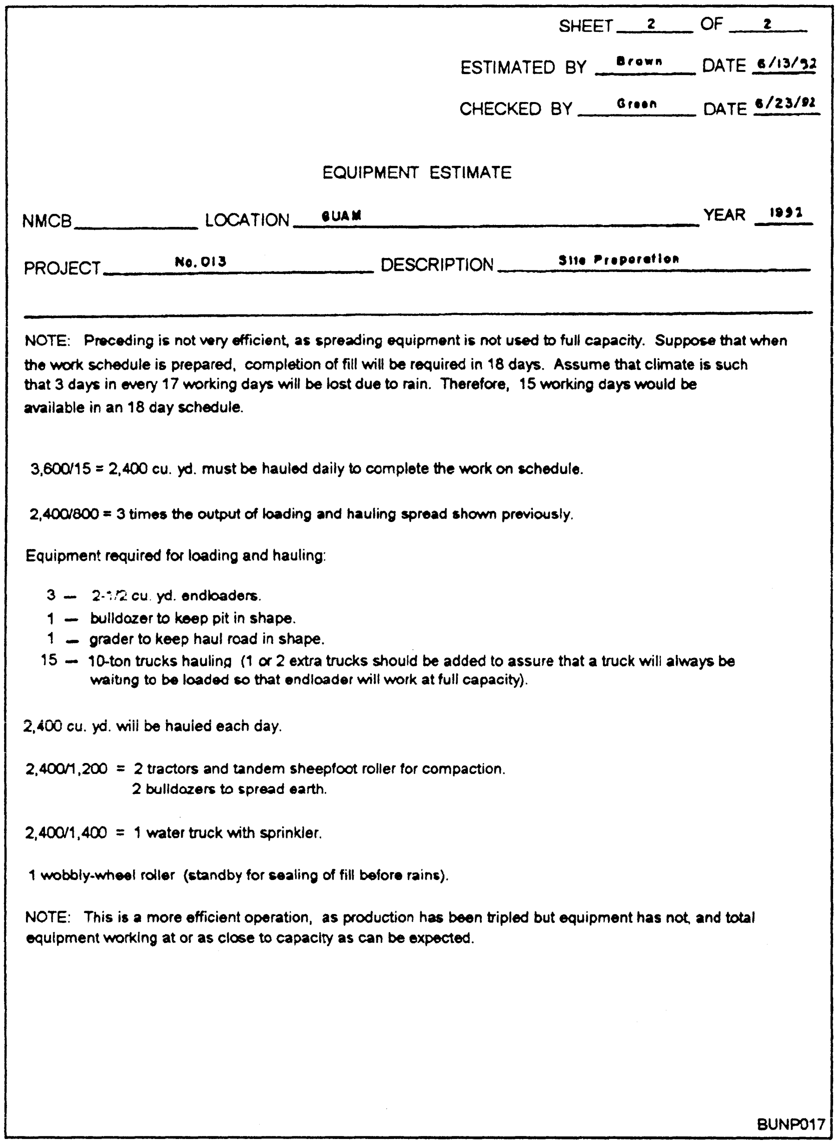
BUNP016

Figure 2-21.—Sample equipment estimate (page 1).

P-437 not only gives the man-hours required but also gives a breakdown of the construction efforts by rating as well as lapse time which is expressed in the following equation. The P-437 estimates all labor on 10 hour workdays; however, do not mistake this with the normal workday of 8 man-hours per man-day.

Detailed Estimates

Use detailed material estimates and equipment estimates to assist you in determining the labor requirements for constructing a given project. Take the individual activity quantities from the activity work sheet to prepare your detailed estimates and then select the man-hours per unit figure from the appropriate table in P-405 and multiply it by the quantity to obtain the total man-hours required. When preparing the activity estimates in the format covered earlier, you may use a copy of the activity estimates as a labor estimate work sheet by adding four columns to it with the headings of Activity, Quantity, Man-Hours per Unit, and Total Man-Days required. Prepare work sheets, whether on the activity work sheet or on another format, in sufficient detail to provide the degree of progress control desired.



SHEET 2 OF 2

ESTIMATED BY Brown DATE 6/13/92

CHECKED BY Green DATE 6/23/92

EQUIPMENT ESTIMATE

NMCB ______ LOCATION GUAM YEAR 1992

PROJECT No. 013 DESCRIPTION Site Preparation

NOTE: Preceding is not very efficient, as spreading equipment is not used to full capacity. Suppose that when the work schedule is prepared, completion of fill will be required in 18 days. Assume that climate is such that 3 days in every 17 working days will be lost due to rain. Therefore, 15 working days would be available in an 18 day schedule.

3,600/15 = 2,400 cu. yd. must be hauled daily to complete the work on schedule.

2,400/800 = 3 times the output of loading and hauling spread shown previously.

Equipment required for loading and hauling:

3 — 2-1/2 cu. yd. endloaders.
1 — bulldozer to keep pit in shape.
1 — grader to keep haul road in shape.
15 — 10-ton trucks hauling (1 or 2 extra trucks should be added to assure that a truck will always be waiting to be loaded so that endloader will work at full capacity).

2,400 cu. yd. will be hauled each day.

2,400/1,200 = 2 tractors and tandem sheepfoot roller for compaction.
2 bulldozers to spread earth.

2,400/1,400 = 1 water truck with sprinkler.

1 wobbly-wheel roller (standby for sealing of fill before rains).

NOTE: This is a more efficient operation, as production has been tripled but equipment has not, and total equipment working at or as close to capacity as can be expected.

BUNP017

Figure 2-22.—Sample equipment estimate (page 2).

When you prepare labor estimates, weigh the various factors that affect the amount of labor required to construct a project. These include weather conditions during the construction period, skill and experience of personnel who will perform the work, time allotted for completing the job, size of the crew to be used, accessibility of the site, and types of material and equipment to be used.

Production Efficiency Guide Chart and Graph

The production efficiency guide chart (table 2-4) lists eight elements that directly affect production. Each production element is matched with three areas for evaluation. Each element contains two or more foreseen conditions to select from for the job in question. Evaluate each production element at some percentage between 25 and 100 according to your analysis of the foreseen conditions. The average of the eight evaluations is the overall production efficiency percentage. Now, convert the percentage to a delay factor, using the production efficiency graph (fig. 2-14), or by the Seabee average for production (67 percent) or by the average of the eight production elements. The field or project supervisors are strongly recommended to reevaluate the various production elements and make the necessary adjustments to man-day figures based on actual conditions at the jobsite.

In reading the graph, note that the production elements have been computed into percentages of production efficiency, which are indicated at the bottom of the graph. First, place a straightedge so that it extends up vertically from the desired percentage, 80019 Kit, Carpenters

Designed for: Field crew of 4 Builders, F/4 men

This kit contains the basic hand tools required for various carpentry jobs in the field. Contained in the kit are: hammers, chisels, hand saws, nail sets, rasps, hatchet, framing squares, and other small hand tools. No electrical or penumatic tools are included in this assembly. Refer to Power Tool Assemblies located at the end of this section for a listing of the various individual power tools.

80030 Kit, Mason Tools

Designed for: Field crew of 4 block or brick layers, F/4 men

This kit contains the basic hand tools required for laying masonry units in place. Contained in the kit are:
masonry chisels, trowels, hammers, levels, and other small hand tools.

80056 Kit, Concrete Placement

Designed for: Finishing concrete

This kit contains the basic hand tools required for finishing concrete. Contained in the kit are: floats, trowels, tampers, canvas tool bag, and other small hand tools. This kit may be augmented by the various assemblies located under Power Tools at the end of this section.

83001 Miscellaneous Construction Tools

Designed for: Augmenting construction tool specialty Tools

This assembly contains equipment and tools not included in other construction kit such as:
wheelbarrows, concrete carts, air-operated sump pump, shovels, water jugs, door hinge mortising kit, and other small hand tools such as saws, auger bits, Dumpy builder level, and post hole digger.

Figure 2-23.—Kit assemblies for BUS.

and then place it horizontally from the point at which it intersected the diagonal line. You can now read the delay factor from the values given on the right-hand side of the chart. Let's look at an example of the process of adjusting man-hour estimates.

Assume that from the work estimate taken from the tables in P-405, you find that 6 man-hours are needed for a given unit of work. To adjust this figure to the conditions evaluated on your job, assume that the average of foreseen conditions you rated is 87 percent. The corresponding delay factor read from the production efficiency graph is 0.80. You find the adjusted man-hour estimate by multiplying this delay factor by the man-hours from the estimating tables (6 MH x 0.8 = 4.8 as the adjusted man-hour estimate).

The activities in the various labor estimating tables are divided into units of measurement commonly associated with each craft and material takeoff quantities. There is only one amount of man-hour effort per unit of work. This number represents normal Seabee production under average conditions. As used herein, 1 man-day equals 8 man-hours of direct labor.

No two jobs are exactly alike, nor do they have exactly the same conditions. Therefore, you, as the estimator, must exercise some judgment about the project that is being planned. The production efficiency guide chart and graph (table 2-4 and fig. 2-14) are provided to assist you in weighing the many factors that contribute to varying production conditions and the eventual completion of a project. You can then translate what is known about a particular project and produce a more accurate quantity from the average figures given on the labor estimating tables.

SCHEDULING

Scheduling is the process of determining when an action must be taken and when material, equipment, and manpower are required. There are four basic types of schedules: progress, material, equipment, and manpower.

Progress schedules coordinate all the projects of a Seabee deployment or all the activities of a single project. They show the sequence, the starting time, the performance time required, and the time required for completion. Material schedules show when the material is needed on the job. They may also show the sequence in which materials should be delivered. Equipment schedules coordinate all the equipment to be used on a project. They also show when it is to be used and the amount of time each piece of equipment is required to perform the work. Labor schedules coordinate the manpower requirements of a project and show the number of personnel required for each activity. In addition, the number of personnel of each rating (Builder, Construction Electrician, Equipment Operator, Steelworker, and Utilitiesman) required for each activity for each period of time may be shown. The time unit shown in a schedule should be some convenient interval, such as a day, a week, or a month.

ELEMENTS

A network represents any sequencing of priorities among the activities that form a project. This sequencing is determined by hard or soft dependencies. Hard dependencies are based upon the physical characteristics of the job, such as the necessity for placing a foundation before building the walls. A hard dependency is normally inflexible. **Soft dependencies** are based upon practical considerations of policy and may be changed if circumstances demand. The decision to start at the north end of a building, rather than at the south end, is an example.

PRECEDENCE DIAGRAMS

Network procedures are based upon a system that identifies and schedules key events into precedence-related patterns. Since the events are interdependent, proper arrangement helps in monitoring the independent activities and in evaluating project progress. The basic concept is known as the critical path method (CPM). Because the CPM places great emphasis Upon task accomplishment, a means of activity identification must be established to track the progress of an activity. The method currently in use is the activity-on-node precedence diagraming method (PDM) where a node is simply the graphic representation of an activity. An example of this is shown in figure 2-24.

Activities

To build a flexible CPM network, the manager needs a reliable means of obtaining project data to be represented by a node. An activity in a precedence diagram is represented by a rectangular box and identified by an activity number.

The left side of the activity block represents the start of the activity. The right side represents the completion. Lines linking the boxes are called connectors. The general direction of flow is evident in the connectors themselves. Figure 2-25 shows a typical activity block used by the NCF.

Activities may be divided into the following two distinct groups:

1. **Working Activities**— Activities that relate to particular tasks.

2. **Critical activities**— Activities that together, comprise the longest path through the network. This is represented by two slashes drawn through an activity connector.

The activities are sequenced logically to show the activity flow for the project. The activity flow can be determined by answering the following questions:

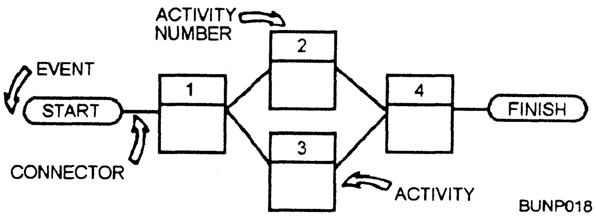


Figure 2-24.—Precedence diagram.

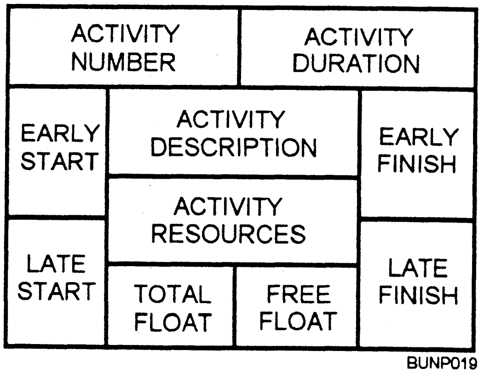


Figure 2-25.—Typical activity block.

What activities must precede the activity being examined? What activities can be concurrent with this activity? What activities must follow this activity?

WORKING ACTIVITIES.— Wlth respect to a given activity, these representations indicate points in time for the associated activities. Although the boxes in the precedence diagram represent activities, they do not represent time, and therefore, they are not normally drawn to scale. They only reflect the logical sequence of events.

CRITICAL ACTIVITIES.— A critical activity is an activity within the network that has zero float time. The critical activities of a network makeup the longest path through the network (critical path) that controls the project finish date. Two slash marks drawn through an activity connector, as shown in figure 2-26, denote a critical path.

The rule governing the drawing of a network is that the start of an activity must be linked to the ends of all completed activities before that start may take place. Activities taking place at the same time are not linked in any way. In figure 2-24, both Activity 2 and Activity 3 start as soon as Activity 1 is complete. Activity 4 requires the completion of both Activities 2 and 3 before it may start.

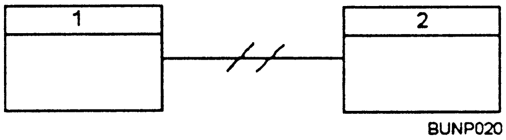


Figure 2-26.—Designation of a critical path.

Use of Diagram Connectors

Within a precedence diagram, connectors are lines drawn between two or more activities to establish a logic sequence. In the next paragraphs, we will look at the diagram connectors commonly used in the critical path method (CPM).

- **FINISH to START** connector, as shown in figure 2-27, is the most widely used connector in a precedence diagram. This connector represents the finish of one activity and the start of another. In the activity block there are boxes labeled EARLY FINISH (EF), LATE FINISH (LF) and EARLY START (ES), LATE START (LS), which is very critical in computing the forward pass and backward pass. These terms are covered later in this section.
- **START to START** connector, as shown in figure 2-28, represents activities that can either parallel each other or that may start at the same time or be delayed a day or two. For example, pre-fab forms can start at the same time as building layout starts or setting forms can begin at the same time as excavation, but you might want to delay the setting of forms by 1 day for the EOs to excavate and to make sure they are clear of where your crew is working.
- **FINISH to FINISH** connector, as shown in figure 2-29, is possible when the start of an activity is independent but is not completed before another activity is completed. Exercise care when you use this logic connection. If possible, the FINISH to START connector should be used for all planning.

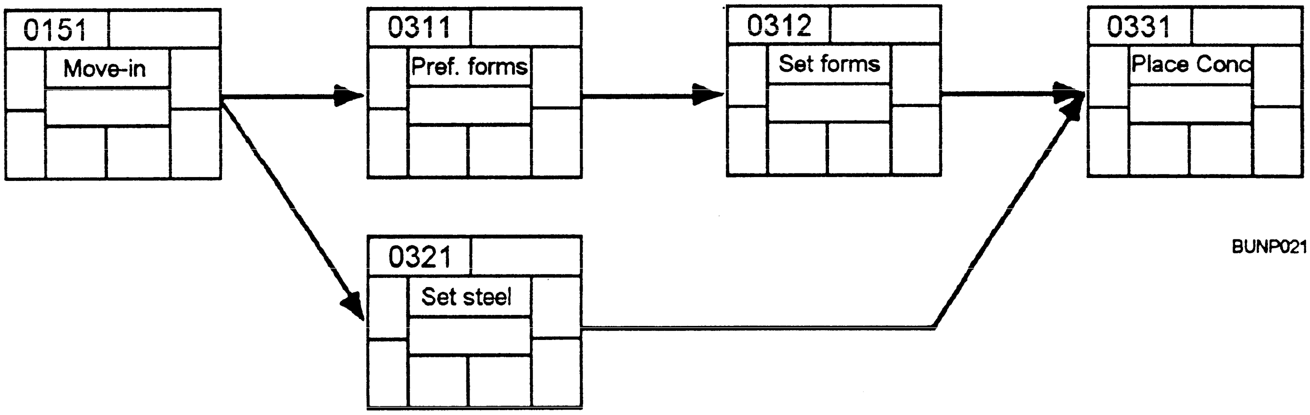
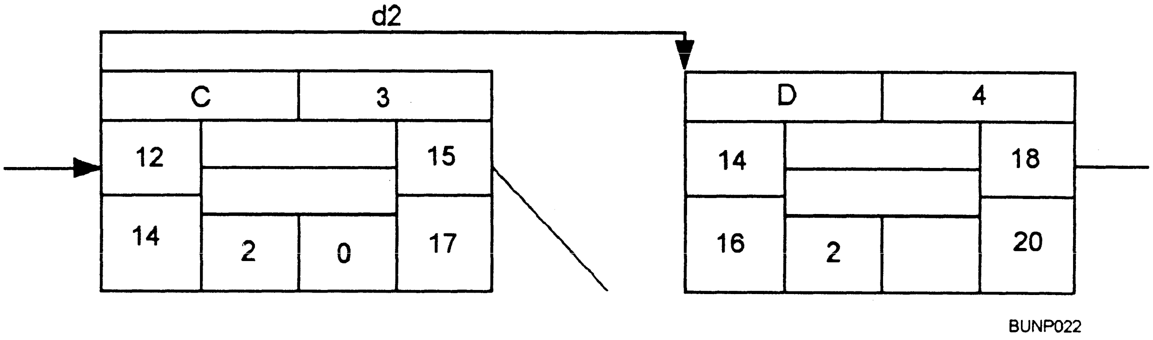
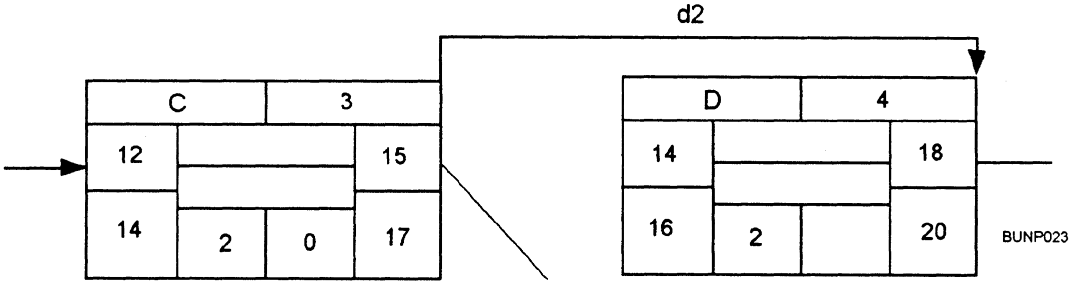


Figure 2-27.—Finish to start connector.



Forward Pass: *Early Start* + Lag = *Early Start* (next activity)
Backwards Pass: *Late Start* - Lag = *Late Start* (preceding activity)
Free Float = *Early Start* (next activity) - Lag - *Early Start*

Figure 2-28.—Start to start connector with a delay.



Forward Pass: Early Finish + Lag = Early Finish (next activity)
Backwards Pass: Late Finish - Lag = Late Finish (preceding activity)
Free Float = Early Finish (next activity) - Lag - Early Finish

Figure 2-29.—Finish to finish connector with a delay.

REPRESENTATION of a DELAY, in certain cases, is used when there may be a "delay or lag" between the start of one activity and the start of another. In this case, the delay maybe indicated on the connector itself, preceded by the letter *d*, as shown in figure 2-28. Here, activity C may start; however, Activity D must wait two days before starting. The delay is stated in the basic time units of the project, so the word *days* can be omitted.

- **SPLITTING CONNECTORS** are seldom used except when the network is of a great size. When two activities are remote and have to be connected, the lines tend to become lost or difficult to follow. In such cases, it is not necessary to draw a continuous line between the two activities. Their relationship is shown by circles with the following activity number in one and the preceding activity number in the other.

In figure 2-30, both Activities 2 and 6 are dependent upon Activity 1.

Construction Schedule

You must put together realistic, workable schedules during the planning and estimating stages of a project if you hope to finish the tasking on schedule during the deployment. Crucial to a workable

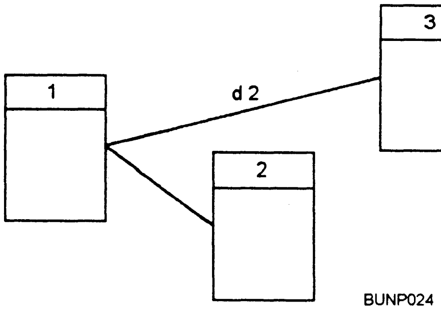


Figure 2-30.—Splitting connectors.

schedule is the proper, logical sequence of activities and good realistic durations. Performing the forward and backward pass will identify the critical path. The critical path gives you a list of milestones (activity completion dates) that must be met. If these milestones are met, the project will be on track and finished by the scheduled completion date.

LEVEL II ROUGHS.— As the construction schedule unfolds, a commitment of resources (labor and equipment) from several different companies is required to ensure you can maintain the schedule. Rough Level II schedules coordinate the planning effort between companies and ensure that no particular company or rating is overtasked during any phase of the deployment. Good coordination in the beginning is less painful than a major overhaul later. Having determined the sequence and approximate duration of each master activity, you can construct a Level II bar chart. Each project will have a Level II. The OPS officers and the company commanders typically track projects using a Level II. Bar charts are covered in greater detail later in this chapter.

LOGIC NETWORK.— The logic network, also refereed to as precedence diagraming, is the basic management tool for controlling, monitoring, and distributing all resources that are directly related to time. The logic network at the planning stage is a pure dependency diagram. All activities are drawn in the order in which they must be accomplished without regard to particular construction preference. One of the major uses of the logic network during the planning stage is to indicate all activities that must be accomplished to complete a particular project (fig. 2-31). The individual network activities should be well-defined elements of work within the project and should be normally limited to a single rating. As a general rule, an activity should be created for any function that consumes or uses direct labor resources. Resources (manpower, equipment, tools, or materials) MUST be tied directly to the CAS sheet and network.

The crew leader constructs a logic network, showing the sequence of construction activities from the first to the last and the dependencies between activities. Make sure no items of work are left out. It is important that you do the logic network when breaking the project down into construction activities. You do not yet have construction activity durations, so you are only concerned about the sequence of work. Each construction activity is represented by an activity block. In the network shown in figure 2-31, activities 0311, 0321, and 0211 cannot start until activity 0151 is finished. Activity 0312 cannot start until 0311 and 0211 are finished, and activity 0331 cannot start until all previous activities are finished.

BASIC SCHEDULE (FORWARD AND BACKWARD PASS).— Using the crew sizes, now you can determine the construction activity durations. Go back to the logic diagram and insert the durations to determine the basic schedule. Practice with the example here and those included later. Some minor revisions may be required to the basic schedule (see resource leveling) before setting the final schedule. On the precedence network, you will need to insert into an activity block the activity number, the description, and the duration for each activity.

The first step in determining the basic schedule is to do a forward pass. The forward pass gives you the total duration of your project. You start with the very first activity and plug in a zero for its early start date. Then add the duration to the early start date to get the early finish date. The early finish date for an activity becomes the early start date for the next activity. Notice that activity 0312 in figure 2-31 has two preceding activities (0211 and 0311) and you chose the larger of the early finish dates (11 vice 10). Remember to add any lag time between the activities. **Lag or delay times are mandatory wait times between activities.** A common example is concrete cure times. Cure times require you to wait several days to weeks after placing concrete before you strip the forms.

Early Start + Duration = Early Finish

Early Finish + Lag (if any)= Early Start (next activity)

Look at the network in figure 2-31; the early start and finish dates for an activity depend on the number and duration of the activities that have to be done before it.

The next step in determining the basic schedule is a backward pass. **The backward pass determines your critical path.** You start by taking the early finish date for the last activity and making it the late finish for the last activity. For each activity, you subtract the duration from the late finish date to get the late start date. The late start date will become the late finish date for the preceding activity. Notice that activity 0211 in figure 2-31 has two follow-on activities and you took the smaller of the late starts (11 vice 12). Follow the equations shown through the network in figure 2-31. For any activity where the early start is the same as the late start and the early finish is the same as the late finish, that activity is critical!

Late Finish - Duration = Late Start

Late Start - Lag (if any) = Late Finish (preceding activity)

TOTAL FLOAT.— Total float is the number of days an activity can be delayed without delaying the project completion date. Looking at activity 0311 in figure 2-31, you see that it could finish as early as day 10 or as late as day 12. The 2 days of leeway between day 10 and day 12 inactivity 0311 are called total float. To calculate the total float, you subtract the early finish date from the late finish date or the early start date from the late start date. The numbers will be the same. If not, you made a math error.

Total Float = Late Start - Early Start (or Late Finish - Early Finish)

FREE FLOAT.— Free float is the number of days an activity can be delayed without taking float away from the next activity. Another way of saying the same thing is that free float is the number of days an activity can be delayed without delaying the early start date of the next activity. To calculate the free float for an activity, you subtract any lagtime and the early finish for the activity from the early start for the next activity. To calculate the free float for activity 0311 in figure 2-31, you would take the early start for activity 0312, subtract any lagtime between 1020 and 1050 (zero in this case), and subtract the early finish for activity 0311 (11 - O - 10 = 1). Free float for activity 0311 is 1 day. You can see that delaying activity 0311 by 1 day will not delay activity 0312 from its early start date. Delaying activity 0311 by 2 days will delay the start of activity 0312 until day 12 and reduce the float for activity 0312 by 1 day (to zero, in this case). The delay of activity 0311 by more than 2 days will delay the project completion date because 0311 has only 2 days of total float.

Free Float = Early Start (next activity) - Lagtime (if any) - Early Finish

CRITICAL PATH.— Looking at activity 0311 in figure 2-31, you could start that activity as early as day 3 or as late as day 5. Now subtract 3 from 5 and enter 2 days as the total float. Where the early start and late start are the same, there is no float. “No float” means you have to start that activity on its early start date. It cannot be delayed without delaying the project completion date. Activities with no float are said to be critical. The first and last activities will always be critical, and there will be a critical path of activities between them. The **critical path** in figure 2-31, is 0151-0211-0322-0331. The critical path allows management to focus attention on those activities that cannot slip.

Advantages of Diagrams

Precedence networks are easy to draw because all the activities can be placed on small cards, laid out on a flat surface, and easily manipulated until a logical sequence is achieved. It is also easy to show the interrelationships and forward progress of the activities. Just draw connector lines. Figure 2-32

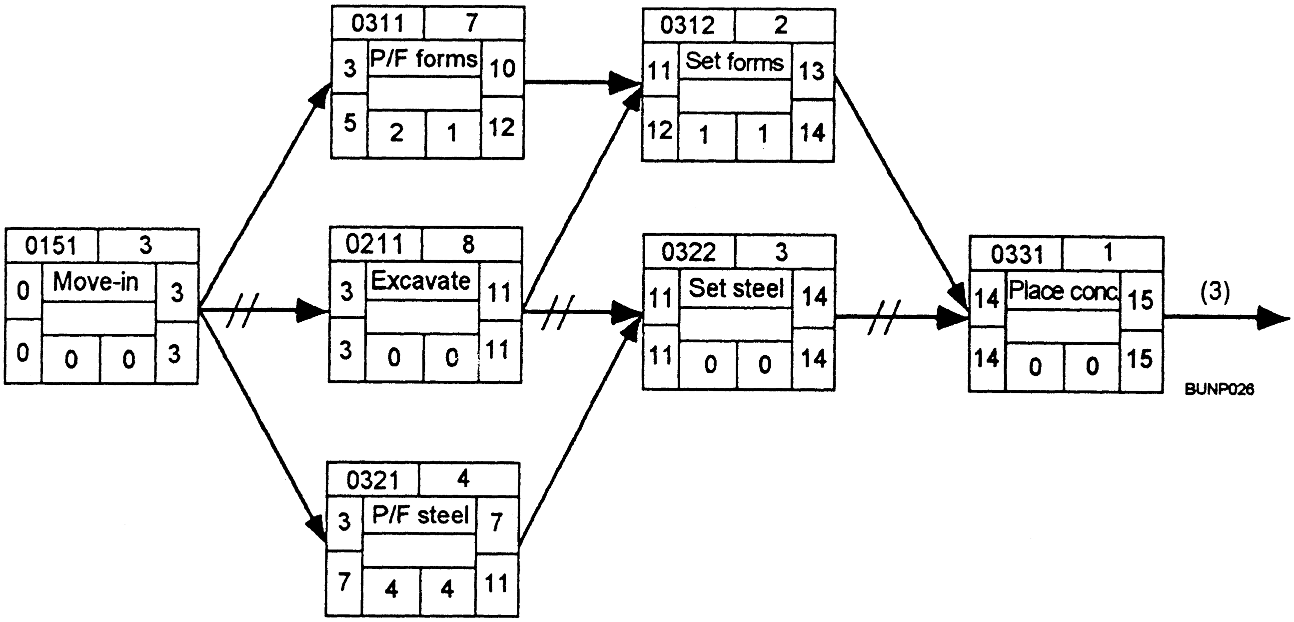
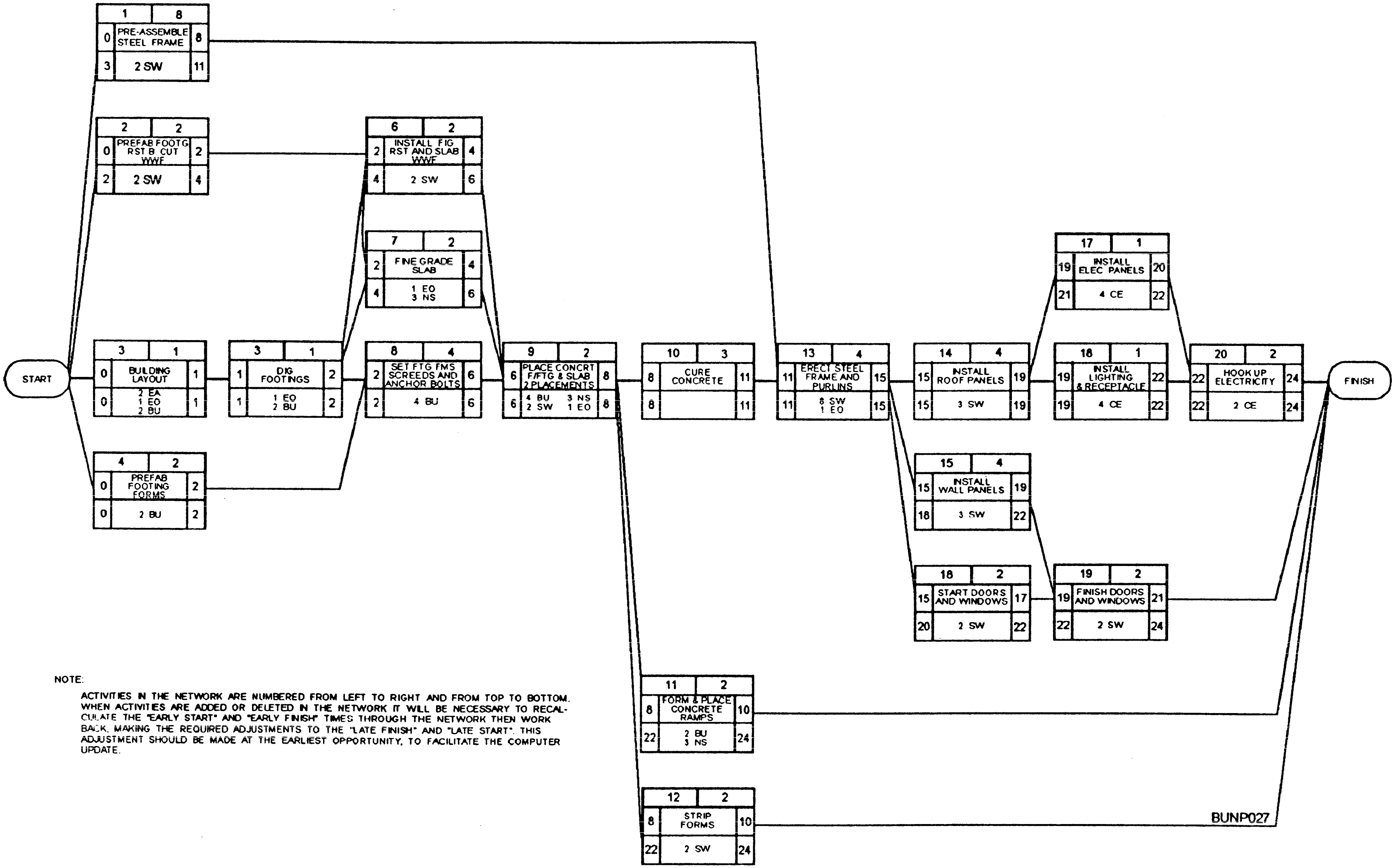


Figure 2-31.—Logic network.



NOTE:

ACTIVITIES IN THE NETWORK ARE NUMBERED FROM LEFT TO RIGHT AND FROM TOP TO BOTTOM. WHEN ACTIVITIES ARE ADDED OR DELETED IN THE NETWORK IT WILL BE NECESSARY TO RECALCULATE THE "EARLY START" AND "EARLY FINISH" TIMES THROUGH THE NETWORK THEN WORK BACK, MAKING THE REQUIRED ADJUSTMENTS TO THE "LATE FINISH" AND "LATE START". THIS ADJUSTMENT SHOULD BE MADE AT THE EARLIEST OPPORTUNITY, TO FACILITATE THE COMPUTER UPDATE.

Figure 2-32.—Typical precedence diagram of a 40-foot by 100-foot PEB.

shows a typical diagram for a 40-foot by 100-foot rigid-frame building.

Level III Bar Charts

Having determined the construction schedule on the precedence network, you must now transfer that information to a bar chart. You can manually draw the bar chart, or you can generate the bar chart on the Seabee Construction Management (CBCM) computer program. All of the "construction activities" are listed down the left-hand column of the bar chart. Refer to the *Seabee Crewleader's Handbook* for a computer generated Level III bar chart. A time scale is at the top of the page. The time scale goes from the first workday of the project to the last workday. The start date, the finish date, and the duration of each construction activity are shown on the bar chart. The double horizontal dash lines represent critical construction activity durations. The single dash lines represent noncritical activity durations. Free floats are shown as dots behind each noncritical activity. For activities with no free float, you have to look at the activity that they are sharing floats with to find the total float.

Resource Leveling

Resource leveling involves matching the construction activities scheduled to the crew size available. You want the entire crew to be gainfully employed every day. You also want to keep up with the scheduled work and not fall behind. To perform resource leveling, you need a known crew size, a time-scaled schedule, and a histogram. The histogram shows how many people in each rating are required on a daily basis to complete the tasks scheduled. You can create these documents by hand or computer. The numbers give the required resources needed to complete the critical activities scheduled for each day. These activities cannot be moved without delaying the project!

The primary task in resource leveling is to schedule the noncritical work as you have people to do the work. You have resource leveled this project for a small detachment scenario. Here the prime/sub arrangement is not practical and extensive cross-rate use of personnel is common. Some minor adjustments on crew sizes and durations maybe required to ensure the full use of the assigned crew. Once all the activities are scheduled, you can input the noncritical resources and delayed start dates (using lags) and create a new bar chart. You can create this new bar chart with the computer or manually.

Level II Bar Chart

You make a Level II bar chart from the information gained from the Level III. Figure 2-33 is a Level II bar chart with master activities listed in a column on the left and the weeks of the entire deployment across the top. The date used is always the Monday of that week. Next to each master activity is the man-day estimate for that master activity. The next column is the weighted percent, which is the master activity man-day estimate divided by the total project man-day estimate expressed as a percent (multiplied by 100). If you look at the Level II bar chart, you will see that master activity 03 has 140 man-days scheduled during the weeks beginning with 19 May through the week of 28 July. Figure 2-33 has a horizontal bar connecting the weeks of 19 May and running to the end of week of 28 July for master activity 03 (concrete construction). The scheduled man-days for activity 03 are printed above the bar.

Once you have all the bars signifying master activity durations and the man-days scheduled on the bar chart, total the man-days scheduled for each 2-week period at the bottom of each column. The cumulative man-days scheduled is equal to the man-days scheduled for each 2-week period added to all previous man-days scheduled. The percent complete scheduled (plot) is equal to the cumulative man-days scheduled divided by the total project man-days. You then draw the scheduled progress curve by plotting the percent complete scheduled at the end of each 2-week period plotted against the percentage scale on the right of the Level II bar chart.

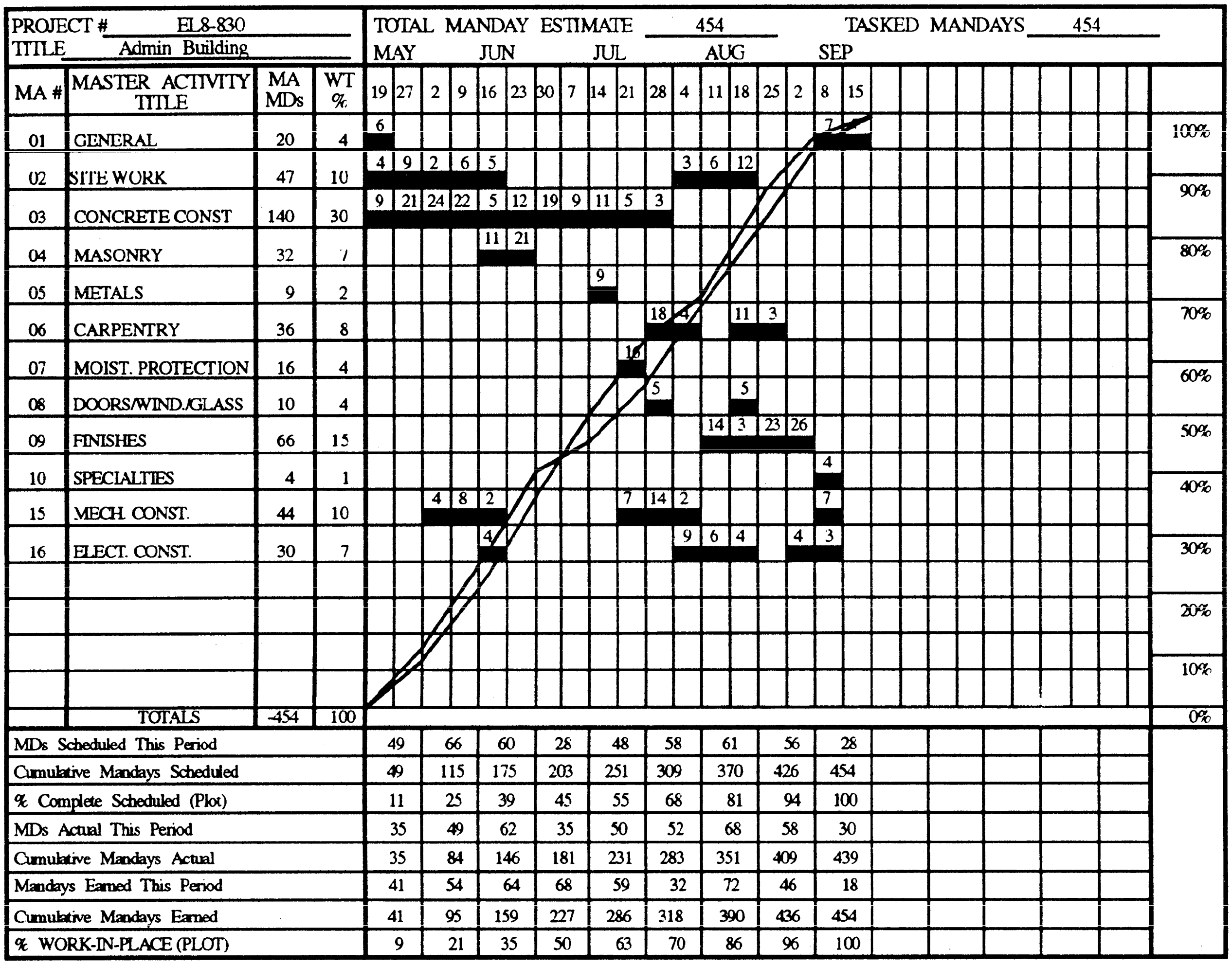
ENGINEERED PERFORMANCE STANDARDS

Engineered Performance Standards (EPS) is one of many sources of facilities maintenance and repair standards. Developed by the Department of Defense, it is the only source of facilities maintenance and repair standards used by DoD personnel.

HISTORY OF EPS

In the early 1950s, the Department of Defense (DoD) became concerned about managing real property maintenance activities. All the services faced a growing problem of maintaining an ever- increasing inventory of facilities (many of which were World War

NCF LEVEL II



MA #	MASTER ACTIVITY TITLE	MA MDs	WT %
01	GENERAL	20	4
02	SITE WORK	47	10
03	CONCRETE CONST	140	30
04	MASONRY	32	7
05	METALS	9	2
06	CARPENTRY	36	8
07	MOIST. PROTECTION	16	4
08	DOORS/WIND./GLASS	10	4
09	FINISHES	66	15
10	SPECIALTIES	4	1
15	MECH. CONST.	44	10
16	ELECT. CONST.	30	7
	TOTALS	454	100

MDs Scheduled This Period	49	66	60	28	48	58	61	56	28
Cumulative Mandays Scheduled	49	115	175	203	251	309	370	426	454
% Complete Scheduled (Plot)	11	25	39	45	55	68	81	94	100
MDs Actual This Period	35	49	62	35	50	52	68	58	30
Cumulative Mandays Actual	35	84	146	181	231	283	351	409	439
Mandays Earned This Period	41	54	64	68	59	32	72	46	18
Cumulative Mandays Earned	41	95	159	227	286	318	390	436	454
% WORK-IN-PLACE (PLOT)	9	21	35	50	63	70	86	96	100

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Figure 2-33.—Level II bar chart.

II vintage) being utilized far beyond their original designed life capacity. Where breakdown maintenance had been the operating policy, the new direction was to raise the level of maintenance so that these facilities could continue to be utilized. However, no additional resources were provided. In the meantime, accelerated new construction programs continually added more maintenance and repair requirements as permanent facilities were completed and turned over to the government.

To realize the fullest and most efficient utilization of available resources, industrial engineering procedures and techniques were applied and maintenance management systems developed. Within its framework came the idea of developing standards for maintenance work. This effort, beginning in 1957, formed the basis for the Navy's system. Several years later the Army and Air Force, who had been developing standards of their own, adopted the Navy's more advanced *Engineered Performance Standards* Program for estimating maintenance work.

EPS was developed by engineers using proven industrial engineering techniques and years of experience and expertise which have gone into the deviation of these standards.

DEFINITION

EPS is the average time necessary for a qualified worker, working at a normal pace, under capable supervision and experiencing normal delays, to perform a defined amount of work, of a specified quality, while following acceptable trade methods.

EPS data is a tool used by planner/estimators to develop consistent, uniform, and accurate facilities maintenance and repair estimates. Any trained planner and estimator who has a good working knowledge of the trade should be able to develop good labor estimates using these standards.

TRAINING

The Department of Defense has designed a training aid to the EPS system called the *Work Estimating Desk Guide for Real Property Maintenance Activities Planners and Estimators.* This manual emphasizes the use and application of the Engineered Performance Standards. Any supervisor stationed at a Public Works Center (PWC) or Public Works Department (PWD) should go through this course using this manual as a reference.

ADVANTAGES OF EPS

Engineered Performance Standards are designed specifically for facilities maintenance type work through the observation of maintenance workers at work. The work is measured through the use of proven industrial engineering techniques, such as Methods-Time Measurement (MTM), work sampling, and time studies. They are designed to relate a given amount of work to the labor hours needed to accomplish the work.

EPS estimates are based on the labor hours needed to do a specified amount of work under normal conditions. When EPS is properly applied under those normal conditions, the craft time should be valid at any work site in any geographical location.

EPS is the only facilities maintenance work estimating source that provides consistent measures of maintenance work productivity. As a benchmark, EPS provides a means of measuring productivity. The variance between EPS estimates and the actual labor time can be evaluated to identify work process problems impeding both the productivity of the work force and the quality of the work output.

Facilities maintenance work does not lend itself to having pinpoint accuracy for any particular single job or task. Rather, the accuracy of EPS based estimates increases as the size of the job increases and the effect of averaging levels the variables stated in the EPS definition: normal pace, capable supervision, normal delays, and acceptable trade methods.

Engineered Performance Standards are developed and consistently applied so that plainer/estimators can estimate a greater variety of jobs with increased accuracy in less time and with less formal data than using conventional data. All EPS data is applied in the same way.

PLANNING AND ESTIMATING

The planner and estimator holds the key position in the Shore Facilities Maintenance System. This person or these persons are responsible for planning technical jobs and estimating the number of man-hours needed to complete the maintenance work.

The estimator defines the scope of a project by specifying the work to be accomplished and the skills required. To help the estimator in this job, the Navy has developed *Engineered Performance Standards* (EPSs). The EPSs give estimates of the time needed to complete the particular craft phases of a job. You will find a complete description of EPSs in the NAVFAC P-700 series. Since these standards save time and usually provide more reliable estimates than individual judgment, the estimators should use them. When an engineered design is needed, the Engineering Branch provides it to the estimator. Two types of estimates are used and each conforms to a particular need.

Scoping Estimate

Typically, the scoping estimate helps management to get an estimate of job costs before assigning a job priority. The formal planning and estimating process can provide this, but only at significant expense. Since a ball park estimate is normally adequate, NAVFAC has encouraged the use of the scoping estimate as a rough, quick estimate of costs. The scoping estimate is particularly useful when you deal with reimbursable customers. You can inform them of the approximate job costs and ask if they want to go on with the work *Unit Price Standards,* NAVFAC P-716.0, should be used when preparing scoping estimates.

Final Estimate

Do not authorize a final estimate until the job is approved. This type of estimate shows all the work operations listed on the job plan and considers the analysis of work operations in detail. The final estimate should be the most accurate forecast possible of the costs, the man-hours, and the material requirements for a given job. Make every effort to provide a final estimate within a reasonable time.

After planning and estimating the job, formalize it as a job order by assigning a job order number and completing the accounting data. The job is ready for scheduling (first into a specific month, then into a specific week) for completion by the Maintenance Branch.

WORK INPUT CONTROL AND SCHEDULING

To assure completion of authorized work efficiently, you must setup some means of control. To help in the orderly flow and completion of work, you need to use work input control and scheduling procedures. These procedures require you to use several forms and charts.

Work Input Control

Work input control is a formal means of managing the total PWD work load. It also serves as a central source of work status information of the Job Requirements and Status Chart, the Manpower Availability Summary, and the Work Plan Summary.

Job Requirements and Status Chart

The Job Requirements and Status Chart, as shown in figure 2-34, provides a ready reference for tracking all the specific and minor jobs established as known maintenance requirements. The chart includes all customer-financed individual jobs and minor construction, alteration, and improvement work. In addition, this chart provides information on proposed planning to determine the status of work not programmed for shop accomplishment. You should enter all new work, upon approval, on this chart. The entry should remain until the authorization of work for shop completion, cancellation, or completion by contract is granted. You can maintain a different Job Requirement and Status Chart for each major type of work, such as alterations and minor construction, customer work, and maintenance and repair.

Manpower Availability Summary and Work Plan Summary

The Manpower Availability Summary and Work Plan Summary (fig. 2-35) show the plan of the department for using the Maintenance or Utilities Branch work force. By breaking down the Work Plan Summary by funding sources, you see that the summary also shows a payroll support plan.

Before formulating and adjusting the monthly shop work load, the job order programmer must know the man-hours available for programming within each work center. When customer funds provide significant support to the PWD, the programmer must know the number of man-hours allotted to each funding source. To decide this information, the programmer should develop a Manpower Availability Summary and a Work Plan Summary for each month.

Monthly Shop Load Plan

The work control method used within the Maintenance Management System is the Shop Load Plan (SLP) (fig. 2-36). The SLP is the Public Works management plan for using shop force and specific job orders for a given month. This monthly plan provides the shop planner with direction on what jobs to schedule within the month. All levels of management from the shops divisions up to the PWO participate in its preparation.

Express the SLP by the obligation of the known available man-hours for each work center and for each job scheduled. The SLP consists of sections for short-range and long-range planning. The short-range plan covers the nearest 3 months, and the long-range plan covers the following 9 months. The suggested loading for the short-term plan is 100 percent for the first month, 90 percent for the second month, and 80 percent for the third month. Jobs that appear on the SLP become the shop backlog. For maximum productivity, you should always try to have a 3- to 6-month backlog to balance the work that goes to the shops.

Shop Scheduling

Shop scheduling takes place in a two-stage scheduling system: (1) master scheduling of specific job orders and (2) weekly and work center scheduling of specific and minor. Master scheduling connects specific jobs to each work center for accomplishment during the following week. Work center scheduling takes up where master scheduling leaves off. The work center supervisor breaks down the weekly assignments into daily assignments for the workers in the shop. After making the daily assignments on specific job orders, the work center supervisor assigns work to the remaining uncommitted shop forces.

The shop plainer/scheduler, by using the SLP of the coming month, consults with the proper shop supervisor to schedule the work for the coming weeks. The man-hour schedule should be consistent with the available man-hours identified for specific job order work on the Manpower Availability Summary and Work Plan Summary.

On a weekly basis, compare the master schedule with the actual man-hours expended by the work

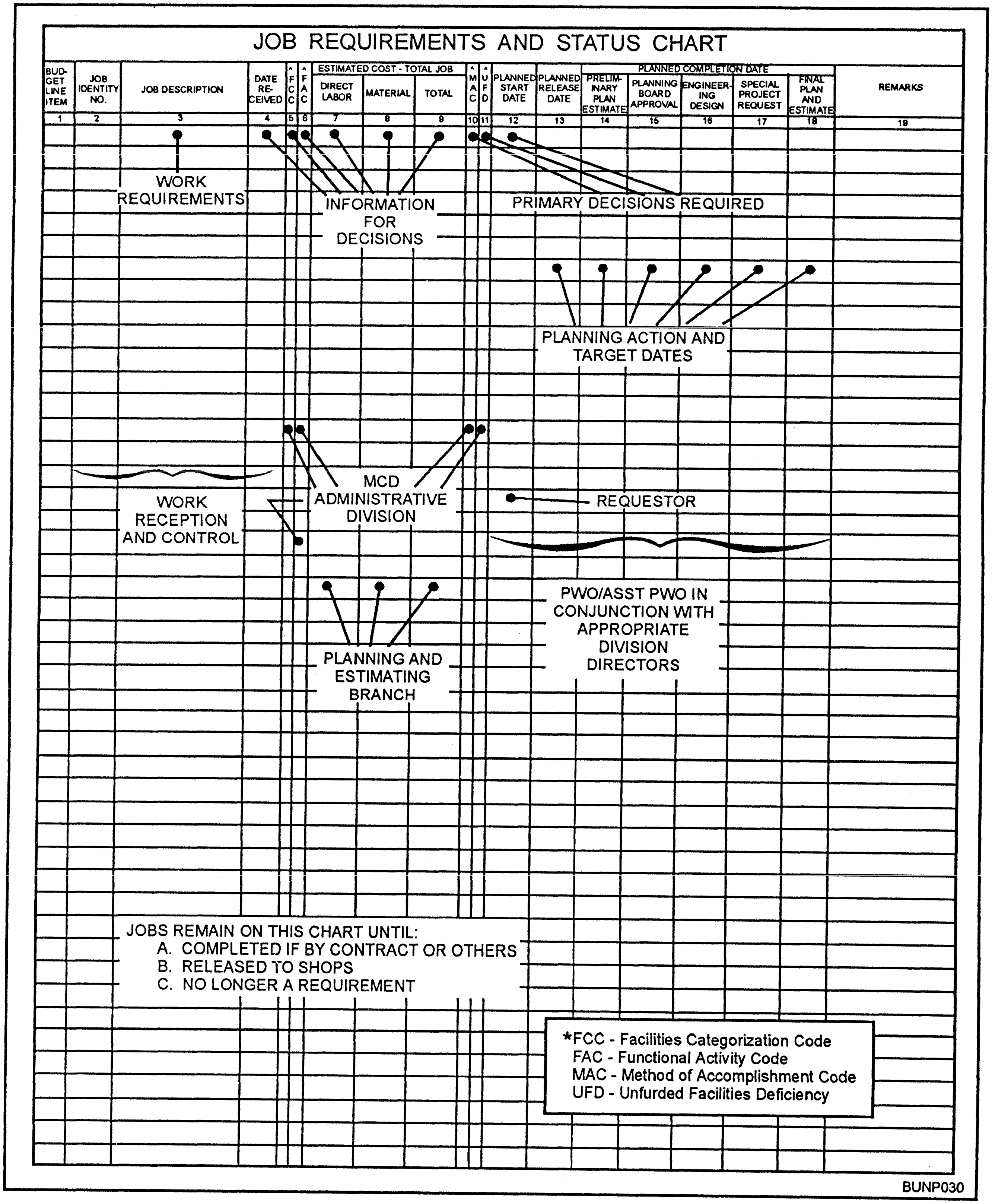
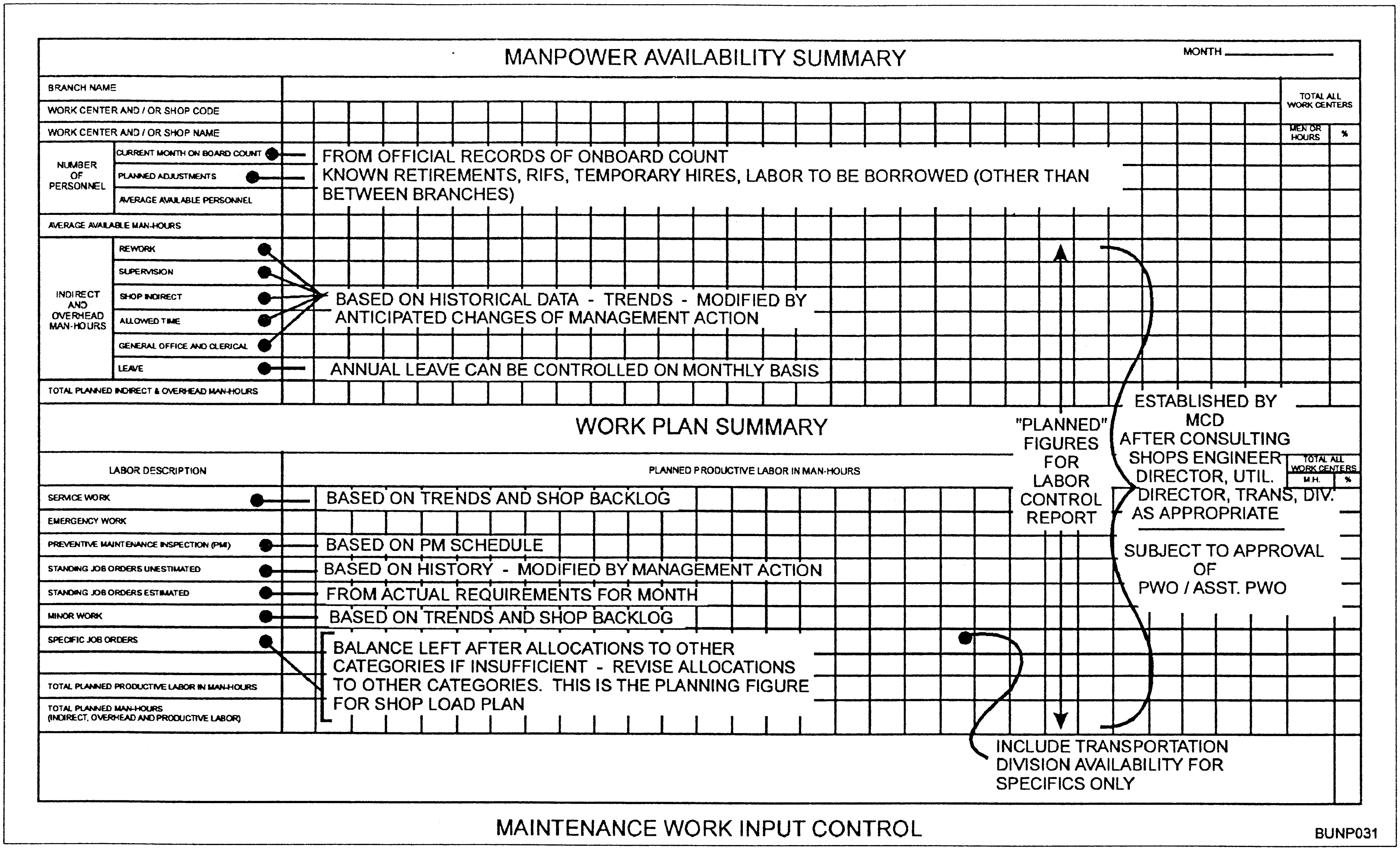


Figure 2-34.—Job Requirements and Status Chart.



MANPOWER AVAILABILITY SUMMARY

MONTH __________

BRANCH NAME

WORK CENTER AND / OR SHOP CODE

WORK CENTER AND / OR SHOP NAME

TOTAL ALL WORK CENTERS

MEN OR HOURS

%

NUMBER OF PERSONNEL

CURRENT MONTH ON BOARD COUNT

PLANNED ADJUSTMENTS

AVERAGE AVAILABLE PERSONNEL

AVERAGE AVAILABLE MAN-HOURS

INDIRECT AND OVERHEAD MAN-HOURS

REWORK

SUPERVISION

SHOP INDIRECT

ALLOWED TIME

GENERAL OFFICE AND CLERICAL

LEAVE

TOTAL PLANNED INDIRECT & OVERHEAD MAN-HOURS

FROM OFFICIAL RECORDS OF ONBOARD COUNT

KNOWN RETIREMENTS, RIFS, TEMPORARY HIRES, LABOR TO BE BORROWED (OTHER THAN BETWEEN BRANCHES)

BASED ON HISTORICAL DATA - TRENDS - MODIFIED BY ANTICIPATED CHANGES OF MANAGEMENT ACTION

ANNUAL LEAVE CAN BE CONTROLLED ON MONTHLY BASIS

WORK PLAN SUMMARY

LABOR DESCRIPTION

PLANNED PRODUCTIVE LABOR IN MAN-HOURS

TOTAL ALL WORK CENTERS

M.H.

%

SERVICE WORK

EMERGENCY WORK

PREVENTIVE MAINTENANCE INSPECTION (PMI)

STANDING JOB ORDERS UNESTIMATED

STANDING JOB ORDERS ESTIMATED

MINOR WORK

SPECIFIC JOB ORDERS

TOTAL PLANNED PRODUCTIVE LABOR IN MAN-HOURS

TOTAL PLANNED MAN-HOURS (INDIRECT, OVERHEAD AND PRODUCTIVE LABOR)

BASED ON TRENDS AND SHOP BACKLOG

BASED ON PM SCHEDULE

BASED ON HISTORY - MODIFIED BY MANAGEMENT ACTION

FROM ACTUAL REQUIREMENTS FOR MONTH

BASED ON TRENDS AND SHOP BACKLOG

BALANCE LEFT AFTER ALLOCATIONS TO OTHER CATEGORIES IF INSUFFICIENT - REVISE ALLOCATIONS TO OTHER CATEGORIES. THIS IS THE PLANNING FIGURE FOR SHOP LOAD PLAN

"PLANNED" FIGURES FOR LABOR CONTROL REPORT

ESTABLISHED BY MCD AFTER CONSULTING SHOPS ENGINEER DIRECTOR, UTIL. DIRECTOR, TRANS, DIV. AS APPROPRIATE

SUBJECT TO APPROVAL OF PWO / ASST. PWO

INCLUDE TRANSPORTATION DIVISION AVAILABILITY FOR SPECIFICS ONLY

MAINTENANCE WORK INPUT CONTROL

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Figure 2-35.—Manpower Availability Summary and Work Plan Summary.

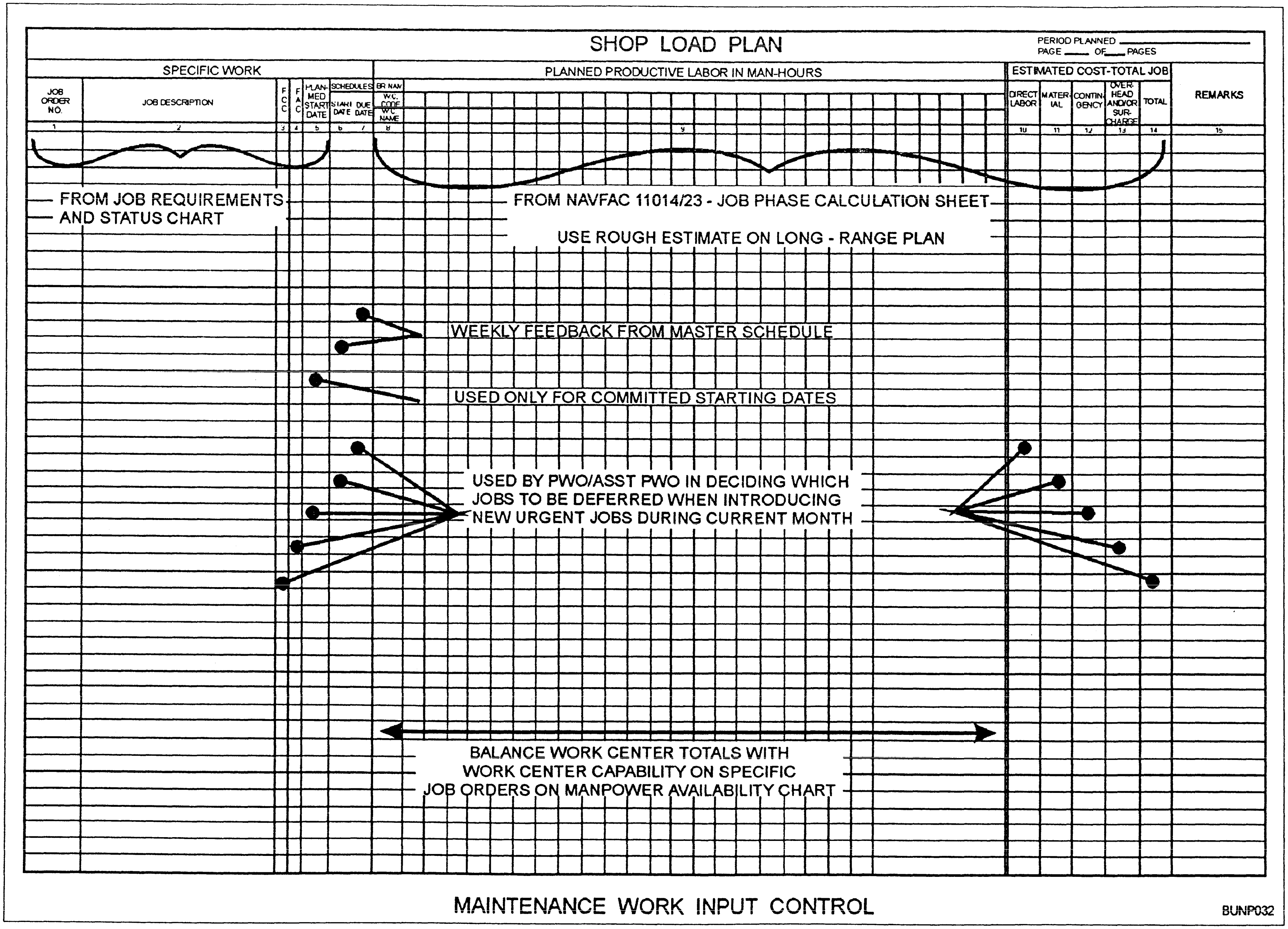


Figure 2-36.—Shop Load Plan.

center to find out if jobs meet the estimate of the master schedule. If a job is off schedule, adjust the work center schedule of the following week without making major changes to the master schedule.

The shop supervisor reviews the master schedule and prepares the work center schedule each week. He or she reviews it daily to ensure the maximum use of shop resources. The shop supervisor coordinates with other shops when a requirement for more than one craft exists.

Shop scheduling is required throughout the job when the shop performs at various stages of the work. For example, the Builders would open an area to allow the plumbers to make a repair and they would then close the area after the repair with the painters arriving later for final touches. To schedule the job properly, you divide the carpenter's time between two distinct work phases. You must make sure all the plumbing repairs are done before the carpenter's return to the work place. Do not schedule the painters until all the other workers have finished their assignments.

This chapter does not attempt to tell you everything about planning, estimating, and scheduling of a construction project; however, the information given you and the references listed throughout this chapter are what you need to know in order to understand planning and estimating procedures.

CHAPTER 3

CONCRETE CONSTRUCTION

LEARNING OBJECTIVE: *Recognize the different characteristics associated with concrete form design and concrete mix design; recognize the procedures in batching concrete and estimate concrete construction and labor. Identify the procedures and methods associated with precast and tilt-up construction.*

Concrete construction, once confined largely to paving and foundations, has been developed to the point where both large and small buildings are now constructed entirely of concrete with concrete joists (usually called floor or grade beams), concrete studs (usually called columns), concrete walls, concrete floors, and concrete roofs.

This chapter explains some of the major factors concerning the design of concrete forms by means of specific examples. Information is also provided on the various methods by which you can select the proportions for quality concrete mixtures and adjust these mixtures to suit job requirements. We also cover types and uses of admixtures and slump testing procedures. We point out some of the types of equipment you are likely to encounter in concrete construction. A brief discussion is also included on precast construction and brick construction. But we must first discuss safety practices and procedures that should be considered the most important aspect of concrete construction work.

CONCRETE SAFETY

In concrete construction, as in all types of construction,a certain degree of danger is involved. To help you do your concrete work safely, we will discuss the various safety precautions concerning concrete.

Form construction and concrete placement have peculiarities in each job; however, certain natural conditions will prevail in all situations. Wet concrete will always develop hydrostatic pressure and strain on the forms. Therefore, all stakes, braces, and other supporting members should be properly secured and inspected before placing the concrete.

All formwork, shoring, and bracing should be designed, fabricated, erected, supported, braced, and maintained so that it will safely support all vertical and lateral loads that might be applied until loads can be supported by the structure.

All nailing should be correctly placed and secured according to the plans and specifications. Careless nailing and exposed nails in formwork are a major cause of accidents.

Adequate scaffolding should be built to permit crew members to stand clear of pouring areas.

Rebar caps are a MUST for all exposed vertical rebar.

Tools, particularly hammers, should be inspected frequently.

GFCIs must be used with all power tools, and ensure the location of the GFCIs are close to your equipment.

Supervisor(s) should check all forms before each pour. Stripped forms should be piled in advance of any movement or change of direction. During night operations, all equipment should be equipped with sufficient flood spotlights to make the perimeter of the operations clearly visible. The pouring bucket and the boom of the paver operating controls should have a synchronized warning device to function automatically with the motion of either the boom or the traveling bucket.

Personnel may be subject to cement poisoning (lime); therefore, ensure they have their shirt sleeves rolled down and wear gloves and goggles when working with concrete.

If concrete buckets and cranes are used in pouring, each bucket should be provided with a tag line or two, depending on the location. A crew member should never ride a free swinging concrete bucket during a pour.

Raising of large form panels should not be attempted in heavy gusts of wind, neither by hand nor by crane.

Skip loader cables and brakes must be inspected frequently to prevent injuries caused by falling skips.

The mixer operator must never lower the skip without first ensuring there is no one under it.

The area around the mixer must be kept clear.

Dust protection equipment must be issued to crew members engaged in handling cement, and they must wear the equipment when so engaged. Workers should stand with their backs to the wind, whenever possible, to prevent cement and sand from being blown into their eyes and faces.

Whenever the mixer drum is being cleaned, the switches must be open, the throttles closed, and the control mechanism locked in the OFF position.

Whenever possible, a flagman or watchman should be stationed near the mixer to warn all hands when a batch truck is backing up to the skip. The watchman should use a whistle to warn any personnel in the danger zone. “DANGER-KEEP AWAY” signs should be placed where they can readily be seen.

FORMWORK

FORMWORK is a temporary structure that supports its own weight and that of the freshly placed concrete as well as the live loads imposed upon it by materials, equipment, and workmen. As a Builder serving in the capacity of a form designer or as the supervisor of a form building crew, you should take into account the three principle objectives when using formwork—economy, quality, and safety.

Economy is the major concern since formwork may represent as much as one third of the total cost of a concrete structure. Savings depend on the ingenuity and experience of the formwork designer or supervisor. Judgment in the selection of materials and equipment, in planning fabrication and erection procedures, and in scheduling reuse of forms will expedite the job and help reduce formwork costs. In designing and building formwork, you should aim for maximum economy without sacrificing quality or safety. Shortcuts in design or construction that endanger quality or safety may be false economy. For example, if the forms do not produce the specified surface finish, much hand rubbing of the concrete may be required; or if forms deflect excessively, bulges in the concrete may require expensive chipping and grinding. Obviously, economy measures that lead to formwork failure also defeat their own purpose. The most commonly used form materials are earth, metal, lumber, plywood, and fiber.

FORM DESIGN

Forms must be designed for all the weight to which they are liable to be subjected, including the dead load of the forms, the plastic concrete in the forms, the weight of crew members, the weight of equipment and materials that may be transferred to the forms, and the impact due to vibration. These factors vary with each project, but none should be neglected. Ease of erection and removal are also important factors in the economical design of forms. Platforms and ramp structures independent of formwork are sometimes preferred to avoid displacement of forms due to loading and impact shock from crew members and equipment. Formwork for concrete must support all vertical and lateral loads that may be applied until these loads can be carried by the concrete structure itself. Loads on the forms include the weight of reinforcing steel and fresh concrete, the weight of the forms themselves, and various live loads imposed during the construction process. Consideration must be given to such conditions as unsymmetrical placement of concrete, uplift, and concentrated loads produced by storing supplies on the freshly placed slab. Rarely will there be precise information as to the loads the formwork maybe subjected to; therefore, the architect or Builder must make some safe assumptions that will hold good for conditions generally encountered.

Vertical Loads

Vertical loads on formwork include the weight of reinforced concrete together with the weight of the forms themselves, which are regarded as dead loads, and the live loads imposed by the crew members and the equipment used during construction. The majority of all formwork involves concrete weighing 150 pounds per cubic foot. Minor variations in this weight are not significant, and in most cases, 150 pounds per cubic foot, including the weight of the reinforcing steel, is commonly assumed for design. Formwork weights vary from as little as 3 or 4 pounds per square foot (psf) to 10 to 15 pounds per square foot. When the frame work weight is small in relation to the weight of the concrete plus the live load, it is frequently neglected. If concrete weighs 150 pounds per cubic foot, it will place a load on the forms of 12.5 pounds per square foot for each inch of slab thickness. Thus a

6-inch slab would produce a dead load of 6 by 12.5 or 75 pounds per square foot, excluding the weight of forms. The recommended minimum construction live load to provide for the weight of crew members and equipment is 50 pounds per square foot of horizontal projection. If powered concrete buggies are used in concreting operations, it is recommended that 75 pounds per square foot be used as a minimum construction live load.

Lateral Pressure

When concrete is placed in the form, it is in a plastic state and behaves temporarily like a fluid, producing a hydrostatic pressure that acts laterally on the vertical forms. If concrete acted as a true liquid, the pressure developed would be equal to the density of the fluid (150 pounds per cubic foot is commonly assumed for concrete) times the depth in feet to the point at which the pressure was being considered. However, plastic concrete is a mixture of solids and water whose behavior only approximates that of a liquid, and then for a limited time only. This lateral pressure is comparable to a full-liquid head when concrete is placed full height within the period required for its initial set. With slower rates of placing, concrete at the bottom of the forms begins to harden, and the lateral pressure is reduced to less than full-fluid pressure by the time concreting is completed in the upper parts of the form.

The effective lateral pressure, a modified hydrostatic pressure, has been found to be influenced primarily by the rate of placing and the temperature of the concrete mix. Other variables that have been found to have an effect on lateral pressure include consistency of concrete, amount and location of reinforcement, vibration, maximum aggregate size, and placing procedures. However, with usual concreting practices, the range of the effects of these variables is generally small and is either neglected or compensated for in design tables.

Lateral Loads

Adequate lateral bracing is extremely important to stability and safety in formwork construction; but all too often, it is treated carelessly or even omitted entirely. Formwork must be braced to resist all foreseeable lateral loads, such as those imposed by wind, dumping of concrete, or any other impact, such as starting and stopping of equipment. There are many types of braces that can be used to give forms stability. The most common type is a diagonal member and horizontal member nailed to a stud or wale. The diagonal member should make a 45-degree angle with the horizontal member. Additional bracing may be added to the form by placing vertical members (strongbacks) behind the wales or by placing vertical members in the corner formed by the intersecting wales.

WALL FORM DESIGN

Concrete forms must be constructed to resist the pressure exerted on them by the freshly placed concrete without deflection (side displacement) beyond a specified maximum. This maximum is very small; for a wall form, for example, the maximum deflection of sheathing, studs, and wales is not over 1/270th of the span.

Placing concrete exerts a very considerable lateral (side) pressure on the form sheathing. The pressure at the bottom of the freshly placed concrete is greater than that at the top and the pressure increases with the height of the form.

When designing formwork, you must ensure that the sheathing, the stud, and the waler spacing are designed to a given pressure (vertical rate of placement).

Vertical Rate of Placement

To determine the vertical rate of placement for concrete wall forms, you divide the quantity of concrete (mixer output) which is placed into the form in an hour (in cubic feet) by the horizontal area of the form space being filled. Suppose you are filling a wall section for a wall 30 feet long by 12 inches thick. The horizontal area would then be 30 square feet. See the formula below.

- *Mixer output (cf/hr) =*

$$\frac{\text{mixer yield (cf)}}{\text{batch time (min)}} \times \frac{60\ \text{min}}{\text{hr}}$$

Let’s take the hourly rate of the 11 S mixer (11 cubic feet per load) which has an hourly output of 4 to 8 cubic yards or from 108 to 216 cubic feet (depending on personnel) in a continuous operation. However, the quantity of concrete placed in the form per hour will depend on how continuous the mixer operation is and how rapidly the mix is transferred from the mixer to the form. This quantity you will have to determine according to your knowledge and circumstances at the jobsite. Let's assume that you estimate 8 cubic yards or 216 cubic feet will be placed in the form per hour. In this case, the vertical rate of placement is 216 cubic feet, divide by 30 square feet of horizontal area, or about 7 feet per hour. See the formula below.

- *Rate of placing (R) (ft/hr) =*

  mixer output (cf/hr)
  plan area (sf)

NOTE. For an economical design, try to keep the rate of placement to 5 feet/hour or less.

Pressure from Vertical Rate of Placement

To determine the maximum concrete pressure, the Builder must know the temperature of the concrete and the rate of placement per square foot. When you know these things, you can determine the maximum concrete pressure by using the chart, as shown in figure 3-1.

For example, to find the maximum concrete pressure, first make a reasonable estimate of the temperature of the concrete, let's say 70°F, and it has a rate of placement at 7 feet per hour. Move across the table to 70°F, then move down the table to 7 feet per hour. In this case, the maximum pressure of concrete is 1,050 pounds per square foot (psf).

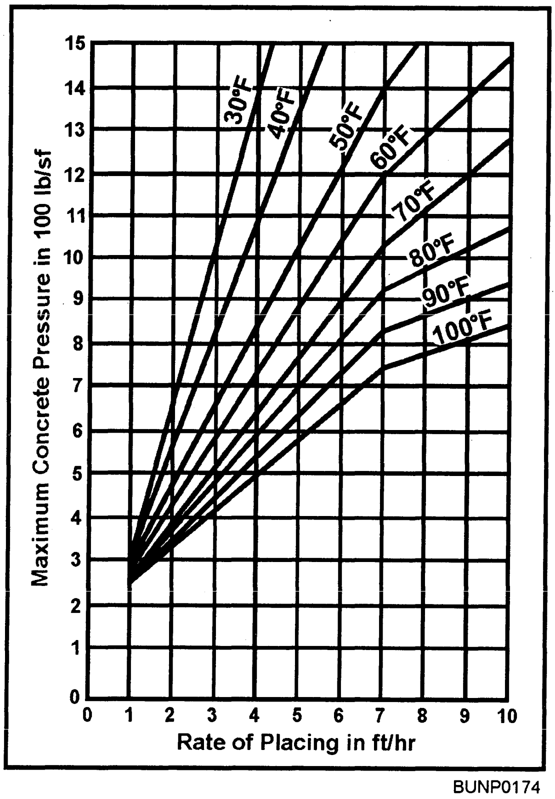


Figure 3-1.—Maximum concrete pressure graph.

MAXIMUM SPACING OF WALL FORM STUDS.— Suppose you want to know the maximum spacing when using 3/4-inch sheathing with a concrete pressure of 600 pounds per square foot. (Refer to table 3-1). Move down the chart to 600 pounds per square foot, then go down the chart to 3/4-inch plywood sheathing. You will find that 14-inch spacing per stud is required. This chart refers to the forms with the face grain running across the supports. If the concrete pressure value falls between the two values in the column, round up to the nearest given value.

To determine the uniform load on a stud (ULS), you multiply the maximum concrete pressure by the maximum stud spacing. Then convert the answer to pounds per linear foot by dividing the result by 12. For example, the maximum concrete pressure is 1,050 pounds per square foot and the stud spacing is 14 inches. Multiply the two values together then divide by 12 which equals 1,225 (lbs/lin ft).

- Uniform load on stud (ULS)
  (lb/lin ft) =

  maximum concrete pressure (lb/sf) × max stud spacing (in)
  12 (in/ft)

MAXIMUM SPACING OF WALL FORM WALES.— When you know the spacing of the studs, the sheathing, and the maximum concrete pressure, the maximum wale spacing is not difficult to determine using the chart shown in table 3-2 and table 3-3. For example, suppose you want to find the maximum wale spacing for 2 by 4 studs, and the concrete pressure is 600 pounds per square foot. Move down the chart until you reach 600 pounds per square foot, then go across to 2 by 4 lumber and you will find that the spacing for the waler and ties are 24 inches.

To determine the uniform load on a wale (ULW), you multiply the maximum concrete pressure (600 pounds per square foot) by the maximum wale spacing (24 inches). Convert the answer to feet by dividing the result by 12, which equals 1,200 (pounds per linear foot).

- *Uniform load on a wale*

  (ULW)(lbs/lin ft) =

  maximum concrete pressure (lb/sf) x *max wale spacing (ft)*

Table 3-1.—Maximum Stud (Joist) Spacing for Plywood Sheathing

Maximum Concrete Pressure	Strong Way (in) 5-ply sanded, face grain parallel to span				Weak way (in) 5-ply sanded, face grain, perpendicular to span			
(lb/sf)	1/2	5/8	3/4	1/7 ply	1/2	5/8	3/4	1/7 ply
75	20	24	26	31	13	18	23	30
100	18	22	24	29	12	17	22	28
125	17	20	23	28	11	15	20	27
150	16	19	22	27	11	15	19	25
175	15	18	21	26	10	14	18	24
200	15	17	20	25	10	13	17	24
300	13	15	17	22	8	12	15	21
400	12	14	16	20	8	11	14	19
500	11	13	15	19	7	10	13	18
600	10	12	14	17	6	9	12	17
700	10	11	13	16	6	9	11	16
800	9	10	12	15	5	8	11	15
900	9	10	11	14	4	8	9	15
1,000	8	9	10	13	4	7	9	14
1,100	7	9	10	12	4	6	8	12
1,200	7	8	10	11	-	6	7	11
1,300	6	8	9	11	-	5	7	11
1,400	6	7	9	10	-	5	6	10
1,500	5	7	9	9	-	5	6	9
1,600	5	6	8	9	-	4	5	9
1,700	5	6	8	8	-	4	5	8
1,800	4	6	8	8	-	4	5	8
1,900	4	5	8	7	-	4	4	7
2,000	4	5	7	7	-	-	4	7
2,200	4	5	6	6	-	-	4	6
2,400	-	4	5	6	-	-	4	6
2,600	-	4	5	5	-	-	-	5
2,800	-	4	4	5	-	-	-	5
3,000	-	-	4	5	-	-	-	5

Table 3-2.—Maximum Spacing (In Inches) for Wales, Ties, Stringers, and 4 inch by 4 inch or Larger Shores Where Member to be Supported is a Single Member

Uniform load (lb/linear ft)	SUPPORTED MEMBER SIZE (S4S)				
	2 × 4	2 × 6	3 × 6	4 × 4	4 × 6
100	60	95	120	92	131
125	54	85	110	82	124
150	49	77	100	75	118
175	45	72	93	70	110
200	42	67	87	65	102
225	40	63	82	61	97
250	38	60	77	58	92
275	36	57	74	55	87
300	35	55	71	53	84
350	32	50	65	49	77
400	30	47	61	46	72
450	28	44	58	43	68
500	27	41	55	41	65
600	24	38	50	37	59
700	22	36	46	35	55
800	21	33	43	32	51
900	20	31	41	30	48
1,000	19	30	38	29	46
1,200	17	27	35	27	42
1,400	16	25	33	25	39
1,600	15	23	31	23	36
1,800	14	22	29	22	34
2,000	13	21	27	21	32
2,200	13	20	26	20	31
2,400	12	19	25	19	30
2,600	12	19	24	18	28
2,800	11	18	23	17	27
3,000	11	17	22	17	26
3,400	10	16	21	16	25
3,800	10	15	20	15	23
4,500	9	14	18	13	21

Table 3-3.—Maximum Spacing (In Inches) for Ties and 4 inch or Larger Shores Where Member to be Supported is a Double Member

Uniform load (lb/linear ft)	SUPPORTED MEMBER SIZE (S4S)				
	2 × 4	2 × 6	3 ö 6	4 ö 4	4 ö 6
100	85	126	143	222	156
125	76	119	135	105	147
150	70	110	129	100	141
175	64	102	124	96	135
200	60	95	120	92	131
225	57	89	116	87	127
250	54	85	109	82	124
275	51	81	104	78	121
300	49	77	100	75	118
350	46	72	93	70	110
400	43	67	87	65	102
450	40	63	82	61	97
500	38	60	77	58	92
600	35	55	71	53	84
700	32	51	65	49	77
800	30	47	61	46	72
900	28	44	58	43	68
1,000	27	43	55	41	65
1,200	25	39	50	38	59
1,400	23	36	46	35	55
1,600	21	34	43	33	51
1,800	20	32	41	31	48
2,000	19	30	39	29	46
2,200	18	29	37	28	44
2,400	17	27	36	27	42
2,600	17	26	34	26	40
2,800	16	25	33	25	39
3,000	15	24	32	24	38
3,400	14	23	30	22	35
3,800	14	21	28	21	33
4,500	12	20	25	19	30

Use table 3-2 or table 3-3 (depending on type of waler system) to determine the tie spacing based on the ULW. This number is the maximum tie spacing in inches based on wale size.

Tie wires or snap ties (depends on what system you use) must be installed at the intersection of studs and wales. Place the first tie at one half of the maximum tie spacing from the end of the wale.

Estimating Studs and Wales

To determine the number of studs on one side of a form, you need to divide the form length by the maximum stud spacing, and add one for a starter. The first and last stud must be placed at each end of the form.

- *Number of studs =*

$$\frac{\text{length of form (ft)} \times 12 \text{ (in/ft)}}{\text{stud spacing (in)} + 1}$$

To determine the number of wales for one side of a form, you must divide the form height by the maximum wale spacing and round up to the next whole number. Place the first wale one half of the maximum space up from the bottom and the remainder at the maximum wale spacing.

To determine the time required to place concrete, you divide the height of the form by the rate of placement. This does NOT include the length of the form. For example, wall height of the form is 10 feet and the vertical rate of placement is 5 feet/hour. Your answer is 2 hours. Figure 3-2 shows how you can estimate man-hours per cubic yard in most situations. These estimates are based on Seabee experiences.

***The following rules apply to figure 3-2:**

1. For each 40 feet wheeled, add 25 percent.

2. For upper stories, add per story: Placed by pump, 7 percent; placed by bucket or crane, 5 percent.

3. Construction that moves in and out of ramps, runways, or staging is not included. For moving in and out use 0.22 man-hours per linear foot.

4. Major items of consideration in planning concrete placement are: method of placement, accessibility, the rate of placement in regard to form design and the amount and frequency of delivery is governed by the ability to screed, tamp, and finish.

Bracing of Wall Forms

BRACES are used against wall forms (fig. 3-3) to keep the forms in place and in alignment from mishaps due to external forces, such as wind, personnel, equipment, vibration, and accidents. For most military applications, this force is assumed to be 12.5 times the wall height, in feet. Braces (normally 2 by 4s) to be used should be equally strong in tension as in compression strength, or braces should be used on both sides of a wall form.

Designing wall forms and the bracing for wall forms should be left to the engineers. We do not have the time or the space in this section to cover all the formulas necessary to design forms. Refer to the

MAN HOURS PER UNIT					
Work Element Description	Unit (CD)	Direct from Chute	Wheeled	Pumped	Crane and Bucket
Place Footings, Foundations:					
Grade Beams		1.0	2.0	1.50	1.50
Slabs on Grade		1.5	3.0	2.00	2.50
Walls to 10′ High		– –	– –	1.68	2.24
Columns		– –	– –	1.68	2.24
Suspended Slabs		– –	– –	1.68	2.24
Beams and Girders		– –	– –	1.68	2.24
Stairs		2.4	4.8	1.68	2.88

Figure 3-2.—Placing concrete labor estimates from P-405.

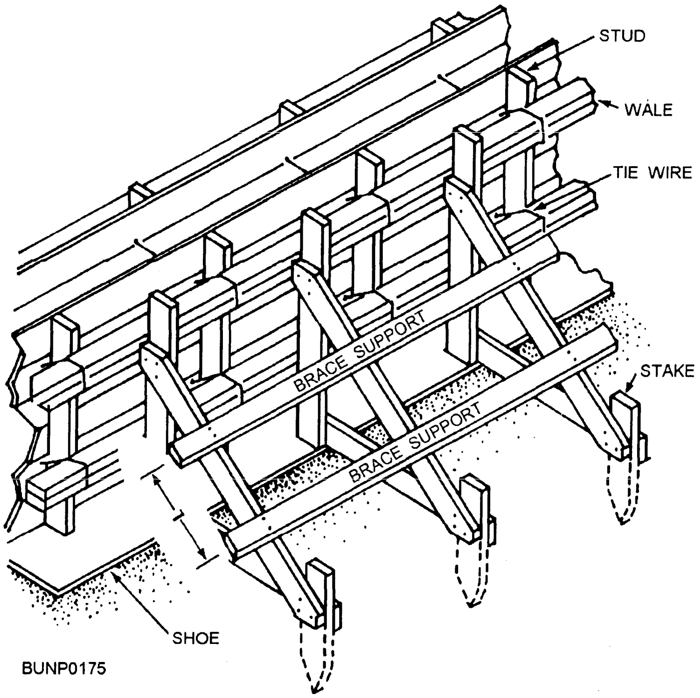


Figure 3-3.—Diagonal bracing supports.

American Concrete Institute (ACI) or the *Architectural Graphic Standards* (AGS) for more information on designing of forms.

COLUMN FORM DESIGN

As with wall forms, column forms are designed according to step-by-step procedures. Wooden forms for a concrete column should be designed by the following steps:

1. Determine the materials available for sheathing, yokes, and battens. Standard materials for columns forms are 2 by 4s and 3/4-inch plywood.

2. Determine the height of the column.

3. Determine the largest cross-sectional dimension of the column.

4. Determine the yoke spacing, as shown in table 3-4, by reading down the first column until the correct height of the column is reached. Then read horizontally across the page to the column headed by the largest cross-sectional dimension. The center-to-center spacing of the second yoke above the base yoke will be equal to the value in the lower interval that is partly contained in the column height line. All subsequent yoke spacings may be obtained by reading up the height column to the top. This procedure gives maximum yoke spacings.

Table 3-4 is based upon use of 2 by 4s and 3/4-inch sheathing. For example, if you had to construct a 9-foot column, the spacing of the yokes starting from the bottom yoke would be 8", 8", 10", 11", 12", 15", 17", 17", and 10". The space between the top two yokes has been reduced because of the limits of the column height.

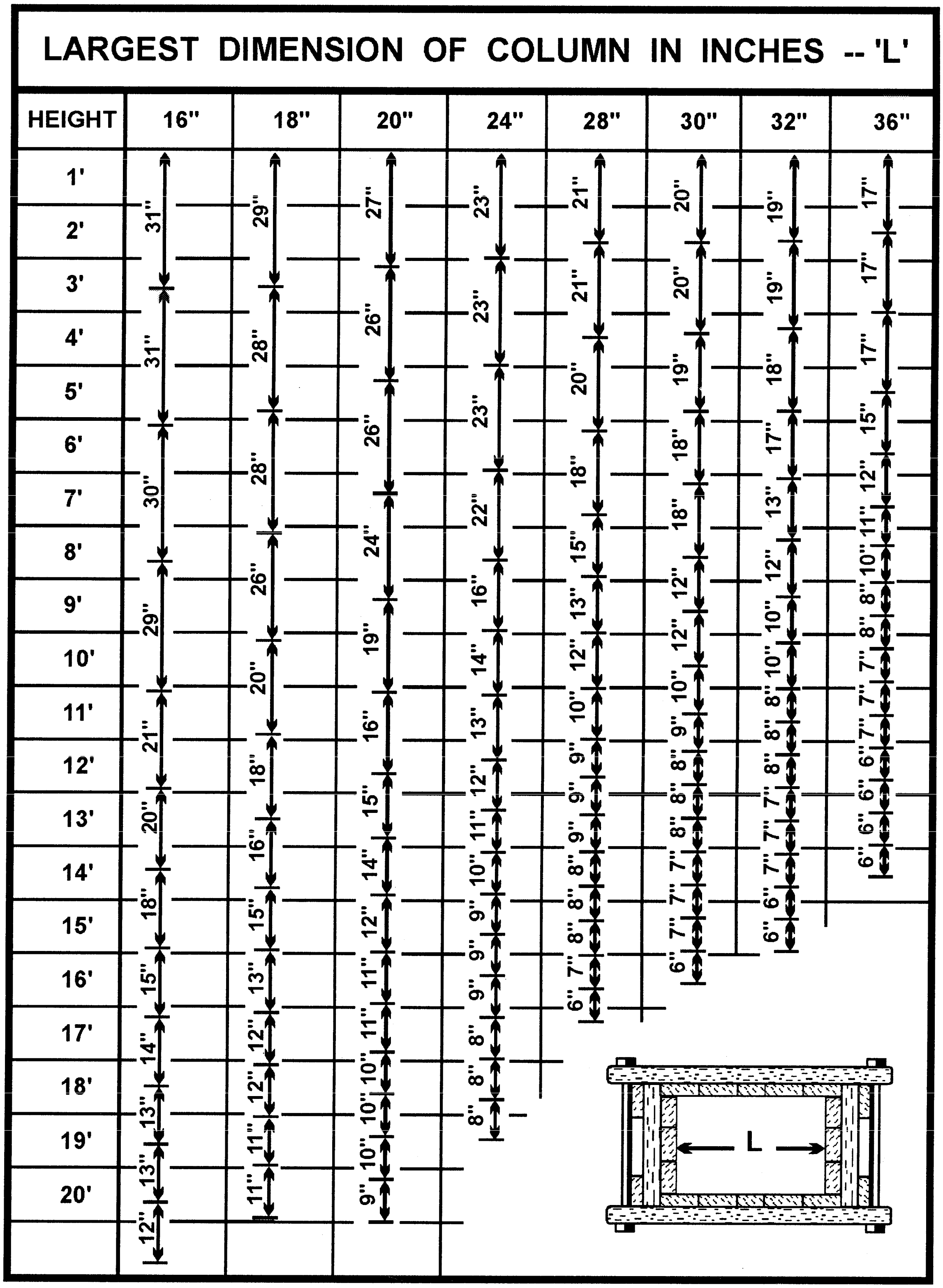
Because of their height and relatively small cross-sectional area, column forms require four-way bracing to ensure alignment and resistance to wind and various other lateral forces that may occur during the placement of the concrete.

OVERHEAD SLAB FORM DESIGN

The general goal of slab form design is a balanced form design. Careful consideration must be given to the design of the formwork due to the danger of failure caused by the weight of the concrete and the live load (LL) of the equipment and personnel on the forms. The following procedures uses some of the same figures used in the wall form design.

See figure 3-4 for the nomenclature for a typical overhead form.

Table 3-4.—Column Yoke Spacing



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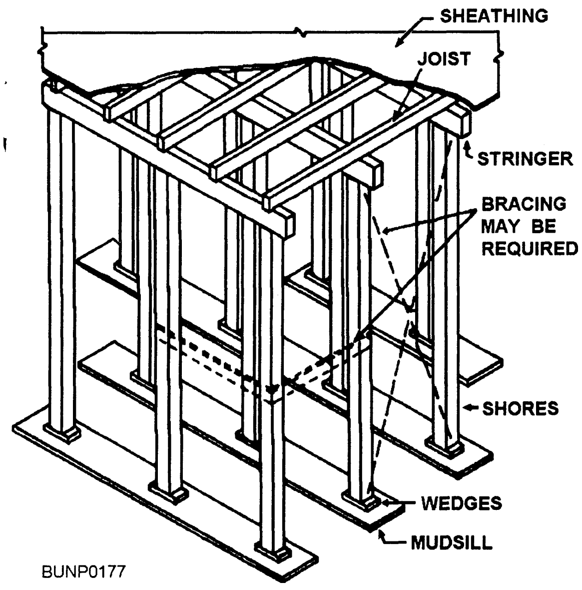


Figure 3-4.—Typical overhead slab form.

- *Sheathing.* Shapes and holds the concrete. Plywood (usually 3/4-inch thick) or solid sheet metal (usually corrugated) is the best for use.
- *Joists.* Supports the sheathing against deflection. Performs the same function as STUDS in a wall form. Normally, you should use 4-inch lumber; however, 2-inch or 3-inch stock can be used if properly designed.
- *Stringers.* Supports the joists against deflection. Performs the same function as WALES in a wall form, except stringers do not need to be doubled. Use 2-inch-thick lumber or larger.
- *Shores.* Supports the stringers against deflection. Performs the same functions as TIES in a wall form and also supports the concrete at the desired elevation. The lumber used for this must be as large as the stringers, but never smaller than 4 by 4 inches in dimension.
- *Lateral bracing.* May be required between adjacent shores to keep the SHORES from bending under load. Usually 1 by 6 inch or larger stock is used for bracing. Bracing of some type will always be required to support the formwork.
- Wedges. Are normally use for two purposes: the wedges are used for leveling of the forms and the forms are easier to strip if wedges are used.
- *Mudsills.* Continuous timber placed on the ground that distributes a load and provides a level surfaces for scaffolding and shoring.

Design Procedures

Step 1. The engineer will design and specify the materials you will need to construct the overhead forms. Ensure that all the correct materials are on the jobsite and your crew is familiar with the materials and structural members.

Step 2. Determine the maximum total load the forms will have to support. The rule of thumb for figuring the total load is live load (LL) plus dead load (DL). The live load (materials, personnel, and equipment) is estimated to be 50 pounds per square foot unless the forms will support engine-powered equipment. In this case, the LL would be 75 pounds per square foot. The dead load (concrete/rebar) is estimated at 150 pounds per cubic foot. However, you cannot add dead load to live load until you convert the dead load to square feet (SF). The formulas are as follows:

$$\text{Total Load (TL)} = \text{Live Load (LL)} + \text{Dead Load (DL)}$$

$$LL = 50 \text{ lbs/sf, or } 75 \text{ lbs/sf with power equipment}$$

$$DL = 150 \text{ lbs/cf} \times \frac{\text{slab thickness (in)}}{12 \text{ in/ft}}$$

For example, if the slab is 6 inches in thickness, the formula would be as follows:

$$DL = 150 \text{ lbs/cf} \times \frac{6 \text{ in}}{12 \text{ in/ft}}$$

$$DL = 75 \text{ lbs/sf}$$

$$TL = 50 \text{ lbs/sf (LL)} + 75 \text{ lbs/sf (DL)}$$

$$TL = 150 \text{ lbs/sf}$$

Step 3. Determine the maximum joist spacing. Use table 3-1 and read the joist spacing based on the sheathing material. Use the maximum TL in place of the maximum concrete pressure. For example, the sheathing is 3/4-inch plywood (strong way), the TL is 150 pounds per square foot, and the joist spacing would be 22 inches.

Step 4. Calculate the uniform load on the joist. The same procedure is used as for determining uniform loads on the structural members in the wall form design.

$$\text{Uniform Load on Joist (ULJ)} = \frac{2L \times \text{joist spacing (in)}}{12 \text{ in/ft}}$$

Step 5. Determine the maximum stringer spacing. Use table 3-2 and the uniform load on the joist is calculated in Step 4. Round this load up to the next higher load located in the left column of the table, then read right to the column containing the lumber material used as the joist. This is the member to be supported by the stringer. The value at this intersection is the on center (OC) spacing of the stringer.

Step 6. Calculate the uniform load on the stringer.

Uniform Load on the Stringer (ULS str) =

$$\frac{TL \times \text{maximum stringer spacing (in)}}{12\ \text{in/ft}}$$

Step 7. Determine the maximum shore spacing.

(a) Maximum shore spacing is based on the stringer strength. Use table 3-2 or table 3-3 (depending on type of stringer) and the uniform load on the stringer, rounded to the next higher load shown in the left column of the table. Read right to the stringer material column and this intersection is the OC spacing of the shore to assure the stringer is properly supported.

(b) Maximum shore spacing is also dependent on shore strength and end bearing of the stringer on the shore. Use the allowable load (see tables 3-5 and 3-6), based on the shore strength and the bearing stress strength of the stringer.

NOTE: Unsupported Length (UL) = Height above the sill - sheathing thickness joist thickness - stringer thickness. This length has been rounded up to the next higher table value. For example, UL = 8 feet in height, minus 3/4-inch sheathing, minus 3 1/2-inch joist thickness, minus 3 1/2-inch stringer thickness, equals 7 feet 4 1/4 inches (round up to 8 feet), so the UL = 8 feet.

(c) Select the most critical shore spacing. Compare the spacing of the shore, based on the stringer strength (Step 7 (a)) and shore load (Step 7 (b)) and select the smaller of the two spacings.

Step 8. Shore bracing check.

(a) Verify that the unbraced length (1) of the shore (in inches) divided by the least dimension (d) of the shore does not exceed 50. If l/d exceeds 50, the lateral and cross bracing must be provided. Table 3-1 indicates the l/d is greater than 50 shore lengths and can be used if the shore material is sound and unspliced.

(b) In any case, it is good engineering practice to provide both lateral and diagonal bracing to all shore members if the material is available.

Overhead Slab Design Form Procedure

EXAMPLE PROBLEM: Design the form for a roof of a concrete structure which is 6 inches thick by 20 feet wide by 30 feet in length. The roof will be 8 feet high above the floor (to the bottom of the slab). The concrete pump truck will be used to place the concrete.

Step 1. Identify the material.

Sheathing: 3/4-inch plywood (strong way)
Joists: 4" x 4" lumber (S4S)
Stringers: 4" x 4" lumber (S4S)
Bracing: 1" x 6" lumber (S4S)
Mudsills: 2" x 12" lumber (S4S)

Step 2. Determine the TL.

$$DL = \text{concrete load} = 150\ lb/cf \times \frac{6\ in}{12\ in/ft} = 75\ lb/sf$$

$$LL = 75\ lb/sfTL = 75\ lb/sf + 75\ lb/sf$$

$$TL = 150\ lb/sf$$

Step 3. Determine the maximum joist spacing. Use table 3-1.

3/4" plywood (strong way) and TL = 150 lb/sf

Joist spacing = 22 inches

Step 4. Calculate the ULJ.

$$ULJ = TL \times \frac{\text{joist spacing (in)}}{12\ in/ft}$$

$$= 150\ lb/sf \times \frac{22\ in}{12\ in/ft}$$

$$= 275\ lb/linear\ foot$$

Step 5. Determine the maximum stringer spacing by using table 3-2.

Load = 275 lb/ft

Joist material = 4" × 4" lumber (S4S)

Max. stringer spacing = 55 in

Table 3-5.—Allowable Load in Pounds on Wood Shores, Based on Shore Strength

UNSUPPORTED LENGTH (IN FEET)	Nominal Lumber Size (in inches) (R indicates rough lumber; S4S indicates surfaced four sides)					
	4 × 4 P	4 ö 4 S4S	4 ö 6 R	4 ö 6 S4S	6 ö 6 R	6 ö 6 R
4	9,900	9,200	15,300	14,400	23,700	22,700
5	9,900	9,200	15,300	14,400	23,700	22,700
6	9,900	9,200	15,300	14,400	23,700	22,700
7	8,100	7,000	12,500	11,000	23,700	22,700
8	6,200	5,400	9,600	8,400	23,700	22,700
9	4,900	4,200	7,600	6,700	23,700	22,700
10	4,000	3,400	6,100	5,400	23,000	21,700
11	3,300	2,800	5,100	4,500	19,000	17,300
12	2,700	2,400	4,300	3,700	16,000	14,600
13	2,300	2,000	3,600	3,200	13,600	12,400
14	2,000	1,700	3,100	2,700	11,700	10,700
15	1,800		2,700		10,200	9,300
16					9,000	8,300
17					7,900	7,300
18					7,100	6,500
19					6,400	5,800
20					5,700	5,200

NOTE: The above table values are based on wood members with the following strength characteristics: Compression parallel to grain = 750 psi; E = 1,100,000 psi.

Table 3-6.—Allowable Loads on Specified Shores, Based on Bearing Stresses

Compression Perpendicular of Member SUPPORTED	Nominal Lumber Size (in inches) (R indicates rough lumber: S4S indicates surfaced four sides)					
	4 × 4 R	4 × 4 S4S	4 × 6 R	4 × 6 S4S	6 × 6 R	6 × 6 S4S
250	3,000	3,100	5,100	4,800	7,900	7,600
350	4,600	4,300	7,100	6,700	11,100	10,600
385	5,100	4,700	7,800	7,400	12,200	11,600
400	5,300	4,900	7,700	7,700	12,700	12,100

For the above table: when the compression perpendicular to the grain of the member being supported is unknown, assume the most critical compression perpendicular to the grain.

Step 6. Calculate the UL stringer.

$$TL \times \frac{max.\ stringer\ spacing\ (in)}{12\ in/ft}$$

$$= 150\ lb/sf \times \underline{55\ in} = 12\ in/ft$$

$$ULS\ str = 687.5\ lb/ft$$

Step 7. Determine the maximum shoring spacing.

(a) Spacing based on stringer strength. Refer to table 3-2.

Load = 687.5 lb/ft (round up to 700)

Stringer material = 4" × 4" (S4S)

Max. shore spacing = 35 in

(b) Spacing based on the shoring strength and end bearing of the stringer, based on the allowable load in tables 3-5 and 3-6.

- Allowable load based onshore strength. (See table 3-5.)

  Unsupported length = 8 ft - 3/4" - 3 1/2" - 3 1/2" =

  7 ft 4 1/4" (round up to 8 ft)

  Allowable load = 5,400 lb

- Allowable load based on end bearing stresses. (See table 3-6.) Since we do not know what species of wood we are using, you must assume the most critical and lowest compression perpendicular to the grain equals 250, and the allowable load for a 4 by 4 (S4S) equals 3,100 pounds.
- Select the most critical load.
- Determine shore spacing based on allowable load.

$$Shore\ spacing = \frac{3{,}100\ lb}{ULS\ str\ (lb/ft)} \times 12\ in/ft$$

$$= \frac{3{,}100\ lb}{687.5\ lb/ft} \times 12\ in/ft$$

$$= 54.1\ in$$

- Select the most critical shore spacing. The spacing determined in step (7(a)) is less than the spacing determined in step (7(b)); therefore, the shore spacing to be used is 35 inches.

Step 8. Shore deflection check.

$$l = 8\ ft - 3/4\ in - 3\ 1/2\ in - 3\ 1/2\ in = 7\ ft\ 4\ 1/4\ in =$$
$$d = the\ actual\ dimension\ of\ a\ 4 \times 4 = 3.5\ in$$

$$l/d = \frac{7\ ft\ 4\ 1/4\ in}{3.5\ in} = \frac{88.25\ in}{3.5\ in}$$

$$= 24.21 \leq 50$$

Therefore, lateral and cross bracing are not required.

Step 9. Summary.

Sheathing: 3/4-inch plywood

Joists: 4" x 4" (S4S) lumber spaced@ 22 inch OC

Stringers: 4" x 4" (S4S) lumber spaced @ 55 inch OC

Shores: 4 x 4 (S4S) lumber spaced@ 35 inch OC

Bracing: Not Required

BEAM FORM DESIGN

Beam forms, like slab forms, carry a vertical load, and they are also subjected to the lateral pressure of freshly placed concrete just as wall forms are. Beams can be formed independently to span walls and columns or monolithically (one continuous pour) as part of a floor slab system. When formed as part of a slab system, a part of the load from the slab forms may be carried by the beam form to the supporting shores and must be accounted for in the formwork design.

Figure 3-5 shows atypical interior beam form with slab forming supported on the beam sides. This drawing indicates that 3/4-inch plywood serves as the beam sides and that the beam bottom is a solid piece of 2-inch dimension lumber supported on the bottom by 4- by 4-inch T-head shores.

Close examination of figure 3-5 shows that when a beam is to be formed as part of a slab system, some of the design procedures have been completed. For example, the lateral pressure against the beam sides is compensated for by the slab joists which butts against the beam sides and rests on the attached ledger. All that remains to complete the design of a beam form is to determine the design load for which the form must be designed. Knowing the design load, the maximum allowable bottom sheathing span (shore spacing) for the materials available can be determined. Next the total load per shore can be determined and the design

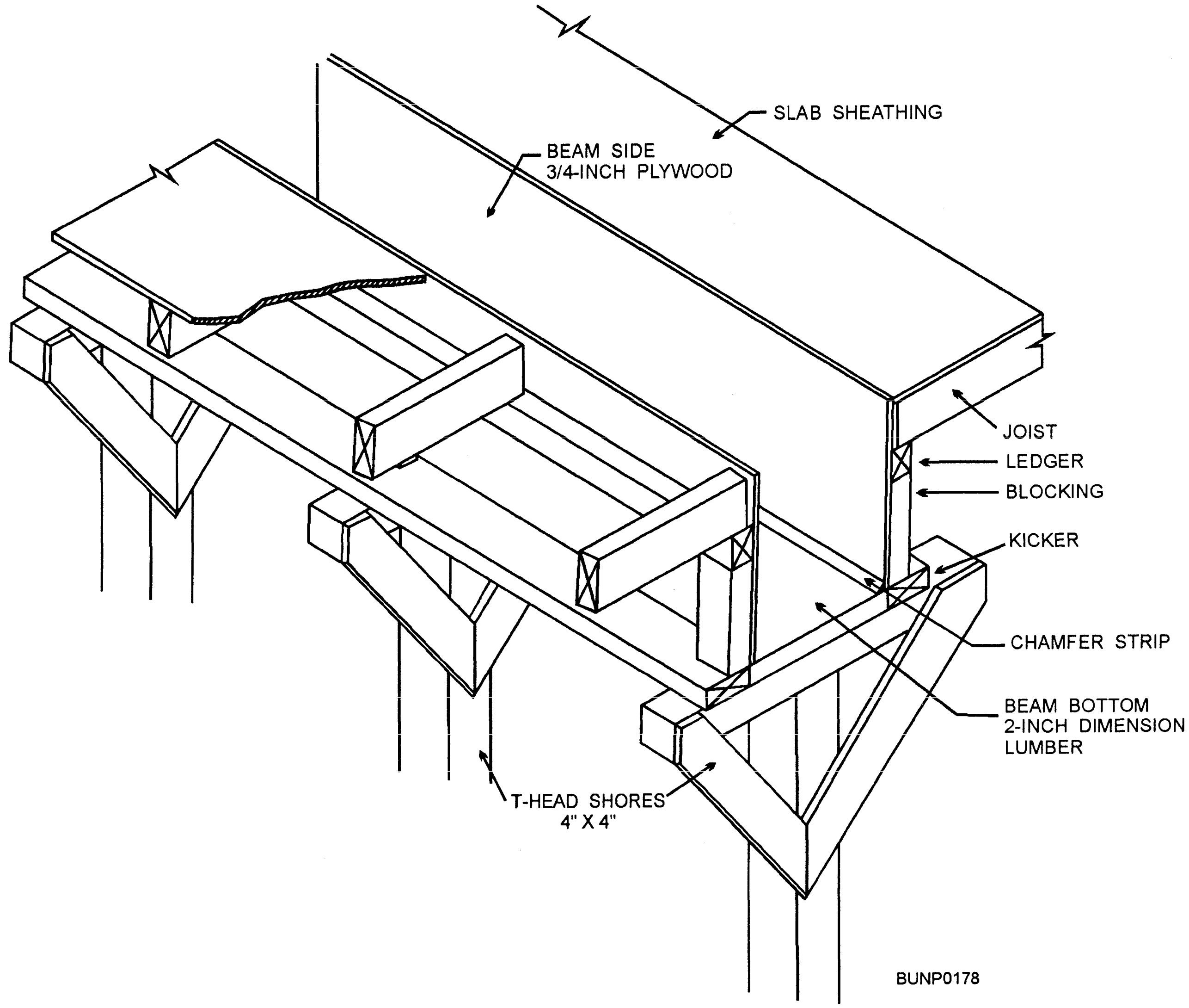


Figure 3-5.—Typical interior beam.

completed with the selection of shore and bracing material that will safely support the vertical and lateral loads. Each of these steps used in beam form design can be accomplished by using the applicable procedures discussed in the previous section on overhead slab form design.

LABOR ESTIMATES

In chapter 2 we covered the procedures that good estimators use to plan, estimate, and schedule projects. In this section we will briefly cover labor estimates for formwork according to the Seabee *Planner's and Estimator's Handbook,* NAVFAC P-405. Figure 3-6 shows the labor chart from the P-405 which is self-explanatory on how to estimate labor. To calculate manpower estimates, you must first estimate the square footage of contact surface (SFCS). After estimating the SFCS of the work element, you then need to determine the units (100 SFCS/unit).

WORK ELEMENT	MAN-HOURS PER UNIT				
DESCRIPTION	UNIT	FABRICATE	ERECT	STRIP	REPAIR
Footing, Foundation Walls, and Grade Beams	100 SFCS	9	7	4	4
Walls to 10 ft high	100 SFCS	8	7	5	5
Columns and Piers	100 SFCS	9	10	5	5
Suspended Slabs	100 SFCS	8	12	4	5
Beams and Girders	100 SFCS	11	10	5	5
Slabs on Grade and Screed (up to 8" thick including edge form)	100 SFCS	...................13 Complete.....................			
Stairs	100 SFCS	...................55 Complete.....................			
Thicken Edge and Slabs Greater Than 8" Thick. Use Grade Beam Estimate	N/A	N/A			

SUGGESTED CREW SIZE: Forming/Stripping: Five Builders
Forming/Stripping (Gang forms): Five Builders and two Equipment Operator

NOTES:

1. Concrete forming estimates are based on using form accessories, form ties, and steel column clamps.

2. Suspended slabs, beam, and girders are figures that use 4-inch × 4-inch shores and wooden wedges. For adjustable shores, deduct 10 percent from erection time.

3. When forming and stripping are combined, stripping and cleaning forms will be approximately 17 percent of total labor.

4. On multiple use jobs, allow three man-hours for form repair per 100 SF of contact surface after four uses.

5. Gang forming usually requires a crane, an operator, and a signalman.

6. Forming walls over 10 ft high, and other high work will increase erection time 10 to 50 percent.

Figure 3-6.—Formwork labor chart.

For example, if you estimated 800 square feet of contact surface, then it is only a matter of dividing 800 by 100, which equals 8 units. Now you enter the column for estimating man-hours per unit and you will see four separate columns: fabricate, erect, strip, and repair. Its just a matter of what scope of work you are performing and multiplying the work element by the scope of work.

You have just finished estimating 800 square feet of contact surface for your foundation wall and now you need to fabricate the formwork. To determine the man-hours required, just multiply the number of units (8) by man-hours per unit (9), which equals 72 man-hours. To find man-days, you would divide 72 man-hours by the number of hours you work in 1 day (determined by your unit) normally 8 hours per day, which will equal 9 duration days per person. So if you had a crew of three, it would only take your crew 3 durations days to fabricate the formwork.

REINFORCED CONCRETE

Reinforced concrete refers to concrete containing steel (bars, rods, strands, wire, and mesh) as reinforcement and designed to absorb tensile and shearing stresses. Concrete structural members, such as footings, columns and piers, beams, floor slabs, and walls, must be reinforced to attain the necessary strength in tension. In this section, we will cover reinforcing steel and briefly discuss column, beam, and wall reinforcement.

REINFORCING STEEL

Steel is the best material for reinforcing concrete because the coefficients of expansion of the steel and the concrete are considered almost the same; that is, at a normal temperature, they will expand and contract at an almost equal rate. (At very high temperatures, steel will expand more rapidly than the concrete, and the two materials will separate.)

Steel also works well as a reinforcement for concrete because it makes a good bond with the concrete. This bond strength is proportional to the contact area surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of the concrete, the stronger the bond. A deformed reinforcing bar is better than a plain round or square one. In fact, when plain bars of a given diameter are used instead of deformed bars, approximately 40 percent more plain bars must be used.

The adherence of the concrete depends on the roughness of the steel surface—the rougher the steel the better the adherence. Thus steel with a light, firm layer of rust is superior to clean steel, but steel with loose or scaly rust is inferior. Loose or scaly rust may be removed from the steel by rubbing the steel with burlap. The requirements for reinforcing steel are strong in tension and, at the same time, ductile enough to be shaped or bent cold.

Reinforcing steel may be used in the form of bars or rods that are either PLAIN or DEFORMED or in the form of expanded metal, wire, wire fabric, or sheet metal. Each type is useful for a different purpose, and engineers design structures with these purposes in mind.

Plain bars are round in cross section. They are used in concrete for special purposes, such as dowels at expansion joints, where bars must slide in a metal or paper sleeve, for contraction joints in roads and runways, and for column spirals. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for the adherence of concrete.

Deformed bars differ from plain bars in that they have either indentations on them or ridges on them, or both, in a regular pattern. The twisted bar, for example, is made by twisting a plain, square bar cold. The spiral ridges along the surface of the deformed bar increase its bond strength with concrete. Other forms used are the round- and square-corrugated bars. These bars are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting. Figure 3-7 shows a few of the various types of deformed bars available. In the United States, deformed bars are used almost exclusively, while in Europe, both deformed and plain bars are used.

Eleven standard sizes of reinforcing bars are in use today. Table 3-7 lists the bar number, area in square inches, weight, and nominal diameter of the 11 standard sizes. Bars No. 3 through 11 and 14 and 18 are all deformed bars. Table 3-8 lists the bar number, area in square inches and millimeters, and nominal diameter of the 11 standard sizes. At various sites overseas, rebar could be procured locally and could be metric. Remember that bar numbers are based on the nearest number of one-eighth inch included in the nominal diameter of the bar. To measure rebar, you must measure across the round/square portion where there is no deformation. The raised portion of the deformation is not measured when measuring the rebar diameter.

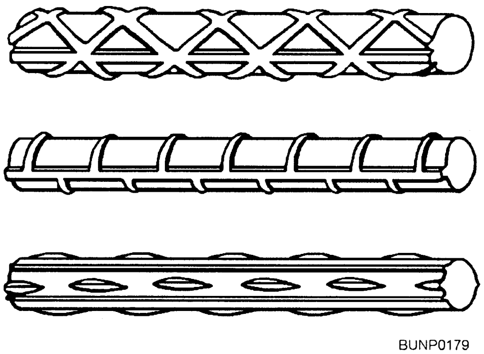


Figure 3-7.—Various types of deformed bar.

Table 3-7.—U.S. Standard Reinforcing Bars

U.S. Standard Reinforcing Steel Bars				
Bar Size Designation	Area Square Inches	Weight lb Per Foot	Diameter	
			inches	mm
#3	.11	.376	.375	9.53
#4	.20	.668	.500	12.7
#5	.31	1.043	.625	15.88
#6	.44	1.502	.750	19.05
#7	.60	2.044	.875	22.23
#8	.79	2.670	1.000	25.40
#9	1.00	3.400	1.128	28.58
#10	1.27	4.303	1.270	31.75
#11	1.56	5.313	1.410	34.93
#14	2.25	7.650	1.693	43.00

Table 3-8.—Comparison of U.S. Standard and Metric Rebar

U.S. Standard Bar		Metric Bar		Metric Bar is:
Bar Size	Area Sq Inches	Bar Size	Area Sq Inches	
#3	.11	10m	.16	45% larger
#4	.20	10m	.16	20% smaller
#4	.20	15m	.31	55% larger
#5	.31	15m	.31	Same
#6	.44	20m	.47	6.8% larger
#7	.60	20m	.47	22% smaller
#7	.60	25m	.78	30% larger
#8	.79	25m	.78	1.3% smaller
#9	1.00	30m	1.09	9% larger
#10	1.27	30m	1.09	14% smaller
#10	1.27	35m	1.55	22% larger
#11	1.56	35m	1.55	0.6% smaller
#14	2.25	45m	2.33	3.5% larger
#18	4.00	55m	3.88	3.0% smaller

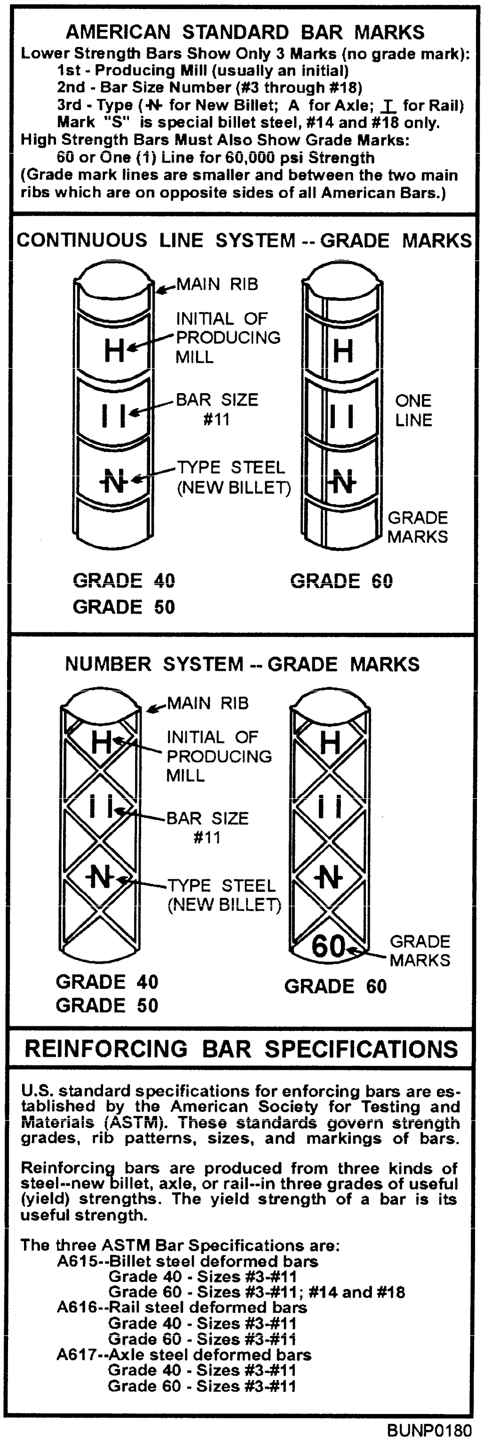
*NOTE: % Difference is based upon area of rebar in square inches.

Reinforcing Bars

Reinforcing bars are hot-rolled from a variety of steels in several different strength grades. Most reinforcing bars are rolled from new steel billets, but some are rolled from used railroad-car axles or railroad rails that have been cut into rollable shapes. An assortment of strengths are available.

The *American Society for Testing Materials* (ASTM) has established a standard branding for deformed reinforcing bars. Two general systems of bar branding are used. Both systems serve the basic purpose of identifying the marker size, the type of steel, and the grade of each bar. In both systems an identity mark, denoting the type of steel used, is branded on every bar by engraving the final roll used to produce the bars so as to leave raised symbols between the deformations. The manufacturer's identity mark that signifies the mill that rolled the bar is usually a single letter or, in some cases, a symbol. The bar size follows the manufacturer's mark and is followed by a symbol indicating new billet steel (-N-), rolled rail steel (-I-), or rolled axle steel (-A-). Figure 3-8 shows the two-grade marking system.

The lower strength reinforcing bars show only three marks: an initial representing the producing mill, the bar size, and the type of steel. The high strength reinforcing bars use either the continuous line system or the number system to show grade marks. [n the line system, one continuous line is rolled into the 60,000 psi bars, and two continuous lines are rolled into the 75,000 psi bars. The lines must run at least five deformation spaces, as shown in figure 3-8. In the number system, a "60" is rolled into the bar following the steel type of mark to denote 60,000 psi bars, and a "75" is rolled into the 75,000 psi bars.



AMERICAN STANDARD BAR MARKS

Lower Strength Bars Show Only 3 Marks (no grade mark):
- 1st - Producing Mill (usually an initial)
- 2nd - Bar Size Number (#3 through #18)
- 3rd - Type (-N- for New Billet; A for Axle; I for Rail)
- Mark "S" is special billet steel, #14 and #18 only.

High Strength Bars Must Also Show Grade Marks:
- 60 or One (1) Line for 60,000 psi Strength

(Grade mark lines are smaller and between the two main ribs which are on opposite sides of all American Bars.)

REINFORCING BAR SPECIFICATIONS

U.S. standard specifications for enforcing bars are established by the American Society for Testing and Materials (ASTM). These standards govern strength grades, rib patterns, sizes, and markings of bars.

Reinforcing bars are produced from three kinds of steel--new billet, axle, or rail--in three grades of useful (yield) strengths. The yield strength of a bar is its useful strength.

The three ASTM Bar Specifications are:
- A615--Billet steel deformed bars
  - Grade 40 - Sizes #3-#11
  - Grade 60 - Sizes #3-#11; #14 and #18
- A616--Rail steel deformed bars
  - Grade 40 - Sizes #3-#11
  - Grade 60 - Sizes #3-#11
- A617--Axle steel deformed bars
  - Grade 40 - Sizes #3-#11
  - Grade 60 - Sizes #3-#11

BUNP0180

Figure 3-8.—American standard reinforcing steel bar marks.

Expanded Metal and Wire Mesh Reinforcement

Expanded metal or wire mesh is also used for reinforcing concrete. Expanded metal is made by partly shearing a sheet of steel, as shown in view A, figure 3-9. The sheet steel has been sheared in parallel lines and then pulled out or expanded to form a diamond shape between each parallel cut. Another type is square, rather than diamond shaped, as shown in view B, figure 3-9. Expanded metal is customarily used during plastering operations and light reinforcing concrete construction, such as sidewalks, and small concrete pads, that do not have to bear substantial weight, such as transformer and air-conditioner pads.

Welded Wire Fabric

Welded wire fabric is fabricated from a series of wires arranged at right angles to each other and electrically welded at all intersections. Welded wire

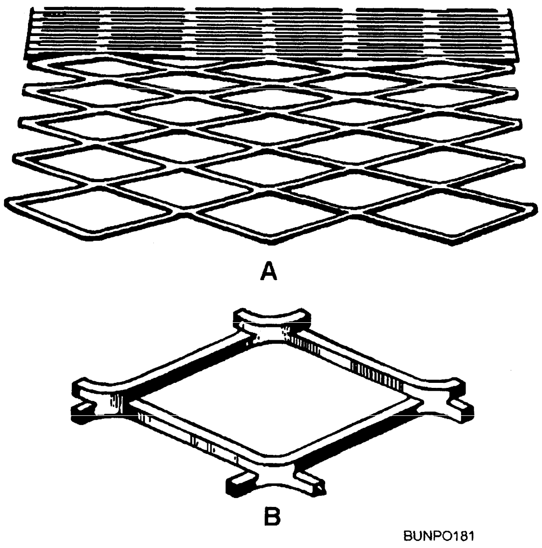


Figure 3-9.—Expanded or diamond mesh steel reinforcement.

fabric, referred to as WWF within the NCF, has various uses in reinforced concrete construction. In building construction, it is most often used for floor slabs on well-compacted ground. Heavier fabric, supplied mainly in flat sheets, is often used in walls and for the primary reinforcement in structural floor slabs. Additional examples of its use include road and runway pavements, box culverts, and small canal linings.

Four numbers are used to designate the style of wire mesh; for example, 6 by 6- 8 by 8 (sometimes written 6 x 6 x 8 x 8 or 6 x 6 - W 2.1 x W 2.1). The first number (in this case, 6) indicates the lengthwise spacing of the wire in inches; the second number (in this case, 6) indicates the crosswise spacing of the wire in inches; the last two numbers (8 by 8) indicate the size of the wire on the Washburn and Moen gauge. More recently the last two numbers are a W number that indicates the size of the cross-sectional area in the wire in hundredths of an inch. (See table 3-9.) WWF is currently available within the Navy stock system using the four-digit system, 6 by 6 - 8 by 8, as of this writing, but if procured through civilian sources, the W system is used.

Light fabric can be supplied in either rolls or flat sheets. Fabric made of wire heavier than W4 should always be furnished in flat sheets. Where WWF must be uniformly flat when placed, fabric furnished in rolls should not be fabricated of wire heavier than W 2.9. Fabricators furnish rolled fabric incomplete rolls only. Stock rolls will contain between 700 to 1,500 square feet of fabric determined by the fabric and the producing location. The unit weight of WWF is

Table 3-9.—Common Stock Sizes of Welded Wire Fabric

STYLE DESIGNATION		Weight Approximate lb per 100 sq. ft.
Current Designation (by W—Number)	Previous Designation (By Steel Wire Gauge)	
PANELS / SHEETS		
6 × 6 — W 1.4 × W 1.4	6 × 6 — 10 × 10	21
6 × 6 — W 2.1 × W 2.1	6 × 6 — 8 × 8	29
6 × 6 — W 2.9 × W 2.9	6 × 6 — 6 × 6	42
6 × 6 — W 4.0 × W 4.0	6 × 6 — 4 × 4	58
4 × 4 — W 1.4 × W 1.4	4 × 4 — 10 × 10	31
4 × 4 — W 2.1 × W 2.1	4 × 4 — 8 × 8	43
4 × 4 — W 2.9 × W 2.9	4 × 4 — 6 × 6	62
4 × 4 — W 4.0 × W 4.0	4 × 4 — 4 × 4	86
ROLLS		
6 × 6 — W 1.4 × W 1.4	6 × 6 — 10 × 10	21
6 × 6 — W 2.9 × W 2.9	6 × 6 — 6 × 6	42
6 × 6 — W 4.0 × W 4.0	6 × 6 — 4 × 4	58
6 × 6 — W 5.5 × W 5.5	6 × 6 — 2 × 2	80
4 × 4 — W 4.0 × W 4.0	4 × 4 — 4 × 4	86

designated in pounds per one hundred square feet of fabric (table 3-9). Five feet, six feet, seven feet, and seven feet six inches are the standard widths available for rolls, while the standard panel widths and lengths are seven feet by twenty feet and seven feet six inches by twenty feet.

COLUMN REINFORCEMENT

A column is a slender, vertical member that carries a superimposed load. Concrete columns, especially those subjected to bending stresses, must always be reinforced with steel. A PIER or PEDESTAL is a compressive member that is short (usually the height is less than three times the least lateral dimension) in relation to its cross-sectional area and carries no bending stress. A bearing wall could be classified as a continuous pier.

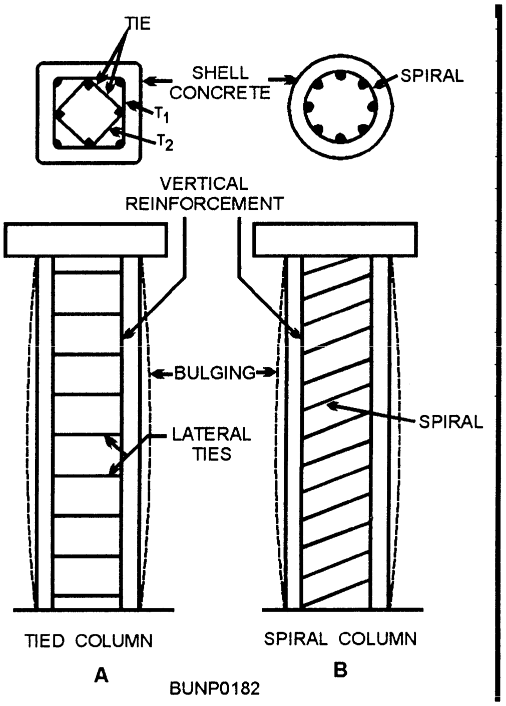


Figure 3-10.—Reinforced concrete columns.

In concrete columns, vertical reinforcement is the principal reinforcement. However, a loaded column shortens vertically and expands laterally; hence, lateral reinforcements in the form of lateral ties are used to restrain the expansion. Columns reinforced in this manner are called tied columns (fig. 3-10, view A). If the restraining reinforcement is a continuous winding spiral that encircles the core and longitudinal steel, the column is called a spiral column (fig. 3-10, view B).

BEAM REINFORCEMENT

Beams are the principal load-carrying horizontal members. They take the load directly from the floor and carry it to the columns. Concrete beams can either be cast in place or precast and transported to the jobsite. Figure 3-11 shows several common types of beam reinforcing steel shapes. Both straight and bent-up principal reinforcing bars are needed to resist the bending tension in the bottom over the central portion of the span. Fewer bars are necessary on the bottom near the ends of the span where the bending moment is small. For this reason, some bars may be bent so that the inclined portion can be used to resist diagonal tension. The reinforcing bars of continuous beams are continued across the supports to resist tension in the top in that area.

WALL REINFORCEMENT

The placement of steel reinforcement in load-bearing walls is the same as for columns, except that the steel is erected in place and not preassembled. Horizontal steel is tied to vertical steel at least three times in any bar length. The wood block is removed

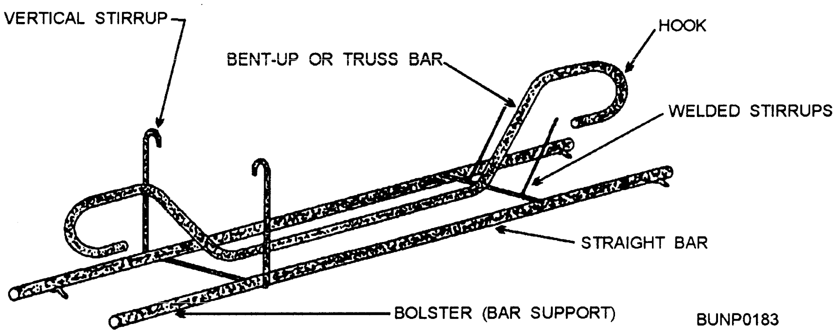


figure 3-11.—Typical shapes of reinforcing steel.

when the form has been filled up to the level of the block, as shown in figure 3-12.

DESIGN OF CONCRETE MIXTURES

From your previous studies, you know that the basic ingredients used in the production of concrete are cement (usually portland cement), water, and both fine and coarse aggregates. You also know that certain admixtures are used occasionally to meet special requirements. The design of a concrete mixture consists of determining the correct amount of each ingredient needed to produce a concrete that has the necessary consistency or workability in the freshly mixed condition and that has desired strength and durability characteristics in the hardened condition.

The characteristics of concrete should be considered on a relative basis and in terms of degree of quality required for a given construction project. Figure 3-13 shows some of the properties of good concrete, their interrelationships, and various elements that control the properties. A study of this figure points up the relative basis of the characteristics. A single batch of concrete cannot possess the maximum of strength, durability, and economy. For example, entrained air makes handling easier and is, therefore, conducive to economy; entrained air promotes watertightness; but entrained air makes concrete less dense and thereby reduces the strength. The goal is to achieve an optimum balance of all the elements. A thorough discussion of all the factors involved in the production of good concrete is beyond the scope of this manual. A wealth of information is available to you in government and commercial publications, especially the *American Concrete Institute* (ACI) manuals.

The design of or the selection of a mix, the necessity for a trial mix, the methods of controlling the mix proportions, and the units of measure to be used in the batching all depend on the nature and size of the job and the extent to which requirements are set forth in the specifications or on the plans.

An example of the simplest form of concrete batching is the mixing of a very small amount of concrete using the 1:2:4 carpenter’s mix. The relative volumes of cement, sand, and gravel could be measured in bucketfuls, or even in shovelful, and with sufficient water added to give reasonable consistency. A more refined procedure is to fabricate a 1-cubic-foot wooden measuring box to give you greater control over the proportions of the ingredients. To mix approximately 1 cubic yard of 1:2:4 concrete, you use the “Rule of 42.” Add the numbers of the mix design together 1 + 2 + 4 = 7, then divide the rule (42) by the mix design (7), which equals 6. This means it

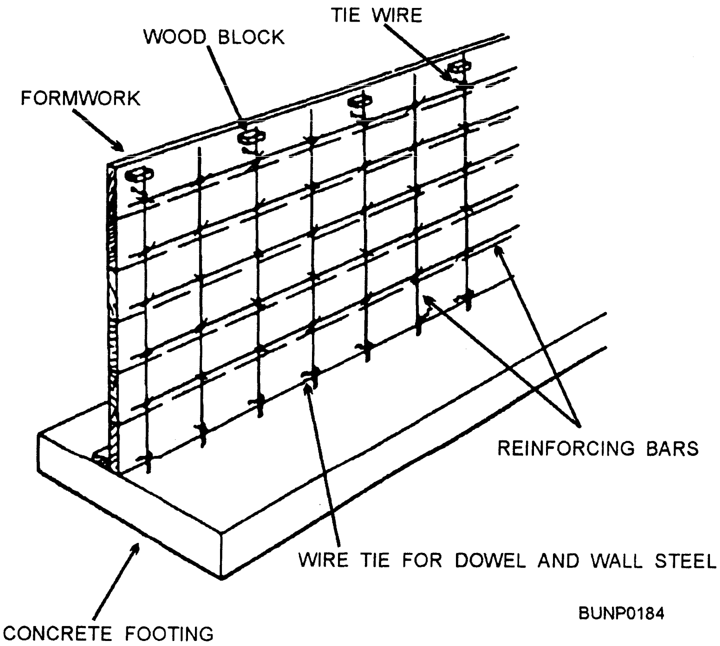


Figure 3-12.—Steel in place in a wall.

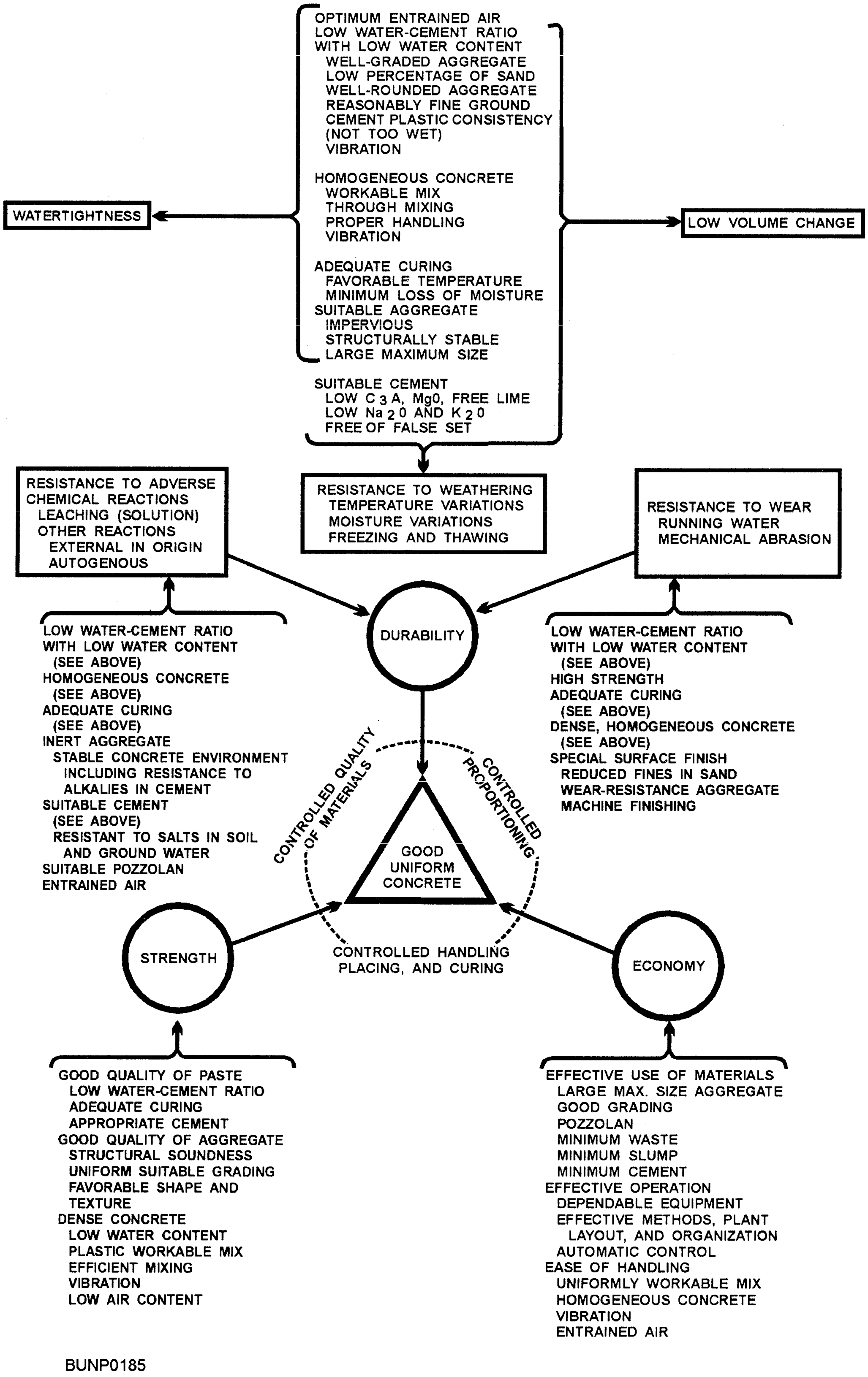


Figure 3-13.—Concrete properties.

will take 6 parts per cubic foot of material. For example:

Cement	1 x 6	6 cubic feet
Sand	2 x 6	12 cubic feet
Gravel	4 x 6	24 cubic feet
Total of dry mix produced		42 cubic feet = 1 cubic yard

NOTE: 1 bag of cement equals 1 cubic foot of cement.

In addition to the carpenter's mix, there are other popular rule-of-thumb mixes:

1:1:2—a very rich mix. Use when great strength is required.

1:2:5—a medium mix. Use in large slabs and walls.

1:35—a lean mix. Use in large foundations or as a backing for masonry.

1:4:8—a very lean mix. Use only in mass placing.

To achieve more control over the proportional quantities of cement, water, and aggregate for a concrete mix, you can use one of three methods (book, trial batch, or absolute volume). These three methods of proportioning concrete mixtures will be briefly covered in this section. First, the BOOK METHOD is a theoretical procedure establishing data to determine mix proportions. Second, the TRIAL BATCH METHOD is based on an estimated weight of concrete per unit volume, and the third method is based on calculations of the ABSOLUTE VOLUME occupied by the ingredients used in the concrete mixture. For a more thorough discussion, you should refer to the most recent edition of *Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete* (ACI 211.1), published by the American Concrete Institute (ACI), and the *Engineering Aid Intermediate/Advanced.*

BOOK METHOD

The BOOK METHOD is a theoretical procedure in which established data is used to determine mix proportions. Because of the variation of the materials (aggregates) used, mixes arrived at by the book method require adjustment in the field following the mixing of trial batches and testing. Concrete mixtures should be designed to give the most economical and practical combination of the materials that will produce the necessary workability in the fresh concrete and the qualities in the hardened concrete.

Selecting Mix Characteristics

Certain information must be known before a concrete mixture can be proportioned. The size and shape of structural members, the concrete strength required, and the exposure conditions must be determined. The water-cement ratio, the aggregate characteristics, the amount of entrained air, and the slump are significant factors in the selection of the appropriate concrete mixture.

Water-Cement Ratio

The water-cement ratio is determined by the strength, the durability, and the watertightness requirements of the hardened concrete. The ratio is usually specified by the structural design engineer, but you can arrive at tentative mix proportions from knowledge of a prior job. Always remember that a change in the water-cement ratio changes the characteristics of the hardened concrete. Use table 3-10 to select a suitable water-cement ratio for normal weight concrete that will meet anticipated exposure conditions. Note that the water-cement ratios in table 3-10 are based on concrete strength under certain exposure conditions. If possible, perform the tests using job materials to determine the relationship between the water-cement ratio you select and the strength of the finished concrete. If you cannot obtain laboratory test data or experience records for the relationship, use table 3-11 as a guide. Enter table 3-11 at the desired f'_c (specified compressive strength of the concrete in pounds per square inch, psi) and read across to determine the maximum water-cement ratio. You can interpolate between the values. When both exposure conditions and strength must be considered, use the lower of the two indicated water-cement ratios. If flexural strength, rather than compressive strength, is the basis of design, such as a pavement, perform the tests to determine the relationship between the water-cement ratio and the flexural strength. An approximate relationship between flexural strength and compressive strength is as follows:

f'_c = compressive strength, psi

R = flexural strength, psi

k = a constant, usually between 8 and 10

Aggregate

Use fine aggregate to fill the spaces between the coarse aggregate particles and to increase the

Table 3-10.—Maximum Permissible Water-Cement Ratios for Various Exposure Conditions

Exposure Condition	**Normal-weight Concrete, Absolute Water-Cement Ratio by Weight**
Concrete Protected from Exposure to Freezing and Thawing or Application of De-Icer ChemicalsSelect water-cement ratio on basis of strength, workability, and finishing needs.	
Watertight Concrete:	
In Fresh Water	0.50
In Sea Water	0.45
Frost Resistant Concrete:	
Thin Sections; Any Section with Less Than 2-inch Cover over Reinforcement and Any Concrete Exposed to De-Icing Salts	0.45
All Other Structures	0.50
Exposure to Sulfates:	
Moderate	0.50
Severe	0.45
Placing Concrete Under Water	Not less than 650 pounds of cement per cubic yard (386 kilograms per cubic meter)
Floors on Grade	Select water-cement ratio for strength, plus minimum cement requirements; see Table 3-7.

Table 3-11.—Relationship Between Water-Cement Ratios and Compressive Strength of Concrete

Specified Compressive Strength	Maximum Absolute Permissible Water:Cement Ratio, by Weight	
f'c psi*	Nonair-Entrained Concrete	Air-Entrained Concrete
2,500	0.67	0.54
3,000	0.58	0.46
3,500	0.51	0.40
4,000	0.44	0.35
4,500	0.38	**
5,000	**	**
*—28-day strength. With most materials, the water-cement ratios shown will provide average strengths greater than required.	**—For strengths above 4,500 psi (nonair-entrained concrete) and 4,000 psi (air-entrained concrete), proportions should be established by the trial batch method.	

workability of a mix. In general, aggregate that does not have a large grading gap or an excess of any size, but gives a smooth grading curve, produces the best mix.

Use the largest practical size of coarse aggregate in the mix. The maximum size of coarse aggregate that produces concrete of maximum strength for a given cement content depends upon the aggregate source as well as the aggregate shape and grading. The larger the maximum size of the coarse aggregate, the less paste (water and cement) required for a given concrete quality. The maximum size of aggregate should never exceed one fifth of the narrowest dimension between side forms, one third of the depth of slabs, or three fourths of the distance between reinforcing bars.

Entrained Air

Use entrained air in all concrete exposed to freezing and thawing, and, sometimes under mild exposure conditions, to improve workability. Always use entrained air in paving concrete regardless of climatic conditions. Table 3-12 gives recommended total air contents of air-entrained concretes. When mixing water remains constant, air entrainment increases slump. When cement content and slump remain constant, less mixing water is required. The resulting decrease in the water-cement ratio helps to offset possible strength decreases and improves other paste properties, such as permeability. The strength of air-entrained concrete may equal, or nearly equal, that of nonair-entrained concrete when cement contents and slump are the same. The upper half of table 3-12 gives the approximate percent of entrapped air in nonair-entrained concrete, and the lower half gives the recommended average total air content percentages for air-entrained concrete based on level of exposure.

MILD EXPOSURE.— "Mild" exposure includes indoor or outdoor service in a climate that does not expose the concrete to freezing or deicing agents. When you want air entrainment for a reason other than durability, such as to improve workability or cohesion or to improve strength in low cement factor concrete, you can use air contents lower than those required for durability.

MODERATE EXPOSURE.— "Moderate" exposure means service in a climate where freezing is expected but where the concrete is not continually exposed to moisture or free water for long periods before freezing or to deicing agents or other aggressive chemicals. Examples are exterior beams, columns, walls, girders, or slabs that do not contact wet soil or receive direct application of deicing salts.

SEVERE EXPOSURE.— "Severe" exposure means service where the concrete is exposed to deicing chemicals or other aggressive agents or where it continually contacts moisture or free water before freezing. Examples are pavements, bridge decks, curbs, gutters, sidewalks, or exterior water tanks or sumps.

TRIAL BATCH METHOD

In the trial batch method of mix design, use actual job materials to obtain mix proportions. The size of the trial batch depends upon the equipment you have and how many test specimens you make. Batches using 10 to 20 pounds of cement may be big enough, although larger batches produce more accurate data. Use machine mixing if possible, since it more nearly represents job conditions. Always use a machine to mix concrete containing entrained air. Be sure to use representative samples of aggregate, cement, water, and air-entraining admixture in the trial batch. Prewet the aggregate and allow it to dry to a saturated, surface-dry condition. Then place it in covered containers to maintain this condition until you use it. This action simplifies calculations and eliminates errors caused by variations in aggregate moisture content. When the concrete quality is specified in terms of the water-cement ratio, the trial batch procedure consists basically of combining paste (water, cement, and usually entrained air) of the correct proportions with the proper amounts of fine and coarse aggregates to produce the required slump and workability. Then calculate the large quantities per sack or per cubic yard. Refer to the *EA Intermediate/Advanced* for further information and calculations of the trial batch method and the absolute volume method.

ABSOLUTE VOLUME METHOD

The ABSOLUTE VOLUME METHOD is based on calculations occupied by the ingredients used in the concrete mixture. For this procedure, select the water-cement ratio, the slump, the air content, the maximum aggregate size, and estimate the water requirement as you did in the trial batch method. Before making calculations, you must have certain other information, such as the specific gravities of the fine and coarse aggregate, the dry-rodded unit weight of the coarse aggregate, and the fineness modulus of the fine aggregate (refer to ACI 214). Now you can determine the dry-rodded unit weight of coarse

Table 3-12.—Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Sizes of Aggregates

Water, lb per cy of Concrete, for indicated maximum Sizes of Aggregate*								
Slump, in	3/8 inch	1/2 inch	3/4 inch	1 inch	1 1/2 inch	2 inch**	3 inch**	6 inch**
Nonair–Entrained concrete								
1 to 2	350	335	315	300	275	260	240	210
3 to 4	385	365	340	325	300	285	265	230
6 to 7	410	385	360	340	315	300	285	
Approximate Amount of Entrapped Air in Nonair–Entrained Concrete, %	3	2.5	2	1.5	1	0.5	0.3	0.2
Air-Entrained Concrete								
1 to 2	305	295	280	270	250	240	225	200
3 to 4	340	325	305	295	275	265	250	220
6 to 7	365	345	325	310	290	280	270	--
Recommended Average Total Air Content, % for Level of Exposure								
Mild Exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate Exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Extreme Exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

*—These quantities of mixing water are for use in computing cement factors for trial batches. They are maximums for reasonably well-shaped angular coarse aggregates graded within limits of accepted specifications.

**—The slump values for concrete containing aggregate larger than 1 1/2 in. are based on slump tests made after removal of particles larger than 1 1/2 in. by wet screening.

aggregate and calculate the quantities per cubic yard of water, cement, coarse aggregate, and air. Finally, subtract the sum of the absolute volumes of these materials in cubic feet from 27 cubic feet per 1 cubic yard to give the specific volume of fine aggregate. If needed, more trial batches should be mixed to obtain the desired slump and air content while you keep the water-cement ratio constant.

MIX VARIATIONS

The proportions arrived at in determining mixes will vary somewhat depending upon which method is used. This occurs because of the nature of these methods. It does not necessarily imply that one method is better than another. Each method begins by assuming certain needs or requirements and then proceeds to determine the other variables. Since the methods begin differently and use different procedures, the final proportions vary slightly. This is to be expected, and it further points out the necessity of trial mixes in determining the final mix proportions.

MIX ADJUSTMENTS

Construction crews in the field convert the designed trial mix proportions into field mix proportions suitable for the mixing equipment available. It must be remembered, however, that the trial mix method was designed under controlled conditions based on certain assumptions that may not exist in the field. For this reason, it often becomes necessary for the field crews to adjust the mix for moisture and entrained air.

ADMIXTURES

Admixtures include all materials other than portland cement, water, and aggregates that are added to concrete, mortar, or grout immediately before or during mixing. Admixtures are sometimes used in concrete mixtures to improve certain qualities, such as workability, strength, durability, watertightness, and wear resistance. They may also be added to reduce segregation, reduce heat of hydration, entrain air, and accelerate or retard setting and hardening. The same results can often be obtained by changing the mix proportions or by selecting other suitable materials without resorting to the use of admixtures (except air-entraining admixtures when necessary). Whenever possible, comparison should be made between these alternatives to determine which is more economical and/or convenient. Any admixture to be in concrete should be added according to current specifications and under the direction of the engineer in charge.

The most commonly used admixture in concrete mixtures is an air-entraining agent of the type discussed in the previous section on "Mix Adjustments" for entrained air. In general, air-entraining agents are derivatives of natural wood resins, animal or vegetable fats or oils, alkali salts of sulfated or sulfonated organic compounds, and water-soluble soaps. Most air-entraining agents are in liquid form for use in the mix water. The instructions for the use of the various agents to produce a specified air content are provided by the manufacturer.

Automatic dispensers, made available by some manufacturers, permit more accurate control of the quantities of air-entraining agents used in the mix. The main reason for using intentionally entrained air is to improve the resistance of the concrete to freezing and thawing exposure. However, there are other important beneficial effects in both freshly mixed and hardened concrete, which include workability, resistance to deicers, sulfate resistance, strength, abrasion resistance, and watertightness.

SLUMP TEST

The slump test measures the consistency of concrete. Do not use it to compare mixes having wholly different proportions or containing different sizes of aggregates. When different batches are tested, changes in slump indicate changes in materials, mix

Table 3-13.—Recommended Slumps for Various Types of Construction

CONCRETE CONSTRUCTION	MAXIMUM SLUMP (IN INCHES*)	MINIMUM SLUMP (IN INCHES*)
REINFORCED FOUNDATION WALLS AND FOOTINGS	3	1
PLAIN FOOTINGS, CAISSONS, AND SUBSTRUCTURE WALLS	3	1
BEAMS AND REINFORCED WALLS	4	1
BUILDING COLUMNS	4	1
PAVEMENTS AND SLABS	3	1
MASS CONCRETE	2	1
*—May be increased 1 inch for consolidation by methods such as rods and spades. 1 inch = 25mm		

proportions, or water content. Table 3-13 gives recommended slump ranges for various types of construction.

COMPRESSIVE TEST

The compressive strength of concrete is the ability to resist a CRUSHING force is, as previously explained, controlled by the water-cement ratio. However, the theoretical compressive strength related to a particular water-cement ratio will be attained only if the actual amount of water added is carefully regulated according to the considerations previously mentioned. Samples cast from the mix being used must be cured and tested to determine what compressive strength was actually attained.

The first step is to obtain a sample of the concrete. The sample should consist of not less than 1 cubic foot when it is to be used for strength tests. Smaller samples may be permitted for routine air content and slump tests.

The procedures used in sampling should include the use of every precaution that will assist in obtaining samples that will be representative of the true nature and condition of the concrete sample as follows:

1. Sampling from stationary mixers except paving mixers. The sample must be obtained by passing a receptacle completely through the discharge stream of the mixer at about the middle of the batch or by diverting the stream completely so that it discharges into a container. Care must be taken not to restrict the flow from the mixer in such a manner as to cause the concrete to segregate. These requirements apply to both tilting and nontilting mixers.

2. Sampling from paving mixers. The contents of the paving mixer must be discharged, and the sample must be collected from at least five different portions of the pile.

3. Sampling from revolving drum truck mixers or agitators. The sample must be taken at three or more regular intervals throughout the discharge of the entire batch, except that samples must not be taken at the beginning or end of the discharge. Sampling must be done by repeatedly passing a receptacle through the entire discharge stream or by diverting the stream completely so that it discharges into a container. The rate of discharge of the batch must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

The sample must be transported to the place where test specimens are to be molded or where the test is to be made and must be remixed with a shovel at the minimum amount to ensure uniformity. The sample must be protected from sunlight and wind during the period between taking and using which must not exceed 15 minutes.

Tests are made on 6- by 12-inch cylinders, cast in cylindrical molds. For the final test, a cylinder is cured for 28 days; however, the PROBABLE 28-day strength that a mix will attain can be estimated by determining the 7-day strength (which actually runs about 2/3 of the 28-day strength). Therefore, one or more cylinders are tested after 7 days of curing.

Test cylinders are cast in either metal or heavy cardboard molds. For filling, a mold is placed on a metal BASE PLATE. To avoid loss of the mix water, you can seal the bottom of the mold to the base plate with paraffin. A cardboard mold is expendable; that is, for stripping it from the test cylinder, it is simply torn off. A metal mold is hinged so that it can be stripped by opening. Before the mold is filled, the inside surface and base are lightly oiled to prevent the concrete from BONDING (adhering) to the mold and plate.

The test specimens should be formed by placing the concrete in the mold in three layers of approximately equal volume. In placing each scoopful of concrete, the scoop must be moved around the top edge of the mold, as the concrete slides from it to ensure a symmetrical distribution of the concrete within the mold. The concrete must be further distributed by a circular motion of the tamping rod. Each layer must be rodded with 25 strokes of a 5/8-inch-round rod, approximately 24 inches in length and tapered for a distance of 1 inch to a spherically shaped end having a radius of approximately one-fourth inch. The strokes must be distributed uniformly over the cross section of the mold and must penetrate into the underlying layer. The bottom layer must be rodded throughout its depth. Where voids are left by the tamping rod, the sides of the mold must be tapped to close the voids. After the top layer has been rodded, the surface of the concrete must be struck off with a trowel and covered with a glass or metal plate to prevent evaporation.

After about 24 hours of hardening, the mold is stripped off and the cylinder is immersed in either water, moist sand, moist sawdust, or moist earth for curing. At the expiration of the curing period (7 or 28 days), the cylinder is CAPPED on both ends with a thin layer of gypsum CASTING PLASTER or sulfur CAPPING COMPOUND. For testing, the cylinder is placed under the piston of a machine capable of applying a very high pressure (for a 6-inch-diameter cylinder with a compressive strength of about 6,000 pounds per square inch, the rupturing pressure must reach about 170,000 pounds). Pressure is applied and increased until the cylinder collapses.

FLEXURAL TEST

The FLEXURAL strength is its ability to resist a breaking force. The flexural strength of concrete is considerably less than its compressive strength. For a flexural strength test, a TEST BEAM, cast in a TEST BEAM MOLD, like the one shown in figure 3-14, is cured and then broken by a BEAM BREAKER.

The test specimen must be formed with its long axis horizontal. The concrete must be placed in layers approximately 3 inches in depth, and each layer must be rodded 50 times for each square foot of area. The top layer must slightly overfill the mold. After each layer is rodded, the concrete must be spaded along the sides and ends with a mason's trowel or other suitable tool. When the rodding and spading operations are completed, the top must be struck off with a straightedge and finished with a wood float. The test specimen must be made promptly and without interruption. Test beams should be cured for a period of 28 days. Like cylinders, the flexural strength may be determined after 7 days, utilizing the probable 28 day strength of concrete.

COMPUTING CONCRETE

To compute the volume of concrete required for a concrete pad, multiply the length of the pad by its width times its thickness to get cubic feet (length x width x thickness). For example, a concrete pad is 20 feet in length by 30 feet in width and has a slab thickness of 4 inches. You first convert the 4 inches into feet by dividing 3 by 12 to get 0.333 feet. Next, multiply the 20 feet by 30 feet to get 600 square feet. Then multiply 600 square feet by 0.333 to determine the volume in cubic yards of concrete required for the pad which, in this case, is 200 cubic feet.

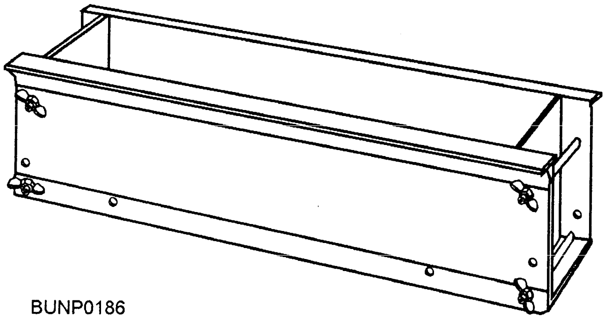


Figure 3-14.—Test beam mold.

Concrete is ordered and produced in quantities of cubic yards. To calculate the number of cubic yards required for the pad, divide the cubic feet of the pad by 27. This is required because there is 27 cubic feet in 1 cubic yard. Therefore, the concrete pad, described in the previous paragraph which has a volume of 200 cubic feet, requires 7.41 cubic yards of concrete.

$$\frac{Length \times Width \times \text{Thickness in feet}}{27} = CD$$

$$30' \times 20' \times 4'' =$$

$$30' \times 20' \times .333 = 200 \text{ cubic feet}$$

$$200 \text{ cf} \div 27 = 7.41 \text{ cubic yards}$$

Concrete projects often present varying degrees of difficulty; therefore, extra concrete is required to compensate for these difficulties. Once the total number of cubic yards of concrete is computed, add a little extra, normally 10 percent, to compensate for waste. To calculate the excess needed. multiply the cubic yards by 10 percent. In the above case, multiply 7.41 cubic yards by .10 to get 0.741 cubic yards. Add the 0.741 percentage to the 7.41 cubic yards for a total of 8.15 cubic yards required for the concrete pad.

Another method for estimating concrete is shown in table 3-52 of the NAVFAC P-405 which covers the 037 rule. This is a decimal equivalent to 1 cubic yard divided by 27 cubic feet which equals .037037. This method is accurate; however, the Seabees prefer the *L* x *W* x T ÷ 27 method.

BATCHING CONCRETE

Batching is the process of weighing or volumetrically measuring and introducing into a mixer the ingredients for a batch of concrete. To produce a uniform quality concrete mix, measure the ingredients accurately for each batch. Most concrete specifications require that the batching be performed by weight, rather than by volume, because of inaccuracies in measuring aggregate, especially damp aggregate. Water and liquid air-entraining admixtures can be measured accurately by either weight or volume. Batching by using weight provides greater accuracy and avoids problems created by bulking of damp sand. Volumetric batching is used for concrete mixed in a continuous mixer and the mobile concrete mixer (crete mobile) where weighing facilities are not at hand.

Specifications generally require that materials be measured in individual batches within the following percentages of accuracy: cement 1%, aggregate 2%, water 1%, and air-entraining admixtures 3%.

The equipment used should be capable of measuring quantities within these tolerances for the smallest to the largest batch of concrete produced. The accuracy of the batching equipment should be checked periodically and adjusted when necessary.

Mixing Concrete

Concrete should be mixed until it is uniform in appearance and all the ingredients are evenly distributed. Mixers should not be loaded above their rated capacities and should be operated at approximately the speeds for which they were designed. If the blades of the mixer become worn or coated with hardened concrete, the mixing action will be less efficient. Worn blades should be replaced and the hardened concrete removed periodically, preferably after each production of concrete.

When a transit mixer (TM) (fig. 3-15) is used for mixing concrete, 70 to 100 revolutions of the drum at the rate of rotation designated by the manufacturer as *mixing speed* are usually required to produce the specified uniformity. No more than 100 revolutions at mixing speed should be used. All revolutions after 100 should be at a rate of rotation, designated by the manufacturer, as *agitating speed.* Agitating speed is usually about 2 to 6 revolutions per minute, and mixing speed is generally about 6 to 18 revolutions per minute. Mixing for long periods of time at high speeds, about 1 or more hours, can result in concrete strength loss, temperature rise, excessive loss of entrained air, and accelerated slump loss.

Concrete, mixed in a transit mixer, should be delivered and discharged within 1 1/2 hours or before the drum has revolved 300 times after the introduction of water to cement and aggregates or the cement to the aggregates. Mixers and agitators should always be operated within the limits of the volume and speed of rotation designated by the equipment manufacturer.

OVERMIXING CONCRETE.— Overmixing concrete damages the quality of the concrete, tends to grind the aggregate into smaller pieces, increases the temperature of the mix, lowers the slump, decreases air entrainment, and decreases the strength of the concrete. Also, overmixing puts needless wear on the drum and blades of the transit mixer.

To select the best mixing speed for a load of concrete, estimate the travel time to the project (in minutes) and divide this into the minimum desired number of revolutions at mixing speed–70. The results will be the best drum speed; for instance, if the haul

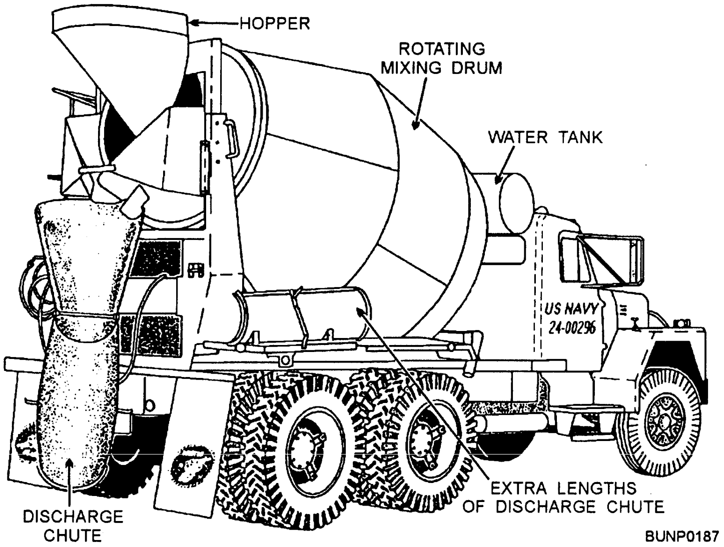


Figure 3-15.—Transit mixer.

is 10 minutes, 70 divided by 10 equals 7. With this drum speed, the load will arrive on the jobsite with exactly 70 turns at mixing speed with no overmixing of the concrete mix and no unnecessary wear on the equipment. If the concrete cannot be discharged immediately, the operator should turn the drum at the minimum agitating speed of 2 revolutions per minute. When the transit mixer arrives at the project having used the minimum amount of mixing turns, the operator is able, if necessary, to delay discharging the concrete. Delay is limited by the maximum of 300 rotations allowed.

REMIXING CONCRETE.— Concrete begins to stiffen as soon as the cement and water are mixed. However, the degree of stiffening that occurs in the first 30 minutes is not usually a problem; concrete that is kept agitated generally can be placed within 1 1/2 hours after mixing.

Fresh concrete left to agitate in the mixer drum may be used; if upon remixing, it becomes sufficiently plastic to be compacted in the forms. Under careful supervision a small amount of water may be added to remix the concrete provided the following conditions are met: (1) maximum allowable water-cement ratio is not exceeded, (2) maximum allowable slump is not exceeded, (3) maximum allowable mixing and agitating time (or drum revolutions) is not exceeded, and (4) concrete is remixed for at least half the minimum required mixing time or number of revolutions.

Adding too much water to make concrete more fluid should not be allowed because this lowers the quality of the concrete. Remixed concrete can be expected to harden quickly. Subsequently, a cold joint may develop when concrete is placed next to or above the remixed concrete.

Mobile Concrete Mixer Plant

The trailer-mounted mobile concrete mixer plant (fig. 3-16) carries cement, sand, and coarse aggregates in divided bins mounted on the unit. The cement is carried in a separate bin located across the rear of the unit, and the sand and aggregate are carried on each side of the unit. Water is carried in a single tank mounted in front of the aggregate bins and is pumped to the mix auger. Sand and aggregates are accurately proportioned by weight and simultaneously dropped with a mixture of cement from the material feed system into the charging end of the mix auger/conveyor at the rear of the unit. At this point, a predetermined amount of water enters the mix auger. The action of this combined auger and paddle homogenizer mixes the ingredients and water rapidly, thoroughly, and continuously to produce a continuous flow of uniformed quality concrete. The material mixing action is a continuous process that can proceed until the aggregate bins are empty. On the other hand, mixing and delivery may be stopped at any time and then started again at the will of the operator. This permits production to be balanced to the demands of the placing and finishing crews and other job requirements.

Operators assigned to the “crete mobile” must thoroughly read and understand the technical manual before operating the plant.

The following are the mobile concrete mixer plant cautions and warnings:

- Follow all preventive maintenance procedures.
- Do not allow any foreign matter in the cement bin.
- Do not allow particles larger than 1 1/2 inch in the aggregate bin.
- Do not allow the waterlines and flowmeters to freeze with water in them.
- Do not run the water pump dry.
- Do not continue to operate the machine if the hydraulic oil temperature exceeds 190°F.
- Wash out the auger within 20 minutes of the last use.
- Never attempt to operate the unit while in motion.
- Never attempt to repair the machine while in operation (always turn the power source off).
- Keep your entire body clear from all moving parts.
- Never attempt to walk on top of the aggregate bin to cross from the cement bin to the water tank (use the ladder).
- Never walk or stand under the auger.
- Never climb inside the aggregate bin (use a small pole to dislodge any aggregate that has bridged).
- Never enter the cement bin while in operation (there are moving parts inside the bin).

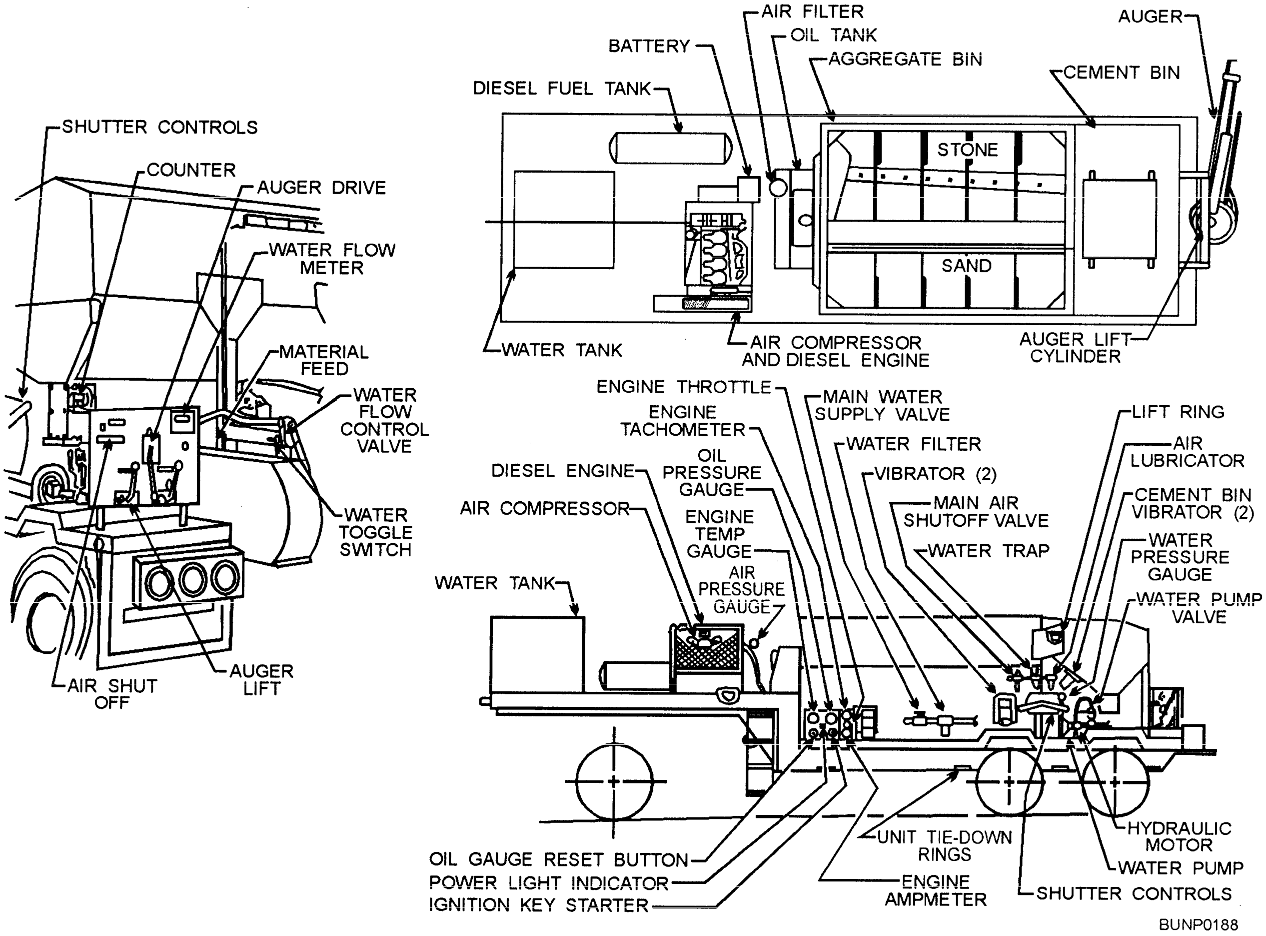


Figure 3-16.—Mobile concrete mixer plant.

TRANSIT MIXER SAFETY

The use of transit mixers on construction projects impose traffic problems that must be considered. Caution must be used during backing of the transit mixer. Backing should be controlled by a signalman, positioned so the operator can clearly observe the directions given. Extreme caution must be used when traveling over uneven terrain on a construction site. The stability of the mixer is greatly reduced with the extra weight of the concrete in the mixer unit. In such cases, a slow speed is recommended.

Some additional safety precautions that must be enforced are as follows:

1. Secure the discharge chute properly, using the lock provided.
2. Check to make certain other personnel are in the clear before starting the mixer charging or discharging.
3. Make sure the mixer is stopped before making any adjustments.

PRECAST AND TILT-UP CONSTRUCTION

Precast and tilt-up construction is the fabrication of structural members or panels at a place other than its final position of use. It can be done anywhere, although these procedures are best adapted to a factory or prefab yard. Jobsite precasting is not uncommon for large projects. Precast concrete can be produced in several different shapes and sizes, including piles, girders, and roof members. Prestressed concrete is especially well-adapted to precasting techniques.

Tilt-up concrete is a special type of precast concrete in which the units are tilted up and placed, using cranes or other types of lifiing devices.

Wall construction, for example, is frequently done with precast wall panels originally cast horizontally (sometimes one above the other) as slabs. This method has many advantages over the conventional method of casting in place in vertical wall forms. Since a slab form requires only edge forms and a single surface form, the amount of formwork and form materials required is greatly reduced. The labor involved in slab form concrete casting is much less than that involved in filling a high wall form. One side of a precast unit cast as a slab may be finished by hand to any desired quality of finishing. The placement of reinforcing steel is much easier in slab forms, and it is easier to attain thorough filling and vibrating. Precasting of wall panels as slabs may be expedited by mass production methods not available when casting in place.

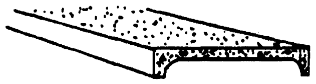
PRECAST CONCRETE

Generally, structural members, including standard highway girders, poles, electric poles, masts, and building members, are precast by factory methods unless the difficulty or impracticability of transportation makes jobsite casting more desirable. On the other hand, concrete that is cast in the position that it is to occupy in the finished structure is called cast-in-place concrete.

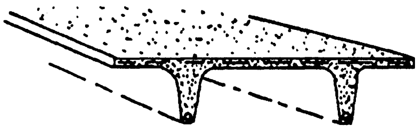
Precast Concrete Floors, Roof Slabs, Walls, and Partitions

The most commonly used precast slabs or panels for FLOOR and ROOF DECKS are the channel and double-T types (fig. 3-17, views A and B).

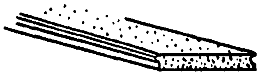
The channel slabs vary in size with a depth ranging from 9 to 12 inches, width 2 to 5 feet, and a thickness of 1 to 2 inches. They have been used in spans up 50 feet. If desired or needed, the legs of the channels may be extended across the ends and, if used in combination with the top slabs, may be stiffened with occasional cross ribs. Wire mesh may be used in the top slabs for reinforcement. The longitudinal grooves, located along the top of the channel legs, may be grouted to form keys between adjacent slabs.



A. CHANNEL



B. DOUBLE-T



C. TONGUE AND GROOVE

Figure 3-17.—Typical precast panels.

The double-T slabs vary in size from 4 to 6 feet in width and 9 to 16 feet in depth. They have been used in spans as long as 50 feet. When the top-slab size ranges from 1 1/2 to 2 inches in thickness, it should be reinforced with wire mesh.

The tongue-and-groove panel (fig. 3-17, view C) could vary extensively in size according to the design requirement. They are placed in position much like tongue-and-groove lumber; that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction.

Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

Panels precast in a horizontal position, in a casting yard or on the floor of the building, are ordinarily used in the makeup of bearing and nonbearing WALLS and PARTITIONS. These panels are placed in their vertical positions by cranes or by the tilt-up procedure, as shown in figures 3-18 and 3-19.

Usually, these panels are solid, reinforced slabs, 5 to 8 inches in thickness, with the length varying according to the distances between columns or other supporting members. When windows and door openings are cast in the slabs, extra reinforcements should be installed around the openings.

A concrete floor slab with a smooth, regular surface can be used as a "casting surface." When this smooth surface is used for casting, it should be covered with some form of liquid or sheet material to prevent bonding between the surface and the wall panel. The upper surface of the panel may be finished as regular concrete is finished by troweling, floating, or brooming.

SANDWICH PANELS are panels that consist of two thin, dense, reinforced concrete-face slabs separated by a core of insulating material, such as lightweight concrete, cellular glass, plastic foam, or some rigid insulating material.

These panels are sometimes used for exterior walls to provide additional heat insulation. The

Figure 3-18.—Precast panels being erected by use of crane and spreader bars.

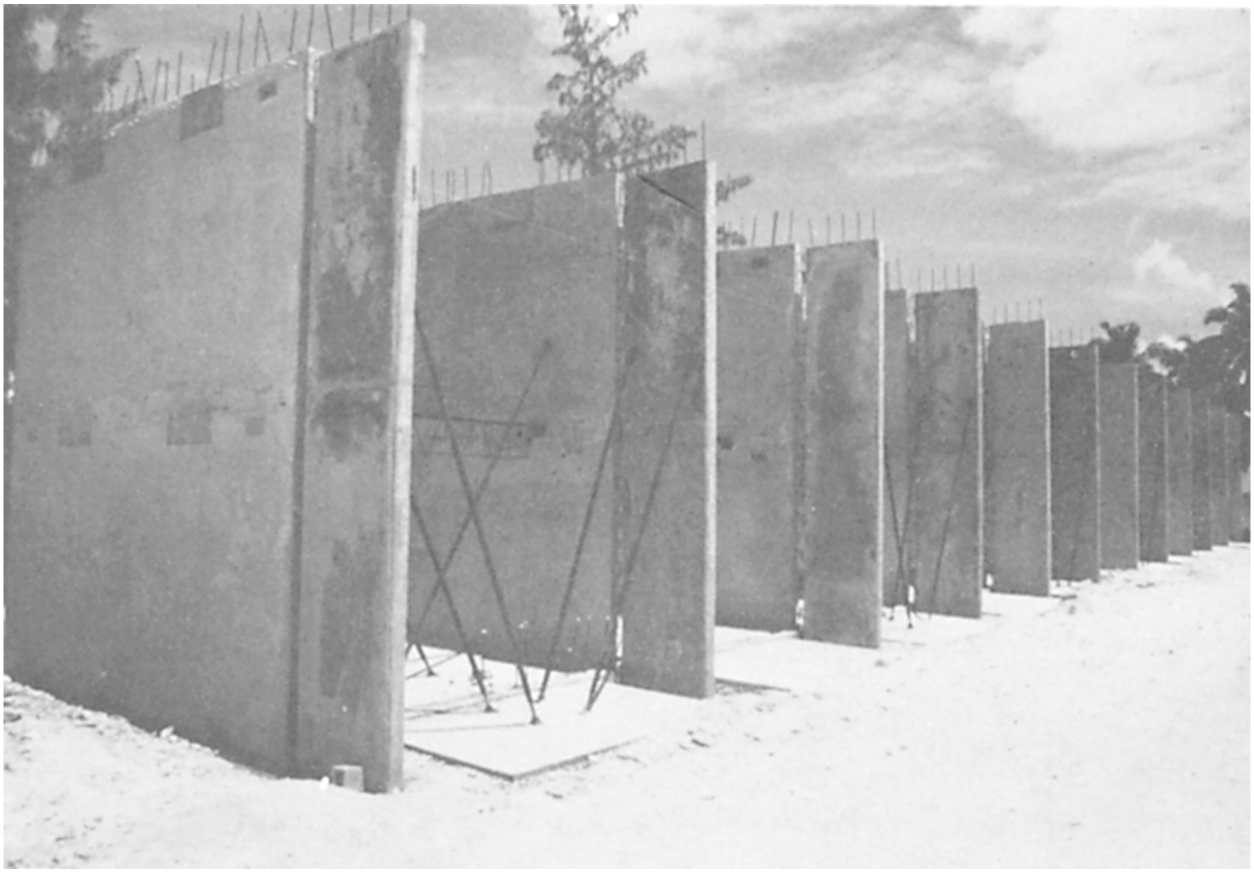


Figure 3-19.—Precast panels in positions.

thickness of the sandwich panels varies from 5 to 8 inches, and the face slabs are tied together with wire, small rods, or in some other manner. Welded or bolted matching plates are also used to connect the wall panels to the building frame, top and bottom. Caulking on the outside and grouting on the inside should be used to make the points between the wall panels watertight.

Precast Concrete Joists, Beams, Girders, and Columns

Small closely spaced beams used in floor construction are usually called JOISTS; however, these same beams when used in roof construction are called PURLINS. The cross sections of these beams are shaped like a “T” or an “I”. The ones with the inverted T-sections are usually used in composite construction where they support cast-in-place floor or roof slabs.

BEAMS and GIRDERS are terms usually applied to the same members, but the one with the longer span should be referred to as the girder. Beams and girders may be conventional precast design or prestressed. Most of the beams will be I-shaped unless the ends are rectangular. The T-shaped ones can also be used.

Precast concrete COLUMNS may be solid or hollow. If the hollow type is desired, heavy cardboard tubing should be used to form the core. A looped rod is cast in the column footing and projects upward into the hollow core to help hold the column upright. An opening should be left in the side of the column so that the column core can be filled with grout. This causes the looped rod to become embedded to form an anchor. The opening is dry-packed.

Advantages of Precast Concrete

Precast concrete has the greatest advantage when identical members are to be cast because the same forms can be used several times. Some other advantages are listed below.

Control of the quality of concrete.

Smoother surfaces and plastering are not necessary.

Less storage space is needed.

Concrete member can be cast under all weather conditions.

Better protection for curing.

Weather conditions do not affect erection.

Faster erection time.

PRESTRESSED CONCRETE

A prestressed concrete unit is one in which engineered stresses have been placed before it has been subjected to a load. When PRETENSIONING is used, the reinforcement (high-tensile-strength steel strands) is stretched through the form between the two end abutments or anchors. A predetermined amount of stress is applied to the steel strands. The concrete is then poured, encasing the reinforcement. As the concrete sets, it bonds to the pretensioned steel. When it has reached a specified strength, the tension on the reinforcement is released. This prestresses the concrete, putting it under compression, thus creating a built-in tensile strength.

POST-TENSIONING involves a precast member that contains normal reinforcing in addition to a number of channels through which the prestressing cables or rods maybe passed. The channels are usually formed by suspending inflated tubes through the form and casting the concrete around them. When the concrete has set, the tubes are deflated and removed. Once the concrete has reached a specified strength, prestressing steel strands or TENDONS are pulled into the channels and secured at one end. They are then stressed from the opposite end with a portable hydraulic jack and anchored by one of several automatic gripping devices.

Post-tensioning may be done where the member is poured or at the jobsite. Each member may be tensioned, or two or more members may be tensioned together after erection. In general, post-tensioning is used if the unit is over 45 feet long or over 7 tons in weight. However, some types of pretensioned roof slabs will be considerably longer and heavier than this.

When a beam is prestressed, either by pretensioning or post-tensioning, the tensioned steel produces a high compression in the lower part of the beam. This compression creates an upward bow or camber in the beam (fig. 3-20). When a load is placed on the beam, the camber is forced out, creating a level beam with no deflection.

Those members that are relatively small or that can be readily precast are normally pretensioned. These include precast roof slabs, T-slabs, floor slabs, and roof joists.

SPECIAL TYPES OF CONCRETE

Special types of concrete are essentially those with unique physical properties or those produced

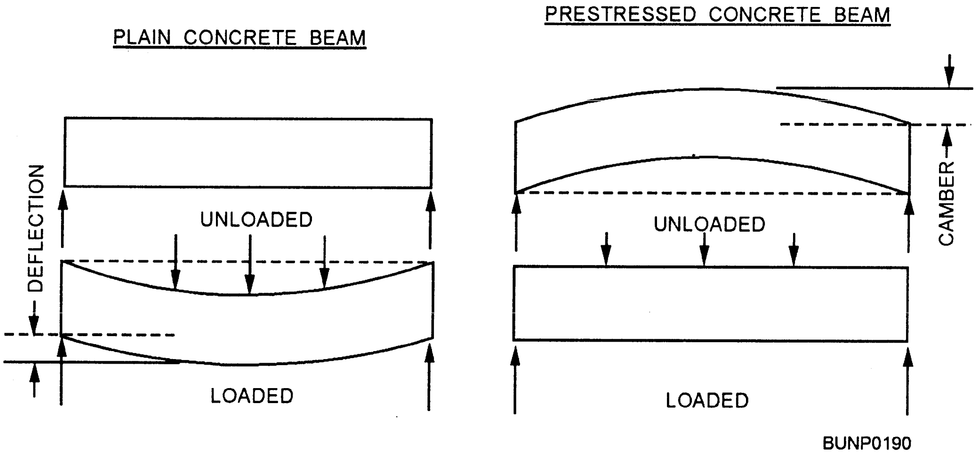


Figure 3-20.—Comparison of plain and prestressed concrete beams.

with unusual techniques and/or reproduction processes. Many special types of concrete are made with portland cement as a binding medium; some use binders other than portland cement.

Lightweight Concrete

Conventional concrete weighs approximately 150 pounds per cubic foot. Lightweight concrete weighs 90 to 120 pounds per cubic foot, depending on its intended use. Lightweight concrete can be made by using either gas-generating chemicals or lightweight aggregates, such as expanded shale, clay, or slag. Concrete, containing aggregates like perlite or vermiculite, is very light in weight and is primarily used as insulating material. Lightweight concrete is usually classified according to its weight per cubic foot.

Semi-lightweight concrete has a unit weight of 115 to 130 pounds per cubic foot and an ultimate compressive strength comparable to normal concrete. Sand of normal weight is substituted partially or completely for the lightweight fine aggregate.

Insulating lightweight concrete has a unit weight ranging from 15 to 90 pounds per cubic foot, and its compressive strength seldom exceeds 1,000 psi. This type of concrete is generally used for insulating applications, such as fireproofing.

Structural lightweight concrete has a unit weight of 85 to 115 pounds per cubic foot and a 28-day compressive strength in excess of 2,500 psi. This type is used primarily to reduce the dead-load weight in concrete structural members, such as floors, walls, and roof sections in high-rise structures.

Heavyweight Concrete

Heavyweight concrete is produced with special heavy aggregates and has a density of up to 400 pounds per cubic foot. This type is used principally for radiation shielding, for counterweights, and for other applications where higher density is desired. Except for density, the physical properties of heavyweight concrete are similar to those of normal or conventional weight concrete.

TILT-UP CONSTRUCTION

Tilt-up concrete construction is a special form of precast concrete building. This method consists basically of jobsite prefabrication in which the walls are cast in a horizontal position, tilted to a vertical position, and then secured in place. Tilt-up construction is best suited for large one-story buildings, but it can be used in multistory structures. Usually, multistory structures are built by setting the walls for the first story, placing the floor above, then repeating the procedure for each succeeding floor. An alternate method is to cast two- to four-story panels.

The wall panels are usually cast on the floor slab of the structure. Care must be exercised to ensure that the floor slab is smooth and level and that all openings for pipes and other utilities are temporarily plugged. The casting surface is treated with a good bond-breaking agent to ensure the panel does not adhere when it is lifted.

Reinforcement of Tilt-Up Panels

The steel in a tilt-up panel is set in the same manner as it is in a floor slab. Mats of reinforcement are placed on chairs and tied as needed. Reinforcement should be as near the center of the panel as possible. Reinforcing bars are run through the side forms of the panel. When welded wire fabric or expanded wire mesh is used, dowel bars are used to tie the panels and their vertical supports together. Additional reinforcement is generally needed around openings.

The panel is picked up or tilted by the use of PICKUP INSERTS. These inserts are tied into the reinforcement. As the panel is raised into its vertical position, maximum stress will occur; therefore, the location and number of pickup inserts are extremely important. Some engineering manuals provide information on inserts, their locations, and capacities.

TILT-UP PANEL FOUNDATIONS.— An economical and widely used method to support tilt-up panels is a simple pad footing. The floor slab, which is constructed first, is NOT poured to the perimeter of the building to permit excavating and pouring the footings. After the panel is placed on the footing, the floor slab is completed. It may be connected directly to the outside wall panel or a trench may be left to run mechanical, electrical, or plumbing lines.

Another method that is commonly used, as an alternative, is to set the panels on a grade beam or a foundation wall at floor level. Regardless of the type of footing, the panel should be set into a mortar bed to ensure a good bond between the foundation wall and the panel.

PANEL CONNECTIONS.— The panels may be tied together in a variety of ways. The location and the use of the structure will dictate what method can or can NOT be used. The strongest method is a cast-in-place column with the panel-reinforcing steel tied into the column. However, this does NOT allow for expansion and contraction. It may be preferable to tie only the corner panels to the columns and allow the remaining panels to move.

A variety of other methods of connecting the panels are also used. A BUTTED connection, using grout or a gasket, can be used if the wall does NOT contribute any structural strength to the structure. Steel columns are welded to steel angles or plates secured in the wall panel. Precast columns can also be used. Steel angles or plates are secured in both the columns and plate and welded together to secure the panel.

When panel connections that do not actually hold the panels in place are used, the panels are generally welded to the foundation and to the roof by using steel angles or plates. All connections must provide waterproof joints. This is accomplished by the use of expansion joint material.

Prefabrication Yard

Precasting is done either in central prefabrication plants or on-site prefabrication plants, depending upon the product and its application. On-site or temporary prefabrication plants are generally more suitable for military operations. These plants are without roofing and, therefore, are subject to weather and climate considerations. The prefabrication yard is laid out to suit the type and quantity of members to be processed. It must be on firm, level ground, providing ample working space and access routes. Bridge T-beams, reinforced concrete arches, end walls, and concrete logs are typical members produced at these plants. A schematic layout of a prefabrication yard suitable for producing such members is shown in figure 3-21. A prefabrication unit of this size can be expected to produce approximately 6,000 square feet of precast walls per day. The output will vary according to the experience of the personnel, equipment capabilities, and product requirements.

CASTING.— The casting surface is very important in making precast concrete panels. In this section, we will cover two common types: earth and concrete. Regardless of which method you use, however, a slab must be cast in a location that will permit easy removal and handling.

Castings can be made directly on the ground with cement poured into forms. These “earth” surfaces are economical but only last for a couple of concrete pours. Concrete surfaces, since they can be reused repeatedly, are more practical.

When building casting surfaces, you should keep the following points in mind:

- The subbase should be level and properly compacted.
- The slab should be at least 6 inches thick and made of 3,000 psi or higher reinforced concrete. Large aggregate, 2 1/2 inches to 3 inches maximum, may be used in the casting slabs.
- If pipes or other utilities are to be extended up through the casting slab at a later date, they should be stopped below the surface and the openings temporarily closed. For wood, cork, or plastic plugs, fill almost to the surface with sand

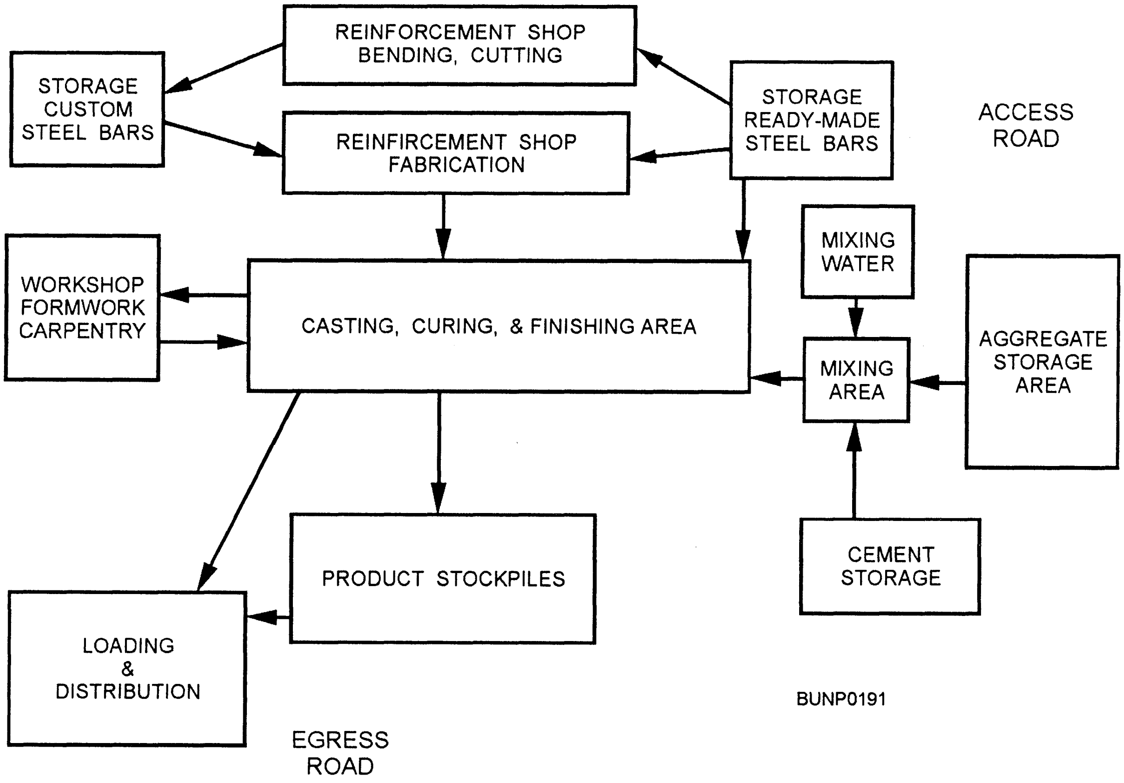


Figure 3-21.—Layout of prefab yard.

and top with a thin coat of mortar that is finished flush with the casting surface.

- It is important to remember that any imperfections in the surface of the casting slab will show up on the cast panels. When finishing the casting slab, you must ensure there is a flat, level, and smooth surface without humps, dips, cracks, or gouges. If possible, cure the casting surface, keeping it covered with water (pending). However, if a curing compound or surface hardener is used, make sure it will not conflict with the later use of bond-breaking agents.

FORMS.— The material most commonly used for edge forms is 2 by lumber. The lumber must be occasionally replaced, but the steel or aluminum angles and channels may be reused many times. The tops of the forms must be in the same plane so that they may be used for screeds. They must also be well-braced to remain in good alignment.

Edge forms should have holes in them for rebar or for expansion/contraction dowels to protrude. These holes should be one fourth of an inch larger in diameter than the bars. At times, the forms are spliced at the line of these bars to make removal easier.

The forms, or rough bucks, for doors, windows, air-conditioning ducts, and so forth, are set before the steel is placed and should be on the same plane as the edge forms.

BOND-BREAKING AGENTS.— Bond-breaking agents are one of the most important items of precast concrete construction. The most important requirement is that they must break the bond between the casting surface and the cast panel. Bond-breaking agents must also be economical, fast drying, easily applied, easily removed, or leave a paintable surface on the cast panel, if desired. They are broken into two general types: sheet materials and liquids.

Many commercially available bond-breaking agents are available. You should obtain the type best suited for the project and follow the manufacturer's application instructions. If commercial bond-breaking agents are not available, several alternatives can be used.

- Paper and felt effectively prevent a bond with a casting surface, but usually stick to the cast panels and may cause asphalt stains on the concrete.

- Plywood, fiberboard, or metal joints, when oiled, can effectively break a bond and can be used many times. However, the initial cost is high and joint marks are left on the cast panels.
- Canvas gives a very pleasing texture and is used where cast panels are lifted at an early stage. It should be either dusted with cement or sprinkled with water just before placing the concrete.
- Oil gives good results when properly used, but is expensive. The casting slab must be dry when the oil is applied, and the oil must be allowed to absorb before the concrete is placed. Oil should not be used if the surface is to be painted, and crankcase oil should never be used.
- Waxes, such as spirit wax (paraffin) and ordinary floor wax, give good-to-excellent results. One mixture that may be used is 5 pounds of paraffin mixed with 1 1/2 gallons of light oil or kerosene. The oil must be heated to dissolve the paraffin.
- Liquid soap requires special care to ensure that an excess amount is not used or the surface of the cast panel will be sandy.

Materials should be applied after the side forms are in place and the casting slab is clean but before any reinforcing steel is placed. To ensure proper adhesion of the concrete, keep all bond-breaking materials off the reinforcing steel.

REINFORCEMENTS AND INSERTS.— Reinforcing bars (rebar) should be assembled into mats and placed into the forms as a unit. This allows for rapid assembly on a jig and reduces walking on the casting surface, which has been treated with the bond-breaking agent.

Extra rebars must be used at openings. They should be placed parallel to and about 2 inches from the sides of openings or placed diagonally across the corners of openings.

The bars may be suspended by conventional methods, such as with high chairs or from members laid across the edge forms. However, high chairs should not be used if the bottom of the cast panel is to be a finished surface. Another method is to first place half the thickness of concrete, place the rebar mat, and then complete the pour. However, this method must be done quickly to avoid a cold joint between the top and bottom layers.

When welded wire fabric (WWF) is used, dowels or bars must still be used between the panels and columns. WWF is usually placed in sheets covering the entire area and then clipped along the edges of the openings after erection.

If utilities are going to be flush-mounted or hidden, pipe, conduit, boxes, sleeves, and so forth, should be put into the forms at the same time as the reinforcing steel. If the utilities pass from one cast panel to another, the connections must be made after the panels are erected but before the columns are poured. If small openings are to go through the panel, a greased pipe sleeve is the easiest method of placing an opening in the form. For larger openings, such as air-conditioning ducts, forms should be made in the same manner as doors or windows.

After rebar and utilities have been placed, all other inserts should be placed. These will include lifting and bracing inserts, anchor bolts, welding plates, and so forth. You need to make sure these items are firmly secured so they will not move during concrete placement or finishing.

POURING, FINISHING, AND CURING.— With few exceptions, pouring cast panels can be done in the same manner as other pours. Since the panels are poured in a horizontal position, a stiffer mix can be used. A minimum of six sacks of cement per cubic yard with a maximum of 6 gallons of water per sack of cement should be used along with well-graded aggregate. As pointed out earlier though, you will have to reduce the amount of water used per sack of cement to allow for the free water in the sand. Large aggregate, up to 1 1/2 inches in diameter, maybe used effectively. The concrete should be worked into place by spading or vibration, and extra care must be taken to prevent honeycomb around outer edges of the panel.

Normal finishing methods should be used, but many finishing styles are available for horizontally Scast panels. Some finishing methods include patterned, colored, exposed aggregate, broomed, floated, or steel-troweled. Regardless of the finish used, finishers must be cautioned to do the finishing of all panels in a uniform manner. Spots, defects, uneven brooming, or troweling, and so forth, will be highly visible when the panels are erected.

Without marring the surface, curing should be started as soon as possible after finishing. Proper curing is important, so cast panels should be cured just like any other concrete to achieve proper strength. Curing compound, if used, prevents bonding with other concrete or paint.

Lifting Equipment and Attachments

Tilt-up panels can be set up in many different ways and with various kinds of power equipment. The choice depends upon the size of the job. Besides the equipment, a number of attachments are used.

EQUIPMENT.— The most popular power equipment is a crane. But other equipment used includes a winch and an A-frame, used either on the ground or mounted on a truck. When a considerable number of panels are ready for tilting at one time, power equipment speeds up the job.

ATTACHMENTS.— Many types of lifting attachments are used to lift tilt-up panels. Some of these attachments are locally made and are called hairpins; other types are available commercially. Hairpin types are made on the jobsite from rebar. These are made by making 180-degree bends in the ends of two vertical reinforcing bars. The hairpins are then placed in the end of the panel before the concrete is poured. These lifting attachments must protrude from the top of the form for attaching the lifting chains or cables, but go deep enough in the panel form so they will not pull out.

Among the commercial types of lifting attachments, you will find many styles with greater lifting capacities that are more dependable than hairpins if properly installed. These are used with lifting plates. For proper placement of lifting inserts, refer to the plans or specs.

SPREADER BARS.— Spreader bars may be permanent or adjustable but must be designed and made according to the heaviest load they will carry plus a safety factor. They are used to distribute the lifting stresses evenly, reduce the lateral force applied by slings, and reduce the tendency of panels to bow.

Point Pickup Methods

Once the concrete has reached the desired strength, the panels are ready to be lifted. The strength of the inserts is governed by the strength of the concrete.

CAUTION

An early lift may result in cracking the panel, pulling out the insert, or total concrete failure. The time taken to wait until the concrete has reached its full strength prevents problems and minimizes the risk of injury.

Several different pickup methods are used. The following are just some of the basics. Before using these methods on a job, make sure that you check the plans and the specs to see if these are stated there. Figure 3-22 shows four different pickup methods: 2, 2-2, 4-4, and 2-2-2.

The 2-point pickup is the simplest method particularly for smaller panels. The pickup cables, or chains, are fastened directly from the crane hook or spreader bar to two pickup points on or near the top of the precast panel.

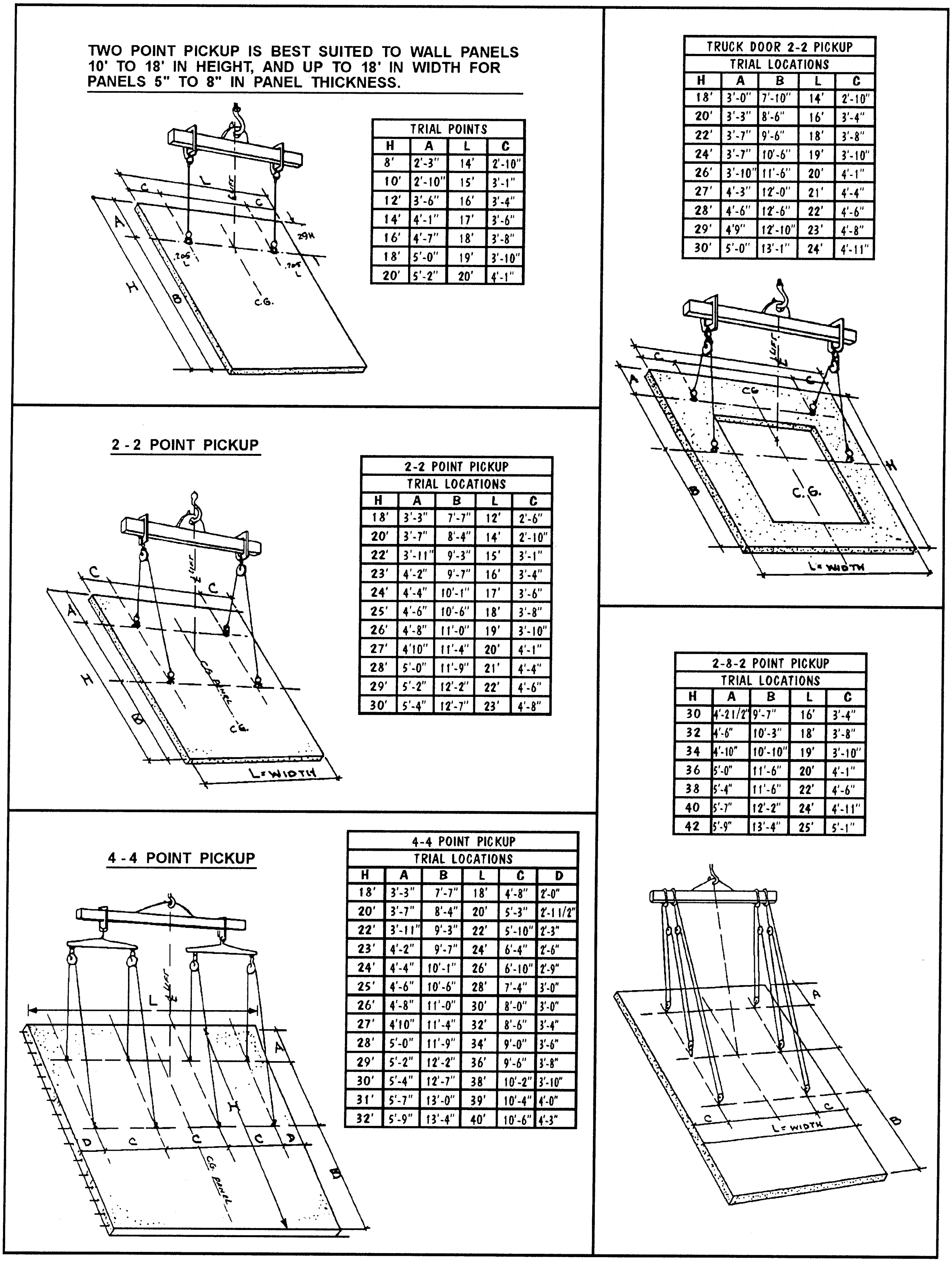
The 2-2 point pickup is a better method and is more commonly used. Variations of the 2-2 are 4-4 and 2-2-2 or combinations of pickup points as designated in the jobsite specifications. These methods use a combination of spreader bars, sheaves, and equal-length cables. The main purpose is to distribute the lifting stresses throughout the panel during erection. Remember, the cables must be long enough to allow ample clearance between the top of the panel and the sheaves or spreader bar.

Erecting, Bracing, and Jointing Panels

Erecting is an important step in the construction phase of the project. Before you start the erecting phase and for increased safety, you should make sure that all your tools, equipment, and braces are in proper working order. All personnel must be well-informed and the signalman and crane operator understand and agree on the signals to be used. During the erection of the panels, make sure that the signalman and line handler are not under the panel and that all unnecessary personnel and equipment are away from the lifting area. After the erection is done, make sure that all panels are properly braced and secured before unhooking the lifting cables.

Bracing is an especially important step. After all the work of casting and placing the panels, you want them to stay in place. The following are some steps to take before lifting the panels:

- Install the brace inserts into the panels during casting if possible.
- Install the brace inserts into the floor slab either during pouring or the day before erection.
- Install solid brace anchors before the day of erection.
- If brace anchors must be set during erection, use a method that is fast and accurate.



TWO POINT PICKUP IS BEST SUITED TO WALL PANELS 10' TO 18' IN HEIGHT, AND UP TO 18' IN WIDTH FOR PANELS 5" TO 8" IN PANEL THICKNESS.

TRIAL POINTS			
H	A	L	C
8'	2'-3"	14'	2'-10"
10'	2'-10"	15'	3'-1"
12'	3'-6"	16'	3'-4"
14'	4'-1"	17'	3'-6"
16'	4'-7"	18'	3'-8"
18'	5'-0"	19'	3'-10"
20'	5'-2"	20'	4'-1"

TRUCK DOOR 2-2 PICKUP				
TRIAL LOCATIONS				
H	A	B	L	C
18'	3'-0"	7'-10"	14'	2'-10"
20'	3'-3"	8'-6"	16'	3'-4"
22'	3'-7"	9'-6"	18'	3'-8"
24'	3'-7"	10'-6"	19'	3'-10"
26'	3'-10"	11'-6"	20'	4'-1"
27'	4'-3"	12'-0"	21'	4'-4"
28'	4'-6"	12'-6"	22'	4'-6"
29'	4'9"	12'-10"	23'	4'-8"
30'	5'-0"	13'-1"	24'	4'-11"

2-2 POINT PICKUP

2-2 POINT PICKUP				
TRIAL LOCATIONS				
H	A	B	L	C
18'	3'-3"	7'-7"	12'	2'-6"
20'	3'-7"	8'-4"	14'	2'-10"
22'	3'-11"	9'-3"	15'	3'-1"
23'	4'-2"	9'-7"	16'	3'-4"
24'	4'-4"	10'-1"	17'	3'-6"
25'	4'-6"	10'-6"	18'	3'-8"
26'	4'-8"	11'-0"	19'	3'-10"
27'	4'10"	11'-4"	20'	4'-1"
28'	5'-0"	11'-9"	21'	4'-4"
29'	5'-2"	12'-2"	22'	4'-6"
30'	5'-4"	12'-7"	23'	4'-8"

2-8-2 POINT PICKUP				
TRIAL LOCATIONS				
H	A	B	L	C
30	4'-21/2"	9'-7"	16'	3'-4"
32	4'-6"	10'-3"	18'	3'-8"
34	4'-10"	10'-10"	19'	3'-10"
36	5'-0"	11'-6"	20'	4'-1"
38	5'-4"	11'-6"	22'	4'-6"
40	5'-7"	12'-2"	24'	4'-11"
42	5'-9"	13'-4"	25'	5'-1"

4-4 POINT PICKUP

4-4 POINT PICKUP					
TRIAL LOCATIONS					
H	A	B	L	C	D
18'	3'-3"	7'-7"	18'	4'-8"	2'-0"
20'	3'-7"	8'-4"	20'	5'-3"	2'-1 1/2"
22'	3'-11"	9'-3"	22'	5'-10"	2'-3"
23'	4'-2"	9'-7"	24'	6'-4"	2'-6"
24'	4'-4"	10'-1"	26'	6'-10"	2'-9"
25'	4'-6"	10'-6"	28'	7'-4"	3'-0"
26'	4'-8"	11'-0"	30'	8'-0"	3'-0"
27'	4'10"	11'-4"	32'	8'-6"	3'-4"
28'	5'-0"	11'-9"	34'	9'-0"	3'-6"
29'	5'-2"	12'-2"	36'	9'-6"	3'-8"
30'	5'-4"	12'-7"	38'	10'-2"	3'-10"
31'	5'-7"	13'-0"	39'	10'-4"	4'-0"
32'	5'-9"	13'-4"	40'	10'-6"	4'-3"

Figure 3-22.—Different types of pickup points.

Although there are several types of bracing, pipe or tubular braces are the most common. They usually have a turnbuckle welded between sections for adjustment. Some braces are also made with telescoping sleeves for greater adaptability. Cable braces are normally used for temporary bracing and for very tall panels. However, their flexibility and tendency to stretch make them unsuitable for most projects. Wood bracing is seldom used except for low, small panels or for temporary bracing.

Jointing the panels is simple. Just tie all the panels together, covering the gap between them. You can weld, bolt, or pour concrete columns or beams. Steps used to tie the panels should be stated in the plans and specs.

CHAPTER 4

MASONRY CONSTRUCTION

LEARNING OBJECTIVE: *Estimate material and labor for concrete masonry units (CMUs) according to NAVFAC P-405. Identify the components, requirements, and construction techniques of laying brick, structural clay tile, and stone masonry.*

MASONRY construction has become increasingly important as a construction material for Seabee construction. The commonly accepted definition of masonry, or unit masonry as it is sometimes called, is a construction method made up of prefabricated masonry units (such as concrete block, brick, clay tile, and stone) laid in various ways and joined together by mortar. In the previous *Builder* training manual, we covered concrete masonry units (CMUs) in depth and the construction techniques on HOW TO lay CMUs. This TRAMAN covers the construction techniques of laying brick, structural clay tile, stone, and the estimating procedures associated with CMUs.

ESTIMATING CONCRETE MASONRY UNITS (CMUs)

Concrete masonry walls are laid out so as to make maximum use of full- and half-length units. This is called modular planning. Architect's and Engineering (A&E) firms and Builders strive to build modular structures. This action minimizes cutting and fitting of units on the job, which, in turn, saves on labor and cost. Table 4-1 lists the nominal length of concrete masonry walls by stretchers. Table 4-2 lists nominal height of concrete masonry walls by courses. Table 4-3 lists the average number of concrete masonry units by size and the approximate number of cubic feet of mortar

Table 4-1.—Nominal Lengths of Concrete Masonry Walls in Stretchers

NUMBER OF STRETCHERS	NOMINAL LENGTH OF CONCRETE MASONRY WALLS	
	Units 15 5/8″ long and half units 7 5/8″ long with 3/8″ thick head joints	Units 11 5/8″ long and half units 5 5/8″ long with 3/8″ thick head joints
1	1′4″	1′0″
1 1/2	2′0″	1′6″
2	2′8″	2′0″
2 1/2	3′4″	2′6″
3	4′0″	3′0″
3 1/2	4′8″	3′6″
4	5′4″	4′0″
4 1/2	6′0″	4′6″
5	6′8″	5′0″
5 1/2	7′4″	5′6″
6	8′0″	6′0″
6 1/2	8′8″	6′6″
7	9′4″	7′0″
7 1/2	10′0″	7′6″
8	10′8″	8′0″

Table 4-1.—Nominal Lengths of Concrete Masonry Walls in Stretchers—Continued

NUMBER OF STRETCHERS	NOMINAL LENGTH OF CONCRETE MASONRY WALLS	
	Units 15 5/8″ long and half units 7 5/8″ long with 3/8″ thick head joints	Units 11 5/8″ long and half units 5 5/8″ long with 3/8″ thick head joints
8 1/2	11′4″	8′6″
9	12′0″	9′0″
9 1/2	12′8″	9′6″
10	13′4″	10′0″
10 1/2	14′0″	10′6″
11	14′8″	11′0″
11 1/2	15′4″	11′6″
12	16′0″	12′0″
12 1/2	16′8″	12′6″
13	17′4″	13′0″
13 1/2	18′0″	13′6″
14	19′4″	14′0″
14 1/2	20′0″	14′6″
15	20′0″	15′0″
20	26′8″	20′0″

Table 4-2.—Nominal Heights of Modular Concrete Masonry Walls in Courses

NUMBER OF COURSES	NOMINAL HEIGHT OF CONCRETE MASONRY WALLS	
	Units 7 5/8Æ high and 3/8Æ thick bed joints	Units 3 5/8Æ high and 3/8Æ thick bed joints
1	0′ 8″	0′ 4″
2	1′ 4″	0′ 8″
3	2′ 0″	1′ 0″
4	2′ 8″	1′ 4″
5	3′ 4″	1′ 8″
6	4′ 0″	2′ 0″
7	4′ 8″	2′ 4″
8	5′ 4″	2′ 8″
9	6′ 0″	3′ 0″
10	6′ 8″	3′ 4″
15	10′ 0″	5′ 0″
20	13′ 4″	6′ 8″
25	16′ 8″	8′ 4″
30	20′ 0″	10′ 0″
35	23′ 4″	11′ 8″
40	26′ 8″	13′ 4″
45	30′ 0″	15′ 0″
50	33′ 4″	16′ 8″

Table 4-3.—Average Concrete Masonry Units and Mortar Per 100 Sq Ft of wall

DESCRIPTION, SIZE OF BLOCK (IN.)	THICKNESS WALL (IN.)	NUMBER OF UNITS PER 100 SQ FT OF WALL AREA	MORTAR (CU FT)
8 × 8 × 16	8	112.5	8.5
8 × 12 × 16	12	112.5	8.5
8 × 3 × 16	3	112.5	8.5
8 × 3 × 12	3	151.5	9.5
8 × 4 × 16	4	112.5	8.5
8 × 4 × 12	4	151.5	9.5
8 × 6 × 16	6	112.5	8.5

required for every 100 square feet of a concrete masonry wall.

NOTE: Actual wall length is measured from the outside edge to outside edge of units and equals the nominal length minus 3/8” (one mortar joint).

NOTE: For concrete masonry units 7 5/8” and 3 5/8” in height laid with 3/8” mortar joints. Height is measured from center to center of mortar joints.

NOTE: Mortar is based on 3/8” joint with a face-shell mortar bed and 10% allowance for waste.

As a Builder, you might find yourself in the field without the tables handy. To solve that problem, we will cover two methods for estimating concrete masonry units (CMUs) without the tables. The first method is CHASING THE BOND, which is using the 3/4 rule and the 3/2 rule. Remember when estimating, always use OUTSIDE measurements to calculate the number of blocks required per course. In most Seabee construction, 8-inch by 8-inch by 16-inch block is used. Using the 3/4 rule (three full block per 4 feet in length) or .75, multiply the length of the wall by .75. For example, a retaining wall that is 10 feet high by 100 feet in length (1,000 sf) will require 75 block for the first course.

Length of course in feet x *rule* 3/4 = *number of CMU per course*

Using the 3/2 rule (three full block per 2 feet in height), multiply the height of the wall by 1.5. For example, the height of the retaining wall is 10 feet. Multiply (10) by the rule 3/2 (1.5) which will equal 15 block high (courses high). See the following formula:

Height of wall in feet x rule 3/2 = courses high

Then, to find the total number of full block (FB) in the retaining wall, multiply the number of block in length by the number of block in height, which, in this example, is 75 CMUs in length times 15 courses high, which equals 1,125 (FB). Let’s take another example:

Given: A building 20-feet long by 8-feet wide by 8-feet high

.75 x 20 x 2 (sides) = 30 (8" x 8“ x 16" block)

.75 x 8 x 2 (sides) = 12 (8" x 8“ x 16" block)

Or you can find the total linear feet (LF) of the building and multiply by .75.

20 x 2 (sides) + 8 x *2 (sides) = 56 LF*

56 x .75 =42 FB

1.5 x 8 = 12 courses high

42 FB x *12 courses = 504* total FB

The second method of estimating CMU is the SQUARE FOOT METHOD. It is usually the quickest and simplest method but NOT the most accurate. However, you, the estimator, will use this method quite frequently. Remember in the first example, the retaining wall was 10 feet high and 100 feet in length. All you do is multiply *L* x *H = SF* in this example; the answer is 1,000 square feet (SF). To find the number of 8" x 8" x 16" block required, you must determine the square footage of one CMU which is .89 SF per block. Next, you divide 1,000 SF by .89 SF/CMU which equals 1,124 FB. You calculated the block for 1,000 SF and the difference was (1) less block figuring by the SF method. See the following formula:

Total SF divided by SF/CMU = total number of CMU

Now calculate the 20 ft x 20 ft x 8 ft building:

20 x 8 = 160 SF x *2 (sides) = 320 SF*

8 x 8 = 64 SF x 2 (sides)= 128 SF

Total = 448 SF

448SF ÷ .89 SF/CMU = 503.4 or 504 total FB block

Or, you can multiply the square footage of the building times the number of block per square foot (1.125 CMU/SF).

448 *SF x 1.125 CMU/SF = 504 CMU*

If you were planning a modular building, you would use the square foot method for quicker estimating, but now there is another step you need to know—the DUPLICATING FACTOR. This means that every course will have a half block at each corner. For example, you estimated 504 FB for this building. To estimate the FB accurately, you would deduct two FB/course or multiply 12 courses x .5 (half block HB) x four corners = 24 FB. Then deduct the 24 FB from the total FB as shown in the following formula:

12 *courses x .5 x 4 corners = 24 FB*

504 FB -24 FB = 480 FB

ESTIMATING DOOR AND WINDOW OPENINGS

When you estimate CMUs, usually the window and door openings are designed to be modular and the window and doorframes are of the same mode. If the design is NOT modular, you can expect a lot of cutting time. When you estimate for openings, just calculate the area of the opening, then subtract the area of the opening(s) from the overall area of the wall or building to get the net area. Then multiply the number of CMU per square foot by the net area.

ESTIMATING MORTAR

Builders have found that it takes about 38 cubic feet of raw materials to make 1 cubic yard of mortar. Therefore, you can use **"rule 38"** for calculating the raw material needed to mix 1 cubic yard of mortar without having to do a great deal of paper work. However, this rule does not accurately calculate the required raw materials for large masonry construction jobs. For larger jobs, use the absolute volume or weight formula. In most cases, though, and particularly in advanced base construction, you may use "rule 38" to make a quick estimate of the quantities of raw materials required.

Here is how you use "rule 38" for calculating mortar: take the rule number and divide it by the sum of the quantity figures specified in the mix. For example, let's assume that the building specification calls for a 1:3 mix for mortar, *1 + 3 = 4*. Since *38 ÷ 4 = 9 1/2,* you need 9 1/2 sacks, or 9 1/2 cubic feet, of cement. To calculate the amount of fine aggregate (sand), you multiply 9 1/2 by 3. The product (28 1/2 cubic feet) is the amount of sand you need to mix 1 cubic yard of mortar using a 1:3 mix. The sum of the two required quantities should always equal 38. This is how you can check whether you are using the correct amounts. In the previous example, 9 1/2 sacks of cement plus 28 1/2 cubic feet of sand equal 38.

In table 4-3, it takes 8.5 cubic feet (CF) of mortar to lay 100 SF of 8" x 8" x 16" block. In the previous example, you estimated the building at 480 SF of wall area. To calculate the amount of mortar to lay the CMU, first convert the 480 SF to units. See the following formula:

480 sf ÷ 100 sf = 4.8 units

then multiply the units by the number of cubic feet of mortar;

4.8 units x 8.5 *cf = 40.8 cf* of mortar

To calculate the ingredients needed to make 40.80 CF of mortar with a 1:1/4:3 mix, the 1/4 being hydrated lime, first calculate the amount of cement using rule 38. Remember the formula: 9 1/2 sacks of cement (94 lb/sk) per cubic yard.

Use the following formula: First, convert cubic feet of mortar to cubic yards, *40.8 cf ÷ 27 cf/cd = 1.51 cubic yard.*

$$\text{Cement: } (1) \times 9\tfrac{1}{2}\ cf = 9\tfrac{1}{2}\ (sacks) \times 1.51\,cd = 14\ sks\ (cf)$$

$$\text{Sand: } \frac{3}{4} \times 9\tfrac{1}{2} = \frac{28\tfrac{1}{2}}{38}\ (cf) \times 1.51\ \text{cd} = 43\ \text{cf}$$

$$\text{Lime: } (\tfrac{1}{4}) \times 9\tfrac{1}{2}\ \text{cf} = 2.5\ (\text{cf}) \times 1.51\ \text{cd} = \underline{4}\ \text{cf}$$

$$Total = 61\ cf$$

ESTIMATING MIXING TIME

Let's briefly cover the mixing time it will take to mix mortar. A typical mortar mixer has a capacity of mixing 4 to 7 cubic feet per batch, and each batch must be mixed for a minimum of 3 minutes. In the most recent example, we calculated a total of 61 cubic feet of raw materials needed to construct this building. Now just divide the number of cubic feet per batch by the total number of cubic feet of raw materials, then multiply that number by the number of minutes per batch. See the following formula:

61 cf ÷ 4 cf/batch = 15 batches

15 batches × 3 min/batch = 45 minutes

The time only indicates the required continuous mixing time. It is not inclusive of the cleaning, the staging, or the transporting time of the material or the time required for you to lay the CMU. Batching procedures will vary with individual preference. Experience is the key to good results in obtaining the desired mix.

ESTIMATING LABOR

This section briefly covers labor estimates for concrete masonry units according to the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405. Table 4-4 shows the labor table from the P-405 on how to estimate labor. When using this table, you will see that 8" x 8" x 16" block takes "one person" (skilled labor) 160 man-hours to lay 1,000 square feet of CMUs. If you were to break this labor down into how many CMUs laid in an 8-hour period, it would be calculated as follows:

1000 sf of wall area= 1,125 CMU

160 man-hours ÷ 8 hour days = 20 duration days

1125 CMU ÷ 20 days= 56.25 CMU/day

Let's take the building example. How many man-hours (MH) will it take with a crew of three nonskilled and one skilled laborer? This is the ratio/proportion part of this calculation.

If 160 MH equals 1,000 SF of wall area (NAVFAC P-405), then, X (MH) equals the square footage of wall area

160 (MH) :1000 Sf :: x (MH) : 448 sf =

160 x 448 :: 1000 x

71680 ÷ 1000 x = 71.68

X = 72 MH

Another method you may use to calculate this is as follows:

$$\frac{x}{160} = \frac{448}{1000}$$

In this equation, you simply cross multiply the following:

160 x 448 = 71680

X *times 1000 = 1000 x,* then divide

71680 ÷ 1000 x

X = 71.68 or 72 MH

In this example, it takes 72 man-hours to lay 448 SF or 504 CMUs. Now divide the number of MH by 8-hour days. It would equal 9 duration days. To see how close the estimate is—one person (skilled) lays

Table 4-4.—Labor Chart for Masonry

Work Element Description	Unit	Man-Hours Per Unit
CONCRETE BLOCK		
12″ × 8″ × 16″	1,000 SF	167
8″ × 8″ × 16″	1,000 SF	160
6″ × 8″ × 16″	1,000 SF	146
4″ × 8″ × 16″	1,000 SF	118
COMMON BRICK 2-1/4″ × 3 3/4″ × 8″		
8″ Thick Wall	1,000 SF	500
12″ Thick Wall	1,000 SF	700
4″ Thick Brick Veneer	1,000 SF	280
Grouting (Conventional Method)	CD	16
Corefill (.125 CF/cell) Conventional Method	CD	16
(Mortar Mixer and Bucket)	CD	
Corefill (TM and Pump Method)	CD	2
Grouting Brickwork		16

56.25 CMU/day and you calculated 9 days. Then multiply 56.25 times 9 which equals 506 block. There is a two block difference which is not much in this example, but it could be if you were estimating thousands of square feet of CMU.

BRICK CONSTRUCTION

Brick masonry is masonry construction in which units of baked clay or shale of uniform size, small enough to be placed with one hand, are laid in courses with mortar joints to form walls. Bricks are kiln-baked from various clay and shale mixtures. The chemical and physical characteristics of the ingredients vary considerably. These characteristics and the kiln temperatures combine to produce brick in a variety of colors and hardness. In some regions, individual pits yield clay or shale which, when ground and moistened, can be formed and baked into durable brick. In other regions, clay or shale from several pits must be mixed.

MASONRY TERMS

To lay brick efficiently and effectively, you must be familiar with the terms that identify the position of masonry units in a wall. The following list, which is referenced to figure 4-1, provides some of the basic terms you will encounter:

- **Course**— One of several continuous, horizontal layers (or rows) of masonry units bonded together.
- **Wythe**— The wythe is a continuous vertical section of a wall, one masonry unit thick. This is sometimes called a tier.

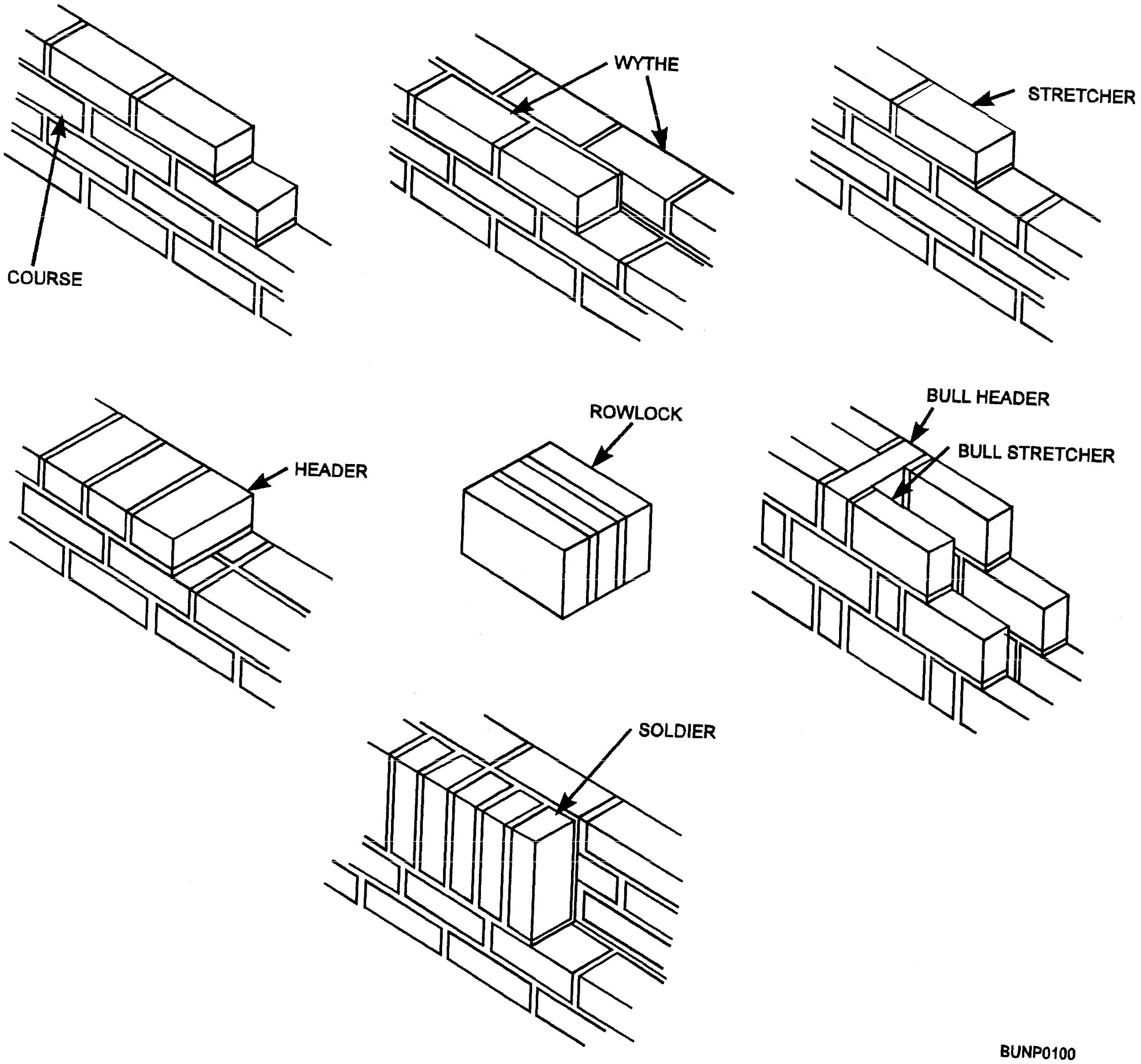


Figure 4-1.—Masonry units.

- **Stretcher—** A masonry unit laid flat on its bed along the length of a wall with its face parallel to the face of the wall.
- **Header—** A masonry unit laid flat on its bed across the width of a wall with its face perpendicular to the face of the wall. It is generally used to bond two wythes.
- **Rowlock—** A header laid on its face or edge across the width of a wall.
- **Bull header—** A rowlock brick laid with its bed perpendicular to the face of the wall.
- **Bull stretcher—** A rowlock brick laid with its bed parallel to the face of the wall.
- **Soldier—** A brick laid on its end with its face perpendicular to the face of the wall.

BRICK TERMINOLOGY

Standard U.S. bricks are 2 1/4 by 3 3/4 by 8 inches nominal size. They may have three core holes or ten core holes. Modular U.S. bricks are 2 1/4 by 3 5/8 by 7 5/8 inches nominal size. They usually have three core holes. English bricks are 3 by 4 1/2 by 9 inches, Roman bricks are 1 1/2 by 4 by 12 inches, and Norman bricks are 2 3/4 by 4 by 12 inches nominal size. Actual brick dimensions are smaller, usually by an amount equal to a mortar joint width. Bricks weigh from 100 to 150 pounds per cubic foot, depending on the ingredients and duration of firing. Fired brick is heavier than underburned brick. The six surfaces of a brick are called cull, beds, side, end, and face, as shown in figure 4-2.

Occasionally you will have to cut brick into various shapes to fill in spaces at corners and other locations where a full brick does not fit. Figure 4-3 shows the more common cut shapes which follow: half or bat, three-quarter closure, quarter closure, king closure, queen closure, and split.

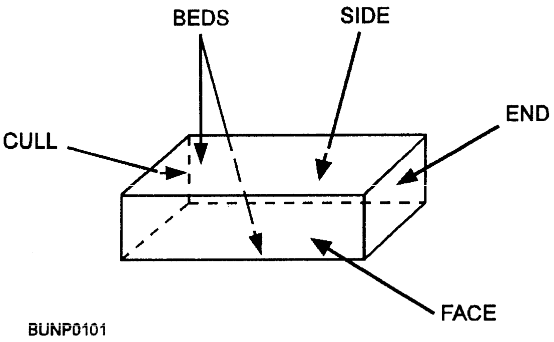


Figure 4-2.—Names of brick surfaces.

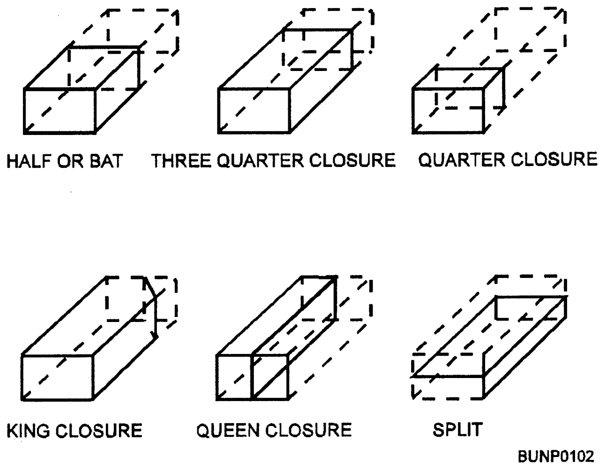


Figure 4-3.—Common cut brick shapes.

BRICK CLASSIFICATION

A finished brick structure contains FACE brick (brick placed on the exposed face of the structure) and BACKUP brick (brick placed behind the face brick). The face brick is often of higher quality than the backup brick; however, the entire wall may be built of COMMON brick. Common brick is made from pit-run clay with no attempt at color control and no special surface treatment, like glazing or enameling. Most common brick is red.

Although any surface brick is a face brick as distinguished from a backup brick, the term *"face brick"* is also used to distinguish high-quality brick from brick that is of common-brick quality or less. Applying this criterion, face brick is more uniform in color than common brick, and it may be obtained in a variety of colors as well. It may be specifically finished on the surface, and, in any case, it has a better surface appearance than common brick. It may also be more durable as a result of the use of select clay and other materials or as a result of special manufacturing methods.

Backup brick may consist of brick that is inferior in quality even to common brick. Brick that has been underburned or overburned, or brick made with inferior clay or by inferior methods, is often used for backup brick.

Still another type of classification divides brick into grades according to the probable climatic conditions to which they are to be exposed. These are as follows:

GRADE SW is brick designed to withstand exposure to below-freezing temperatures in a moist climate like that of the northern regions of the United States.

GRADE MW is brick designed to withstand exposure to below-freezing temperatures in a drier climate than that mentioned in the previous paragraph.

GRADE NW is brick primarily intended for interior or backup brick. It may be used exposed; however, it can only be used in regions where no frost action occurs.

TYPES OF BRICKS

Brick masonry units may be solid, hollow, or architectural terra cotta. All types can serve a structural function, a decorative function, or a combination of both. The various types differ in their formation and composition.

Building brick, also called common, hard, or kiln-run brick, is made from ordinary clay or shale and is fired in kilns. These bricks have no special shoring, markings, surface texture, or color. Because building bricks are generally used as the backing courses in either solid or cavity brick walls, the harder and more durable types are preferred.

Face brick is better quality and has better durability and appearance than building brick. Because of this, face bricks are used in exposed wall faces. The most common face brick colors are various shades of brown, red, gray, yellow, and white.

Clinker brick is overburned in the kiln. Clinker bricks are usually rough, hard, durable, and sometimes irregular in shape.

Pressed brick is made by a dry-press process, rather than by kiln firing. Pressed bricks have regular, smooth faces, sharp edges, and perfectly square corners. Ordinarily, they are used like face brick.

Glazed brick has one surface coated with a white or colored ceramic glazing. The glazing forms when mineral ingredients fuse together in a glasslike coating during burning. Glazed bricks are particularly suited to walls or partitions in hospitals, dairies, laboratories, and other structures requiring sanitary conditions and ease of cleaning.

Fire brick is made from a special type of clay. This clay is very pure and uniform and is able to withstand the high temperatures of fireplaces, boilers, and similar constructions. Fire bricks are generally larger than other structural bricks and are often hand-molded.

Cored bricks have ten holes—two rows of five holes each-extending through their beds to reduce weight. Walls built from cored brick are not much different in strength than walls built from solid brick. Also, both have about the same resistance to moisture penetration. Whether cored or solid, use the more available brick that meets building requirements.

European brick has strength and durability about equal to U.S. clay brick. This is particularly true of the English and Dutch types.

Sand-lime brick is made from a lean mixture of slaked lime and fine sand. Sand-lime bricks are molded under mechanical pressure and are hardened under steam pressure. These bricks are used extensively in Germany.

STRENGTH OF BRICK MASONRY

The main factors governing the strength of a brick structure include brick strength, mortar strength and elasticity, bricklayer workmanship, brick uniformity, and the method used to lay brick. In this section, we'll cover strength and elasticity. "Workmanship" is covered separately in the next section.

The strength of a single brick masonry unit varies widely, depending on its ingredients and manufacturing method. Brick can have an ultimate compressive strength as low as 1,600 psi. On the other hand, some well-burned brick has compressive strength exceeding 15,000 psi.

Because portland-cement-lime mortar is normally stronger than the brick, brick masonry laid with this mortar is stronger than an individual brick unit. The load-carrying capacity of a wall or column made with plain lime mortar is less than half of that made with portland-cement-lime mortar. The compressive working strength of a brick wall or column laid with plain lime mortar normally ranges from 500 to 600 psi.

For mortar to bond to brick properly, sufficient water must be present to hydrate the portland cement in the mortar completely. Bricks sometimes have high absorption rates, and, if not properly treated, can "suck" the water out of the mortar, preventing complete hydration. Here is a quick field test to determine brick absorptive qualities. Using a medicine dropper, place 20 drops of water in a l-inch circle (about the size of a quarter) on a brick. A brick that absorbs all the water in less than 1 1/2 minutes will suck the water out of the mortar when laid. To correct this condition, thoroughly wet the bricks an allow time for their surfaces to air-dry before placing them.

BRICKLAYING METHODS

Good bricklaying procedure depends on good workmanship and efficiency. Efficiency involves doing the work with the fewest possible motions. Each motion should have a purpose and should achieve a definite result. After learning the fundamentals, every Builder should develop methods for achieving maximum efficiency. The work must be arranged in such a way that the Builder is continually supplied with brick and mortar. The scaffolding required must be planned before the work begins. It must be built in such away as to cause the least interference with other crew members.

Bricks should always be stacked on planks; never pile them directly on uneven or soft ground. Do not store bricks on scaffolds or runways. This does not, however, prohibit placing normal supplies on scaffolding during actual bricklaying operations. Except where stacked in sheds, brick piles should never be more than 7 feet high. When a pile of brick reaches a height of 4 feet, it must be tapered back 1 inch in every foot of height above the 4-foot level. The tops of brick piles must be kept level, and the taper must be maintained during unpiling operations.

BONDS

The term *bond*, as used in masonry, has one of the following three different meanings: structural bond, mortar bond, or pattern bond.

Structural bond refers to how the individual masonry units interlock or tie together into a single structural unit. You can achieve structural bonding of brick and tile walls in one of the following three ways:

Overlapping (interlocking) the masonry units.

Embedding metal ties in connecting joints.

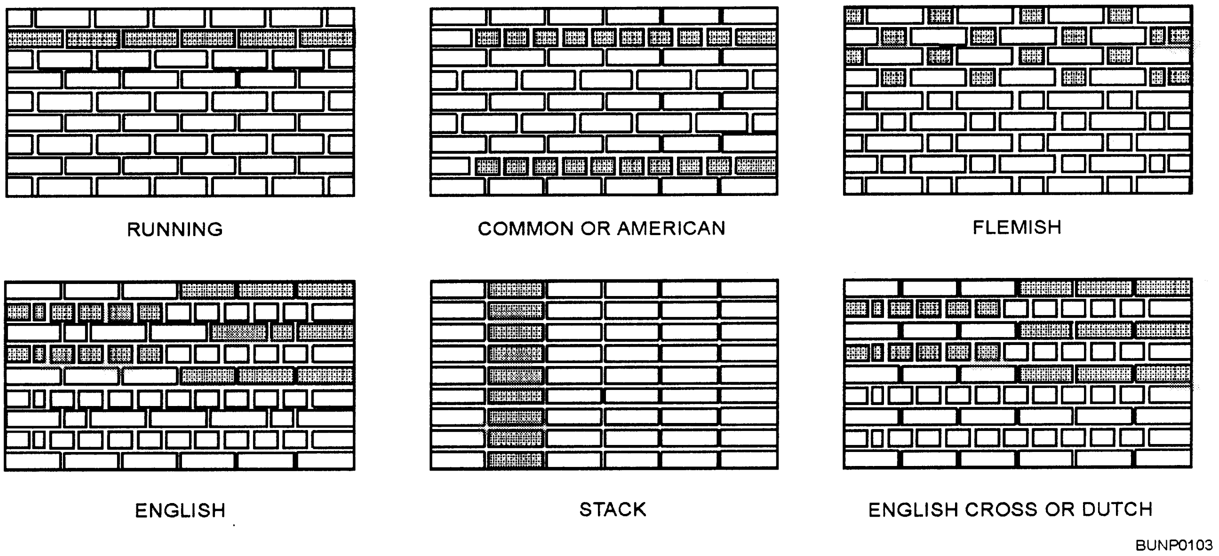
Using grout to adhere adjacent wythes of masonry.

Mortar bond refers to the adhesion of the joint mortar to the masonry units or to the reinforcing steel.

Pattern bond refers to the pattern formed by the masonry units and mortar joints on the face of a wall. The pattern may result from the structural bond, or it may be purely decorative and unrelated to the structural bond. Figure 4-4 shows the six basic pattern bonds in common use today. They are running, common or American, Flemish, English, stack, and English cross or Dutch bond.

The running bond is the simplest of the six patterns, consisting of all stretchers. Because the bond has no headers, metal ties usually form the structural bond. The running bond is used largely in cavity wall construction, brick veneer walls, and facing tile walls made with extra wide stretcher tile.

The common, or American, bond is a variation of the running bond, having a course of full-length headers at regular intervals that provide the structural bond as well as the pattern. Header courses usually appear at every fifth, sixth, or seventh course, depending on the structural bonding requirements. You



RUNNING

COMMON OR AMERICAN

FLEMISH

ENGLISH

STACK

ENGLISH CROSS OR DUTCH

Figure 4-4.—Types of masonry bonds.

can vary the common bond with a Flemish header course. In laying out any bond pattern, be sure to start the corners correctly. In a common bond, use a three-quarter closure at the corner of each header course.

In the Flemish bond, each course consists of alternating headers and stretchers. The headers in every other course center over and under the stretchers in the courses in between. The joints between stretchers in all stretcher courses align vertically. When headers are not required for structural bonding, you can use bricks, called blind headers. You can start the corners in two different ways. In the Dutch corner, a three-quarter closure starts each course. In the English corner, a 2-inch or quarter closure starts the course.

The English bond consists of alternating courses of headers and stretchers. The headers center over and under the stretchers. However, the joints between stretchers in all stretcher courses do not align vertically. You can use blind headers in courses that are not structural bonding courses.

The stack bond is purely a pattern bond without overlapping units; however, all vertical joints are aligned. You must use dimensionally accurate or carefully rematched units to achieve good vertical joint alignment. You can vary the pattern with combinations and modifications of the basic patterns shown in figure 4-4. This pattern usually bonds to the backing with rigid steel ties or 8-inch-thick stretcher units when available. In large walled areas or load-bearing construction, insert steel pencil rods into the horizontal mortar joints as reinforcement.

The English cross, or Dutch, bond is a variation of the English bond. It differs only in that the joints between the stretchers in the stretcher courses align vertically. These joints center on the headers in the courses above and below.

When a wall bond has no header courses, use metal ties to bond the exterior wall brick to the backing courses. Figure 4-5 shows three typical metal ties.

Install flashing at any spot where moisture is likely to enter a brick masonry structure. Flashing diverts the moisture back outside. Always install flashing under horizontal masonry surfaces, such as sills and copings; at intersections between masonry walls and horizontal surfaces, such as a roof and parapet or a roof and chimney; above openings (doors and windows, for example); and frequently at floor lines, depending on the type of construction. The flashing should extend through the exterior wall face and then turn downward against the wall face to form a drop.

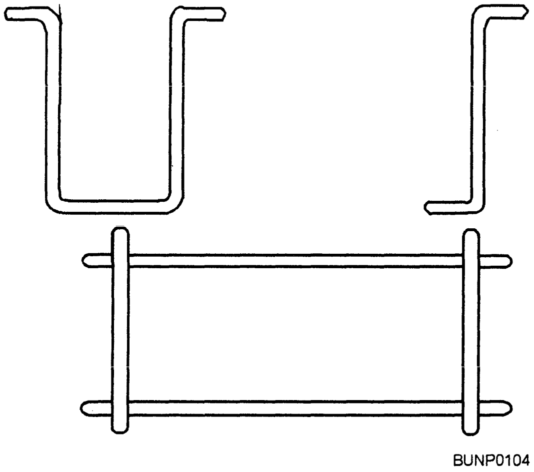


Figure 4-5.—Metal ties.

You should provide WEEP HOLES at intervals of 18 to 24 inches to drain water to the outside that might accumulate on the flashing. Weep holes are even more important when appearance requires the flashing to stop behind the wall face instead of extending through the wall. This type of concealed flashing, when combined with tooled mortar joints, often retains water in the wall for long periods, and by concentrating the moisture at one spot, it does more harm than good.

MORTAR JOINTS AND POINTING

No set rule governs the thickness of a brick masonry mortar joint. Irregularly shaped bricks may require mortar joints up to one-half inch thick to compensate for the irregularities. However, mortar joints one-fourth inch thick are the strongest. Use this thickness when the bricks are regular enough in shape to permit it.

A slushed joint is made simply by the deposit of mortar on top of the head joints and allowing it to run down between the bricks to form a joint. You cannot make solid joints this way. Even when you fill the space between the bricks completely, there is no way you can compact the mortar against the brick faces; consequently, a poor bond results. The only effective way to build a good joint is to trowel it.

The secret of mortar joint construction and pointing is in how you hold the trowel for spreading mortar. Figure 4-6 shows the correct way to hold a trowel. Hold it firmly in the grip, as shown, with your thumb resting on top of the handle, not encircling it. If you are right-handed, pick up the mortar from the outside of the mortar board pile with the left edge of your trowel (fig. 4-7, view 1). You can pick up enough to spread one to five bricks, depending on the wall

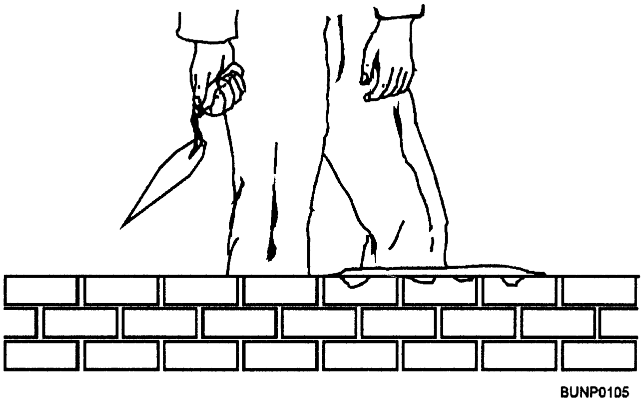


Figure 4-6.—Correct way to hold a trowel.

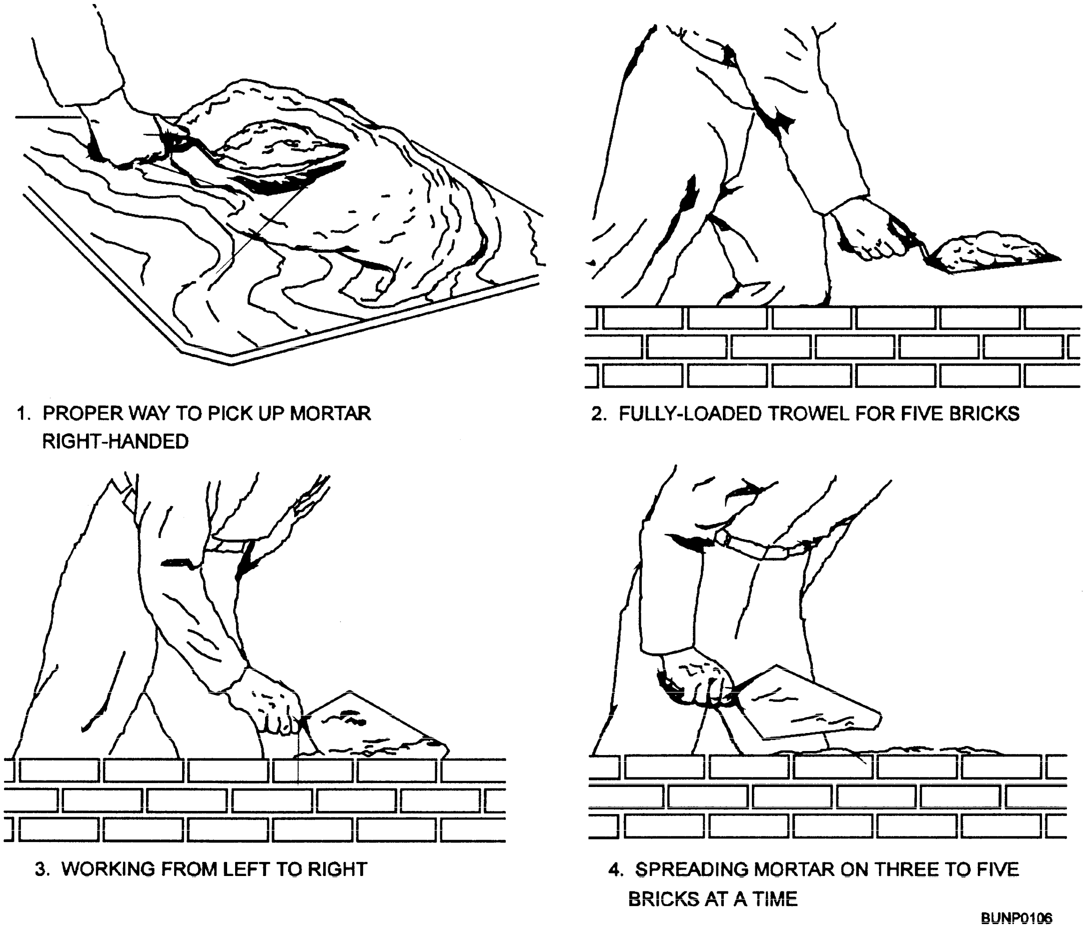


Figure 4-7.—Picking up and spreading mortar.

space and your skill. A pickup for one brick forms only a small pile along the left edge of the trowel. A pickup for five bricks is a full load for a large trowel (view 2).

If you are right-handed, work from left to right along the wall. Holding the left edge of the trowel directly over the center line of the previous course, tilt the trowel slightly and move it to the right (view 3), spreading an equal amount of mortar on each brick until you either complete the course or the trowel is empty (view 4). Return any mortar left over to the mortar board.

Do not spread the mortar for a bed joint too far ahead of laying—four or five brick lengths is best. Mortar spread out too far ahead dries out before the bricks become bedded and causes a poor bond (fig. 4-8). The mortar must be soft and plastic so that the brick will bed in it easily. Spread the mortar about 1 inch thick and then make a shallow furrow in it (fig. 4-9, view 1). A furrow that is too deep leaves a gap between the mortar and the bedded brick. This action reduces the resistance of the wall to water penetration.

Using a smooth, even stroke, cut off any mortar projecting beyond the wall line with the edge of the trowel (fig. 4-9, view 2). Retain enough mortar on the trowel to butter the left end of the first brick you will lay in the fresh mortar. Throw the rest back on the mortar board.

Pick up the first brick to be laid with your thumb on one side of the brick and your fingers on the other (fig. 4-10). Apply as much mortar as will stick to the end of the brick and then push it into place. Squeeze out the excess mortar at the head joint and at the sides (fig. 4-11). Make sure the mortar completely fills the

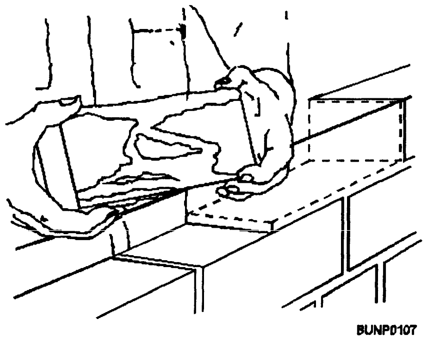
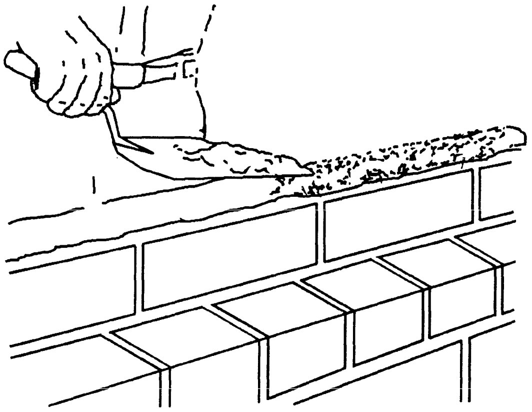
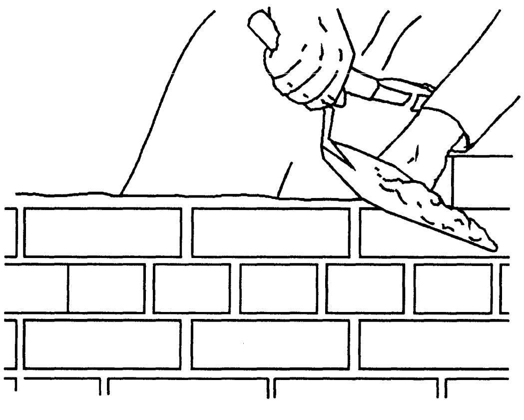


Figure 4-8.—A poorly bonded brick.



1. MAKING A FURROW



2. CUTTING OFF EXCESS MORTAR

Figure 4-9.—Making a bed joint in a stretcher course.

Figure 4-10.—Proper way to hold a brick when buttering the end.

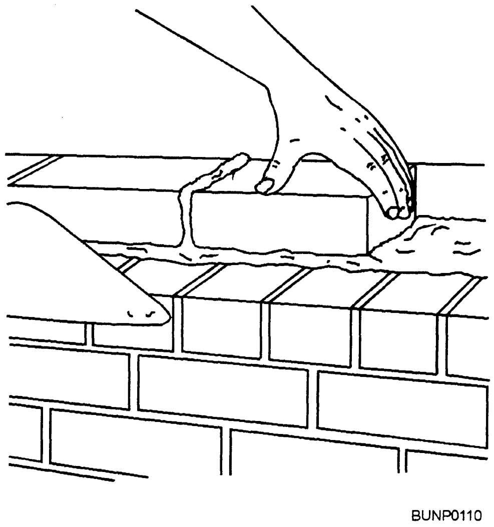
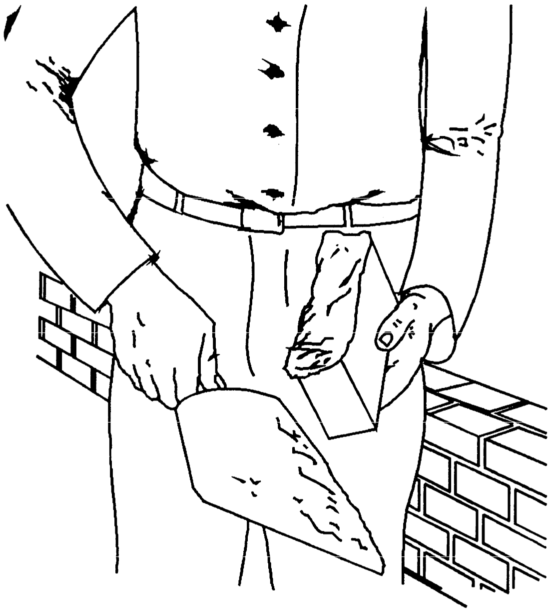


Figure 4-11.—Making a head joint in a stretcher course.

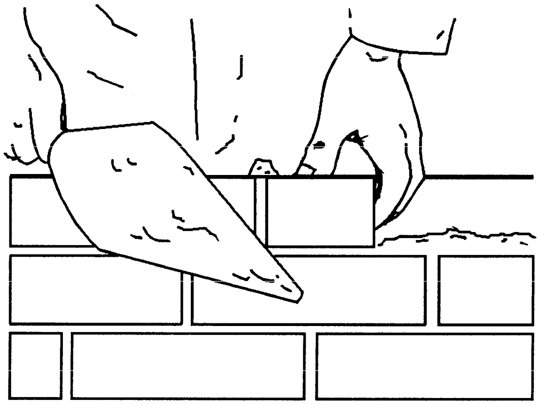
head joint. After bedding the brick, cut off the excess mortar and use it to start the next end joint. Throw any surplus mortar back on the mortar board where it can be restored to workability.

Figure 4-12 shows how to insert a brick into a space left in a wall. First, spread a thick bed of mortar (view 1), and then shove the brick into the wall space (view 2) until mortar squeezes out of all four joints (view 3). This way, you know that the joints are full of mortar at every point.

To make a cross joint in a header course, spread the bed joint mortar several brick widths in advance. Then spread mortar over the face of the header brick before placing it in the wall (fig. 4-13, view 1). Next, shove the brick into place, squeezing out mortar at the top of the joint. Finally, cut off the excess mortar, as shown in view 2.



1. SPREADING MORTAR OVER BRICK FACE



2. CUTTING OFF EXCESS MORTAR

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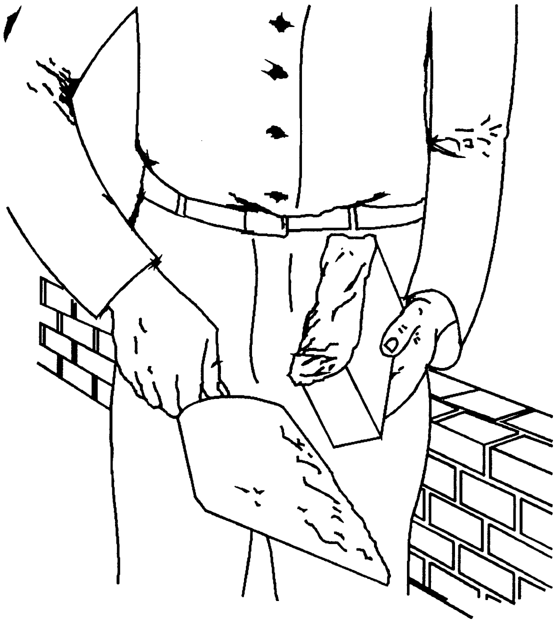
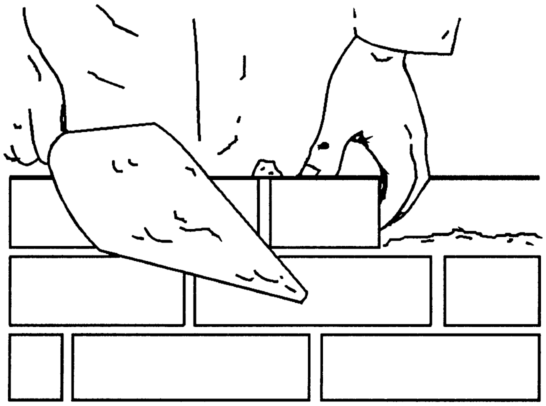
Figure 4-12.—Inserting a brick in a wall space.



1. SPREADING MORTAR OVER BRICK FACE

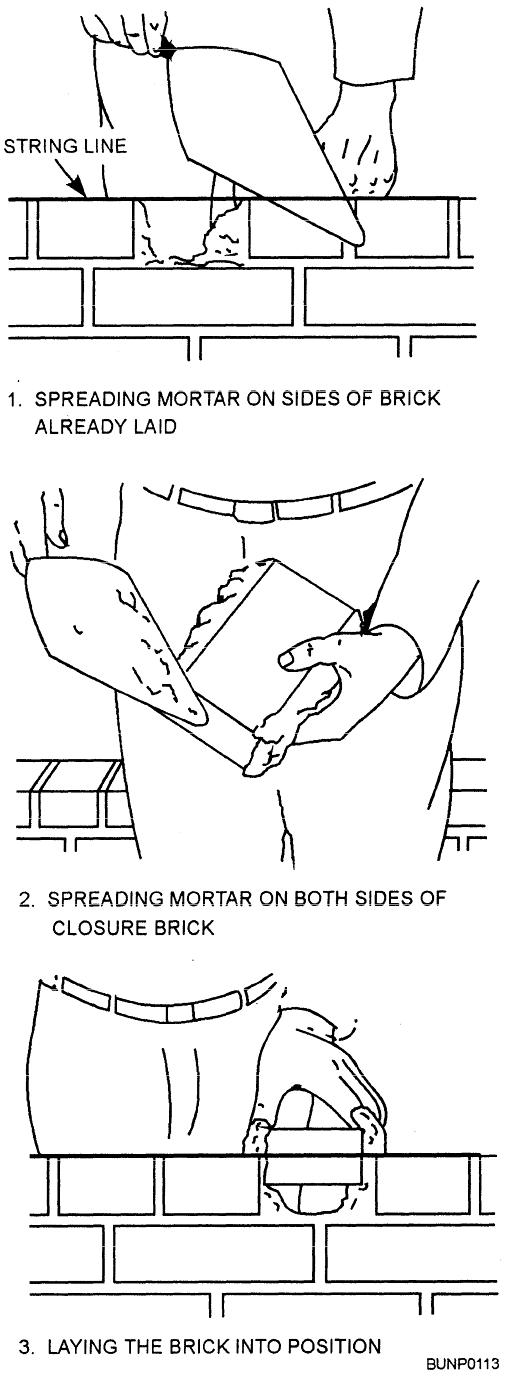


2. CUTTING OFF EXCESS MORTAR

BUNP0112

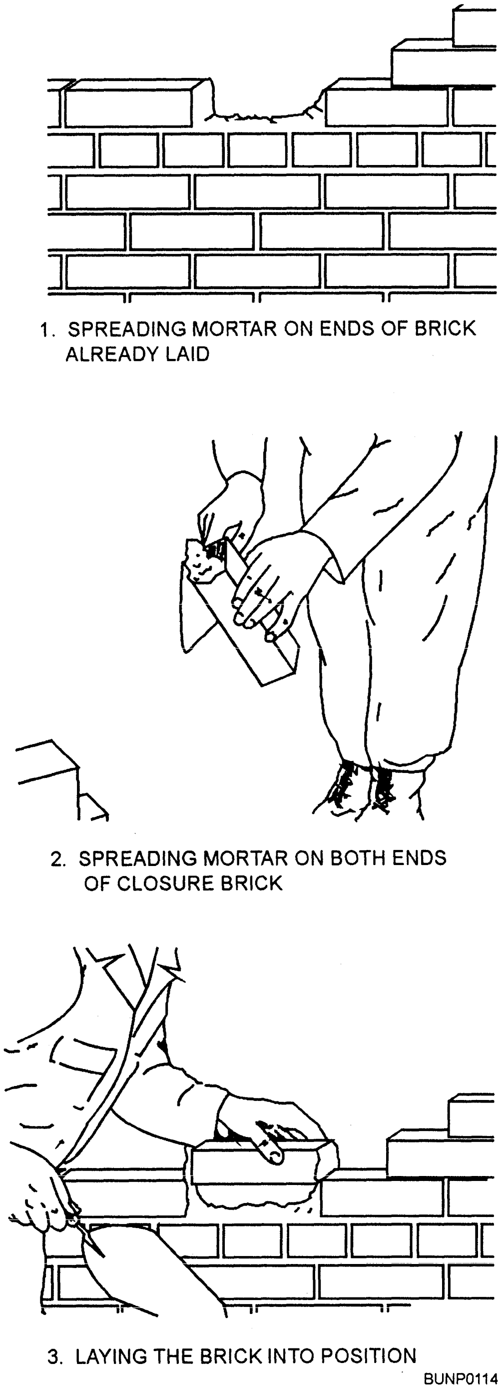
Figure 4-13.—Making a cross joint in a header course.

Figure 4-14 shows you how to lay a closure brick in a header course. First, spread about 1 inch of mortar on the sides of the brick already in place (view 1), as well as on both sides of the closure brick (view 2). Then lay the closure brick carefully into position without disturbing the brick already laid (view 3). If you do disturb any adjacent brick, cracks will form between the brick and the mortar, allowing moisture to penetrate the wall. You should place a closure brick for a



1. SPREADING MORTAR ON SIDES OF BRICK ALREADY LAID
2. SPREADING MORTAR ON BOTH SIDES OF CLOSURE BRICK
3. LAYING THE BRICK INTO POSITION

Figure 4-14.—Making a closure joint in a header course.



1. SPREADING MORTAR ON ENDS OF BRICK ALREADY LAID
2. SPREADING MORTAR ON BOTH ENDS OF CLOSURE BRICK
3. LAYING THE BRICK INTO POSITION

Figure 4-15.—Making a closure joint in a stretcher course.

stretcher course (fig. 4-15), using the same techniques as for a header course.

As we mentioned earlier, pointing is the filling of exposed joints with mortar immediately after laying a wall. You can also fill holes and correct defective mortar joints by pointing, using a pointing trowel.

CUTTING BRICK

To cut a brick to an exact line, you should use a chisel (fig. 4-16), or brick set. The straight side of the cutting edge of the tool should face both the part of the brick to be saved and the bricklayer. One mason's hammer blow should break the brick. For extremely hard brick, first roughly cut it using the brick hammer,

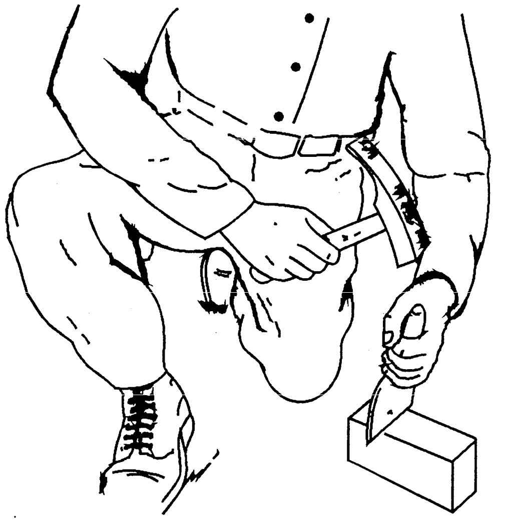


Figure 4-16.—Cutting brick with a chisel.

head, but leave enough brick to cut accurately with the brick set.

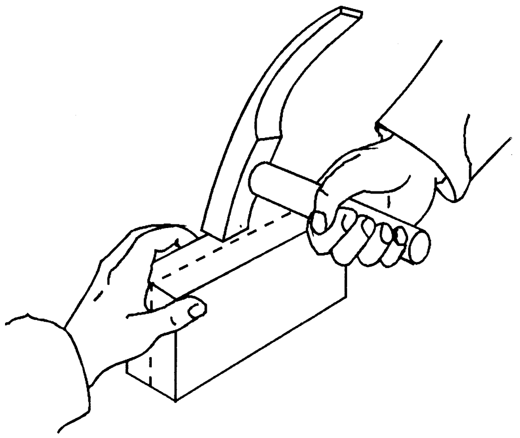
Use a brick hammer for normal cutting work, such as making the closure bricks and bats around wall openings or completing corners. Hold the brick firmly while cutting it. First, cut a line all the way around the brick using light hammer head blows. Then a sharp blow to one side of the cutting line should split the brick at the cutting line (fig. 4-17, view 1). Trim rough spots using the hammer blade, as shown in view 2.

FINISHING JOINTS

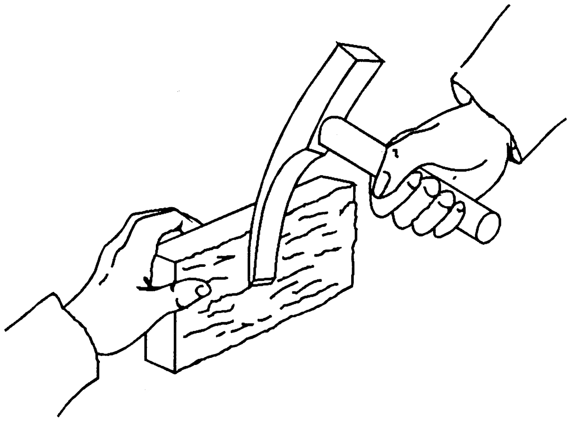
The exterior surfaces of mortar joints are finished to make brick masonry waterproof and to give it a better appearance. When joints are simply cut to the face of the brick and not finished, shallow cracks will develop immediately between the brick and the mortar. Always finish a mortar joint before the mortar hardens too much. Figure 4-18 shows several types of joint finishes—the more important of which are concave, flush, and weather.

Of all joints, the concave is the most weather-tight. After you remove the excess mortar with a trowel, make this joint using a jointer that is slightly larger than the joint. Use force against the tool to press the mortar tight against the brick on both sides of the mortar joint.

The flush joint is made by holding the trowel almost parallel to the face of the wall while drawing its point along the joint.



1. STRIKING BRICK TO ONE SIDE OF CUTTING LINE



2. TRIMMING ROUGH SPOTS

Figure 4-17.—Cutting brick with a hammer.

A weather joint sheds water from a wall surface more easily. To make it, simply push downward on the mortar with the top edge of the trowel.

ARCHES

A well-constructed brick arch can support a heavy load, mainly due to the way weight is distributed over its curved shape. Figure 4-19 shows two common arch shapes-elliptical and circular. Brick arches require full-mortar joints. The joint width is narrower at the bottom of the arch than at its top, but it should not narrow to less than one-fourth inch at any point. As laying progresses, make sure the arch does not bulge out of position.

Templet

It is impossible to construct an arch without support from underneath. These temporary wooden

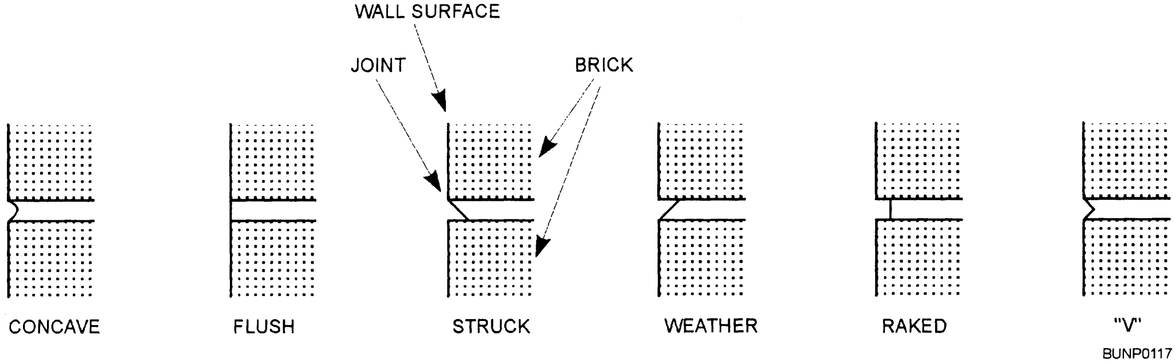


Figure 4-l8.—Joint finishes.

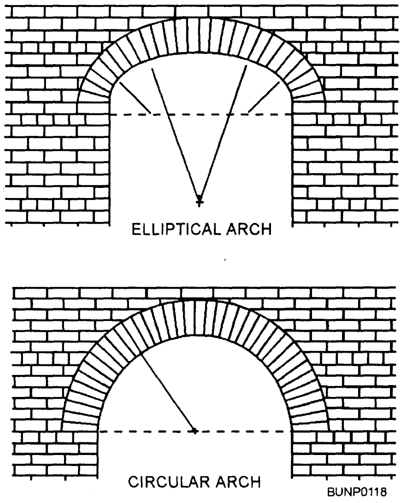


Figure 4-19.—Common arch shapes.

supports must not only be able to support the masonry during construction but also provide the geometry necessary for the proper construction and appearance of the arch. Such supports are called templets.

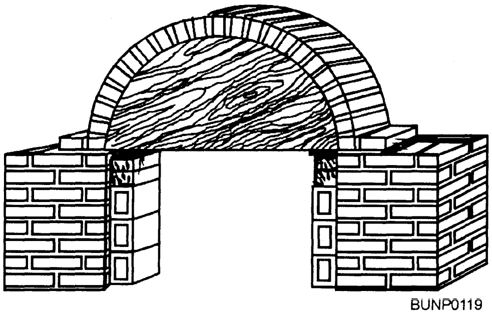


Figure 4-20.—Using a template to construct an arch.

DIMENSIONS.— Construct a brick arch over the templet (fig. 4-20) that remains in place until the mortar sets. You can obtain the templet dimensions from the construction drawings. For arches spanning up to 6 feet, use 3/4-inch plywood to make the templet. Cut two pieces to the proper curvature, and nail them to 2 by 4 spacers that provide a surface wide enough to support the brick.

POSITIONING.— Use wedges to hold the templet in position until the mortar hardens enough to make the arch self-supporting. Then drive out the wedges.

Layout

Lay out the arch carefully so that you don’t have to cut any bricks. Use an odd number of bricks so that the key, or middle, brick falls into place at the exact arch center, or crown. The key, or middle, brick is the last one laid. To determine how many bricks an arch requires, lay the templet on its side on level ground and set a trial number of bricks around the curve. Adjust the number of bricks and the joint spacing (not less than one-fourth inch) until the key brick is at the exact center of the curve. Then mark the positions of the bricks on the templet and use them as a guide when laying the brick.

ESTIMATING BRICK AND MORTAR

When estimating the number of brick and the quantity of mortar, you need to know the exact size of the brick and the thickness of the mortar joint. This information is found in the plans or specifications. Table 4-5 shows the quantities of material required for brick walls.

NOTE: Quantities of brick include the thickness of the mortar joint and no allowance for waste.

Table 4-5.—Quantities of Material Required for Brick Walls

Size of Brick	Wall area SF	Number of Brick	Joint Size	Mortar CF/1000 Brick
2 1/4″ × 3 3/4″ × 8″	100	616	1/2Æ	11.7
2 1/4″ × 3 5/8″ × 7″ 5/8	100	686	3/8Æ	8.7
3″ × 41/4″ × 9″	100	480	1/2Æ	5.7

The following example shows the square foot method of estimating the number of bricks for a 4-inch wall measuring 8 feet high and 14 feet long. Specifications call for the use of US. standard brick with a 1/2-inch mortar joint. The brick face with its mortar joints measures 2 3/4 inches high by 8 1/2 inches long. The correct steps to follow are:

Step 1. Find the surface area by multiplying the height and the length of a brick (include mortar joint). In this case, 2 3/4" x 8 1/2= 2.75 x 8.50= 23.38 sq in. per brick.

Step 2. Find the number of bricks per square foot of wall. In this case, the number of brick is 6. 16/sq ft for a 4-inch wall.

Step 3. Find the area of the brick wall by multiplying its height by its length. 8 ft x 14 ft = 112 sq ft.

Step 4. Then multiply the area of the wall by the number of bricks per square foot. In this case, 112 x 6.16 or 690 bricks plus 10% waste which equals 760 brick.

NOTE: If there are windows, doors, and other openings on the wall, you subtract the area of these openings from the overall area of the wall to get the net area. Then in step 4, you multiply the number of bricks per square foot by the net area.

In finding how much mortar is required to build this wall, divide the number of bricks by 1,000, then multiply the result by the factor given in table 4-5 and allow 20% for waste. See the following formula:

760 ÷ 1000 = .76

.76 x 11.7 (cf of mortar/1000 brick) = 8.90 cf of mortar

8.90 x 20% (waste) = 10.68 or 10.7 CF of mortar

Therefore to construct this wall with U.S. standard brick with a 1/2-inch mortar joint, you require 760 brick and 10.7 CF of mortar.

STRUCTURAL CLAY TILE

Hollow masonry units, made of burned clay or shale, are called variously structural tiles, hollow tiles, structural clay tiles, structural clay hollow tiles, and structural clay hollow building tiles, but they are most commonly called building tile. In building tile manufacture, plastic clay is pugged through a die, and the shape that emerges is cut off into units. The units are then burned much as bricks are burned.

The apertures in a building tile, which correspond to the cores in a brick or a concrete block, are called CELLS. The solid sides of a tile are called the SHELL, and the perforated material enclosed by the shell is called the WEB. A tile that is laid on one of its shell faces is called a SIDE-CONSTRUCTION tile; one that is laid on one of its web faces is called an END-CONSTRUCTION tile. Figures 4-21 and 4-22

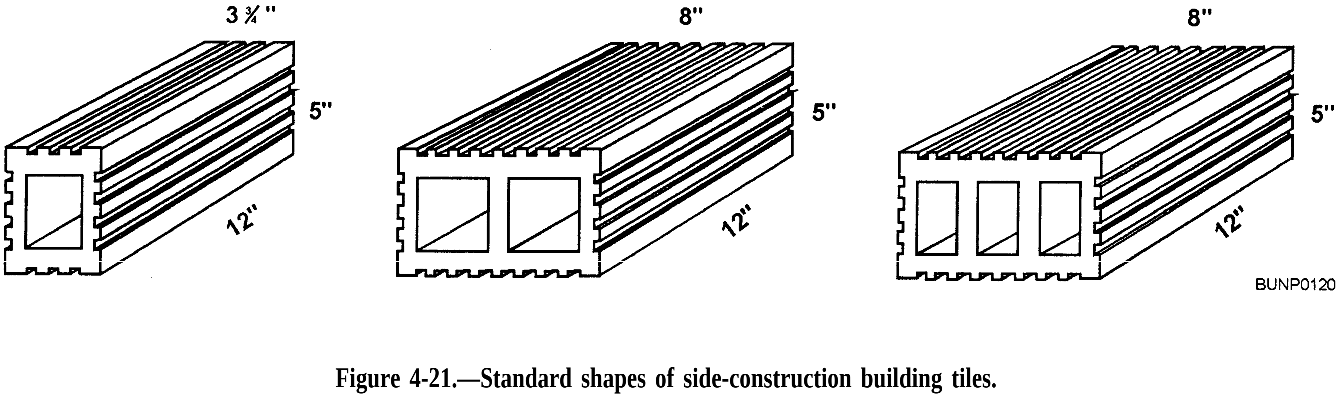


Figure 4-21.—Standard shapes of side-construction building tiles.

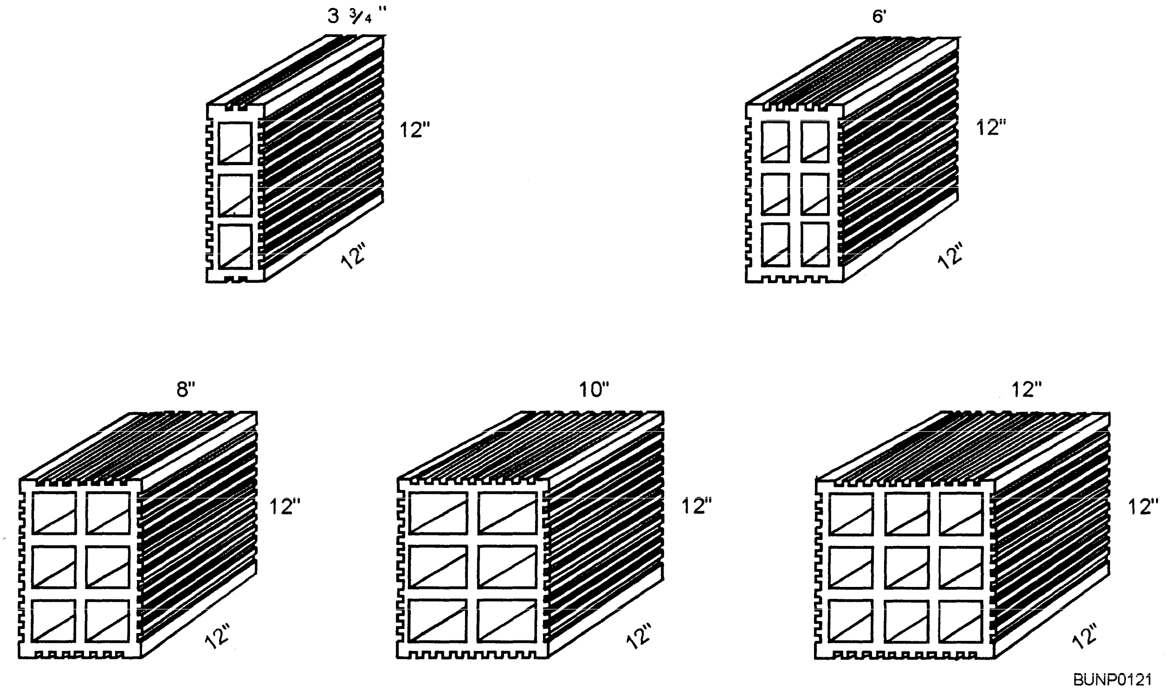


Figure 4-22.—Standard shapes of end-construction building tiles.

show the sizes and shapes of basic side-and end-construction building units. Special shapes for use at corners and openings, or for use as closures, are also available.

PHYSICAL CHARACTERISTICS

The compressive strength of the individual tile depends on the materials used and the method of manufacture in addition to the thickness of the shells and webs. A minimum compressive strength of tile masonry of 300 pounds per square inch based on the gross section may be expected. The tensile strength of structural clay tile masonry is small. In most cases, it is less than 10 percent of the compressive strength.

The abrasion resistance of clay tile depends primarily upon its compressive strength. The stronger the tile, the greater its resistance to wearing. The abrasion resistance decreases as the amount of water absorbed increases.

Structural clay facing tile has excellent resistance to weathering. Freezing and thawing action produces almost no deterioration. Tile that will absorb no more than 16 percent of its weight of water has never given unsatisfactory performance in resisting the effect of freezing and thawing action. Only portland cement-lime mortar or mortar prepared from masonry cement should be used if the masonry is exposed to the weather.

Walls containing structural clay tile have better heat-insulating qualities than walls composed of solid units, because of the dead air space that exists in tile walls. The resistance to sound penetration of this type of masonry compares favorably with the resistance of solid masonry walls, but it is somewhat less.

The fire resistance of tile walls is considerably less than the fire resistance of solid masonry walls. It can be improved by the application of a coat of plaster to the surface of the wall. Partition walls of structural clay tile 6 inches thick will resist a fire for 1 hour provided the fire produces a temperature of not more than 1700°F.

The solid material in structural clay tile weighs about 125 pounds per cubic foot. Since the tile contains hollow cells of various sizes, the weight of the tile varies, depending upon the manufacturer and type. A 6-inch tile wall weighs approximately 30 pounds per square foot, while a 12-inch tile wall weighs approximately 45 pounds per square foot.

USES FOR STRUCTURAL CLAY TILE

Structural clay tile may be used for the exterior walls of either the load-bearing or nonload-bearing type. It is suitable for both below-grade and above-grade construction.

Structural load-bearing tile is made from 4- to 12-inch thicknesses with various face dimensions. The use of these tiles is restricted by building codes and specifications, so consult the project specification.

Nonload-bearing partition walls from the 4- to 12-inch thicknesses are frequently made of structural clay tile. These walls are easily built, light in weight, and have good heat-and-sound insulating properties.

Figure 4-23 shows the use of structural clay tile as a back unit for a brick wall.

Figure 4-24 shows the use of 8- by 5- by 12-inch tile in wall construction. Exposure of the open end of the tile can be avoided by the application of a thin tile, called a SOAP, at the corner.

STONE MASONRY

Stone masonry units consist of natural stone. In RUBBLE stone masonry, the stones are left in their natural state without any kind of shaping. In ASHLAR masonry, the faces of stones that are to be placed in surface positions are squared so that the surfaces of the finished structure will be more or less continuous plane surfaces. Both rubble and ashlar work may be either RANDOM or COURSED.

Random rubble is the crudest of all types of stonework. Little attention is paid to laying the stones in courses, as shown in figure 4-25. Each layer must contain bonding stones that extend through the wall, as shown in figure 4-26. This produces a wall that is well tied together. The bed joints should be horizontal for stability, but the “builds” or head joints may run in any direction.

Coursed rubble consists of roughly squared stones assembled in such a manner as to produce

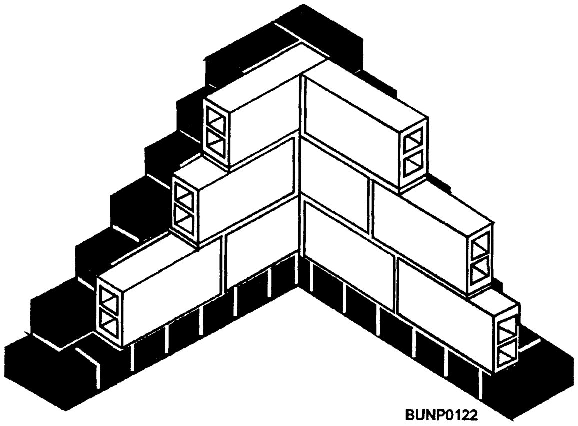


Figure 4-23.—Structural tile used as a backing for bricks.

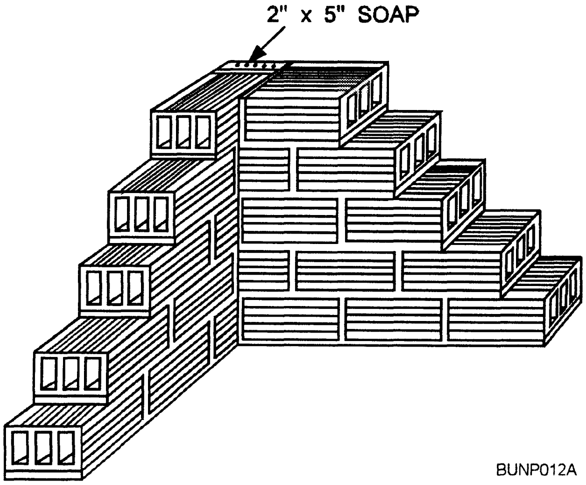


Figure 4-24.—Eight-inch structural clay tile wall.

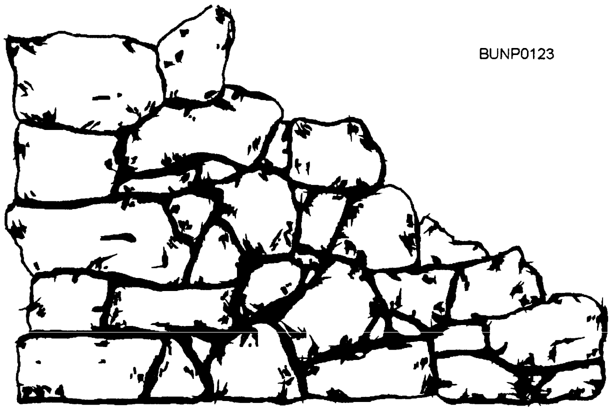


Figure 4-25.—Random rubble stone masonry,

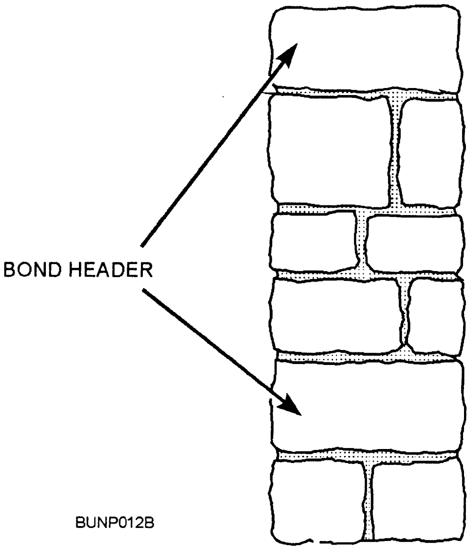


Figure 4-26.—Layers of bond in random stone masonry.

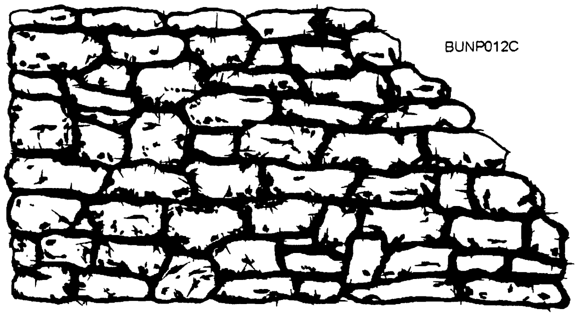


Figure 4-27.—Coursed rubble masonry

approximately continuous horizontal bed joints, as shown in figure 4-27.

The stone used in stone masonry should be strong and durable. Durability and strength depend upon the chemical composition and physical structure of the stone. Some of the more commonly found stones that are suitable are limestone, sandstone, granite, and slate. Unsquared stones obtained from nearby ledges or quarries or even fieldstones may be used. The size of the stone should be such that two people can easily handle it. A variety of sizes are necessary to avoid using large quantities of mortar.

The mortar used in stone masonry may be composed of portland cement and sand in the proportions of 1 part cement to 3 parts sand by volume. Such mortar shrinks excessively and does not work well with the trowel. A better mortar to use is portland cement-lime mortar. Mortar made with ordinary portland cement will stain most types of stone. If staining must be prevented, nonstaining white portland cement should be used in making the mortar. Lime does not usually stain the stone.

CHAPTER 5

SHOP ORGANIZATION AND MILLWORKING

LEARNING OBJECTIVE: *Determine the requirements necessary to lay out and operate a builder's shop safely. Recognize and explain the procedures in developing good millworking techniques and be able to lay out, construct, and install cabinets.*

As a first class or second class petty officer, you will at some point in your naval career be in charge or supervise a shop. You maybe tasked to plan the layout of equipment and materials needed to set up a new shop from scratch. In doing so, you will find that certain factors that are applicable in setting up a new shop are also applicable when taking over as a supervisor of a shop already in existence.

SHOP ORGANIZATION

Where there are Seabees, there is likely to be some sort of builder or maintenance shop. When taking over a shop already setup, you may often find it worthwhile to make a study of the layout of equipment and materials to determine if changes could help provide a smoother work flow and higher production.

PURPOSE OF A SHOP

In planning the layout and organization of a shop, you should carefully analyze the purpose of the shop. What kind of work will be done here? How much work must be turned out under normal conditions? Is the shop a specialized shop or a general-purpose shop? Does the shop meet all safety and environmental precautions?

SAFETY will be given top priority. It is strongly recommended that all portions of the area be clearly visible to the instructor and the student. Aisles of travel will be designated by painted lines, and these aisles should be a minimum of 3 to 4 feet in width. Use nonskid flooring in critical areas. Equipment and storage racks must be arranged so the entrance and exit to the building can be kept clear and will be accessible in the event of fire or emergency. Locate stationary machines so that the moving parts will NOT constitute a hazard to either the operator or to other shop personnel. Be certain that your shop layout will allow easy access to fire-fighting equipment, electrical control panels, and junction boxes. Because safety and environmental requirements change on a continuing basis, we can not cover every aspect to safety in a shop. Refer to the School *Shop Development Manual* by Rockwell Manufacturing Company, the *Navy Occupational Safety and Health Manual,* OPNAVINST 5100.23, and the *Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations* (29 CFR PART 1910).

You must also consider the particular advantages and limitations of the proposed shop space. How large is it? How many personnel will be expected to work in the shop at the same time? What kind of tools will be available? Where are the power outlets located? Can good lighting be arranged? What type of ventilation will be readily available?

The function of the shop will have an important bearing on the equipment needed and the minimum space required. At times, you may NOT get the amount of space desired and have to do the best you can with whatever space is available. In some instances, two spaces may be available, but one is unacceptable because of major problems that would be encountered.

ARRANGEMENT OF A SHOP

Good arrangement is required in all shops, regardless of each shop's function. The arrangement of equipment, layout tables, and soon, in a shop should be in the order of the work flow of the project that is most dominant in that shop. The layout in figure 5-1 maybe used as a guide in laying out a carpentry shop.

In planning the arrangement of equipment, consider such factors as sequence of operations, working space, clear shop entrance and exit, adequate workbenches, and safety. The positioning of equipment, layout tables, and so on, do NOT have to be the same in one shop as in another.

Try to place stationary machines so that the work will flow in an orderly and logical sequence. It is probably easier to do this in a specialized shop than it is in a general-purpose shop where the work differs considerably from one day to another.

In shops where there is a series of operations to be performed, the relative position of the various pieces of equipment has an important bearing on efficient operations. Not only should the equipment be accessible, but it should also be arranged to save wasted motion and to reduce walking distance.

This will enable your personnel to turn out more work when their equipment is close at hand. Clearance between adjacent machines should be such that the operators will NOT get in the way of one another. Electrical outlets should be readily available to the workbenches. Needless delays are caused by having to rig extension cords from poorly located outlets.

Your plans should include adequate means for storing tools and materials. When considerable amounts of materials must be kept on hand and space permits, a special storeroom maybe used for storage of materials. Where desirable, a portion of this storeroom may also be used for storage of tools and equipment. When a storeroom is available, however, it may still be advantageous to store certain material in the shop near the machines or equipment on which it is used. Refer to the *Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations* (29 CFR PART 1910) for more information on storage of tools, material, and equipment.

The amounts and types of materials stored in your shop will depend largely upon the space available and the intended purpose of your shop. In most shops, you will probably need facilities for storing such items as bolts, nuts, nails, screws, and paint. Whatever the type of shop, you should make an effort to see that your storage facilities are arranged to give the greatest possible amount of free working space.

FLOOR

In today's industry, concrete is the most widely used flooring material and possibly the most unsatisfactory flooring material for shops. Even when painted or sealed to eliminate dust, the concrete floor is

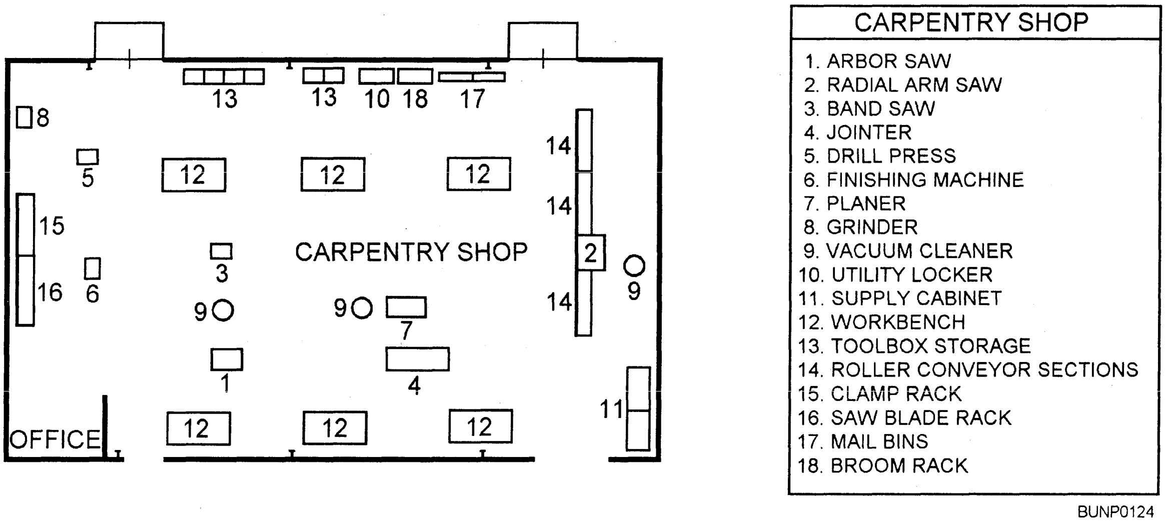


Figure 5-1.—Typical layout of a carpentry shop.

still hard and very slippery. This is why nonskid paints are used so extensively.

Wood is the preferred floor material; however, it is the most expensive. Tile floors have become popular recently due to their low initial cost and ease of replacement. Some caution should be exercised in specifying the exact type of tile due to solvents and other inherent damaging effects when used in a shop.

Walls and Ceilings

The WALLS should be made of CMU, tile, or other material that can be easily cleaned and very durable. Windows should be placed as high up in the walls as possible to let natural light in. As a general rule, windows are required to be placed a minimum of 54 inches from the floor. If you want to put an acoustical plaster or other soundproof material on the walls, be sure it is a minimum of 5 feet from the floor. CEILING heights for a shop should be at least 12 feet high. Although cost will be a definite factor, acoustical material or treatment is highly recommended for the ceiling.

Office Space

You will also need space for an office. As a rule, try to locate the office in an area of the shop where you will be least disturbed by noise. The shop layout plan should make provision for a bulletin board upon which safety posters, maintenance posters, instructions and notices, plan-of-the-day, and such other information may be posted, as appropriate.

The bulletin board should be located in a prominent place in the shop, preferably near the entrance where personnel will be likely to pass during the day. If necessary, artificial lighting should be provided so that material on the bulletin board can be easily read. The material posted on the bulletin board should be changed frequently, expired notices promptly removed, current plan-of-the-day posted early, and posters and other material rotated periodically.

MILLWORKING

MILLWORK is shaped items of wood that are made, in most cases, from well seasoned kiln-dried lumber (4 to 9 percent moisture content) that requires manufacturing. Most millwork products are used in the interior of buildings and is installed by finish carpenters. However, the Builders do various types of construction and the need to understand millwork concepts and construction techniques associated with millwork is essential.

Millworking not only includes interior trim products but, casework, doors, kitchen and bathroom cabinets, window frames and sashes, stairs, furniture, specialized items made to order, and woodwork that is turned. The majority of the millwork in the construction industry is constructed and sold by two methods:

- *Setup* millwork which is assembled and ready to be installed with minimal or no fitting, such as prehung doors, molding, cabinets, and so on.
- *Knocked-down* millwork which is assembled by the Builder on the jobsite, such as window frames, doorframes, flooring products, some furniture units, stairs and accessories, and so on.

Most products are produced in a manufacturing mill or plant and are ready to be installed by fastening to the wall or floor. If the need arises for you to install these types of products, refer to the manufacturer's instructions and/or the plans and specifications.

As the Builder in charge of a shop, you and your crew will be tasked at times to make plaques, flag cases, bookcases, shelving units, and cabinets. Many of these projects you are tasked with will be nothing more than an idea and you will be required to interpret by sketching their idea on paper and developing this idea into a workable drawing.

In the previous BU training manual (TRAMAN), you learned the basic concepts of drawings, interior and exterior trim, and casework mentioned in this section. However, with the large scope of products and changing technology, these products could not be covered sufficiently due to time and space constraints. The next section will cover designing, constructing, and installing millwork products.

CABINETMAKING

Cabinetmaking is primarily used in interior finish carpentry, such as furniture, kitchens, bathrooms, and casework. A&E firms, Builders, or cabinetmakers that specialize in cabinetry, usually plan their cabinetwork as built-in unit. Floor plans usually show the cabinetwork location, while elevation plans usually provide detailed dimensions, as shown in figure 5-2.

DESIGNING A PRODUCT

Builders are often provided with complete working drawings of a product to be constructed. The drawings usually contain information to build the product, such as size, style, material, construction, and finish. Sometimes the Builder must design, sketch, and make a working drawing from the customer's verbal specifications or from simple line drawings. To make a working drawing from the incomplete instructions supplied by the customer, the Builder must

1. know the principles of good cabinet design;
2. be familiar with popular cabinet styles;
3. develop a sketch that meets the customer's specifications and conforms to good design principles;
4. make a working drawing from the sketch in order to build the product.

When designing a product, you must consider the purpose, strength, size-shape proportion, appearance, time, and cost of the product. The time designing helps avoid mistakes and saves time in the long run. One of the most important considerations in designing a product is its purpose. A product's purpose maybe the deciding factor in determining the design. For example, a bookcase must be the proper size and strength to hold the desired quantity and kind of books. Cabinets and furniture are usually make only strong enough to fulfill their purpose. The strength required of a object may determine such things as the type of joint, the size, and the kind of wood. It is often better to use strong woods like oak, ash, or maple to give the strength required by a product. Oversized softwood, like pine, may also be used. However, using oversize parts gives a massive and awkward appearance to a product.

Some furniture and cabinets must be built to standard sizes in order to serve its purpose. A dining table that is too low will not serve its purpose. A kitchen cabinet counter top that is too narrow will not accommodate a sink. In addition to size and shape, the designer must also consider proportion. The proportion of a cabinet is the relationship between its dimensions which include its width, height, and length. Some proportions are more pleasing to the eye than others.

The appearance of a cabinet maybe largely due to its purpose, location, and finish. If the product is to be painted, a less expensive material maybe used. If it is stained with a clear finish, a better quality material should be used. The appearance of cabinet doors may be changed by cutting shapes in doors instead of solid doors. The edges of the doors may be lipped or cut square according to the appearance desired.

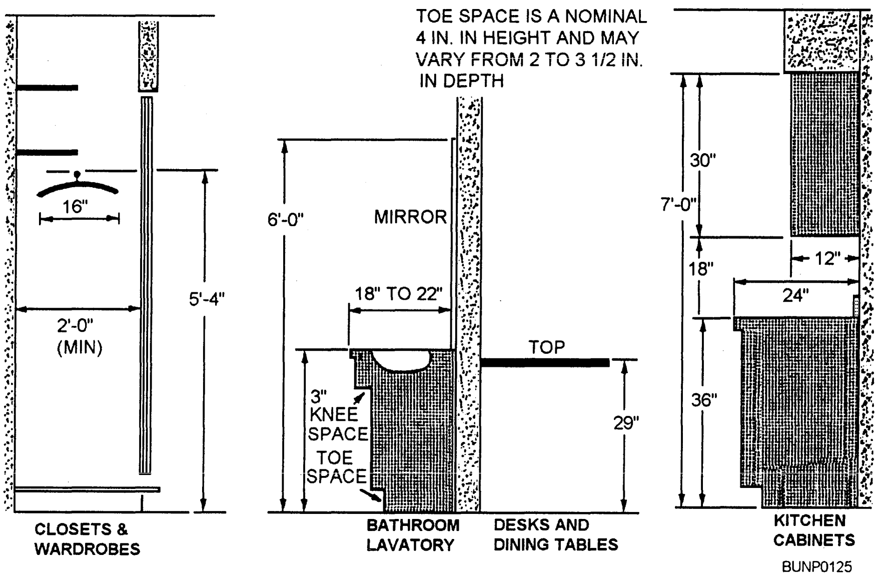


Figure 5-2.—Typical dimensions for cabinetwork.

One of the important considerations in designing cabinetwork is the time required to construct it. Time may affect the type of joint, kind of material and fasteners, method of construction and kind of finish. To save time, you may use a butt joint reinforced by corrugated fasteners instead of the more complicated and time-consuming mortise-and-tenon joint. To save time, you may use nails instead of screws, or a quick-drying sprayed finish may be selected.

The quality of the finished product is also a factor in designing. High-quality products take more time and cost more to construct. The Builder must decide the minimum quality level that will be accepted and produce it at minimum cost.

Making a Sketch

A sketch is a free-hand drawing which lets the designer experiment with the elements of a design. It is the preliminary step to a working drawing. The first step in designing and building an object is to make several drawings to experiment with design, size, and proportion. After the design and size have been determined, next determine the type of wood to be used, the finish, and the construction details, such as joints, style (Early American, traditional, contemporary, and so on), location, and type of fasteners. Different kinds of drawings may be used according to which best illustrates the information, such as perspective, orthographic projection, pictorial or exploded (fig. 5-3),

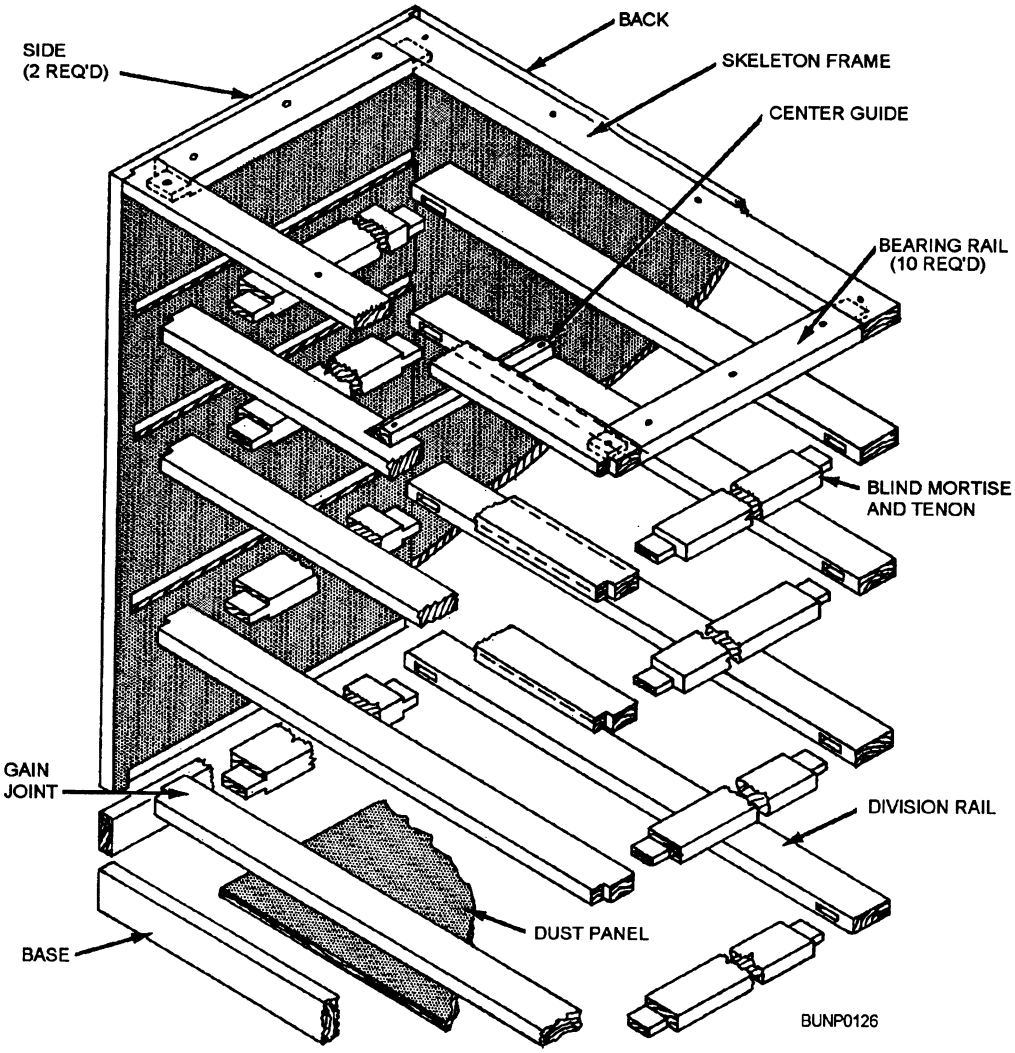


Figure 5-3.—Exploded drawing and nomenclature of a cabinet.

and/or detailed drawing. Refer to the *Architectural Graphics Standard (AGS)* for complete information on these kinds of drawings.

Working Drawings

When enough sketches have been made, the ideas developed are put into the form of working drawings. A working drawing is one made with drawing tools, such as a T square, triangle, or compass. It is drawn to exact scale (fig. 5-4). It provides most of the information required to build the object. Some features, like the type of joint, glue, or fasteners, are left to the discretion of the Builder however.

When working drawings are developed, drafting standards are followed closely. The drawing should be centered on the page. Lines should be standard weights. The drawings should be adequate dimensions and

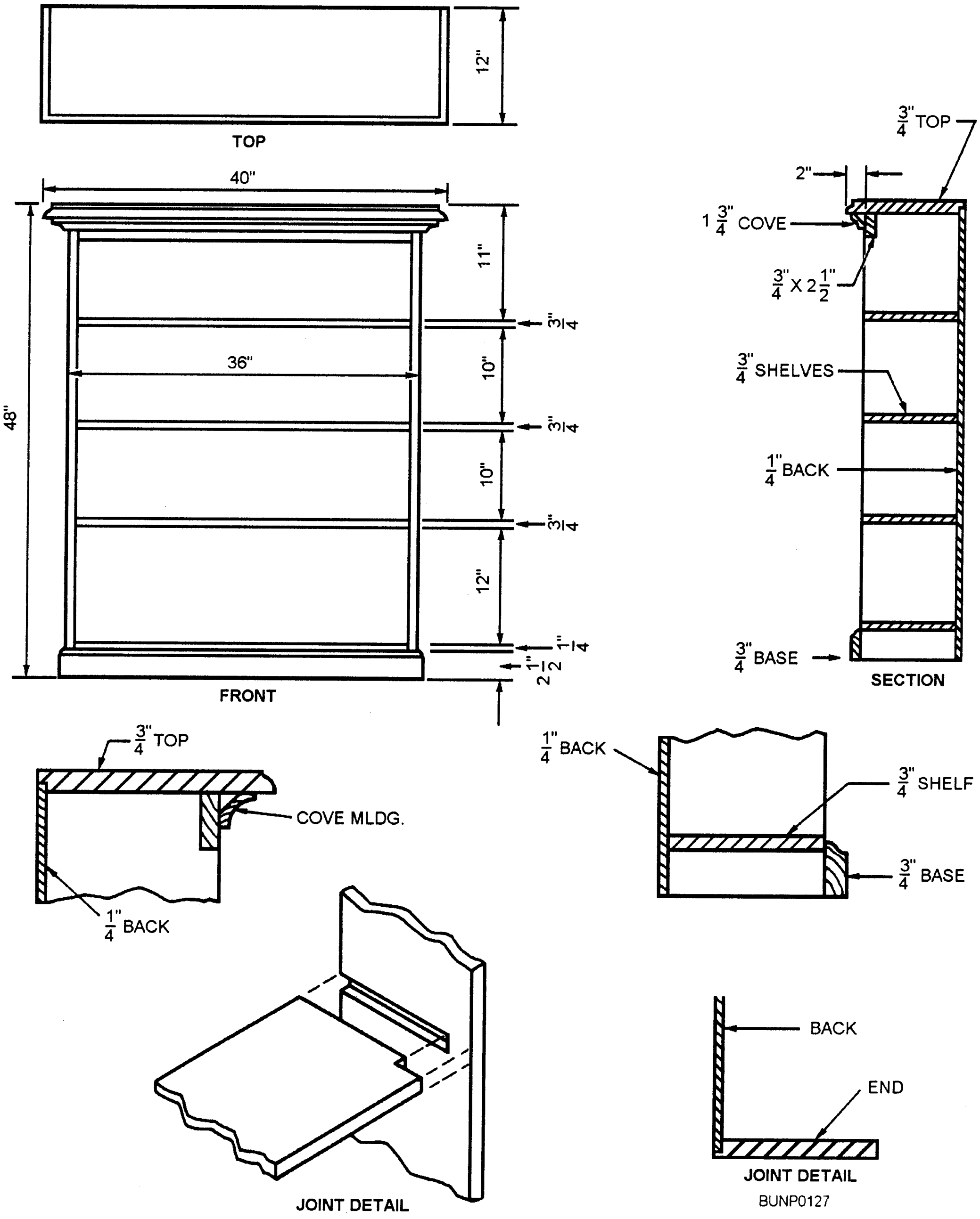


Figure 5-4.—A working drawing of a bookcase.

include all necessary notes. Lettering should be neat and legible.

PLAN AND LAYOUT

After the working drawings are completed and approved, a plan and layout of procedures are done. This saves time and eliminates mistakes. A good cabinetmaker will always lay out and plan the work before starting to build. A number of construction problems are solved during this planning period. With a good layout and plan, those who do the work have few questions.

Layout Rod

One of the most common ways to lay outwork is to use a rod. A rod is normally a 1-inch x 2-inch strip of lumber which indicates the actual location of all the parts of the cabinet. One side of the rod is used for marking the width. Another is used for marking the height, the third side is for the depth, and the fourth side is used if other cabinets are to be built that differ in only one dimension. This technique is similar to laying out studs on a floor in rough framing. The rod shows the locations where the cuts would be—the drawers, the shelves, the rails and stiles—any detail it takes to construct a cabinet. Cabinetmakers use different techniques and methods in developing these rods and making a layout rod more easier to read.

Making a Cutting List

Once the rod layout is complete, all measurements for cutting the stock should be taken from it. A cutting list can then be made listing all the parts and sizes. A cutting list must include the quantity of each component, the thickness, width, and length of stock, exact cut of each component, and should include the type of joint for each component.

Developing a Plan of Procedure

A plan of procedure must be developed before making a piece of cabinetwork. This involves writing down all the steps of construction.

The complexity of the work may determine the order of the steps to be taken to complete a job. In most cases, the following order should be used:

1. Make a layout rod from the sketch or drawing. However, many Builders or cabinetmakers bypass this step due to their experience in cabinetry.

2. Make a cutting list, using the measurements obtained from the layout rod and drawings.

3. Select the right type of stock for the project; then cut the stock to rough lengths. Rough length is 2 or 3 inches longer than actually required. Cutting to rough lengths makes handling the stock easier and facilitates machining.

4. Face one side of the stock. Facing produces a straight surface and eliminates any cup, bow, or twist.

5. Plane the stock to thickness. This is the first step to bring the stock to size. Make sure all parts are planed at the final setting of the planer to ensure equal thicknesses.

6. Joint one straight edge on each piece. This straight edge will be held against the fence of the table saw for ripping to width.

7. Rip the stock to the required width. Use the correct saw blade for the smoothness of the edge desired. Rip all pieces of the same width without changing the setting of the rip fence.

8. Cut the stock to the overall length. This is the last step in cutting the pieces to their overall finished size. Use a stop block to cut equal lengths.

9. Make rabbets, dadoes, mortises, tenons, and bore holes; and perform other machining as necessary. Set up machinery and make all similar cuts without changing the setup.

10. Sand the inside faces before assembling. Once you assemble the inside of a cabinet, it is difficult to sand. These surfaces must be smoothed before assembling.

11. Assemble the parts. When possible, assemble the parts using only clamps (no glue or fasteners) to check the quality of fit. Then assemble the piece permanently as required. After assembly, wipe off any excess glue that may make finishing difficult.

12. Prepare exterior surfaces for finishing by sanding if the exterior surfaces were not sanded before assembly. Handle the pieces carefully to avoid marring the finished surfaces.

13. Apply the finish. The finish may consist of filling, staining, and applying clear or pigmented coatings.

14. Install the necessary hardware. Hardware is often installed before finishing; then remove and replace after finishing. If there is no danger of marring

finish, the hardware is installed after finishing. The finish is not usually applied to the hardware.

CASEWORK CONSTRUCTION

"Casework" is defined as boxlike components of cabinetwork, normally rectangular. Casework may contain shelves or drawers for storage. Doors or covers are sometimes fitted to enclose the storage space. Examples of casework are bookcases, chests, desks, display cases, and kitchen cabinets. Casework consists of a skeleton frame, face frame, two ends, legs, and the bottom back and top (fig. 5-5).

Skeleton Frames

The skeleton frame is made to fit in the interior of the case. It consists of stiles (vertical members) and rails (horizontal members) only. Panels fitted into the frame are called dust panels. The skeleton frame serves a number of purposes:

- It provides a means of fastening the case top to the case and holding the ends together at the top.

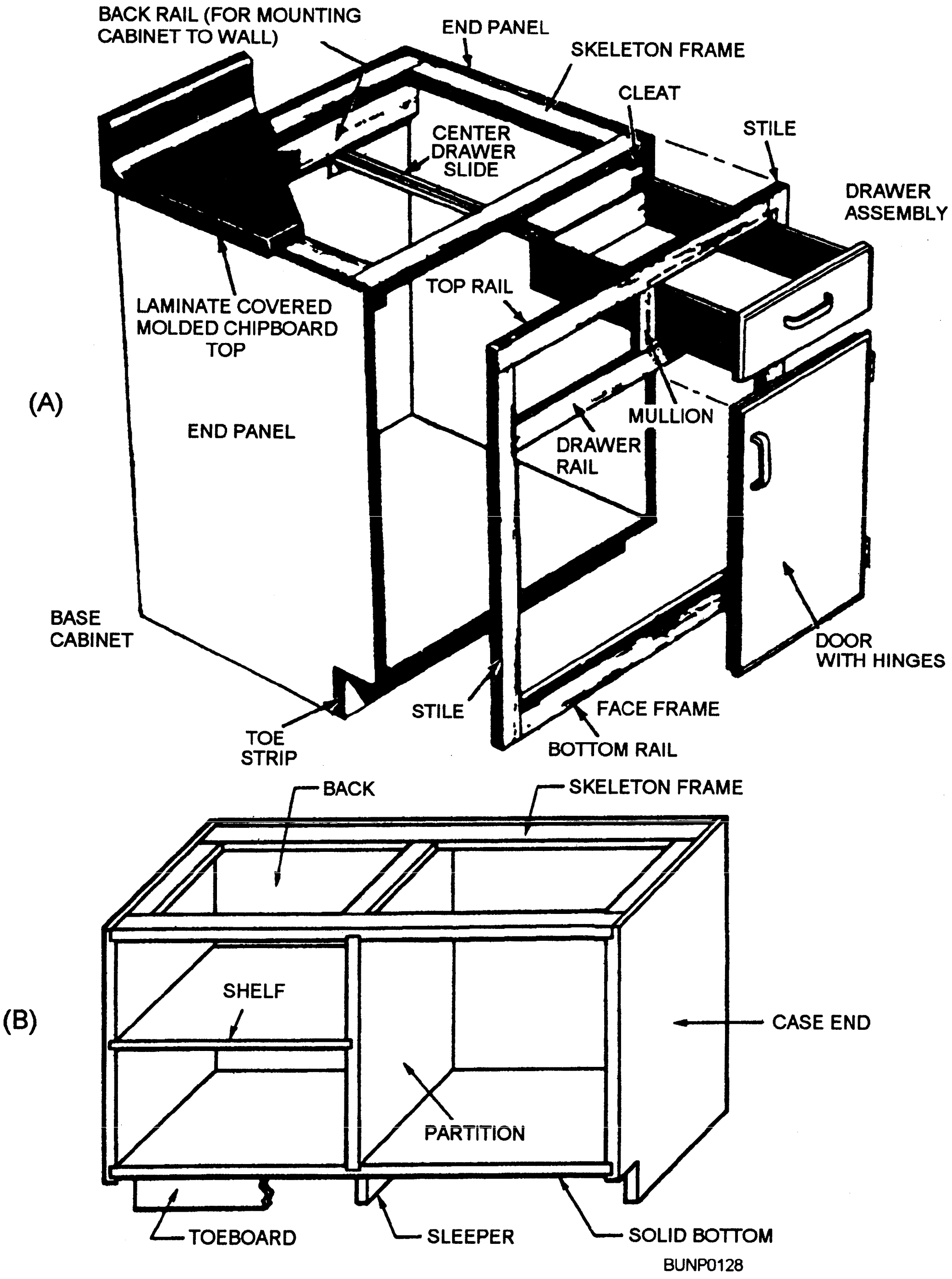


Figure 5-5.—Typical case construction.

- It fastens and holds the ends together at the bottom.

- It separates and supports drawers.

- It is used vertically as divisions when solid partitions are not required.

Skeleton frames are assembled before being installed in the case. Dowels, biscuit joint, or mortise-and-tenon joints are recommended joints used to make a skeleton frame.

ENDS.— The case ends are made of solid edge-glued lumber or plywood. They may also be paneled frame with stiles and rails and plywood or hardboard panels. Paneled ends are made similar to paneled doors using either doweled or mortise-and-tenon joints.

The back edge is usually rabbeted to receive the cabinet back. If the case is to be fitted to the wall, the rabbet is cut deep to recess the back and allow the projecting material to be scribed to the wall.

The front edge is joined to the face frame with a butt, rabbeted, or mitered joint. If a butt joint is used, the front stile of the case end is made narrower than the back stile because of the thickness of the face frame.

Case ends may also be dadoed to receive the top, bottom, fixed shelves, skeleton frame, and dust panels of the case.

LEGS.— Sometimes the stiles of the case ends extend below the bottom and act as legs. The front stiles of the ends also act as a stile for the front frame. In this type of construction, it is usual for the skeleton frame to be notched around the leg. It then extends to the front and becomes the face frame and dividing rails for the drawers.

PARTITIONS AND SLEEPERS.— Partitions are vertical members dividing the interior of the case into sections. They tie the top and the bottom of the case together and are usually dadoed into the top and bottom. The skeleton frame, dust panels, and shelves are cut in between the partitions and are usually dadoed into the partitions. Partitions are also known as divisions or standards.

Sleepers extend from the bottom of the case to the floor and are located directly under the partitions. They provide support of the case to the floor and keep the bottom from sagging.

SHELVES.— Shelves must be strong enough to support the weight placed on them. They must also be wide enough and correctly spaced for their intended purpose. Shelves may be made of solid wood, plywood, particle board, or glass.

Bookcase shelves should be from 8 to 10 inches wide and spaced 10 to 14 inches apart. The length of a 3/4-inch-thick shelf should be no more than 36 to 42 inches without intermediate supports. Supports should be spaced close enough to keep shelves from sagging under the weight placed upon them.

One way of increasing the strength of a shelf is by installing strongbacks. A strongback is a strip of wood screwed on the edge to the underside of the shelf. It is placed either on or near the front or back edge of the shelf or both edges of the shelf.

Fixed shelves are usually dadoed in or supported on wood cleats (fig. 5-6). A cleat is a small strip of wood

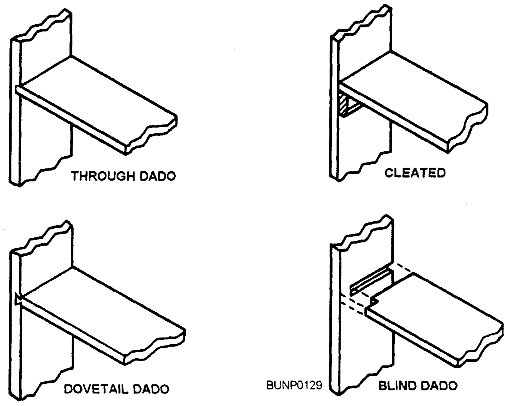


Figure 5-6.—Fixed shelf construction.

screwed to the inside of the case to support the shelf. A through dado or dovetail dado maybe used to support a shelf. A better method is to use a blind dado to conceal the joint.

Adjustable shelves may be supported with metal shelf standards and clips that are either surface-mounted or set flush in grooves. A pair of notched and numbered standards supports the shelves at both sides of the case. They are fastened 1 to 2 inches in from the back and front edges. When they are installed, the same number appears right side up at the bottom of all four standards. The clips can then be inserted in the correct notch, so the shelf lies flat.

Another method of supporting adjustable shelving is by inserting wood dowel pins or commercial shelf pins into four holes at each shelf location. Two vertical rows of equally spaced, 1/4-inch holes are drilled on either side of the case about 1 to 2 inches in from the front and back edges. The holes are spaced approximately 2 inches apart for ordinary work. The holes should be drilled deep enough, so the pins will not fall out when the shelf is placed upon them.

Adjustable shelves are sometimes installed by using ratchet strips. Ratchet strips are strips of wood with notches cut at equal intervals on one edge. These strips are fastened to the front and back edges of the case on the inside. A ratchet cleat is cut to length with ends matching the notches to fit in between the ratchet strips. The ratchet cleat may be moved to any notch to support the shelf.

Another method of making ratchet strips is by boring a series of equally spaced, 3/4-inch holes along strips of 1-inch by 4-inch lumber. The strips are cut in half along the center lines of the holes. Ratchet cleats with rounded ends are then cut to match the ratchet strips.

BOTTOMS AND TOEBOARDS.— The bottom of a case is usually made of solid lumber, particleboard, or plywood, unless a dust panel is used when a drawer is supported by the bottom. Case bottoms are sometimes raised above the bottom rail of the face frame to act as a stop for doors. Another design eliminates the bottom rail of the face frame. The door or drawer then covers all of the bottom edge which also acts as a stop.

To cover the space between the bottom and the floor and to provide toe clearance, install a toeboard. The toeboard is usually set back from the face of the case 2 1/2 to 3 inches.

Cabinet Facing

After completing the frame construction and shelving, apply finished facing strips to the front of the cabinet frame. These strips are sometimes assembled into a framework (called a faceplate or face frame) by commercial sources before they are attached to the basic cabinet structure. The vertical members of the facing are called stiles, and the horizontal members are known as rails.

As previously mentioned for built-in-place cabinets, you cut each piece and install it separately. The size of each piece is laid out by positioning the facing stock on the cabinet and marking it. Then the finished cuts are made. A cut piece can be used to lay out duplicate pieces.

Cabinet stiles are generally attached first, then the rails (fig. 5-7). Sometimes a Builder will attach a plumb end stile first, and then attach rails to determine the position of the next stile.

Use finishing nails and glue to install facing. When hardwoods are being nailed, drill nail holes where you think splitting might occur.

Face Frames

Face frames are preassembled units, usually joined with dowels, biscuits, or mortise-and-tenon joints, into which drawers and doors are fitted, as shown in figure 5-4. Face frames are joined to cabinet ends with a butt, rabbeted, or mitered joint. The face frame must fit the case accurately, so doors and drawers may be installed easily at a later stage.

If flush doors are to be hung on the face frame, the frame is made about 1/16 inch thicker than the door to

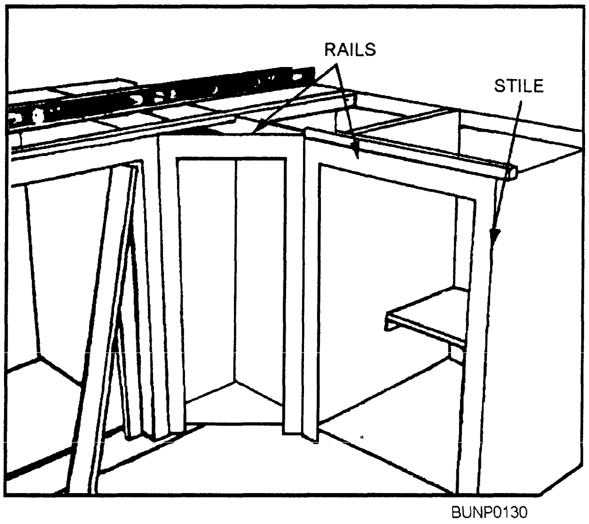


Figure 5-7.—Facing being placed on a cabinet.

be hung. This prevents the doors from binding against the door stops. If the end of the case is to be fitted against a wall, approximately 1/2 inch is added to the width of the stile on that end for scribing.

Doorstops are installed on the back side of the face all around the door openings if flush doors are to be hung. Doorstops project about 5/1 6 inch inside the opening and usually are made of thinner material than the face frame. They are applied with screws and glue because they take much abuse and a strong joint is needed.

Case Tops

The case top is installed according to its location. If it is above the line of vision, the top is cut in between the case ends, so the ends of the top are not visible. The top may also be lowered between the case ends. This provides clearance between the ceiling and the top of the case and also acts as a stop for the top ends of doors. If the top is below the line of vision, it is placed above the case ends.

In most cases, tops are fastened to the cabinet with screws driven up through the top of the skeleton frame.

Counter Tops

The standard kitchen counter top is 36 inches high, 25 inches deep, and 1 1/2 inches thick. This provides enough room for an average-size sink and ample working space on the surface. The counter top is held in place by driving screws up through the top frame of the base unit.

The counter top usually has a 3/4-inch overhang, made of plywood or particle board. It is doubled up by fastening a 2 1/2-inch-wide strip flush with the edges and ends. This gives the appearance of a heavier counter top.

If a backsplash is used, it is usually 4 inches high. It has a 1/4-inch projection on the side that goes against the wall. This projection allows the installer to scribe the counter top to uneven wall surfaces. Prefabricated counter tops may be purchased and cut to any desired length. Special fasteners hold the lengths together.

DESIGNING CABINETS

The Builder should know the proper procedures and correct dimensions on how to build and install cabinets. There are two basic kinds of cabinets—the base unit and the wall unit. The base unit sets on the floor; the wall unit hangs on the wall.

The distance between the wall and base units is usually 16 to 18 inches. The distance is enough accommodate most articles that are placed on counter tops, like coffee pots, toasters, blenders, and mixers. The top shelf in the wall unit should not be over 6 feet from the floor if it is to be in easy reach.

Base Unit

The height of the base unit must be 36 inches to the surface of the countertop. The width must allow for the 3/4-inch overhang of the counter top. Therefore, a standard base unit is usually 34 1/2 inches high by 24 1/4 inches deep. Toe space is provided beneath the base unit. The back edges of the end pieces project 1/4 inch beyond the cabinet back to allow for scribing.

Usually the base unit is constructed with drawers just below the counter top. The drawer opening height is 5 1/2 inches. Some base units contain all drawers or all doors (fig. 5-8).

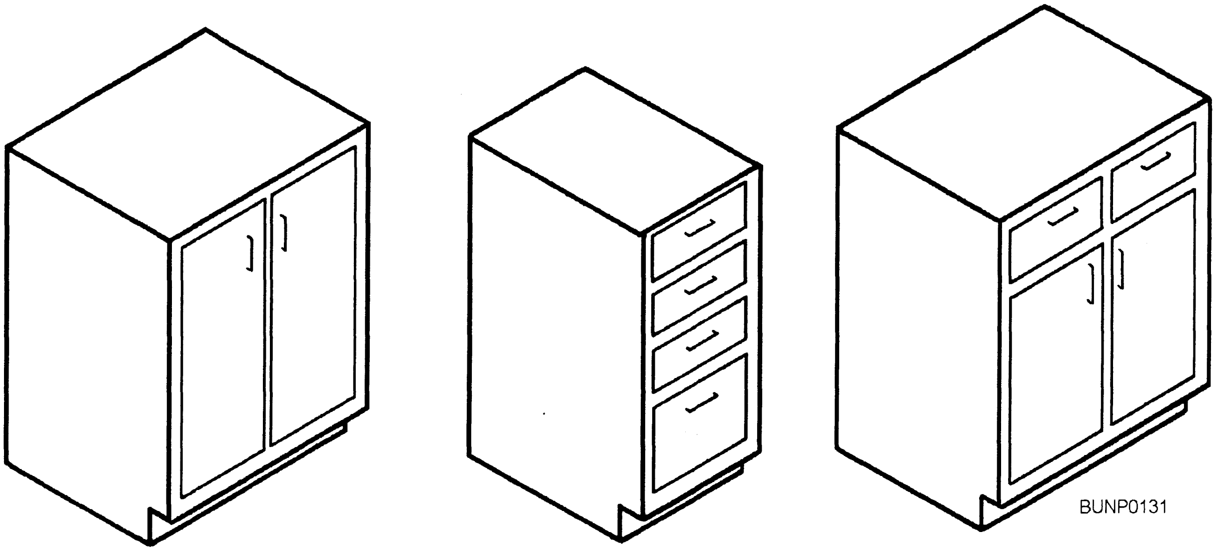


Figure 5-8.—Typical base units.

The base unit has a face frame and skeleton frame. A number of joints can be used to fasten the stiles and rails together, as shown in figure 5-9. The stiles are always mortised and the rails are always tenoned (fig. 5-10).

Wall Unit

A typical full-size wall unit is usually 12 inches deep and 30 inches high (fig. 5-11). A wall unit above a range is 18 inches high. Above a sink, it is 22 inches high, while over a refrigerator, it is only 15 inches high.

The number and spacing of shelves depend on the purpose of the cabinet. Shelves may be fixed or adjustable. Shelves are usually spaced from 3 to 12 inches according to the customer's wishes.

The wall unit, like the base unit, has a face frame on which to fit and hang doors. These face frames are usually made of 1-inch by 2-inch solid lumber. The actual size is 3/4 inch by 1 1/2 inch.

An allowance is made on the back edges of the end pieces for scribing. Mounting strips must be included in the wall units. Screws are driven through these strips to hold the cabinet on the wall.

CONSTRUCTING A BASE UNIT

Earlier we covered the steps on how to plan a procedure before constructing apiece of cabinetry. The

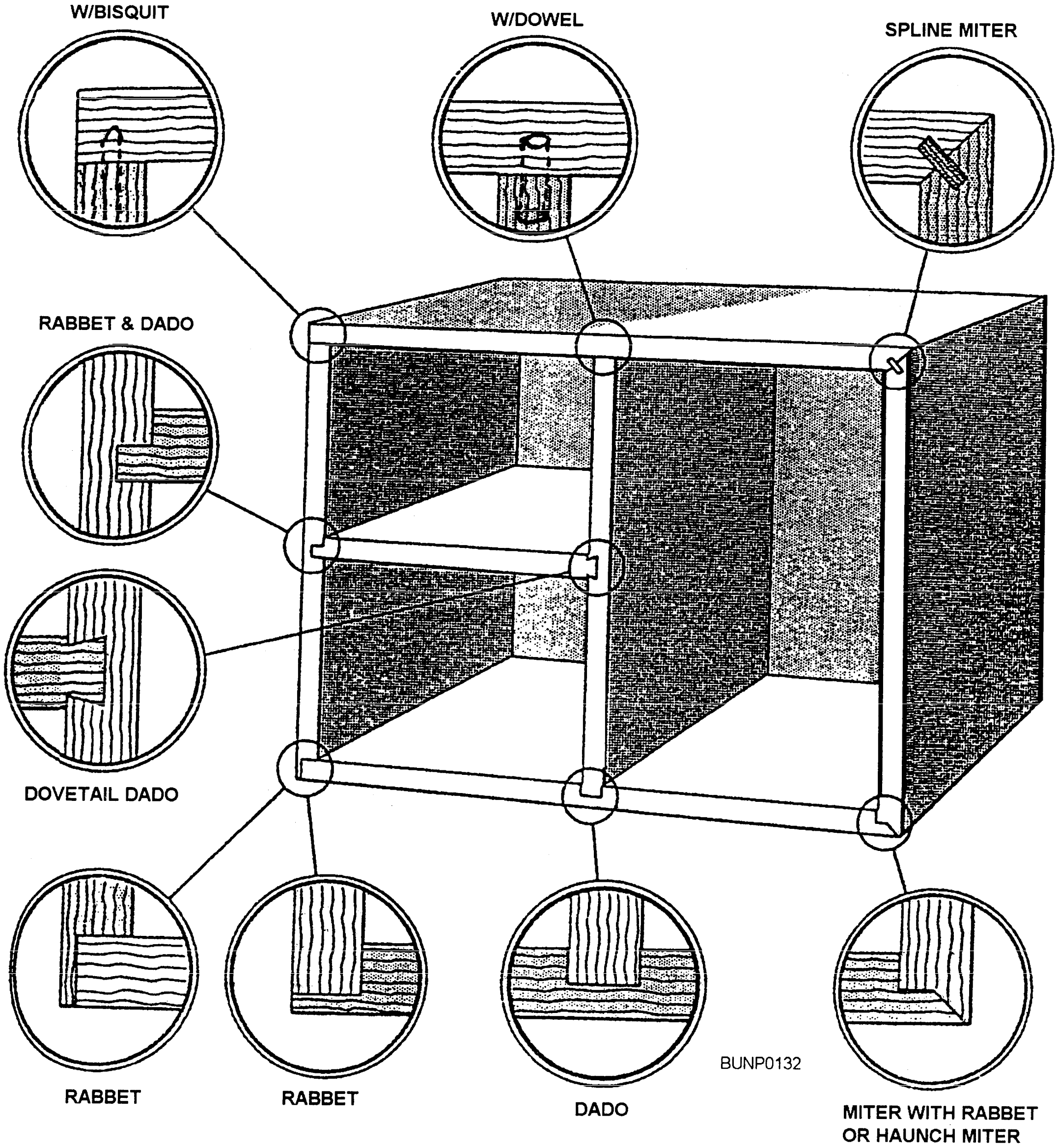


Figure 5-9.—Types of joints.

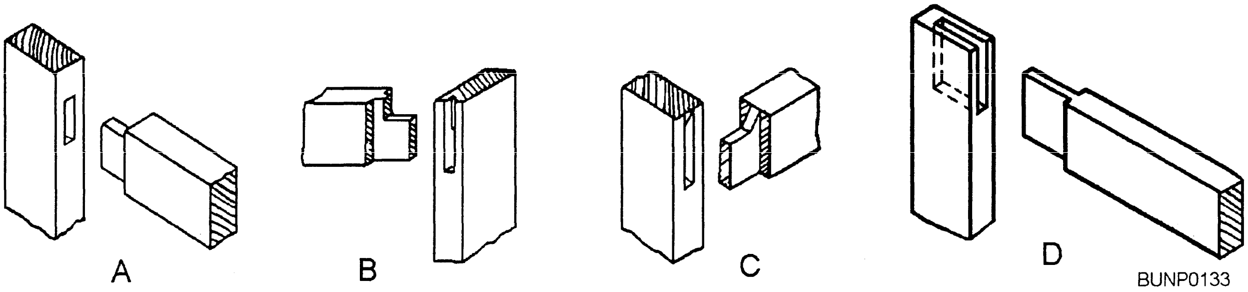


Figure 5-10.—Types of mortise-and-tenon joints.

following steps are a guide to constructing the base unit of a cabinet:

1. Review your drawings and specifications.

2. Select the lumber or plywood to be used; then develop a cutting list from the layout rod and/or drawing.

3. Determine the best joints to use on the face frame and the skeleton frame stiles and rails.

4. Cut out and assemble the face frame by gluing and clamping. After the glue has set, remove the clamps and sand both faces. You then set the frame aside.

5. For the base unit, cut out the skeleton frame similar to steps 3 and 4. Then cut a groove (dado) 1/4-inch wide by l/2-inch deep on one edge of the four skeleton frame stiles.

6. Use a stub mortise-and-tenon joint l/4-inch thick by l/2-inch long on all the skeleton frame rails.

7. Layout the location of the rails on the stiles and assemble the skeleton frames by clamping and gluing. When they are dry, remove the clamps and set aside until needed.

8. Rabbet the back edges of the ends 1/2 inch by 1/2 inch. This rabbet will allow the end panels to project out beyond the plywood back for scribing the cabinet to the wall. Make sure the rabbet is cut from the inside face of the plywood, so the good face will show on the outside of the cabinet.

9. Lay out and cut the toe spaces on each end panel. The top of the cut is flush with the bottom rail of the face frame. The bottom of the cut is flush with the toeboard.

10. Cut out the toe spaces so that a right hand and left and end panel is obtained. Cut from the inside face to avoid splintering the face side.

11. Dado the inside of the end panels 3/16-inch deep and 3/4-inch wide for the bottom, shelf, and skeleton frame. Make a blind dado for the cabinet shelf.

12. Assemble the end panels, bottom, shelf, and skeleton frames with glue and clamps, finish nails, or screws. Make sure all edges line up.

13. Install the toeboard between the end panels by fastening with glue and finish nails through the end

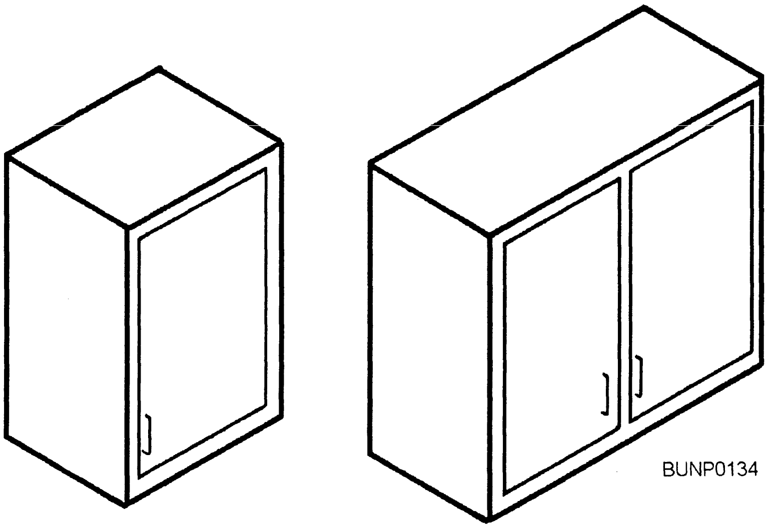


Figure 5-11.—Typical wall units.

panels and down through the case bottom. Remove any bow by keeping the toeboard the same distance from the front edge of the bottom all along its length.

14. The back helps hold the case rigid. The case must be absolutely square before fastening the back. Use the Pythagorean theorem to find the diagonals. This will square up the frame.

15. Fasten the back to the end panels, bottom, shelf, and skeleton frame. Straighten any bow when fastening.

16. Fasten the face frame to the front of the case. Keep the top edge of the bottom rails flush with the top surface of the case bottom and the outside stiles flush with the face of the case ends.

CONSTRUCTING A WALL UNIT

All the steps in constructing the base unit apply to constructing the wall unit. However, there are certain steps NOT needed, such as constructing toeboards, openings for drawers, and the installation of a counter top, which we will cover later in this chapter.

OTHER CONSTRUCTION METHODS

Cabinets are constructed in a number of different ways than those described in this unit. Construction depends on the quality desired, the time required, the materials used, and the experience of the craftsmen.

Cabinets may be made of hardwood, plywood, solid hardwood, or a combination of softwood, plywood, and solid softwood lumber. Often particle board is used, sometimes with a vinyl coating on one side to eliminate finishing the inside of the cabinet.

In many cases, the end panels are not dadoed to receive the interior pieces. Skeleton frames are eliminated. The end panels are then held together at the top by the back and face frames. Sometimes the back is not installed and a 1-inch by 3-inch or 1-inch by 4-inch strip is used between the ends at the top, flush with the back edge.

Members of the face frame in lesser quality work are butted against each other. They are fastened together with power-driven corrugated fasteners on the inside of the frame. In some cases, the bottom rail of the frame is eliminated. The front end of the bottom acts as the bottom rail of the face frame.

INSTALLING CABINETS

The cabinetmaker often is required to install kitchen and bathroom cabinets. Cabinets must be installed in a straight, level, and plumb line. This action requires skill because floors and walls are not level or plumb, especially in older buildings.

When cabinets are installed, many installers prefer to mount the wall units first, so work does not have to be done over base units. Let’s cover the installation of a kitchen cabinet (fig. 5-12).

Wall Units

The first step in the installation of the wall unit is to locate the bottom of the wall unit (normally 52 inches); then measure up 52 inches from the lowest point of the floor. This usually leaves a 16-inch space between the counter top of the base unit and the bottom of the wall unit. Second, using a level and straightedge, draw a level line from the mark across the wall. The bottom of the wall units are installed to match this line.

Next, you need to locate the wall studs. When a stud is found, mark the location with a pencil; then measure 16 inches in both directions from the first mark to locate the next studs. Drive a finish nail to test for solid wood. If studs are not found at 16-inch intervals, then tap the wall with a hammer to locate each stud or use a stud finder.

At each stud, use a level and draw a plumb line down below the line for the bottom of the wall cabinets. Projecting below the wall units makes it easier to locate the studs when installing both wall and base units.

Then mount a temporary ledger board (1 by 2) to the wall along the bottom of the cabinet line. This action will help level and support the wall unit.

The following procedures are only a guide to installing the wall units:

1. Place the unit on the ledger board or a stand that holds it near the line of installation. If the unit is not level, use wood shims to bring the unit to level.

2. Test the front edge of the unit with a level for plumbness. If the unit is not plumb, shim it between the wall and its back edge with wood shims until it is plumb. If the unit is not plumb to the wall, you need to cut the back edge of the cabinet.

3. Scribe the back edge by riding a set of dividers against the wall and marking the back edge of both end panels to the contour of the wall.

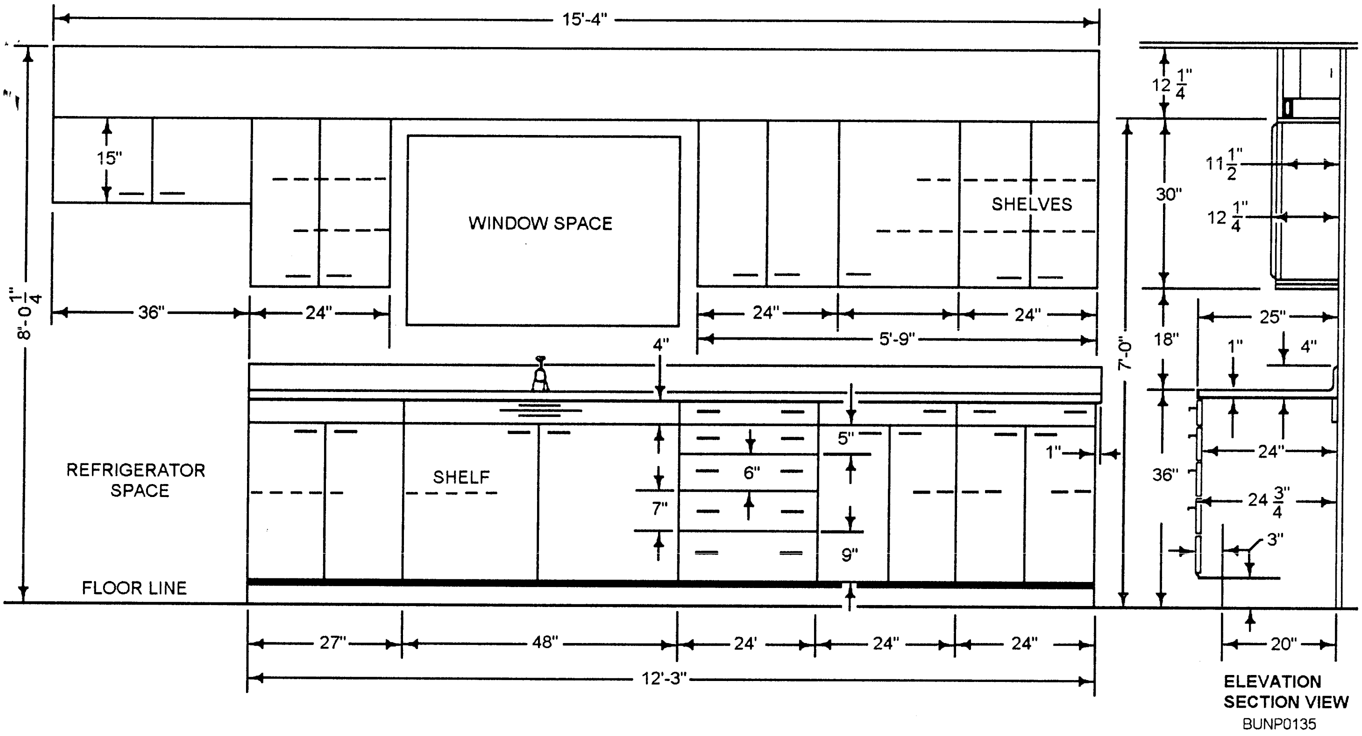


Figure 5-12.—Kitchen cabinet details.

4. Take the cabinet down off the ledger board; then cut the back edges with either a handsaw or a plane to the scribed line. Use a plane if you have to take off less than an 1/8 of an inch. Use a handsaw, rather than the saber or circular saw, because these saws cut on the upstroke and can splinter out the face side. The handsaw cuts on the downstroke which will not splinter the face.

5. Place the cabinet back into position; then fasten the cabinet into place with wood screws. Screws should be of sufficient length to hold the cabinet securely.

Adjacent cabinets are installed in the same manner. The back edges of these cabinets are scribed so their face frames are flush with the cabinet previously installed. Adjacent cabinets are fastened to each other by means of screws or bolts through the ends or through the stiles of the face frame.

Base Units

Before base cabinets are installed, draw a level line 16 inches plus the thickness of the countertop below the line previously drawn for the location of the wall units. This action will be the location of the top of the base units without the counter top. However, check your plans and specifications for the proper height on the counter top because it may vary.

1. First, locate and mark the location of all wall studs where the cabinets are to be hung. Find and mark the highest point in the floor. This action will ensure the base cabinet is level on uneven floor surfaces. (Shims should be used to maintain the cabinet at its designated leveled height.)

2. Start the installation of a base cabinet with a corner or end unit. After all base cabinets are in position, fasten the cabinets together. To get maximum holding power from screws, place one hole close to the top and one close to the bottom.

3. Starting at the highest point in the floor, level the leading edges of the cabinets. After leveling all the leading edges, fasten them to the wall at the studs to obtain maximum holding power.

Here are some helpful hints for the general construction of cabinets:

- Cabinet parts are fastened together with screws or nails. They are set below the surface, and the holes are filled with putty. Glue is used at all joints. Clamps should be used to produce better fitting glued joints.
- A better quality cabinet is rabbeted where the top, bottom, back, and side pieces come together. However, butt joints are also used. If panels are less than 3/4-inch thick, a reinforcing block

should be used with the butt joint. Fixed shelves are dadoed into the sides.

- Screws should go through the hanging strips and into the stud framing. Never use nails. Toggle bolts are required when studs are inaccessible. Join units by first clamping them together and then, while aligned, install bolts and T-nuts.

Counter Tops

After the base units are fastened in position, the counter top is laid on top of the units and against the wall. Here are some helpful hints for installing counter tops:

1. Move the counter top, if necessary, so that it overhangs the same amount over the face frame of the base cabinets.

2. Adjust dividers for the difference between the amount of overhang and the desired amount of overhang. Scribe this amount on the backsplash if it has a scribing strip.

3. Cut the backsplash to the scribed line and fit it to the wall.

4. Fasten the counter top to the base cabinets with screws up through the top skeleton frame of the base units. Use a stop on the drill bit so you do not drill through the counter top.

In some cases, backsplashes are not built with scribing strips. To fit the backsplash to the wall, hold the counter top in the desired position. Press the backsplash against the wall at intervals and mark its outside face on the countertop. Remove the countertop and fasten the backsplash to the counter top on the marked lines. Fasten the counter top and backsplash in position.

Another method is to leave off the laminate on the face of the backsplash. Fasten the counter top in position. Hold the backsplash down tight on the counter top and nail it to the wall through its face. Then laminate the face of the backsplash on the job after it has been fastened in position. The disadvantage of this method is that it is difficult to remove the backsplash if the counter top has to be replaced.

DRAWERS

Builders use many methods of building drawers. The three most common methods are the multiple dovetail, lock-shouldered, and square-shouldered methods (fig. 5-13).

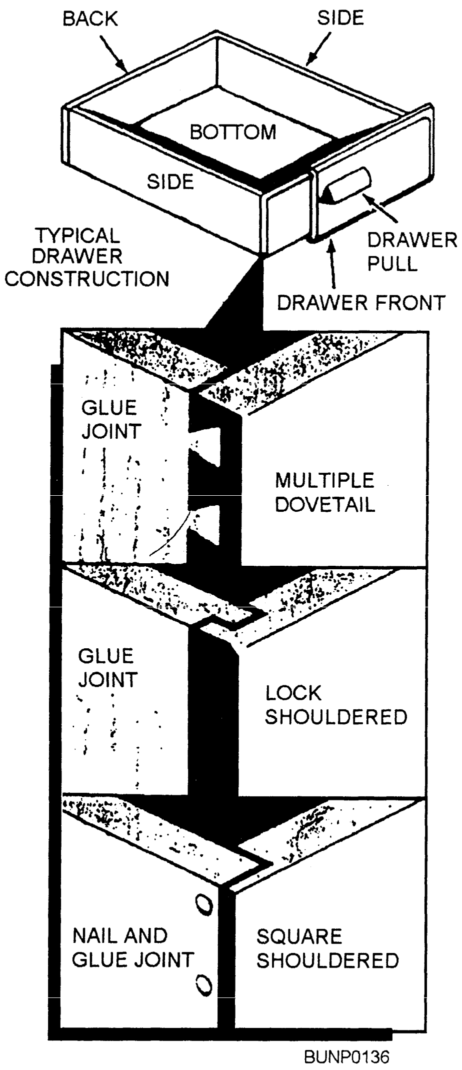


Figure 5-13.—Three common types of joints used in drawer construction.

Several types of drawer guides are available. The three most commonly used are the side guide, the corner guide, and the center guide, as shown in figure 5-14, view A.

The two general types of drawer faces are the lip and flush faces, as shown in figure 5-14, view B. A flush drawer must be carefully fitted. A lip drawer must have a rabbet along the top and sides of the front. The lip style overlaps the opening and is much easier to construct.

Drawer dimensions are usually given as width, height, and depth, in that order. The width of the drawer is the distance across the drawer opening. The height is the vertical distance of the opening. The depth is the distance from the front to the back.

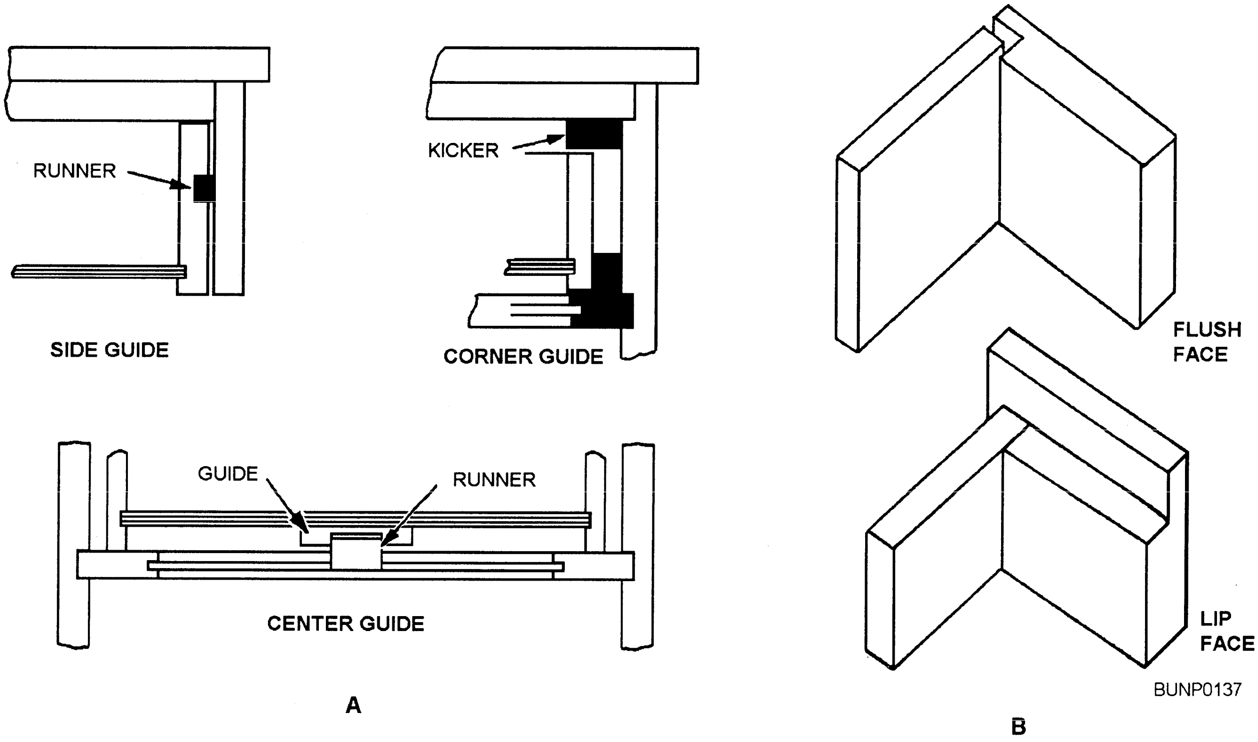


Figure 5-14.—Types of drawer guides (view A) and faces (view B).

Usually drawer fronts are made of 3/4-inch plywood or solid wood. The design must be in keeping with the cabinet. Sides and backs are generally l/2-inch-thick solid wood. Sides are made thicker if they are to be grooved for certain types of drawer guides. The drawer bottom is usually make of l/4-inch plywood or hardboard. Smaller drawers may have 1/8-inch hardboard bottoms.

CABINET DOORS

The four types of doors commonly used on cabinets are the flush (inset), lipped, overlay, and sliding doors.

A *flush door,* like the flush drawer, is the most difficult to construct. For a finished look, each type of door must be fitted in the cabinet opening within 1/16-inch clearance around all four edges. A *lipped door* is simpler to install than a flush door since the lip, or overlap, feature allows you a certain amount of adjustment and greater tolerances. The lip is formed by cutting a rabbet along the edge. *Overlay doors* are designed to cover the edges of the face frame. Several types of *sliding doors* are used on cabinets. One type of sliding door is rabbeted to fit into grooves at the top and bottom of the cabinet. The top groove is always made to allow the door to be removed by lifting it up and pulling the bottom out.

Door Construction

Doors are constructed as solid, flexible, folding, or paneled doors.

Solid doors are made of plywood, hardboard, particle board, or glued-up solid lumber. Designs are often grooved into the door with a router, or molding may be applied to give the door a more attractive appearance.

Flexible doors are made of thin strips glued together on a canvas back or held together with special edge joints. They are used on roll-top desks and other cabinets when the door must slide around a comer.

Paneled doors have an exterior framework of solid wood and a center containing one or more panels. The panels may be solid wood, plywood, hardboard, metal, plastic, glass, or some other material and come in many different designs. The exterior framework can be shaped in a number of ways also.

Door Installation

Cabinet doors can be installed as overlay, lipped, flush, and sliding. *Overlay doors* cover the opening, usually by 3/8 inch on all sides, and swing on overlay hinges. *Lipped doors* are rabbeted over the opening and swing on offset hinges. *Flush doors* fit inside the opening and swing on either surface hinges or butt hinges, *Sliding doors* roll on tracks of metal or plastic.

HINGES

Hinges are made in many styles and shapes. If the kind of hinge is not specified, select a design that blends well with the cabinet being constructed. Some types of hinges are the surface, butt, offset, semiconcealed, pivot, piano hinge, and the new European-style hinge.

The *surface hinge* mounts on the exterior surface of the door and frame. It is made straight for flush doors or offset for lipped doors. This type of hinge is used when it is desirable to show the hardware, such as early American furniture.

The *butt hinge* is used on flush doors when little hardware must show. When it is installed, only the pin of the butt hinge shows when the door is closed. These hinges require a little extra time to install. It is recommended that you recess or mortise the hinge into the wood.

The *offset hinge* is used on lipped doors that are made from plywood. The offset hinge comes in various sizes to match the thickness of the plywood and the offset hinge must be mortised, rather than surface-mounted.

The *semiconcealed hinge* is designed for lipped and overlapping doors. This hinge has one leaf exposed on the face of the cabinet and the offset leaf is mortised into the door. Before the door is rabbeted, check the hinge to ensure that you rabbet the door to the proper depth.

The *pivot hinge* is used on overlay doors. It is fastened to the top and bottom of the door and to the inside of the case. It is used frequently when there is no face frame on the case. The doors completely cover the face of the case.

The continuous or *piano hinge* is a one-piece hinge that usually extends the whole length of the door. It is installed like a butt hinge, and only the hinge pin is exposed. This type of hinge is used when the door is subjected to heavy use.

The *European hinge* can be used on overlay or flush doors and is an excellent hinge used for frameless cabinets. This hinge has two leafs—the hinge cup leaf and the adjustable leaf. The hinge cup fits into a 1 3/8-inch hole (use a forstner bit to drill hole) on the cabinet door. The other leaf is screwed to the side panel of the cabinet. This leaf has an oval adjustment screw that allows the hinge to adjust up and down while the center mechanism adjustment has two screws that adjusts the hinge left and right.

The number and size of hinges depend on the dimensions of the door. There are two rules to follow: First, on any door that is longer than 2 feet, install three hinges; second, the total length of the hinges should equal at least one sixth of the length of the hinged edge. For example, if the door is 24 inches in height, use two 2-inch hinges; if the door is 34 inches, use three 2-inch hinges. When only two hinges are required, they are usually placed one quarter of the way from the top and bottom of the door. When three hinges are required, install the first hinge in the center and the other two hinges are placed 4 to 5 inches from the top and bottom.

CATCHES

Some hinges are self-closing; therefore, they eliminate the need for installing catches to hold the door closed. Others require catches. There are many kinds of catches available for holding doors.

Catches should be placed in the most out-of-the-way position possible. For instance, they are placed on the underside of shelves instead of on top.

Magnetic catches are used widely. They are available in single or double magnets of varying holding power. An adjustable magnet is attached to the inside of the case and a metal plate to the door. Other types of catches are the roller type and the friction type.

Elbow-type catches are used to hold one door of a double set. It must be released by reaching in back of the door. These are used when one of the doors is locked against the other.

Bullet catches are spring-loaded and fit into the edge of the door. When the door is closed, the catch fits into a recessed plate mounted on the frame.

LAMINATING COUNTER TOPS

In cabinetwork, the countertops are usually covered with a 1/16-inch layer of high-pressure plastic laminate. Although this material is very hard, it does not possess great strength and is serviceable only when it is bonded to plywood, particle board, or wafer wood. This base, or core material, must be smooth and is usually 3/4-inch thick.

Plastic laminate is a very tough material. It is widely used for surfacing counter tops, kitchen cabinets, and many other kinds of cabinetwork. It can be scorched by an open flame but resists heat, alcohol, acids, and stains. Another advantage of plastic laminate is that no finishing is required. It also cleans easily with mild detergent.

Laminates are known by such trade names as *Formica, Micarta, Texolite, Wilson Art, Melamite,* and many others. They are manufactured in many colors and designs including many wood grain patterns. Surfaces are available in gloss, satin, textured, and other finishes. The distributor supplies samples or chips of the different colors and finishes to help the customer decide which to use.

Thicknesses

Generally two thicknesses of laminates are widely used: thick and thin.

Thick laminate is about 1/16-inch thick. It is used on horizontal surfaces, such as counter tops, tables, dressers, and desk tops.

Thin laminate is about 1/32-inch thick. It is used on vertical surfaces, such as the sides and front of kitchen cabinets. This is because vertical surfaces take less wear than horizontal surfaces. Thin laminate makes a more pleasing appearance because of the thin edge line it presents when trimmed. It is also less expensive than the thick laminate.

A thinner laminate, called backer laminate, is also available. It is used to cover the inside of doors and the underside of tabletops to give a balanced construction to the core.

Width and Lengths

Plastic laminate sheets come in widths of 24, 30, 36, 48, and 60 inches and lengths of 5, 6, 8, 10, and 12 feet. Sheets are usually 1 inch wider and longer than the size indicated.

Most distributors cut sheets in half through their width or length. This action increases the range of sizes. Since the material is relatively expensive, it is wise to carefully plan and order the most economical sizes.

Inspecting the Surface

Before a counter top is laminated, make sure all surfaces are flush. There should be no indentations where the pilot of the router bit will ride. Check for protruding nailheads and points. Plane or sand surfaces that are not flush. Fill in any holes and sand them smooth. Drive nailheads flush, fill, and sand.

Cutting Laminate to Rough Size

There are a number of ways to cut laminate. Whatever method is used, cut the pieces 1/4 to 1/2 inch wider and longer than the surface to be covered. Laminate must be handled carefully, because it is very brittle. It may crack if dropped or handled roughly.

One method of cutting laminate is to use a straightedge and a router with a flush trimming bit. This method is used frequently by installers on the job and in the shop. It is easier to run the cutting tool across a larger sheet than to move a large sheet across the cutting tool. Also, the router bit leaves a smooth edge.

The table saw can produce a smooth edge, cut with a 60-tooth, triple-chip carbide blade. Laminate may also be cut with a portable circular saw, saber saw, or band saw. However, these tools will not give a clean, ship-free edge.

Working with Laminates

Plastic laminates can be cut to rough size with a table saw, portable saw, or saber saw. Use a fine-tooth blade, and support the material close to the cut. If no electrical power is available, you can use a finish handsaw or a hacksaw. When laminates are cut with a saw, place masking tape over the cutting area to help prevent chipping the laminate. Make cut markings on the masking tape.

Measure and cut a piece of laminate to the desired size. Allow at least 1/4-inch extra to project past the edge of the counter top surface. Next, mix and apply the contact bond cement to the underside of the laminate and to the topside of the counter top surface. **Be sure to follow the manufacturer's recommended directions for application.**

Adhering Laminates

Allow the contact bond cement to set or dry. To check for bonding, press a piece of waxed brown paper on the cement-coated surface. When no adhesive residue shows, it is ready to be bonded. Be sure to lay a full sheet of waxed brown paper across the counter top. This allows you to adjust the laminate into the desired position without permanent bonding. Now, you can gradually slide the paper out from under the laminate, and the laminate becomes bonded to the counter top surface.

Be sure to roll the laminate flat by hand, removing any air bubbles and getting a good, firm bond. After the laminate is sealed to the counter top surface, trim the edges by using either a router with a special guide or a small, block plane. If you want to bevel the countertop edge, use a mill file.

ADHESIVES

Seabees use many different types of adhesives in various phases of their construction projects. Glues (which have a plastic base) and mastics (which have an asphalt, rubber, or resin base) are the two major categories of adhesives.

The method of applying adhesives, their drying time, and their bonding characteristics vary. Some adhesives are more resistant to moisture and to hot and cold temperatures than others.

> **SAFETY NOTE:** Some adhesives are highly flammable; they should be used only in a well-ventilated work area. Others are highly irritating to the skin and eyes. ALWAYS FOLLOW MANUFACTURER'S INSTRUCTIONS WHEN USING ADHESIVES.

Glues

The primary function of glue is to hold together joints in millwork and cabinetwork. Most modern glues have a plastic base. Glues are sold as a powder to which water must be added or in liquid form. Many types of glue are available under brand names. A brief description of some of the more popular types of glue is listed below.

Polyvinyl resin, or white glue, is a liquid that comes in ready-to-use plastic containers. It does a good job of bonding wood together, and it sets up (dries) quickly after being applied. Because white glue is not waterproof, it should not be used on work that will be subjected to constant moisture or high humidity.

Aliphatic resin, or yellow carpenter's glue, is a liquid that comes in ready-to-use plastic containers. Yellow glue is somewhat stronger than white glue and is more resistant to moisture, lacquers, and solvents.

Urea resin is a plastic-based glue that is sold in a powder form. The required amount is mixed with water when the glue is needed. Urea resin makes an excellent bond for wood and has fair water resistance.

Phenolic resin glue is highly resistant to temperature extremes and water. It is often used for bonding the veneer layers of exterior grade plywood.

Resorcinol glue has excellent water resistance and temperature resistance, and it makes a very strong bond. Resorcinol resin is often used for bonding the wood layers of laminated timbers.

Contact cement is used to bond plastic laminates to wood surfaces. This glue has a neoprene rubber base. Because contact cement bonds very rapidly, it is useful for joining parts that cannot be clamped together.

Mastics

Mastics are widely used throughout the construction industry. The asphalt, rubber, or resin base of mastics gives them a thicker consistency. Mastics are sold in cans, tubes, or canisters that fit into hand-operated or air-operated caulking guns.

These adhesives can be used to bond materials directly to masonry or concrete walls. If furring strips are required on a wavy concrete wall, the strips can be applied with mastic, rather than by the more difficult procedure of driving in concrete nails. You can also fasten insulation materials to masonry and concrete walls with a mastic adhesive. Mastics can also be used to bond drywall (gypsum board) directly to wall studs. They can also be used to bond gypsum board to furring strips or directly to concrete or masonry walls. Because you don't use nails, there are no nail indentations to fill.

By using mastic adhesives, you can apply paneling with very few or no nails at all. Wall panels can be bonded to studs, furring strips, or directly against concrete or masonry walls. Mastic adhesives can be used with nails or staples to fasten ply-wood panels to floor joists. The mastic adhesive helps eliminate squeaks, bounce, and nail popping. It also increases the stiffness and strength of the floor unit.

CHAPTER 6

QUALITY CONTROL

LEARNING OBJECTIVE: *To describe the purpose and identify the procedures and methods of inspecting construction projects and materials under the Construction Quality Control Program.*

In the previous chapters, we covered ways in which to plan, organize, read plans and specifications, estimate, schedule, manage, and execute construction projects. Now, let's cover how construction projects need to be constructed with quality in mind.

In the Seabee community, the word *quality* ranks right along with safety. The customer would like to see a quality project done safely and in a timely manner. Doing quality work for the customer will bring job satisfaction to you and increase the chances of the customer coming back for possible future work. Having satisfied customers leads to getting new customers, which means job security.

For NAVFAC to ensure quality workmanship, it has developed the following quality management programs of their own:

- *Construction Contract Quality Management Program,* NAVFAC P-445
- *Facilities Support Contract Quality Management Program,* MO-327
- *Construction Quality Control (CQC) Program,* COMSECOND/COMTHIRDNCBINST 4355.1 (series)

These three programs deal with quality; however, they pertain to certain aspects of quality.

1. The NAVFAC P-445 states how the contractor and the government will produce a quality project on time and in compliance with the terms of the contract.

2. The MO-327 provides naval shore activity guidance on obtaining quality public works support services through quality assurance.

3. The COMSECOND/COMTHIRDNCBINST 4355.1 prescribes the policy, the objectives, and the procedures to ensure that the required quality is achieved on construction projects assigned to NCF units.

Before we cover quality control, let's first define QUALITY and distinguish the differences between quality control (QC) and quality assurance (QA). At times, the construction industry tends to get these terms confused.

- QUALITY is an acquired skill to the degree of being excellent. The Navy recognizes QUALITY as individual contribution and team effort in an organization working together to improve the process/system or product. TEAMWORK is essential.

- QUALITY ASSURANCE is concerned with the quality of the end product, not with the procedures used to get to that product. Surveillance and inspections are the methods used to review performance standards. The receiving officer in charge of construction (ROICC) usually oversees these methods. Surveillance and inspections are covered thoroughly in the *NCF/Seabee Petty Officer 1 & C,* NAVEDTRA 12543.

- QUALITY CONTROL reviews each step or procedure used in completing tasks on the way to the completed product. Quality control checks are normally performed daily. NMCBs, CBUs, and other construction units run the quality control program.

QUALITY CONTROL

Quality control is a management system of published and enforced standards which ensures that a construction project is completed with a specified minimum quality. A product that falls below minimum standards will not satisfy the customer or its intended purpose, and it may require excessive maintenance costs. A product that exceeds the standards generally consumes more resources than planned; however, it's better to exceed the standards than to not meet the standards.

Quality control is the responsibility of each member in the chain of command. Each person in the construction chain of command must be familiar with personnel responsibilities to ensure a quality project. You must remember that plans and specifications are the construction standards and may vary from project to project.

A project which costs a life or serious injury is not a quality project. Safety and good housekeeping are very important elements in obtaining a finished product of acceptable quality.

ENSURING QUALITY

The crew leader must plan quality into any project and develop a QC plan for each project. This plan ensures that the quality of the construction meets the standards in the plans and specifications. The development and implementation of a QC plan can be broken down into steps covered in the material that follows.

Establish Quality Measures

The first step in ensuring quality is to establish the means of measuring QC progress. The crew leader must review the plans and specifications and identify the required quality criteria. For instance, the quality criteria for reinforcing steel would be the size, the placement, the anchoring, and the distance lapped. Quality measures must be specific (for example, the specifications may require that rebar be at least 1 1/2 inches from inside of the forms and the rebar must be lapped 24 inches at splices). QC measures are to be listed in "plain language" on the CAS sheet. These measures are then transferred to the QC plan. The crew leader, the QC rep, and the inspector (ROICC) should agree in advance on how the various tests are to be performed and exactly what the requirements are. For example, when laying block and the requirement is within 1/4-inch plumb within 10 feet, will this be measured with a string line, a level, or some other method? Figures 6-1 and 6-2 are samples of project QC plans.

PROJECT QC PLAN

I. Project Name and Number

II. Project Location

III. Prime Contractor
Subcontractors (a)
(b)

IV. Project Scope

V. Type of Testing Required (soil, concrete, etc.)

VI. Type of Associated Risk (fire, fumes, noise, etc.)

VII. Special Training Requirements

VIII. Special License Required

IX. Engineering Controls (guards rails, welding curtains, etc.)

X. Testing Equipment Required (state how it is to be used)

XI. Personal Protective Equipment Required for Testing

Project Planner: ______________________________
Print name, rate and company/det

QC Chief: Approved/Disapproved ______________________________
Signature

Reason for disapproval ______________________________
____

Figure 64.—Project QC plan cover sheet.

QUALITY CONTROL PLAN

PROJECT NUMBER ______________ **PROJECT TITLE** ______________________ **DATE** ________

ACTIVITY NUMBER	ACTIVITY DESCRIPTION	QUALITY CONTROL REQUIREMENT	SPECIFICATION REFERENCE	REMARKS / RESULTS

BUNP0138

Figure 6-2—QC plan.

The second step in ensuring quality is the proper selection of construction methods that are essential to safe, quality construction. Construction methods must be determined very early in the planning stage of the project, as they impact on equipment, tools, material, labor, training, and safety requirements. Construction methods selected in the planning stage will also, to a great extent, determine the quality of the finished product. Commonly accepted construction practices have resulted from people doing the same work for many years. This is usually the most effective way to accomplish safe, high-quality work. Use these accepted practices where you have the skills and equipment to do so and discuss these methods with the crew, the chain of command, and the QC inspector.

Identify Required Training and Equipment

The crew leader must be aware that many activities require specialized training or qualifications. Some activities, such as welding certifications or cable splicing, may only be satisfied through formal instruction. Formal training for a great many activities is simply impractical. It is frequently necessary to identify the skills required and find alternate sources of training. The most common source of informal training is on-the-job training (OJT). Use OJT when you can identify at least one person who knows how to perform the task correctly (either yourself, a crew member, or a QC rep) and schedule enough time to show the remaining crew the proper techniques. Remember that one purpose of projects is to provide training for our people. Teaching your crew the proper methods and techniques should be high on your list of priorities. Besides the required training, the required equipment must also be available to accomplish the task according to the method selected. Finishing a large concrete pad without the use of a power trowel (whirly-bird) might prove to be difficult. Renting one with project funds may be an option if you do not have one at the deployment site.

Ensure Personnel Awareness

Another important step in the implementation of a QC plan is personnel awareness. Each crew member must understand what the quality measures are and inspect the work of the crew for quality on a daily basis. Before you start work on an activity, all crew members should be briefed about critical measurements, inspection items, potential problems, and each member's responsibility for quality. Remember, quality is everyone's responsibility. If you use the crew briefing checklist shown in figure 6-3, all of these items will be addressed.

Evaluate Completed Work

The last major step in QC plan development is the daily QC inspection report. This daily report is required for all projects. The purpose of this report is to document the completion of all required checks, tests, and inspections. All work completed or in progress either is or is not according to the specifications. The daily report is signed by both the QC inspector and the crew leader and then forwarded to the operations officer or detail OIC with a copy to the ROICC office, the company commander, and the crew leader. Figure 6-4 is a form for the daily QC report. All checks, tests, and inspections are listed on the back of the CAS sheet.

MASTER ACTIVITY PREP LIST

Project Number ____________________
Project Title ____________________
Activity Number ____________________
Activity Description ____________________
Early Start Date ____________________
Late Finish Date ____________________
Estimated Duration ____________________

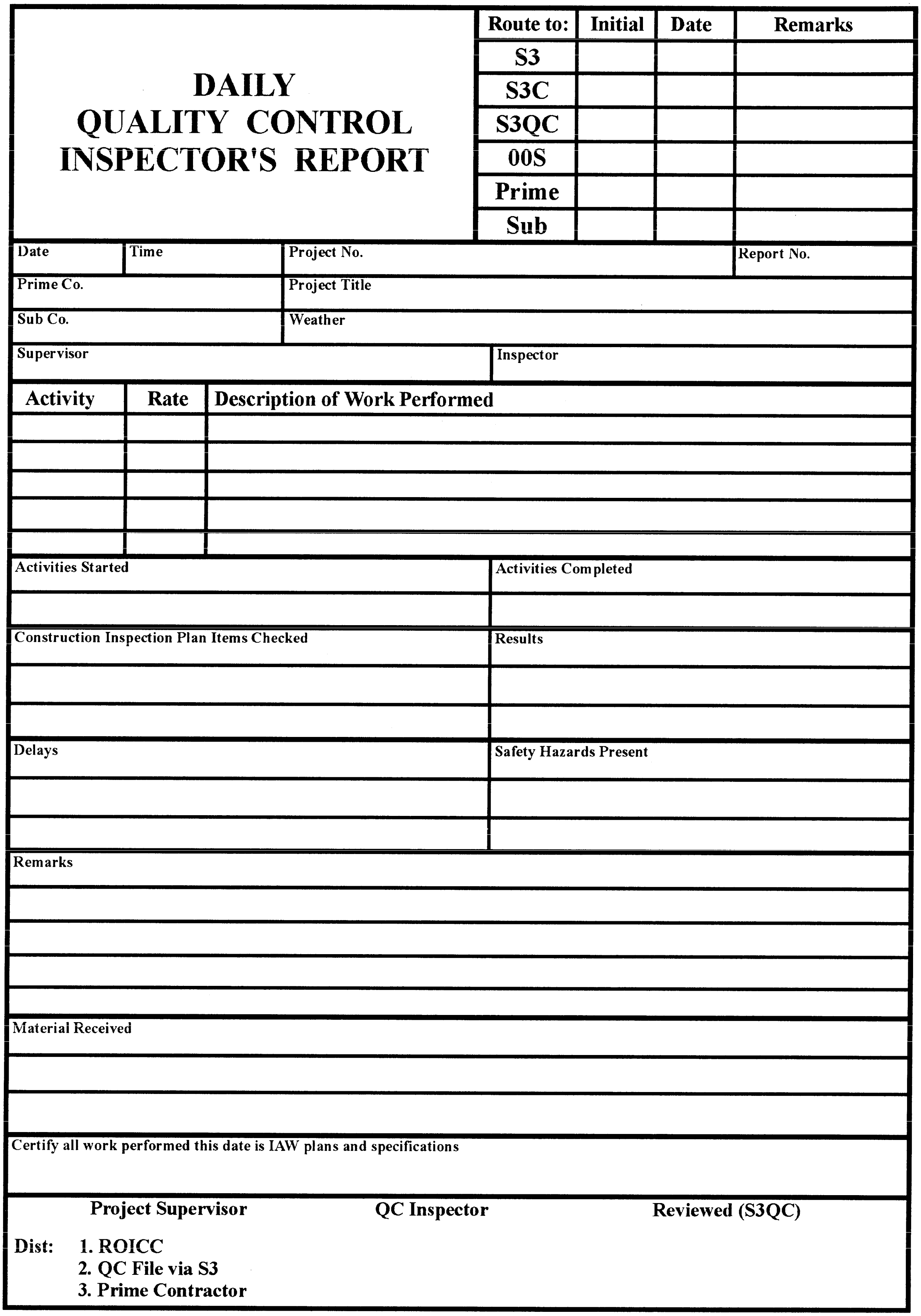
Resource check to be completed by the crew leader before commencement of work: (Y/N)

Have the construction methods been clearly described on the CAS sheets? ______
Are all the materials estimated on the CAS sheets on site, stored properly, and in compliance with the plans and specifications? ______
Have required shop drawings been prepared? ______
Has the equipment listed on the CAS sheets been reserved? ______
Are the tools listed on the CAS sheets on site or being reserved? ______
Is the safety equipment/personal protective gear listed on the CAS sheets on site or reserved? ______

Briefing of crew to be completed by the crew leader before commencement of work: (√)

Discuss all required tests and inspections. ______
Establish levels of quality for each element of the work. ______
Discuss all other pertinent parts of the specifications. ______
Discuss each individual's job and establish specific measures of performance. ______
Define each crew member's responsibility and authority. ______
Clearly outline the sequence of work activities. ______
Discuss all safety requirements from the CAS sheets and instruct crew members in the proper use of safety equipment. ______
Stress the importance of good housekeeping. ______

Figure 6-3.—Master activity prep list.



DAILY QUALITY CONTROL INSPECTOR'S REPORT

Route to:	Initial	Date	Remarks
S3			
S3C			
S3QC			
00S			
Prime			
Sub			

Date

Time

Project No.

Report No.

Prime Co.

Project Title

Sub Co.

Weather

Supervisor

Inspector

Activity	Rate	Description of Work Performed

Activities Started

Activities Completed

Construction Inspection Plan Items Checked

Results

Delays

Safety Hazards Present

Remarks

Material Received

Certify all work performed this date is IAW plans and specifications

Project Supervisor **QC Inspector** **Reviewed (S3QC)**

Dist:
1. ROICC
2. QC File via S3
3. Prime Contractor

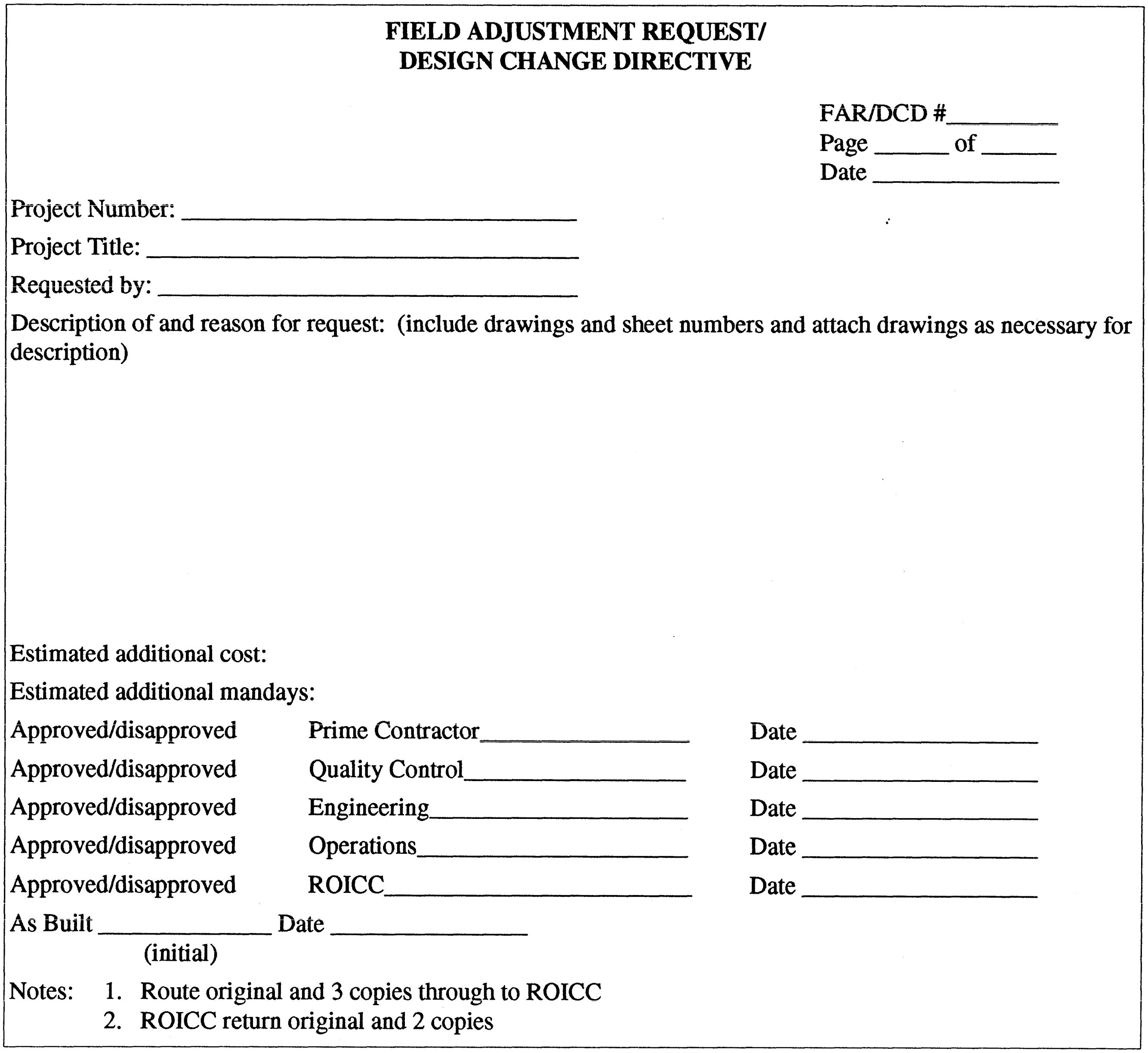
BUNP0139

Figure 6-4.—Daily QC Inspector's Report.

Everyone on the crew should know in advance what the inspections will consist of and what the end results are.

ROICC INTERFACE

The ROICC is responsible for the inspection and surveillance of ongoing NCF projects and for reviewing daily QC reports to ensure compliance with the plans and specifications. The ROICC office also has to approve any battalion recommended field adjustment requests (FARs) or customer requested changes. Scope changes require the approval of the customer's major claimant. Any changes that require 50 or more man-days of additional direct labor or any changes that increase the cost of the project by $500 or more require the approval of COMSECONDNCB/COMTHIRDNCB. The ROICC also conducts the final inspection and accepts only those facilities built according to the plans and specifications. The QC staff provides direct liaison between the battalion and the ROICC on all matters, such as change requests and project specification questions. No field changes can be made without a request being forwarded through the QC staff and being approved in writing by the ROICC. Change requests must include the same level of detail as the original specification. The engineering division can provide assistance on sketches for your change requests. Figure 6-5 is a sample design change request. A log of all design change requests in a format similar to figure 6-6 must be kept in folder six of the project package.



FIELD ADJUSTMENT REQUEST/
DESIGN CHANGE DIRECTIVE

FAR/DCD #________
Page ______ of ______
Date _______________

Project Number: ________________________________
Project Title: ________________________________
Requested by: ________________________________
Description of and reason for request: (include drawings and sheet numbers and attach drawings as necessary for description)

Estimated additional cost:
Estimated additional mandays:
Approved/disapproved Prime Contractor________________ Date __________________
Approved/disapproved Quality Control________________ Date __________________
Approved/disapproved Engineering____________________ Date __________________
Approved/disapproved Operations_____________________ Date __________________
Approved/disapproved ROICC_________________________ Date __________________
As Built _____________ Date _______________
(initial)

Notes: 1. Route original and 3 copies through to ROICC
2. ROICC return original and 2 copies

Figure 6-5.—Design change request.

FIELD ADJUSTMENT REQUEST (FAR)/DESIGN CHANGE DIRECTIVE (DCD) SUBMITTAL LOG

FAR #	Description	Spec Section	Drawing Number	Date to Ops	Date Returned	Approved/ Disapproved

BUNP0140

Figure 6-6.—Field Adjustment Request Submittal Log.

INSPECTIONS

A Builder who is well-qualified and has shown the capability to handle the responsibility of an important position may be selected to serve in the role of QC inspector for the OPS Department of a NMCB. In addition, qualified Builders may find themselves assigned to a Public Works Department where they will serve as project and maintenance inspectors for the facilities at their base. A good guide to use for checking your projects is the *Construction Inspector's Guide*, EP 415-1-261, published by the U.S. Army Corps of Engineers.

In this section, we will cover the responsibilities of the inspector and point out items checked in inspecting various parts of buildings and other structures. Bear in mind that inspections are broad in scope, so every area covered in an inspection is not listed; however, you are provided with the basics of performing an inspection. In addition to the checkpoints given here, other important points could be included in your inspection, based on plans and specification, local building codes and regulations, manufacturer's specifications, special requirements, and so on. Remember that as crew leaders and project managers, you are also inspectors of your own projects.

INSPECTORS' RESPONSIBILITIES

The prime function and responsibility of the inspector is to make certain that the work is performed in every aspect with the drawings and specifications. These requirements are usually, but not always, sufficiently exacting to necessitate high standards of quality in both materials and workmanship. In the case of temporary or emergency construction, quality requirements may be lowered intentionally. Therefore, the inspector must be careful to make certain that the work is of the required quality while being equally careful not to demand a quality of work superior to that required. In addition, the inspector should ensure that any construction changes, omissions, or additions are made to the blueprint to show the final, as-built conditions.

In some cases, the specifications for the project or the standard specifications that are included as references may establish definite tolerances over or under the measurements that will be accepted. Then the inspector only has to verify that the work is within the specified limits. However, on most phases of the work, specific tolerances cannot be fixed, and intelligent judgment is required in interpreting such requirements as plumb, true, level, and perfect. The inspector's intention is that the workmanship be of the most suitable grade for the purpose for which the finished project is to be used. The inspector, therefore, should have a comprehensive, practical knowledge of the grades of workmanship satisfactory in the various classes of structures and in the various details of the work.

The acceptable degree of accuracy is dependent on many factors. Structural framing may have to be true within one-sixteenth of an inch or, in some cases, within one-eighth of an inch. Concrete work can seldom be held closer than one-eighth of an inch; but in some special types of structures, much larger tolerances must be permitted and allowed.

The inspector must make sure that the principal center line, column lines, and controlling overall dimensions and elevations are correct; that minor errors are not permitted to accumulate, but are compensated for continuously; that exposed work is visually acceptable; and that special care is taken when greater than ordinary precision for the type of work is necessary for some special reason.

It is important that the inspector make clear at the outset of the work what will be expected and that the initial portions of the work fulfill these expectations. Invariably, the standards of accuracy established and enforced during the first few days of work will set the pattern for the rest of the work. Inspectors must be consistent in the standards they exact. They must be reasonable, but not be too lenient in this respect.

Inspections of temporary construction must be limited to assure the work is adequate and safe for the purpose for which it was intended. The inspectors should, however, be alert to note any defective construction, unsound materials, possible weaknesses, and hazards and then call them to the attention of their superiors.

Inspectors are responsible for the effective application of the safety program for the projects to which they are assigned. This responsibility covers the prevention of accidents that would cause physical injury or property damage. In the event that inspectors encounter difficulty in correcting an existing hazard, a safety violation, or preventing a future hazard, they should immediately report such conditions to a superior for the proper action and/or guidance.

An extremely important and relatively difficult phase of an inspection is in the checking of a project as it nears completion to make sure that every item required for the completion of the project has actually been provided. The use of a checkoff system is essential for this purpose. This system should be adopted and initiated early enough to allow ample time for delivery and installation of any items that might be overlooked. This is particularly necessary in times of emergency when long lead time between ordering and delivery is encountered for many critical items of material and equipment. Inspectors must maintain a strict watch over cleanup items particularly where portions of the work may be concealed in later stages. Because of the inherent tendency of construction projects to drag out to a slow finish, the inspectors will have to exert greater pressure to obtain full and rapid compliance with the time requirements for completing the project.

Inspectors may be responsible for maintaining accurate and detailed records of performance of their work and of various pertinent matters. Records and reports should be in a clear, complete form so that no possible misinterpretation of the facts or uncertainty about events may arise.

As an inspector, you have contact with other people and need an understanding of human relations. You must use tact and courtesy in dealing with others. If you give criticism, you should do so constructively and in a manner that will not cause resentment. You must avoid showing any favoritism or partiality. And, in particular, you must avoid making any statements or taking any action that might discredit any supervisors or foremen when their subordinates are present.

It is imperative that you, as an inspector, conduct yourself at all times in a manner commensurate with the highly responsible position you occupy. You must be absolutely honest in your dealings with others. Integrity is a fundamental requisite. You must be trustworthy, loyal, diligent, and punctual. You must be dignified, steady, and poised in all your actions. When your job involves supervising others, as the inspector, you must be firm, but fair, in handling your subordinates. You must maintain your self-respect and win the respect of all your associates, always keeping in mind that a harmonious relationship is more successful than one hampered by friction and discord.

The rest of this chapter covers commonly encountered problems in the inspection of construction projects or maintenance of facilities. This chapter is not intended to identify every inspection processor identify new construction technology. For more information, refer to the *Construction Inspector's Guide,* NAVFAC P-456 (series), or the *Construction Inspector's Guide, EP-415-1-261,* U.S. Army Corps of Engineers.

CONCRETE CONSTRUCTION

When assigned to inspect concrete construction, you must have a thorough understanding of the standard specifications and the best techniques and methods for meeting those specifications. Concrete construction must meet the requirements set by the *American National Standards Institute (ANSI),* A10.9, "Safety Requirements for Concrete Construction and Masonry Work."

The standard specifications cover a wide range of possible conditions and allow a choice of types of cement, sizes and types of aggregates, and classes of concrete. The specific requirements for each project must, therefore, be set forth in a definitive manner in the drawings and specifications for the work. You should verify that all variables and options permitted by the standard specifications are fixed by the project documents and you should call any apparent omissions to the attention of a superior.

Preparatory Work

As soon as the batch plant is set up or a local batch plant has been identified for producing and delivering concrete, familiarize yourself with the functional arrangement, transportation, and check all equipment to make sure it is in good working order. You should be present at any trial runs made and make sure that any deficiencies that develop are corrected. If any serious deficiencies are apparent that cannot be readily overcome and that might affect the efficiency of the operations, you should inform your superior of the situation.

Before permitting any concrete to be placed, you must submit a “hard card” to the ROICC or the OPS Department. A “hard card,” or Concrete Placement Clearance Form (fig. 6-7), is a checklist to be completed before placement of the concrete. This is an excellent checklist for you to ensure yourself and the ROICC that every aspect has been thoroughly covered and your crew is ready to place the concrete.

You must make sure that the formwork complies in all respects with the applicable requirements of the specifications. When old forms are reused, make sure they have been properly repaired and cleaned. If the forms are of considerable height, you must see that openings have been provided as necessary for placing concrete without excessive drop. See chapter 4 for these requirements. Before placing concrete, you must make sure that all debris has been completely removed from inside the forms and that the contact surfaces of the forms have been wetted, oiled, or coated as specified. Generally, form contact surfaces are oiled before being erected. When used for footings, abutments, and other large sections, you should oil the forms after erection if care is taken to avoid getting oil on the reinforcement.

All reinforcement must be checked in detail to make sure that it is of the specified size, length, type, form, and spacing; is clean and free from loose rust or scale; is firmly secured by approved devices against displacement; and is accurately located to assure that the required cover will be obtained. Splices must be checked for location, length of lap, clearances between bars, and clearance of bars to forms and dirt. When welded butt or lap splices are required or permitted, you must check the quality, the size, and the amount of weld.

You must be sure that all anchors, inserts, dowels, sleeves, pipes, and similar fixtures that have to be embedded in the concrete are accurately placed and firmly secured to the forms. Before and during placing operations, you must check the concrete mixture for conformity with specifications. This means verifying slump tests, air-entrainment tests, and the preparation of laboratory test samples for compressive and flexural strength tests.

Placing

When ready-mixed concrete is to be used, you must ensure the requirements of the specifications for the method of mixing and delivery are fully met. When job mixing at a central plant at the site is adopted, make sure the methods of transporting the concrete assure rapid delivery without segregation or loss of material.

Concrete may be conveyed from the mixer or delivery point to the forms by carts, buckets, chutes, pneumatic methods, pumping, or tremie. You must make sure that the methods and equipment meet with the approval of your superior when so required. You must, in all cases, be satisfied that the concrete, as placed, is acceptable in all respects and likewise require correction of deficiencies in methods or equipment if the concrete is not of acceptable quality.

You must make sure that the concrete does not displace the reinforcement and that construction joints and expansion joints are provided at all required locations and are properly located and formed. If concrete is placed in cold weather by a tremie or under other special circumstances, you must make sure that the special precautions required are taken.

Finishing

You must remember the importance of uniformity of the finish and the surface texture. To inspect, you should familiarize yourself with the proper techniques for achieving satisfactory results and with the causes and methods of avoiding the common defects in the finish. Excessive surface water, for example, results from too wet or too sandy a mix or from overworking. Such excess water should be removed by blotting methods or by evaporation, and not by sprinkling dry cement on the surface. Excessive troweling brings laitance to the surface and gives a surface that soon dusts and deteriorates. The drying of concrete too rapidly leads to hair cracks. Placing a topping over dry concrete causes alligator cracking from rapid absorption of water by the base course. You must assure yourself that the methods and techniques used prevent such defects and deficiencies.

Curing

Specifications contain specific requirements for the protection and curing of concrete, including special requirements for certain cases. You must determine which requirements are correct for the project. You should give careful attention to the requirements for the length of the curing period required and the length of time forms or supports must be kept in place. You must make sure that the curing methods fully protect the concrete against drying out prematurely. If membrane water proofing is permitted, make sure that the membrane seal is applied so that no gaps or holidays

CONCRETE PLACEMENT CLEARANCE FORM

PART I Date ______________

Project Number ________ Title ______________ Location ______________

Date/Time Desired ______________ QTY Strength (PSI) ______________

Slump (in.) ______ Max Aggregate Size ______ Admixtures ______________

Type of Placement ( ) Roof ( ) Slab ( ) Wall ( ) Other

Finish Required (type): Tolerance ( ) ± 1/4 in. ( ) Other

PART II

	Conforms to Requirements		
Item	N/A	.Crew Leader	QC Insp
Subgrade Prep			
Elevation			
Dimension			
Compaction			
Capillary Barr (sand)			
Vapor Barrier			
Misc. (insec, drain rack, etc.)			
Forms			
Elevation			
Dimensions			
Alignment			
Bracing			
Condition			
Keyways			
Water Stop			
Embedded Items			
Anchor Bolts			
Sleeves			
Misc.			
Reinforcing			
Size			
Location and Spacing			
Chairs (meshups)			
Bracing			

	Conforms to Requirements		
Item	N/A	Crew Leader	QC Insp
Electrical			
Conduit inst/stubbed up			
Sleeves (foundations)			
Pull Cords			
Mechanical			
Sleeves (foundations)			
Sub slab piping			
- pressure tested			
Floor Drains (elevation & location)			
Floor Cleanouts (elevation & location)			
Stubups (location, type)			
Placing/Finishing Equipment			
Screed Boards Set			
Screed Boards Checked			
Placing Tools Set			
Placing Tools Checked			
Finishing Tools Set			
Finishing Tools Checked			
Curing Materials			
Testing Materials (cylinders, slump cone, etc. arranged for or on site)			

Submitted: ______________________ ______________

Approved: ______________________ ______________

Crew Leader Date

Scheduled For: ______________________ ______________

QC Inspector Date

Remarks

BUNP0141

Figure 6-7.—Concrete Placement Clearance Form.

occur. Likewise, you require a second application over uncovered areas.

FOUNDATIONS

Various types of foundations are used in the construction industry today. Because of space limitations, let's consider only two of the main types—mat foundations and spread footings.

Mat Foundations

The mat (raft or floating) foundation is a continuous footing that supports a reinforced concrete slab covering a minimum of 75 percent of the total area within the exterior walls. It is normally used when the subsoil is not considered good enough for spread footings. Mat foundations may take the form of a hollow concrete box with intermediate walls or columns to permit taking advantage of the weight of the earth removed in the excavation to offset, in part, the load imposed on the mat foundations. When inspecting, you must make sure that the subgrade is carefully leveled to the specified elevation so that the concrete will be of full thickness and that special sand or gravel is spread and compacted if called for. Be alert to detect any wide variations in the quality of the subgrade.

Spread Footings

The spread footing (fig. 6-8) is the lowest foundation support and is wider at the base than at the rest of the foundation. For example, a common 8-inch concrete retaining wall is placed on a 16-inch footing. Spread footings are designed for a definite load per square foot, based on prior investigations of the site, or on general knowledge of the characteristics of the soil in the area. Usually, the drawings indicate both the sizes of the various footings and the load on which they are based, normally twice the size of the foundation wall. Your primary function is simply to make sure the footings are the correct size, with satisfactory concrete reinforcement, or other parts, as shown or specified. However, be alert to detect any significant variations in the quality of the substrata from that indicated by boring records or assumed designed loads.

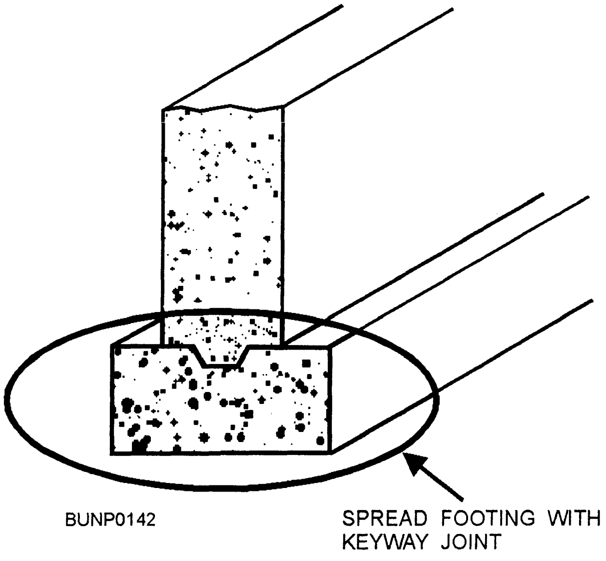


Figure 6-8.—Spread footing with a keyway joint.

It is essential that anchor bolts be set with the utmost accuracy relative to both position and level. Errors discovered after the concrete has set are extremely expensive to correct. This is particularly vital when sleeves are not specified or permitted to allow for lateral play. Anchor bolts are usually set to a template, which is carefully aligned with the building lines and leveled to a definite elevation. You must check the setting and verify beyond question that the template is accurate within permissible tolerances before permitting concreting to proceed. Check the templates periodically during the course of the work to make sure they have not been disturbed. Pay particular attention to the bolt settings to make certain that there is sufficient thread exposed above the top of the steel base plate to permit full engagement of the nuts without excessive projection of the threaded bolt. You must also make sure that the anchor bolts are provided with hooks, L-bends, swaging, or other anchorage devices, as shown or specified. When sleeves are specified, you should make sure that the bolts are centrally located in the sleeves to provide leeway in adjustment in all directions. Ensure that the sleeves are NOT installed in such a manner as to decrease the holding power of the bolts. Later, take care to make sure that the sleeves are properly filled with grout, lead, or sulfur, as the specifications may require, after the steel has been erected and aligned.

CONCRETE FLOORS

Concrete floors may be built on the ground at grade or on well-reinforced overheads. Structural concrete floors may be of flat slab, beam and slab, beam and girder, or steel decking.

On floor construction, you must be sure that forms and supports are designed and installed so that they are readily adjusted to exact grade. Also, ensure that slab forms and beam and girder side forms can be removed after the specified curing period without disturbing the forms under the soffits of beams and girders. You should never permit the removal of soffit forms and supports and reshoring in advance of the time specified. Furthermore, make certain that all forms are accurately and adequately constructed, are adjusted to exact grade, are lined with absorptive lining if specified, and are oiled or otherwise treated as indicated. Take special care to secure clean, true surfaces with straight edges and uniform chamfer strips if the underside of the structural floor will be exposed in the finished work. You must check the work to make sure that all inserts, hangers, anchors, sleeves, and other fittings are provided as required and are accurately located.

You must be sure that curing is performed as shown in the project specifications and that forms and form supports are left in place for the minimum length of time specified for slabs, beam and girder sides, and beam and girder soffits. In addition, you must note particularly concrete that may have been frozen and report the circumstances and conditions to the proper authority.

CONCRETE FRAMING

Concrete framing of buildings generally consists of columns, girders, beams, and slabs. Slab construction consists of columns, capitals, plinths, and slabs with girders and beams used only to frame around openings and to support spandrel walls (area of wall between the header of one window and the sill of the window above).

On building construction, you must be sure that all wall ties, anchors, inserts, and other appliances for fastening are installed in the forms in the exact locations needed and that all the openings for pipes, ducts, vents, and other purposes are formed in the correct locations. A thorough check must be made before permission is given to start concreting. This action ensures that no item has been overlooked.

On building work, pay special attention to the accuracy of alignment, the trueness of exposed surfaces, and the finish. You must ensure that full compensation is made for the change of floor levels caused by the shrinkage of columns. You must give close attention to the location of construction joints and expansion joints, if required. You must make sure that slab forms are kept in position for the full period specified, that forms under beam and girder soffits are kept in place for the additional period required, and that all concrete is cured in the proper manner for the full period prescribed.

CMU WALLS

Concrete masonry units (CMUs) are made with stone, gravel, shale, slag, or cinders as the coarse aggregate. Units usually are made with nominal widths of 3, 4, 6, 8, 10, or 12 inches. Walls and webs usually are 2 inches in nominal thickness, but actual thicknesses may run one-fourth to three-eighths inch less. Units are made with 2, 3, 4, and 6 cores. They are also manufactured in half units and in special units, such as jamb blocks, end blocks, headers, and double-corner units.

In construction involving the use of concrete block, check all material for damage, imperfections, stains, color, size, and marking and make certain that only material conforming fully with the requirements is used in the work. You should also verify the course heights, bond, color pattern, and similar basic requirements.

You must make sure that all masonry units are handled carefully at all stages of the work to prevent damage and see to it that scaffolds and floors are not overloaded by stacking them too heavily.

You must determine that joints conform to the specifications in materials, type, pointing, and finish. To assure sound watertight construction, you must ensure that joints are:

- Completely filled for their entire length and depth and are free of voids.
- Correctly struck without excessive troweling and that the horizontal joints are truly level and that the vertical joints are broken, staggered, or patterned as specified or shown.

When inspecting, you must determine that all joints are tooled to the specified form, if indicated. Where pointing is specified, you must ensure that the mortar joints are raked out to the specified depth, saturated with clean water, refilled solidly with mortar, and tooled. You should also require that all surplus mortar and stains be removed as the work progresses. You should ensure that horizontal or bed joints are finished first and then the vertical joints.

In addition, make sure that the exposed surfaces of masonry units are washed with water and brushed with a stiff brush until all mortar stains have been removed. A weak solution of muriatic acid may be used for stubborn stains, but care should be exercised to require thorough flushing with clean water. Finished terra cotta facing should be cleaned with a stiff brush, using soap powder boiled in water. The brushing should be continued until all stains and dirt are removed. The facing should then be rinsed thoroughly with clean water. Do not permit the use of wire brushes, abrasives, or metal tools because they may damage the surface, the color, the edges, and the joints.

CONCRETE FINISHES

Concrete floor finishes may be either integral with or placed separately from the structural slab and may have coloring pigment or hardening agents incorporated. You must be sure that materials and workmanship conform to the requirements specified for the type required in the project specifications. You must make sure that color pigment or integral hardener is added following the specifications or approved manufacturer's instructions.

If the finish is to be placed integrally, you must see that it is applied within the specified time limit, and to do this, you must ascertain whether the number of qualified finishers is adequate to keep pace with the rate of placing of the floor slab or that this rate is decreased.

When a separate finish is required, you must ensure that the surface of the slab is well-roughened, thoroughly cleaned of all loose material, and brushed with neat cement grout immediately before the finish is placed. Furthermore, be sure that the finishing concrete is placed at the driest practicable consistency to minimize shrinkage; that the dusting on of cement to absorb excess water is not permitted; and that the surface is floated to a true, even surface, level or slightly pitched as specified, and is troweled smooth without voids, exposed aggregate, or other visual defects. However, you should ensure that troweling is not continued to excess because checking, crazing, and excessive dusting of the finished floor may result.

Make certain that the surface is cured as directed and for the time specified. Then also make certain that surface hardening treatments, if required, are applied after the surface is thoroughly cured, using approved chemicals of the type and in the amounts specified.

Painting of concrete, stucco, and similar surfaces is done primarily for decorative purposes or for dampproofing walls. Paints usually are of white portland cement base with color but may be of an oil base. In an inspection of painting, you must be sure that the materials conform to the project specification or the referenced standard specifications. You must also determine whether surfaces are clean and free from dust, efflorescence, and other contamination and whether they are adequately cured. When portland cement paint is used, be certain that the surface is thoroughly wetted. If oil-based paints are used, ensure that the surface is thoroughly cured, pretreated as specified, and thoroughly dry.

STEEL-FRAMED CONSTRUCTION

Steel construction is used principally on shop buildings requiring relatively long-span construction and on multistory buildings for comparatively light occupancy. In most cases, factory inspection of material, fabrication, and shop assembly will have been made. The inspector must make certain that the steelwork as delivered is correctly identified, sorted, handled, and stored.

Steel Floor Framing

In the construction industry today, steel-framed systems continue to gain popularity. The material used most often is light-gauge galvanized steel. The steel floor framing methods are similar to the wood-framed systems and the two are interchangeable.

As the inspector, you must give special attention to the alignment and plumbing of columns and posts. Joists, beams (usually wide-flanged), and girders must be level and set at the prescribed distance below the finished floor. You must ensure that all steel is held and adequately braced by clips, brackets, ties, and anchors until the steel can be riveted or welded. The inspector must be certain that adequate erection bolts are used to hold all joining surfaces tightly together at joints and to hold the assembled steel in alignment. You must also make sure that mismatched holes are drilled or reamed and not drifted.

On welded work, the inspector must ensure the following:

- That suitable electrodes are used, as specified.
- That all base metal at welds is cleaned, brought into correct position, and clamped or backed up as necessary.
- That welds are made in the approved sequence to minimize internal stresses and distortion.
- That welds are of satisfactory quality, length, and size.
- That the parent metal is not damaged.

- On truss joints, verify that lengths of welds are proportioned as indicated so that eccentricity of the welded joint to the line of stress is avoided.

- That all loose slag is removed.

- That special care is taken to make sure that welds made overhead or in awkward or restricted positions are sound and full.

- That the shop coat and welds are touched up as specified and that the specified number of coats of field PAINT is applied.

- That the paint used is of the type, the quality, and the color specified. (For more information, consult the *Steelworker,* Volume 2, NAVEDTRA 12530).

Metal-framed Walls

Metal-framed walls are similar in design to wood-framed walls. They have channel-shaped studs and "C" shaped studs that are fastened to the metal channel that serves as the bottom and top plate. The tops of the door and window openings are supported by channel-shaped headers. However, lumber may be used for header material. if the plans and specifications specify it. The metal "C" stud material is available in various sizes. The most popular stud widths are 6 inches, 3 1/2 inches, and 2 1/2 inches, and the header and joist widths are 6 inches, 8 inches, and 10 inches. The thickness of the galvanized steel ranges from 14 gauge to 20 gauge steel. For the double-top plate, you may use 2 by material as long as the plans and specifications specify lumber vice metal. When inspecting these metal walls, make sure the proper self-drilling screws are used, check for tolerance and gauge of metal, and be sure the bottom plate is securely fastened to the floor. Also, ensure the knockouts are aligned properly for easier runs for the electrical and mechanical lines. There is one mistake commonly made when working with metal framing and that is cutting of the metal. When you cut metal or scratch metal it tends to oxidize resulting in the creation of rust. How fast the oxidation occurs depends upon the climate. To prevent oxidation, coat the cut ends with a galvanize paint or a primer.

WOOD-FRAMED CONSTRUCTION

In light-frame construction. buildings are constructed according to the location of country and local building codes. As the inspector, you must be familiar with these codes and regulations. In some areas of the country, buildings must be constructed with special resistance to wind and rain. In other locations a building is constructed according to other disaster problems, such as locations prone to earthquakes, cold climates, snow loads, and humid climates. All require quality construction and special designs. Structures should be built to reduce the effects of shrinkage, warping, and resistance to fire hazards.

This section will not cover all aspects of inspecting light framed construction; however, as an inspector or crew leader, you need to be knowledgeable about what to look for when inspecting this type of construction.

Wood Floors

Wood floors for buildings of frame construction usually consist of finished flooring laid on subflooring that is supported by floor joists. Wood floors usually consist of planks surfaced on four sides (S4S), laid on edge with tight joints, and supported by floor beams of dimensional timber spaced at fairly long spans as specified in the drawings and specifications.

As the inspector, you must ensure the following:

- That all lumber is of the specified grade and type according to specifications.

- That all beams are true.

- That flooring material is resting squarely on the joist.

- That floor joists are the correct size and overall length, and are sound and free from excessive warp.

- That the floor joists are installed bearing on sills or beams or supported by straps or hangers, and that are braced with cross bridging and/or with solid bridging, as specified.

- That the tops of the floor joists are brought to a true, level plane.

- That subflooring of the specified kind, grade, and size is installed, made tight, and thoroughly nailed.

- That building paper is laid, if prescribed.

Wood floors are frequently installed on steel framing, particularly in light industrial buildings where steel bar joists are used. In some cases, floor joists are installed on the steelwork, and the wood floor construction is the same as for frame construction. In other cases, floor decking, consisting of heavy planking with square, shiplap, or tongue-and-groove joints, is with square, shiplap, or tongue-and-groove joints, is laid, driven tight, and bolted directly to the steelwork with carriage bolts. You must make sure that all materials and workmanship conform to the requirements of the specifications and that the floor is finished smooth and even.

Wood-freed Walls

Wood (stick) framing is widely used throughout the construction industry; however, the cost doubles that of metal framing. It is still the preferred method of construction, particularly for emergency and temporary construction. Quarters and temporary barracks may be of typical frame-house construction. Storehouses, particularly of the large one-story type, may have frames of wood posts, beams, and joists with wood roof sheathing. Shop buildings may have to be built of wood when steel and concrete are not available. Such structures may require heavy built-up timber columns and trusses, particularly if crane runways have to be provided. Large, wooden hangars have been built, necessitating trusses, with each member consisting of a number of heavy planks.

Structures that require wide-span construction have occasionally been framed with laminated wood arches, consisting of a large number of plies of relatively thin planks, glued together, with a special waterproof, durable glue. In addition, you may encounter many other special types of framing. With changing technology, glued-laminated beams will be a thing of the past and plastics may take over—who knows? We just cannot cover every aspect of the construction industry.

As the inspector, you must familiarize yourself fully with the drawings and specifications and the standard specifications used for references. Make sure the framing material is of the specified grade, size, and the surface has been inspected and grade marked.

You must make certain that the nails, bolts, screws, connector rings, and other fastening devices conform to the requirements in type and size. Also, ensure that metal ties, straps, hangers, stirrups, joist hangers, and similar accessories are suitable and correctly used. Where numerous plies of lumber are held together by long through-bolts, you should recheck the tightness of the nuts before the project is finally accepted because shrinkage of the lumber may have caused them to loosen.

As an inspector, make sure that the wall material conforms to the specifications as to the kind of wood, grade, and manufacture or has been inspected or grade marked. You must ensure that the wall sheathing is tight and covered with a building wrap (vapor barrier) and flashed as necessary for weathertightness. Also, make certain that siding is applied carefully so that the lines are straight and true and that laps and exposed faces are correct. In addition, make sure that nails are the specified kind and weight, are driven flush, recessed, or blind, as specified; and that, if recessed, they are filled over with a suitable plastic wood putty.

Wood partitions are used in all frame construction. In most cases, wood partitions are composed of 2- by 4-inch wood studs with sills and plates of the same material. Studs are doubled at openings, and the top plates are usually doubled to provide strong splices.

Headers, encountered in light-frame construction, are required at all openings of load-bearing and non-load bearing walls. Remember, non-load bearing headers run parallel with the joist, and unless the opening is more than 3 feet wide, a single 2 by 4 (laid flat) is sufficient as a header. Load-bearing headers run perpendicular to the joist and carries the load immediately above the openings. Load-bearing headers should be doubled and laid on edge. If the opening is more than 3 feet in width, the header will need additional strength to carry the load imposed upon it from above. Check the local building codes, plans, and specifications, and *Architectural Graphics Standard* (AGS) for more information on headers.

Wood partitions to be finished on both sides are covered with wood lath, metal lath, plasterboard, or some other base or may be covered in drywall construction with wallboard of various types. Wood partitions in offices are frequently covered by paneling. This type of construction uses studs spaced fairly wide apart (2 feet) with either tongue-and-groove panels, wallboard, masonite, or other material used for wall coverings. Such partitions frequently extend only part way to the ceiling, and the upper panels maybe glazed, glass panels, or glass block. In the Tropics, wood partitions may be surfaced on one side only, leaving the studding fully exposed on the other side to eliminate all concealed spaces and permit effective control of termites and other vermin.

As the inspector, you must ensure the following:

- That all partitions are adequately anchored to the floor, the walls, and the ceiling, as specified, and are adequately braced and stiffened at all splices and corners.

- That studs are set truly plumb and in line, and are well nailed to sills and plates.

- That plaster base or other surfacing or panels and trim are carefully and accurately installed so that a neat, workmanlike finish is obtained. When necessary, make sure that all fastenings are completely concealed behind the trim and that the latter is nailed with finished brads.

Wood Roofs

You may have occasion to inspect various types of roofs, including concrete, corrugated metal, wood, and so on. Although this chapter is broad in scope, it does not cover all the different types of roofs. The subject matter is limited to wood roofs.

When a pitched roof is inspected, you, as the inspector, must ensure the following:

- That all framing is cut accurately to exact length. It must be beveled or mitered as necessary to assure proper bearing of the cut at all meeting faces, and it must be securely nailed.

- That all bracing, trusses, collar ties, king post, and end studs are provided according to the drawings and specifications.

- That sheathing is laid tight and straight and that it is nailed according to the specifications. You should be sure that sheathing on pitched roofs is started at the eaves, with the face grain laid perpendicular to the rafters and with the horizontal joints staggered at mid-sheet intervals.

Thickness of plywood is very important to any roof, and this is where local codes tend to differ due to load design, wind resistance, or type of roofing material. Normally 1/2-inch plywood is the minimum; however, 7/16-inch oriented stranded board (OSB) is widely used in residential construction.

THERMAL AND MOISTURE PROTECTION

The material and its installation, used in thermal and moisture protection, is critical to any construction. In the construction industry, insulation is usually thought of in relation to heat transmission, although sound is an equally important item to consider. There are so many different types of thermal and moisture protection, such as waterproofing, dampproofing, vapor and air retarders, fireproofing, various types of insulation (blanket, batt, and loose), and joint sealers. However, with limited space, we will briefly cover waterproofing, building insulations, and joint sealers.

Waterproofing

Waterproofing is the material used that results in the protection of an area, structure, or individual member from the presence of water, whether it is in the form of a liquid or a vapor.

Membrane waterproofing is achieved by the placement of a moisture-impervious membrane, such as bituminous membrane (felt paper), polyethylene (plastic), or sheet rubber. When a membrane waterproofing material is applied to a surface, that surface must be clean and free from foreign material and kept dry. You must ensure quality workmanship and proper installation procedures are strictly followed.

Insulation

Insulation materials are resistant to the passage of either heat, and sound, or both. Typical insulation materials include the following: foamed glass, foamed plastics, glass fibers, cork, asbestos fibers, and granular fibers, such as vermiculite and perlite. Insulating materials are often designed to trap dead air space.

Before the installation of these materials, make sure that no moisture has damaged the material due to handling or transporting. Again, adhere to quality workmanship during installation.

Fiber glass (blanket, batt, or loose) must be inspected for the approved manufacturer's specifications for the proper **R** value and thickness. Fiber glass is usually covered on one or two sides with either a paper backing or foil backing or wrapped with a plastic wrap. It also may be blown in loose.

When fiber glass insulation is inspected, make sure that the proper procedures are followed according to the specifications or manufacturer's specifications. In the construction industry today, "fiber glass" is treated almost like "asbestos." Check with your safety officer or environmental officer for the proper handling techniques.

In masonry construction "vermiculite and perlite" are excellent sound-proofing insulation to fill all the hollow cores that are not already filled by concrete. Vermiculite and perlite are also used as an additive to plaster or joint compound to texture the ceilings and sound proofing.

Joint Sealers

The purpose of joint sealers (caulking) is to obtain a watertight structure. In masonry walls, a space about

1/4-inch wide and 1 l/2-inch deep should be allowed around all door and window frames to allow for adequate caulking. When caulking is applied, ensure the joints are <u>clean</u> and filled with the proper backing material, such as oakum, rockwood, styrofoam, or a urethane foam. Open spaces between wood and masonry sills must be caulked. Remember, watertightness is what you are trying to achieve. Air flow loss is very common through window and doorframes due to improper installation of the jambs. Remember, the presence of foreign material will prevent a good bond of the caulking material.

CEILINGS

In view of space limitations, our conclusion of finishes for ceilings is held to three materials: acoustical tile, acoustical plaster, and drywall. However, since drywall is classified as a finish, we will cover this in the next section.

Acoustical Tile

Acoustical tiles are available in various materials, such as wood, vegetable, or mineral fiber, perforated metal, or cemented shavings in different thicknesses, shapes, and dimensions and with varying textures, perforations, and joint treatment. They may be nailed, clipped, or cemented in place, depending on the ceiling construction.

The inspector must make sure that the tile, hardware for fastening, and adhesive cement conform to the project specifications or the standard specifications referenced therein. You must make sure that tiles are handled and stored carefully and are not allowed to get wet or even damp. Furthermore, be sure that all marred, broken, or damaged tiles are culled and not used.

If the tile is installed on suspended ceilings, the inspector must make certain that the furring construction is strong, rigid, and according to the specifications. If wood furring is prescribed, you must be sure that the furring strips are spaced accurately and suited to the tile width. Tiles must be fastened to furring strips by either blind nailing (nailheads that are concealed) or by screwing through the perforations, as specified. If metal furring channels are prescribed, you must ensure that the tiles are fastened to the channels with approved coupling devices and hangers. When tiles are applied to a finished solid surface, they are cemented with special adhesives, usually with five spots per tile, one near each comer and one in the center, applied to the back of the tiles, and pressed into place to a true, level plane. The inspector must make certain that all work is accurate and true to plane and line; that all special fitting around pipes, sleeves, and fixtures is neatly done; and that all tiles adhere tightly to the backing material.

Acoustical Plaster

Acoustical plaster is a manufactured product composed usually of asbestos fiber and rock-wool fibers, lime or cement binder, and an aerating agent, factory-blended, ready for mixing with water. It is available in white and in light pastel colors.

Acoustical plaster is seldom used in the industry today because the material is composed of asbestos fiber. However, with the continuing renovations to our naval facilities, you will encounter ceilings with acoustical plaster. Take the necessary precautions and contact your safety officer and ROICC before the installation of, or the removal of, this product.

Acoustical plaster is usually applied over a scratch course of gypsum plaster. The inspector must make certain that this coat is applied as prescribed, cross scratched for bond, and allowed to dry thoroughly. You must be sure that the acoustical plaster is applied in the prescribed number of coats to the specified thickness; that the undercoats are each leveled, rodded, and scratched; and that the finish coat is brought to a true, level surface of uniform texture with a minimum of troweling to avoid reduction in acoustical qualities. As the inspector, make sure that the plaster conforms to any special requirements of the specifications, such as porosity, density, or hardness.

FINISHES

The inspection of finishes for floors, walls and partitions, and ceilings is an important phase of your job. Be sure that each finishing job is properly done and gives a neat, attractive appearance. Now we will cover some items to look for during an inspection of interior and exterior finishes.

Interior Finishes

Interior finishes are those materials installed to cover the surfaces of the floors, the walls, and the ceilings. Because of the broad scope of material on finishes, we cover this topic by focusing on floor tile, drywall, and wall tile.

FLOOR FINISH.— Floor finish is any material used as the final surface of a floor. There are a wide variety of materials available for this application—wood, quarry tile, resilient tile, glazed tile, sheet vinyl, carpet, and block flooring, such as slat block, laminated block, and solid-unit block. Unfortunately, we are limited with space and the Navy tends to use resilient tile as its primary surface, because it's easy to apply, durable, and cost-effective.

Resilent Flooring.— As the inspector, you must keep in mind that floor tile, especially 9-inch by 9-inch tile, was commonly made of asbestos fibers until the late 1970s. So if there is any demolition to be done, it is vital to take a sample of the flooring first.

You must ensure that the flooring material is placed starting from the center and working outward; this method ensures that the border tile is of equal size. Reminder: Read the specifications; usually the specifications will call for two coats of wax applied to the surface before occupancy.

Floor Tile.— Floor tiles are of several varieties, such as flint tile, unglazed or semiglazed ceramic tile, or quarry tile. Glazed ceramic tile, such as that generally used for a wall finish, is occasionally used. Flint and ceramic tiles are usually of small size and of hexagonal, square, or rectangular shape and are delivered with the patterns assembled in panels of about 12 inches square, cemented on the face to the paper. These tiles are also available in various square and rectangular sizes and in a variety of colors, shades, and textures.

You must ensure that tiles for both field and borders are of the kind, size, color, texture, and pattern specified and that adequate quantities are on hand to assure completion of each room or area. You must determine that mortar for beds and wire mesh or other reinforcement, if required, conform to the specifications.

Also, make sure that the structural floor is prepared and ready to receive the tile and to assure a true, level, finished floor. If the floor is of wood, you must make certain that the floor joists are leveled at the top and that the subfloor is set down as necessary to provide an adequate mortar bed. If the floor slab is concrete, you must make sure that it is depressed below the finished floor grade as required, roughened to provide bond, thoroughly cleaned, and wetted down immediately before the mortar bed is placed. Likewise, see to it that the mortar bed is placed and screeded and that tiles are set immediately and tamped level and true with straight, even, uniform joints. You must ensure that tile placed as paperbacked panels is set so that the pattern repeats truly and so that joints between panels match those established within the panels. You must be particularly careful to determine that the tile is laid parallel to the principal walls and that all special work required to fill in corners and irregular areas is placed so that joints are true and the pattern is faithfully reproduced without offset or other error. You must be sure that all joints are carefully and neatly filled with mortar, as specified, and that the floor is cleaned of all mortar. After the mortar has set, check the floor for loose tile, irregularities, or other defects that require the connection of such. Quarry tile may be specified to be set in bituminous mastic or in colored white cement mortar. You must determine that the mortar conforms to the specified requirement and that tiles are set level with even joints and are solidly embedded.

WALLS AND PARTITIONS.— Various types of materials are used as finishes for walls and partitions. However, we will only cover drywall and wall tile.

Drywall.— Drywall construction has replaced the plastering methods for walls and ceilings in the construction industry. More than 80 percent of the homes today use some form of gypsum wallboard. It has been developed as an economical finish for walls and ceilings because of the increased cost of plasterwork and the relative scarcity of expert plasterers. Essentially, it consists of panels of wallboard of various types with joints tight, true, and effectively concealed.

As an inspector, you must be sure that the studding on which the wall is to be installed is brought carefully to a plumb, true plane. You must ascertain that all materials used are strictly adhered to by the specifications and that the wallboard is applied accurately (remember the nailing patterns for walls and ceilings). Check the walls for the required number of coats of joint compound, as required, and that the finished wall is true and uniform in texture and appearance with joints substantially invisible.

Wall Tile.— Glazed ceramic tile, glazed vitrified (waterproof) clay tile, and plastic tile are used for wall finishes for baths, galleys, mess halls, hospital rooms, and other applications for which a highly sanitary, easily cleaned, impervious wall finish is required. Tiles are furnished with various types of grooves, ridges, or clincher button heads on the back to assure bond.

You must make sure that the tile furnished conforms to the specifications in kind, quality, size, color, glaze, texture, and grip. Also, that all necessary specials, such as base, corners, decorative band, fixtures, and trim, are of a true matching color or of the color or pattern specified.

A good checklist for inspecting the workmanship of tile should include the following:

1. Ensure the mortar scratch coat is applied and allowed to dry, as specified, and that it is ready in all respects to receive the tile.
2. Ensure that the mortar bed for tile is applied in the required thickness and made true.
3. Ensure that the tile is applied and tapped to true, plumb alignment with all joints straight, plumb, or level and of uniform thickness.
4. Ensure that the color schemes and patterns are faithfully followed and correctly arranged and cut around fixtures.
5. Ensure that wainscoting is extended to the specified height.
6. Ensure that bases align correctly with the finished floor and that joints are filled with plaster of paris, cement, or other mortar as specified.
7. Ensure that all tile walls are cleaned thoroughly without scratching the glazed surface.

Exterior Finishes

Exterior finish includes all the exterior materials of a structure, such as walls, roofs, decks, patios, and so on. In this section we will concern ourselves with stucco and built-up roofs, which are common trades that the Builders perform.

STUCCO.— Stucco usually is specified as composed of portland cement, hydrated lime, sand, and water and may have integral waterproofing or coloring pigment added. Painted or galvanized metal lath, expanded metal, or wire mesh is used for the support of stucco, except on masonry walls, and requires nails, staples, and wire for fastenings. The inspector must make certain that all material conforms to the requirements of the project specifications and the referenced standard specifications.

Stucco may be applied on masonry, concrete, or wood-frame walls. As the inspector, make sure that the masonry has an unglazed rough surface with joints struck flush and adequate key to assure a good bond. Concrete is often given a “dash” coat of neat cement and sand before the stucco is applied. If the base is wood-frame walls, the inspector must determine whether the lath or wire is securely fastened to the framing and tied together to form a taut, strong support to the stucco. Specifications usually will require application in a three-coat system as follows: scratch, brown, and color coat.

The inspector must make sure that all masonry joints are filled, struck smooth, and allowed to set before applying the scratch coat. You should then make certain that the scratch coat is pressed thoroughly into the joints for the masonry or into the openings of metal or wire lath to assure adequate key and bond. You must determine that this coat is applied carefully to level and plumb irregularities, that it is scored or combed tier completion to provide good bond, and that it is permitted to dry for the specified period.

The brown coat is usually of the same composition as the scratch coat. The inspector must make sure that the scratch coat is wetted immediately before the brown coat is started; that the brown coat is applied, rodded, and floated to bring all surfaces to true, flat, plumb planes; that the surface is combed by fine cross-hatching to provide a bond for the finish coat; and that the coat is permitted to dry for the prescribed period.

The color coat, also called the finish coat, is a relatively thin coat of special composition to provide the finished surface with texture and color. It is your responsibility to make sure that this coat conforms to the specifications in composition, including colored aggregate, pigment, and integral waterproofing, if prescribed; that it is carefully applied to assure true, plane or curved surfaces and sharp edges; and that on completion it is protected from excessive heat and kept moistened for the specified period to preclude hairline cracks, fading, and checking.

The inspector must also make sure that all surfaces are true; that the surface texture conforms to the finish specified and to the approved sample, if any; and that the color is of a permanent type, and matches, after the stucco is dry, the color specified or indicated by a previously approved sample.

BUILT-UP ROOFING.— A number of different types of roofing are used on structures. One of the main types found on Navy-built structures is BUILT-UP ROOFING. The following information deals with this type of roofing.

Built-up roofing, as the name implies, is a membrane built up on the job from alternate layers of bitumen-saturated felt and bitumen. Because each roof is custom made, the importance of good workmanship cannot be overemphasized.

In inspecting built-up roofing, you should verify the particular combination of plies, felt, binder, and cover indicated in the project specifications.

You must be sure that the felt conforms to the requirements in kind, grade, weight, and other specified characteristics and that the material is not crushed, tom, or otherwise damaged as it is used.

Likewise, ensure that the primer and binder furnished are asphalt or tar as described, that the material conforms to the specification requirements for the indicated type, and that it is kept free from water, oil, and dirt.

The standard specifications limit the material used for surfacing to gravel or slag; however, the project specifications may permit or require a special material, such as white marble chips. You must verify the types of material required or permitted and ensure that the material furnished conforms and is of suitable size, gradation, and cleanliness. No surfacing is required for roofing that calls for asbestos felt.

Where a wood roof is concerned, you must ensure the following:

- That the roof deck has been prepared suitably to receive the roofing before permitting the roofing to be started.
- That all large cracks and knotholes have been covered with the tin nailed in place.
- That the roof is suitably smooth, clean, and dry.
- That felt or metal valley lining is installed in all valleys, as required for the type of roofing being used.
- That the roof is covered with a layer of unimpregnated felt or resin-sized building paper and then covered with two layers of saturated felt, all lapped, nailed, mopped, and turned up or cut off at junctions with vertical surfaces, as specified.

Where concrete and similar roofs are concerned, the inspector must ensure the following:

- That all cracks, voids, and rough spots are filled level and smooth with grout and are thoroughly dry.
- That all sharp or rough edges are smooth.
- That all loose mortar and concrete are removed and the surface is broom clean.
- That felt or metal valley lining is installed in all valleys, as specified, for the type of roofing being used.
- That the roof is covered with a primer of hot pitch or asphalt and then covered with two layers of saturated felt, all lapped, mopped, and turned up or cut off at junctions with vertical surfaces, as indicated. On precast gypsum or nailable concrete roofs, the specifications may require that these first two plies be nailed.

With all roofs, you must be certain that any additional layers of binder and felt are applied as required by the specifications. You must make sure that each lap and layer are mopped full width with the specified quantity of hot binder, without gaps, so that felt nowhere touches felt; that the binder is applied at a temperature within the specified range and no burnt tar or asphalt is used; and that these layers are turned up, as indicated. You must be sure that the entire finished surface is uniformly coated with binder poured on at the specified rate and then covered with the required quantity and kind of covering material. You must make sure that all roofing is free from wrinkles, air or water bubbles, and similar irregularities and that all plies are firmly cemented together.

TRIM

There are basically three types of trim, and these are metal, wood, and plastic. Since plastics and metal are seldom used in the Navy, we will cover only wood trim.

Wood trim or millwork may be of either rare or common varieties of hard or softwood. Regardless of species, millwork usually must be thoroughly seasoned, air-dried or kiln-dried, free from knots and sap, and must be of an even, straight grain.

As the inspector, you must make sure that the trim has been factory-inspected or grade-marked and is of the species, grade, dimensions, pattern, and finish prescribed; that molded lines are true and sharp without fuzz, flats, or splintered edges; and that the material has been suitably dried and is not warped or curled.

You must make certain that the installation of wood trim is made with the specified quality of workmanship. On high-grade work, the inspector must ensure the following:

- That all trim is set plumb with square comers.
- That all corners are miter cut and coped, if necessary, for close fit on internal comers, and provision is made for expansion and shrinkage.

- That where long runs are installed in more than one piece, miter cuts and lap splices are used.

- That where curved bends are needed, the trim is kerfed on the back so that the cuts are invisible from the front and are close enough together to create a smooth, uniform curve without kinks.

- That all trim is nailed securely and that the nails or brads are suitable to avoid splitting.

- That finishing nails are set adequately, but not so deeply as to pull through the wood.

- That all joints and visible seams are sealed with wood filler and that all trim is suitably primed and field painted.

DOORS

An inspection of structures should include both exterior and interior doors. The following sections provide information on some of the different types of doors used at Navy activities. Items that should be checked in an inspection of specific types of doors also are pointed out.

Exterior Doors

Exterior doors are constructed mainly of solid wood, fiber glass, sheet metal, aluminum, or structural glass. Wood doors may be of hardwood or softwood. Metal doors may be of a metal-faced frame with an insulated foam core.

Hinged doors are used for most personnel entrances. They may be single-leaf or double-leaf. Two or more pairs of double-leaf doors maybe used for main entrances. Hinged doors may be of solid wood, metal-faced, filled-panel, or rolled-metal construction. They vary in style from simple stock patterns to highly ornamental designs in bronze, aluminum, Monel Metal, or stainless steel. Hinged doors may have exposed or concealed hinges mounted on the jamb or top and bottom set in the head and threshold. Most screen doors are the hinged type.

You must be sure that hinged doors are of the material, grade, size, type, and design specified and conform to the specifications. Usually, doors will have been factory-inspected. You must determine that they are accurately fitted to the frames with minimum clearance at head, jambs, and sill; that they are weather-stripped, glazed, and fitted with hardware, as specified; and that they are painted, varnished, or otherwise finished as required.

Large openings may be closed by horizontal sliding or rolling doors, usually suspended by hangers from rollers that travel on horizontal or slightly inclined tracks and guided by troughs, grooves, or similar devices at the bottom. These doors vary from simple barn doors to the massive, steel-framed doors used for airplane hangars. Doors of this type of large size usually run on wheels mounted in the bottom chord and travel on rails set at grade.

When horizontal sliding or rolling doors are inspected, you must be sure that the doors are plane and free from wind, and that the doors are mounted so that adequate operating clearance is obtained, but that suitable weathertight closure is also obtained when they are closed. You must also make certain that tracks, rollers, roller suspensions, and operators are accurately aligned and adjusted for smooth operation.

Large shop and storehouse openings are frequently closed by steel rolling doors. These doors consist of a large number of interlocking horizontal slats that can be rolled up on a drum mounted above the head of the door opening. The slats are held loosely in channel guides at the jambs. The doors are counterbalanced by a spring tension device for ease of movement and may be operated either by motor or by hand.

In an inspection of steel rolling doors, you must ensure the following:

- That the slats are true and undamaged and interlock with adjacent slats, as intended, and that the slat assembly is mounted truly on the roller or drum and is correctly fastened so that the slats roll up smoothly and evenly, maintaining their horizontal position.

- That slat ends are provided with guide castings, as specified or approved, and that these guide castings fit accurately into the side guides with sufficient depth of bearing to assure against their pulling out and with sufficient clearance to assure easy operation.

- That the spring counterbalance or other balancing device is tensioned for the required ratio of the total load and maintains satisfactory tension throughout the operating range.

- That operating machinery is suitably aligned and adjusted, and that all accessories specified are provided and installed.

Interior Doors

Interior doors are made of wood (hard or soft), wood veneer, and sheet metal. Hollow core doors are usually filled with a sound-absorbing material that is fire resistant. Most interior doors are of the single-leaf HINGED TYPE. Double-swing doors will be specified for some locations.

Sliding doors may be specified for closets and for large openings between rooms. They usually will be arranged to slide into concealed recesses when opened. Fire doors are frequently arranged to slide or roll down an inclined track automatically when released by the melting of a fusible link in the anchoring device.

Doors of numerous special types will be encountered, such as elevator doors, trap doors, clutch doors, lattice and louver doors, incinerator doors, vault doors, and accordion doors.

You must be sure that all doors conform to specifications and are free from any defects that impair their strength, durability, or appearance. Also, ensure that all doors are of the prescribed types, that doors and door hardware are installed correctly and accurately, and that doors operate freely and close tightly. You must be sure that sufficient clearance is provided above the finished floor to accommodate floor coverings when necessary. Likewise, make sure that the swing of the doors is in accord with drawings and schedules.

WINDOWS AND SKYLIGHTS

Special care is needed in the inspection of windows and skylights. Windows and skylights come in many different sizes and shapes. They are usually preassembled at the factory or millworking shop.

Windows

Wood windows usually are of the double-hung or casement types. You must be sure that the panels and sashes are of the specified type and grade of wood, that they conform to the requirements for each unit, and that they are carefully handled and fully protected against damage.

The inspector must ensure the following:

- That frames are carefully installed plumb and square, and that sashes are fitted neatly so that they operate freely, but without rattling.

- That sash weights or spring balances are installed and adjusted correctly and that all hardware and weather stripping specified are installed and adjusted satisfactorily.

- That casement sashes are hinged to swing in or out, as required and that they fit accurately and are suitably weather stripped.

- That bolts and other hardware are accurately positioned and adjusted.

Steel and vinyl-clad windows are available in many types. Among the more common windows are double-hung, pivoted, commercially projected, architecturally projected, casement, top-hinged, and detention or security types. You must be sure that the windows are of the prescribed type, size, grade, and section of members and conform to the specifications in details and workmanship and, also, that the windows installed in each opening conform to the schedule shown or specified. You must make certain that windows are carefully handled and stored and are free from distortion when they are installed. You must be sure that all anchors, bolts, and clips needed for fastening the windows in place are installed; that frames are set accurately and truly and are caulked, as specified; that ventilators are set accurately and adjusted so that they operate freely and close tightly; and that all operators and other moving parts are made to operate smoothly and easily without strain.

Most aluminum windows are built of extruded shapes of relatively light sections. They are available in most of the types listed for steel windows in the preceding paragraph, but they are generally of the double-hung or casement types. Requirements for inspection are substantially the same as for steel windows. You must be sure that aluminum is of the grade and temper specified. Usually, the manufacturers caution that windows must be kept locked and unopened until they are set and glazed. As the inspector, you should insist that this practice is followed. You must determine that care is taken to avoid marring the members during installation because of their relative softness.

Skylights

Skylights of the framed type maybe constructed of galvanized iron, asbestos-protected metal, copper, aluminum, stainless steel, or Monel Metal. You must be sure that the skylights conform to the details shown; that all necessary steel supports, base curb, and reinforcement are provided; that skylights are flashed to all adjoining work in a watertight manner; that bars are provided with suitable shoulders for the support of the glass and with gutters for the collection of condensation; that glass is set on felt or in putty, as prescribed; and that caps are set and adjusted to be watertight without imposing restraint or strain on the glass.

Skylights may be provided by installing corrugated glass in panels on roofs of corrugated types. As the inspector, you must be sure that glass is of the type, thickness, and size specified; that the glass is fastened securely but without restraint or strain; and that the installation is made completely watertight.

GLAZING

Glass may be clear window, polished plate, processed, rolled figure sheet, figured plate, wire, prism, corrugated, safety, or heat-absorbing.

You must make sure that the glass for each location is of the type, grade, thickness, surface finish, color, and size specified and that conforms to include metalwork and steel structures, woodwork, and concrete work. To inspect different types of jobs, you must know what to look for in each type of surface.

PAINTING

As an inspector, you need a thorough knowledge of paint material, equipment, painting procedures, and disposal. You must also be able to inspect both exterior and interior jobs involving different types of surfaces, such as metalwork, woodwork, and concrete work.

“Paints that are on the market today may not be on the market tomorrow.” The never-ending advancement in technology and environmental restrictions in today’s society will find new methods in the way of new paint materials, equipment, and in the way we paint. Many products today come either primed for painting or have a “baked on enamel” finish, ready to install.

Paint materials have really changed over the years. Technology has gone from lead-based paints to lead-free paints, from enamel to water-based (latex) enamel, which is much safer for the environment, and so on. Remember, if you need to rehab an old building and paint removal is necessary, you are probably looking at a lead-based surface. If this is the case, check with the safety officer, the environmental officer, or the ROICC, so he or she can sample the exterior paint for lead. Also, when painting, make sure the paints are applied at temperatures above 40°F. Preparation is the key to any good paint job.

Exterior Painting

The inspection of exterior work includes steel structures and woodwork. To inspect different types of jobs, you must know what to look for in each type of surface.

STEEL STRUCTURES.— Thorough preparation of the surfaces to be painted is the most important and the most frequently slighted element of good painting. Preparation of surfaces is of particular importance when paints with synthetic resin vehicles are to be used because they require exceptionally clean, dry surfaces for satisfactory results. As the inspector, you must be sure that steel surfaces are cleaned by wire brushing, sandblasting, gritblasting, flame cleaning, cleaning with solvent, or airblasting, as may be specified; that all surface rust, dirt, grease, oil, and loose scale are removed; and that tight scale is also removed if so specified. When the use of chemical rust removers is specified or permitted, you must make sure that the preparation is of an approved type and is brushed on thoroughly and allowed to dry; and furthermore, that all loose material is brushed off. Galvanized surfaces must either be treated with diluted muriatic, phosphoric, or ascetic acid, rinsed, and allowed to dry or be treated with the approved proprietary treating agents, as may be specified.

You must be sure that ready-mixed paint, which tends to settle in the container, is thoroughly remixed to uniform consistency either by hand or power stirring. Usually, it is necessary that the lighter fluid be poured off into another clean container, that the heavier residue be stirred until it is uniform, and then the lighter liquid be added gradually, with continuous stirring, until the paint has been worked to a smooth, even, homogeneous mixture. You must also make sure that paints delivered with pigments and vehicles in separate containers are similarly mixed, preferably with power stirrers. You must make sure that thinning is permitted only when specifically authorized and that the amount of thinner added is limited to the minimum required for satisfactory application.

You must be certain that paint is applied only under satisfactory atmospheric conditions. The specifications usually specify the minimum temperatures at which painting may be done. You must ensure that paint is not applied in a highly humidor rainy atmosphere or when condensation on the metal surface may occur and that the paint surface is visually dry before permitting painting to proceed. Specifications may prescribe application by brush or spray or permit either method.

When paint is applied by brush, you must be sure that each coat is thoroughly worked with suitable brushes until a smooth, even coat is obtained, free from brush marks, laps, holidays, and drips of excess paint. You must make sure that the paint is worked thoroughly into all joints, cracks, and crevices, verify the coverage obtained and that the area covered per gallon is within acceptable limits. You must make certain that each coat is allowed to dry thoroughly before the next coat is applied and that the prescribed number of coats, each conforming to the requirements of the specifications, is applied. Nonferrous metal is usually not painted. When it is prescribed, you must prepare, prime, and paint the surfaces, as specified.

WOODWORK.— You must make sure that surfaces are thoroughly dry and clean and are otherwise suitably prepared for painting before permitting work to proceed. You must determine that the priming coat is intact and is of suitable consistency to protect the wood, but not so tight that moisture in the wood is prevented from evaporating. For exterior work, sandpapering will not be specified. You must be sure, however, that the wood is smooth enough to assure the continuity and adherence of the paint film; that holes and cracks are puttied or filled with wood filler; and that knots and pitch streaks are sealed with shellac, varnish, or other sealer, as prescribed.

You must be certain that the paints are of the specified type and quality; are mixed, colored, and thinned to provide a paint of uniform consistency and color; and are applied by brushing, using high-quality brushes, until the coat is smooth, even, free from brush marks, and of uniform thickness, texture, and color. Also, you must be sure that all cracks and crevices are sealed; that the paint is not brushed too thin to assure satisfactory hiding power; that each coat is allowed to dry thoroughly to a firm film before permitting application of the next coat; and that the specified number of coats is applied.

To stain shingles and trim, use either the dipping or the brushing method. You must be sure that, when dipped, the material is loosened so that the stain reaches all immersed surfaces; that it is left immersed until the stain has fully penetrated the grain; that excess stain is drained off; and that stain is replenished and stirred to assure uniformity.

Interior Painting

Paint for interior walls and ceilings is usually a flat wall paint. For small jobs the specifications may permit the use of approved commercial ready-mixed paints. Interior enamel may be specified where a semigloss or gloss washable finish is desired on woodwork or walls. The specifications may require either a standard undercoat for primer under enamel, or they may permit the use of the enamel with thinner. Paint and enamel may be obtained with color added, or color-in-oil may be added to the white paint on the job.

In general, requirements for inspection of interior painting are the same as those already described for exterior painting. Specifications may require the sanding of interior woodwork or rubbing with steel wool. Priming of plaster surfaces with a glue size may also be required. You must be sure that finish coats are of uniform gloss and color and are free from suction spots, highlights, brush marks, and other imperfections.

Special Work

Aluminum windows, doors, and trim usually will not be painted but will be given an alumilite or other anodic surface treatment at the factory. When painting is specified, it will be necessary to clean the surface thoroughly, so the surface is free from all dust, dirt, oil, and grease; to apply a primer of the type specified; and to apply one or more coats of paint, as required.

Where dissimilar metals are in contact, electrolysis may occur that uses the rapid corrosion of the anodic or positively charged material. Magnesium, zinc, and aluminum corrode when in contact with steel; steel and iron corrode when in contact with copper, brass, or bronze; and copper and its alloy corrode when in contact with the precious metals. Zinc coating protects steel at the expense of the zinc coating. You must be sure that aluminum is well-isolated from steel and that steel is well-isolated from copper by felt, varnish, or other methods, as specified. Cathodic protection by impressed current is another method of resisting galvanic action.

Before paint can be applied successfully to bright galvanized metal, the surface film must be removed and adequate tooth provided by treating the surface with diluted hydrochloric, phosphoric, or acetic acid. A 5 percent solution usually is specified. You must determine that the surface is completely treated and is then rinsed thoroughly with clean water. A small amount of lime sometimes is added to neutralize any residual acid. When dry, surfaces so treated are primed and painted like other metalwork. Refer to the *Paint and Protective Coating* manual, NAVFAC MO-110, for further information pertaining to procedures on painting.

PILE CONSTRUCTION

The inspection of pile driving is an extremely important phase of an inspector's duties. There is probably no other type of construction work that requires quick, sound decisions to be made on the spot as frequently. Every inspector assigned to supervise pile-driving operations needs to be familiar with all aspects, procedures, and details regarding the materials, the equipment, and the techniques used in pile-driving operations.

Pile Driving

The accuracy with which piles must be located varies with the nature of the work. Extreme accuracy in positioning is not essential; for example, in a large mat foundation supported on piles at relatively wide centers. However, accuracy is important in closely spaced footing clusters, and it is particularly important in such cases as bridge bent piers, in which the upper part of the piles is exposed and any misalignment is immediately noticeable and objectionable. The inspector must make sure that piles are positioned with the accuracy required by the circumstances but should avoid arbitrary and unduly burdensome requirements when they are not reasonable. When close tolerances are essential, the specifications may require the use of templates to assure proper centering. In such cases, the inspector must make sure that the templates provided are strong enough to withstand the abuse to which they are subjected and that they are maintained square and rigid.

You must take care to see that the pile is handled without undue strain or shock, that the pile is set plumb in the leads, and that the pile-driver leads are themselves plumb. Give special attention to the rigging used for lifting precast concrete piles to prevent overstraining and cracking the piles. It is difficult to reposition a pile that has been started slightly out of position, and it is almost impossible to straighten up a pile that has been started crooked.

The inspector must be present during the driving of every pile and a digging permit must be present along with the proper safety procedures for the driving of the pile.

The inspector must make sure that the hammer used is heavy enough to be effective, considering the weight of the pile. The hammer should weigh as much as the pile being driven, and preferably it should be up to twice the weight of the pile. Hammers that are too light waste their energy in impact and inertia effects. In driving the piles down, force is so little that its effectiveness causes gross erroneous indications of bearing capacity, far above what the pile will actually sustain. The hammer must strike the pile squarely, or additional energy will be lost in springing the pile sideways. When batter piles are being driven, the inspector must make sure that the leads are set for the proper batter and that the piles are held true to top position and batter as they are driven. If timber piles are being driven, the inspector must make sure that protective rings of proper size are used at the heads of the piles to protect them from splitting and that pile shoes of approved design are used and properly secured when called for or required.

Use jetting to facilitate driving piles through many types of soil. As the inspector, follow the specifications insofar as they prescribe specific requirements for jetting. Usually, jetting is done by one or more pipes with nozzles hung from the driver and operated independently of the pile. Some precast concrete piles have been used with the jet pipes cast in the piles. Such cast-in jets cannot be moved around as needed to obtain the best effectiveness, and their use has been largely discontinued. The inspector should permit the widest latitude possible regarding methods of jetting. However, he or she must make sure that jetting is discontinued a sufficient distance above the final point elevation of the pile to ensure that the pile base is in undisturbed soil and that the bearing capacity, calculated from the average penetration of the last few blows, is a reliable index.

The inspector must make sure that the piles are driven to the minimum point elevation specified or to the minimum penetration below the ground, bottom of footing, or mud line, as may be specified. If neither point elevation nor minimum penetration is shown or specified, the inspector should make sure that the driving is continued until the penetration per blow is reduced to the limit indicated by the formula for the required bearing capacity. If jetting is permitted, the inspector must make sure that the driving is continued into undisturbed material. If the required bearing capacity is obtained with every short pile, the inspector should report the situation to his or her superior promptly and request further instructions.

Difficulties Encountered in Pile Driving

Various defects are encountered in working with piles. Some of the common defects the inspector may encounter in wood and concrete piles are covered next.

WOOD PILES.— The inspector must be alert to detect and take steps to correct deficiencies in equipment and methods which may damage wood piles. The inspector must learn to recognize the indications of such failures and require that the methods be modified, if necessary. Overdriving is usually indicated by bending or staggering the hammer. Breaking or shearing is indicated by sudden resumption of easy driving after the pile has apparently been driven to practical refusal. Similar behavior may occur when the pile breaks through a hard crust into a softer stratum. Sudden hard driving may indicate that the pile has struck a boulder. Sudden change of direction may indicate that the pile has sheared or broken or that the pile has glanced off a boulder. The inspector should inform the superior when such difficulties recur and that there is doubt as to the cause and should recognize that damaged piles may endanger the safety of the structure supported by them.

CONCRETE PILES.— Common failures that may occur in precast concrete piles are cracking and spalling or shattering of the head.

Cracking may occur as a result of faulty mixes or curing, but it usually results from carelessness or improper rigging in handling. Piles should be inspected frequently and minutely during driving to make sure cracks do not exist. They are particularly dangerous in the portion above the mud line where they may permit corrosion of the reinforcement to occur. When numerous cracks occur, report the situation to your superior so that a fill-engineering investigation can be made and the causes corrected.

Spalling or shattering of the heads usually occurs in precast concrete piles, because the proper followers and driving blocks are not used. The equipment should be modified if these troubles develop consistently. Piles with badly shattered heads cannot be repaired effectively so that they can be driven with assurance that fill-bearing capacity is obtained. It may, in extreme cases, be necessary to remove and replace the pile. If the pile is not damaged badly enough to warrant rejection, the inspector should require the removal of all unsound concrete and building up to the finished cutoff.

With cast-in-place piles, difficulties are sometimes experienced through tearing of the shells or partial collapse after the mandrel is removed. A customary emergency measure is to drive a second shell inside the damaged shell. All shells should be inspected by throwing a beam of light down the shaft with a mirror and determining that they are sound, intact, and tight. Piles that are rejected as defective must be filled with concrete to eliminate a hole in the ground that could subsequently decrease the bearing capacity of adjacent piles.

The main difficulties with steel piles are twisting and distortion of the heads. Take special care to see that caps of proper design are provided to prevent this action.

TIMBER CONSTRUCTION

This section relates primarily to the inspection of the field construction of timber structures. Some of the major items to be covered in the inspection are given below.

Delivery and Storage

When timber is delivered to the site of the work for incorporation into the structure being constructed, the inspector must make sure that it has been inspected and grade-marked as required by the specifications or as approved by proper authority and that inspection certificates have been furnished by the inspecting agency. These certificates must be properly identified as pertaining to the material delivered, and the tally of material delivered must be correct. If it is treated material, the inspector must make sure that the inspection reports of treatment are received, identified, and indicate that the treatment complies with requirements. If inspection before delivery has been waived for any reason, the inspector must make sure that the timber conforms in species, dimensions, and quality to the requirements of the specifications.

The inspector must make sure that all timber is unloaded with reasonable care so that it is not damaged in handling. Exercise special care when handling timber treated with creosote or other preservatives to preclude damage penetrating the more heavily treated surface layer.

The inspector must require that timber be stored in a well-drained area so that it will be clear of the ground; that it be stacked so that there is good circulation of air through the pile; that in stacking, one end be raised so that water will drain off without standing; and that the layers be adequately supported so that the lower layers will not be crushed by the weight of the material above them. Preferably, the high end of the stack should be cantilevered forward at the top to provide an cave effect. Kiln-dried timber, finish lumber, and millwork must be stored under cover.

Fabrication

The inspector must allow latitude on the type and arrangement of plant and equipment to be used on the job, but you must make sure that the plant is adequate for the work, is arranged to minimize interference with others or with station operations, and is safe. The scope of the plant will depend both on the magnitude of the work and on the extent of manufacture and prefabrication before erection.

When a large volume of rework is involved, all cutting, matching, and shaping, and as much prefabrication as possible will generally be done at a central woodworking plant at the site before erection. This procedure assures more accurate work at considerable saving in labor and is to be encouraged as tending to assure a better job. The inspector should give special attention to checking first runs of each production run to make sure that each piece is cut and shaped to correct dimensions and pattern. When required by the project specifications, the inspector must check to see that all fabrication is accomplished before treatment.

Prefabrication or preassembly may be practical on a larger scale if the character of the work permits. The inspector should check all jigs and fixtures used in such processes to make sure that the units are true to exact dimensions within permissible tolerances and that the units are complete in all respects with attachments, holes for field bolts, and grooves for ring connectors, as required. The inspector must also make sure that handling devices for the completed units are adequate to assure their conveyance without distortion or damage. If the material is treated, he or she must make sure that all cuts and holes are given the surface treatment specified.

Erection

The erection plant will usually consist of automotive or locomotive cranes or travelers with the necessary slings, strongbacks, and lifting devices. The inspector must ensure that the equipment has satisfied all the weight-handling requirements, is safe to operate, and is in good working order.

The inspector must make sure that the erection methods used are safe, allow the work to be done effectively, and are in keeping with the workmanship and quality of the Seabees. The inspector must then ensure the following:

- That all members are of the correct dimensions and are cut square or formed to exact shape and that they are fitted together truly with full bearing and without shims or other adjusting devices, except as specifically permitted.
- That bolt holes are round and undersized for drive fit.
- That all members are aligned correctly.
- That the work is adequately braced, guyed, or supported at all times to assure against distortion or collapse.
- That all bolts, driftpins, ring connectors, and other hardware are of the specified dimensions and materials, and galvanized if required, and are properly installed and tightened or driven to proper depth without damaging the timber.

The inspector must reject and require replacement of any timber or hardware damaged during erection. The inspector should make sure that temporary holding or aligning devices are provided and used as necessary to assure tight, accurate work, that these devices do not injure or mar the finished work, and that they are removed upon completion of erection. On work involving the connection of a number of plies of heavy material, it is essential that ample length of tread bolts is available if the timber shrinks. The inspector must make sure that all other detailed requirements of the specifications are fully met.

CHAPTER 7

MAINTENANCE INSPECTIONS

LEARNING OBJECTIVE: *Identify defects and damages associated with building inspection and maintenance, and determine proper procedures for repairs to naval facilities and structures.*

A newly constructed building, regardless of how well it is constructed, will start to deteriorate the moment you apply the material. Proper maintenance and repairs are necessary from time to time to keep any structure in first-class condition. An effective maintenance inspection program will disclose whether specific types of maintenance or repairs are needed on buildings or other structures. The maintenance program should be designed to do the following: (1) promptly detect deficiencies and damages and (2) expeditiously perform economical and workmanlike repairs. These requirements are essential if the maintenance standards are to be achieved.

Detection is provided by inspection of facilities at regularly scheduled frequencies by qualified inspectors. The inspection program should also include emergency inspections to cover contingencies such as the following:

- Before and after unusual and severe storms where high velocity winds, abnormal tides, and heavy wave action have been experienced.
- When heavy snowstorms and extremely low temperatures are anticipated or experienced.
- After the occurrence of any type of operational hazard

In some instances, an inspection will turn up minor defects that can be corrected promptly and, as a result, prevent the occurrence of major defects requiring extensive repairs. As a Second or First Class Builder, you may be called upon to conduct maintenance inspections at Navy activities. This is a responsible job and one that should be assigned to well-qualified personnel.

The types of structures that you inspect will depend upon the types available at your activity. So, consider those discussed here as typical of the many types that you will find at some activities. Let us emphasize, too, that this instruction is not intended to list every item that should be checked during an inspection of a specific type of structure. Additional and more detailed information applicable to the maintenance inspection of structures, roofing, painting, and waterfront facilities can be found in the appropriate MOs which are published by NAVFAC and listed in the *Index of Naval Facilities Engineering Command,* NAVFAC P-349.

At some activities, forms that provide a checklist may be available showing major items to be covered in the inspection of the structure concerned. These forms may be prepared locally and, therefore, may differ from one activity to another. At times, of course, forms may not be available and the inspector will have to depend upon past experience in building and construction, as well as sound judgment, determine what to look for in the inspection.

After completing an inspection, you may have to make a written report on your findings. You may also make recommendations on the type and extent of repairs needed to correct certain defects. You must remember that each inspection is important and should be done carefully, thoroughly, and with safety in mind.

INSPECTION of BUILDINGS

Many checkpoints can be covered in a maintenance inspection of buildings, especially when the inspection extends from the basement up to and including the roof. We will not attempt here to cover all items that might involve a complete and thorough inspection of an entire building. We will, however, cover some of the primary items of concern to an inspector at Navy activities.

FOUNDATIONS

The foundation of a building transfers the dead and live loads of the superstructure to the soil that has enough bearing capacity to support the structure in a permanent, stable position. Footings are used under foundation components, such as columns and piers, to spread concentrated loads over enough soil area to bring unit pressure within allowable limits. Foundation design is determined not only by the weight of the superstructure but also by occupancy or use of the building or structure and by the load-bearing capacity of the soil at the site. The latter conditions may change and introduce maintenance and repair problems even in initially well-designed foundations.

Foundations should be inspected at least annually and more often where climate, soil conditions, or changes in building occupancy or structural use present special problems. Evidence of initial foundation failure may be found during routine inspection of other structural components.

Foundation Displacement

A foundation should be checked regularly for proper elevation and alignment. Complete failure in a foundation is rare; however, some settling or horizontal displacement may occur.

Some common causes of foundation movement include the following:

- Inadequate footings.
- The structure is overloaded.
- Excessive groundwater that reduces the bearing capacity of the soil.
- Inadequate soil cover that fails to protect against frost heaving.
- Adjacent excavations that allow unprotected bearing soil to shift from under foundations to the excavated area.

Some indications of localized foundation displacement are:

- Cracked walls
- Damaged framing connections
- Sloping floors
- Sticking doors
- Leakage through a displaced roof

Corrective actions that can be taken to alleviate foundation displacement include the following:

- Replace any missing or dislodged part of the foundation immediately.
- Repair cracks or open joints in concrete or masonry foundation walls.
- Replace defective wood members.
- Replace unstable fill around the foundation with clean properly compacted fill.
- Remove growing roots of trees or shrubs that may dislodge footings or foundations.
- Increase bearing area of inadequate footings.
- Maintain enough soil cover to keep footings below the freezing zone.
- Prohibit loads from exceeding the design loads of buildings and structures.
- Isolate foundations from heavy machine operations by providing independent footings and foundations for heavy machines.
- Air-conditioning equipment, cooling towers, and compressors should be provided with cork or rubber isolation mounts to prevent transmission of vibrations to the structural frame of the building.

When excavations are made near the footings of buildings, care must be taken in removing bearing soil under existing structures. Temporary stabilization can be gained by shoring, underpinning, or needling to relieve pressure of the footings on the soil. Sheetpiling may be driven and supported laterally to contain the bearing stress in the soil under the footings.

When water erosion removes soil from around and under footings some means of erosion prevention, such as ditching or the use of splash blocks, must be used.

Footings that fail because of insufficient bearing area must have their bearing area increased. The amount of movement in the wall dictates the repairs necessary. Minor settlement, especially when uniform, may require no repair. If serious settlement occurs, the wall may have to be jacked back to its original elevation, a new footing provided, and repairs made to the wall.

Improved drainage is the basic solution to the most common groundwater problems (fig. 7-1). Moisture in structures caused by a high water table can be drained away from a foundation by the installation of open-joint drain tiles surrounded by loose gravel fill. The drains should be laid so as to drain the water away from the footings and into a sump with a

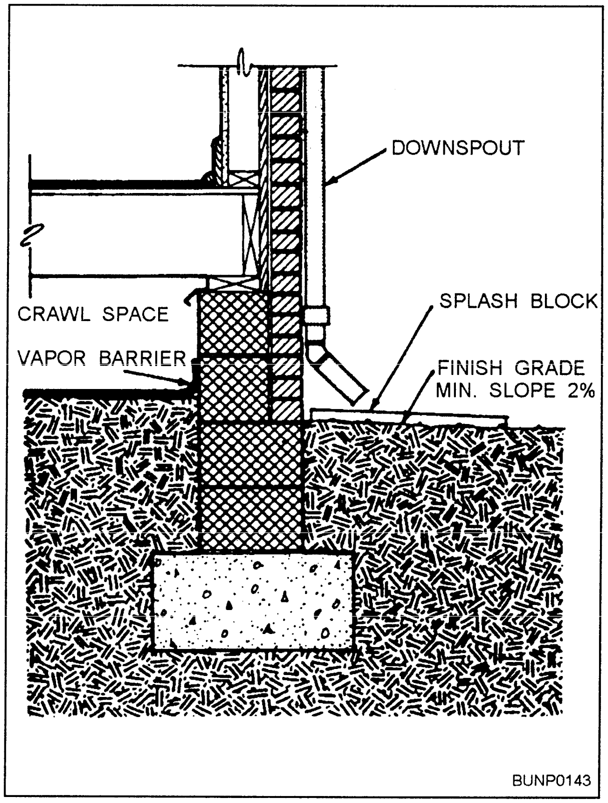


Figure 7-1.—Proper drainage for storm water.

float-controlled electric pump. Drain tiles should generally be pitched from a high point around the perimeter of the building to a low point below the floor slab where the sump and pump are located. Where roof drainage causes a foundation water problem, gutters and downspouts should be installed, preferably connected to a storm sewer. Gutters that are improperly hung or allowed to become clogged will overflow and lose their effectiveness. Leaks in gutters should be repaired promptly. Splash blocks or drain tiles should be installed in the absence of storm sewer connections to prevent pooling of water below downspouts. The drainage of surface water toward a building can be reversed by sloping the ground surface away from the foundation wall. Where that is not possible, ditching or installing drain tiles will serve the same purpose. The general grade of crawl spaces should not be lower than the surrounding area that should be graded to drain away from the building.

Foundations are subject to deterioration whether from material or construction deficiencies or from environmental conditions. The deterioration of foundation materials must be observed directly unless the effects are severe enough to cause foundation settling. Excessive moisture from surface or subsurface sources is a major cause of timber deterioration, providing the necessary condition for wood decay and encouraging insect infestation. Improperly seasoned wood is subject to cracking, splitting, and deflection. Concrete and masonry are subject to cracking, spalling, and settling, particularly under adverse ground and climatic conditions. Steel and other ferrous metals are subject to corrosion in the presence of moisture and sometimes by contact with acid-bearing soils. Signs of corrosion are darkening, rusting, and pitting of the metal.

Corrective actions taken to alleviate the deterioration of the foundation materials given above are covered in detail later in this chapter in the section dealing with the maintenance and repair of waterfront structures.

Crawl Spaces

Considerable deterioration extending from the foundation to the building superstructure can be caused by neglect of crawl spaces, especially in climates where it is necessary to enclose the space to maintain comfortable floor temperatures. Unventilated crawl spaces contribute materially to rapid absorption of moisture into structural wood and other materials, and the spaces soon become a natural habitat for fungus growth and termites. Sills, joints, and subflooring may be affected by wood decay. Condensation may occur in the studding spaces above the floor level and cause paint failures.

Crawl spaces should be carefully checked periodically. In checking these spaces, ensure that they are clean, clear, and accessible. An accumulation of rubbish in the space may provide a natural harbor for insects and rodents as well as impede access and possibly interfere with drainage. Scrap wood is a clear invitation to termites.

Look for disorganized storing of any material in crawl spaces. Also, check for accumulations of water that may breed mosquitoes, cause fungus growth, and weaken soil bearing under footings.

Ensure that all ventilation openings are covered with suitable hardware cloth or copper screening to prevent entry of birds and rodents. In addition, see that access doors to crawl spaces are provided with a suitable padlock and kept closed.

Wood Decay

Wood decay is caused by wood-rotting fungi that grow in damp wood. Fungi attack wood members in contact with damp masonry foundations, moist ground or standing water, and water pipes on which moisture condenses. Poor ventilation around the wood hastens the process of decay.

Wood decay is indicated by the following:

- A damp, musty odor
- Opening or crumbling of the wood
- The presence of fine, dusty, reddish-brown powder under the building
- A hollow sound when the timber is tapped
- Easy penetration of timber by a sharp-pointed tool
- Corrective actions taken to alleviate wood decay include the following:
- Removal of fungus-infested lumber. Spray infested areas with wood preservative.
- Elimination of the source of moisture. Add fill around masonry and grade swales to lead water away from the foundation. Where land contours do not promote runoff, install drain tiles around the foundation and lead them to a storm drain, or provide a dry well at a lower elevation than the water table at the foundation.
- Provision of ventilation to affected areas.
- Replacement of infested lumber with lumber treated with wood preservative.

Termite Control

An inspection should include a check, where applicable, for termites. Wood and wood-and-masonry members are susceptible to termite attack. Subterranean termites become established in wood that is in contact with moist soil. Their presence may be indicated by earthlike shelter tubes leading from the ground to the infested wood. Dry-wood termites live all their lives in dry, sound, and seasoned wood. A reliable sign of dry-wood termite attack is the finding of pellets in the immediate area. Among basic methods of preventing termite infestation are soil treatment, use of wood preservatives (such as pentachlorophenol), removal of surplus wood and other debris from the site, preventing contact of lumber with the ground, and covering openings into attic spaces with suitable hardware cloth or copper screening.

Moisture Control

In crawl spaces or “dead” areas under non basement structures, moisture control problems other than building drainage develop from condensation of moisture rising from damp soil. The ideal method of preventing ground moisture from entering the building is to provide an impermeable vapor barrier on the warm side of insulation in floors and walls. In existing buildings this is not possible unless it is done in the course of major renovation.

The most practical solution is to provide a soil cover of water-resistant material. Fifty-five pound roll roofing has been the most widely used and successful solid cover; however, recent tests indicate that 0.006-inch polyethylene plastic sheeting is effective and lighter to handle than roofing paper. The effective life of these plastic covers has not been established when used exposed to the air or under slabs. Soil covers may be rolled out on the soil from foundation wall to wall. It is not necessary to form a complete seal over the soil; but more than 90 percent of the soil should be covered, and cracks should be limited to 1 inch. Removal of trash and debris and leveling of sharp dips and mounds in the soil will increase the life of the cover.

BASIC SUPPORTING MEMBERS

For inspection purposes, the basic supporting members of wood frame structures are divided into the following three groups: (1) sills and beams, (2) posts and columns, and (3) girders and joists.

Sills and Beams

Inspection and timely repair of sills and beams set on foundation walls, piers, or columns are important to the general maintenance of a structure. As in the case of uneven settlement of the foundation, severe damage can be done to the basic building by a reduction of the ability of the sill or beam to maintain upper components in their fixed position. Sill and beam defects can lead to many lesser but troublesome and expensive repairs of wall and ceiling cracks and misaligned doors and windows. Wood sills and beams should be inspected periodically for dry rot, and termite and rodent damage.

Sills and beams should be kept to a correct grade by the use of slate or steel shims and mortar pointing. Reinforcing plates, extra tie-downs, or other means should be used to correct misalignment. Timbers, exposed to ground moisture or severe weathering, must be treated often enough to prevent deterioration, and sufficient ventilation must be assured to avoid rotting.

Posts and Columns

To prevent periodic deterioration, thorough inspection should be made of all posts and columns in contact with the ground. They should be treated with a preservative to resist decay and damage by termites. Posts and columns should be maintained plumb and in alignment.

Inspection of posts should include a test for soundness, made by jabbing the post on all sides with an ice pick or other sharp instrument; the amount of penetration indicates the soundness of the wood. In most softwoods, such as pine and fir, the pick should penetrate more than one-half inch; in hardwoods, such as gum and oak, penetration should not exceed three-eighths inch. Columns are more difficult to inspect in finished buildings; but when there are indications that columns are out-of-plumb, the covering finish material should be removed and a thorough inspection made. Out-of-plumb or misaligned columns may be indicated by cracks in plaster or other finish, but the same defects may be caused by failure of other structural components. Repairs and/or replacement work should not be made until the true cause of defects has been established.

If the foundation is not level because of uneven settling, the defect should be corrected before any attempt is made to plumb or align posts or columns. The floor above should then be shored with jacks or other devices and the supporting members plumbed and realigned.

Posts or columns that show signs of failure caused by overloading should be surveyed by an engineer competent to recommend repairs or replacement in terms of overall structural soundness.

Girders and Joists

As the other basis supporting members, periodic inspection and timely repair of girders and joists are important to the general maintenance of a structure. Wood joists and girders are usually of a size that is not easily dried; consequently, it is normal to expect shrinkage and seasoning splits and checks.

Checks and splits should be carefully recorded as to size, location, and depth. If records indicate increase in length or depth, then stitch bolts may be required. Stitch bolts are required in all structural members that have deep checks or splits three-eights inch or greater in width and/or have slope of grain greater in width than 1 inch in 14 inches.

In the event of a structural failure, an engineering study should be made to determine whether the failure can be properly patched or if the entire girder or joist should be replaced. Many methods can be used to reinforce girders and joists. However, the selection of the proper methods should be determined by the loads to be carried, the cost, and clearance and accessibility. When either a permanent or temporary post is placed under a failure of a girder or joist, consideration of the size of the post and the cap, as well as adequacy of base support under the post, should be considered. Joist repair can be facilitated if the new member is sized one dimension smaller than the original member. Bridging that is removed should be replaced with solid bridging.

FLOORS AND STAIRS

Floor materials found in shore establishment buildings and structures for various occupancies include wood, concrete, terrazzo, and clay tile. Common floor coverings include asphalt, vinyl tile, and linoleum.

Wood Floors

Wood floors should be inspected quarterly for the following:

- Loose nails
- Warped, cupped, or loose boards
- Raised ends
- Slivers
- Cracks
- Loose knots
- Raised nails
- Water damage
- Damage from improper cleaning or condensation
- Wood decay

If floor damage requires replacement of strips or planks, the steps for the procedure are as follows:

1. Make two longitudinal cuts in the damaged strip or plank. (See fig. 7-2, view A.)

2. Remove the section between the two cuts by cutting the strip with a chisel at midpoint. (See fig. 7-2, view B.)

3. Remove the remainder of the damaged strip, taking care not to damage the tongues and grooves of adjoining boards. (See fig. 7-2, view C.)

4. Remove the lower part of the groove of the new closure strip or plank. (See fig. 7-2, view D.)

5. Insert the tongue of the closure into the groove of the adjoining board, and nail with two eightpenny annular ring finishing nails through the top surface. When possible, the end joints should be located so the nails will enter the joist. In new closure areas of flooring laid in mastic on concrete, remove the existing mastic and apply new mastic of the type recommended by the flooring manufacturer before installing the new closure.

6. Set exposed nails. (See fig. 7-2, view E.)

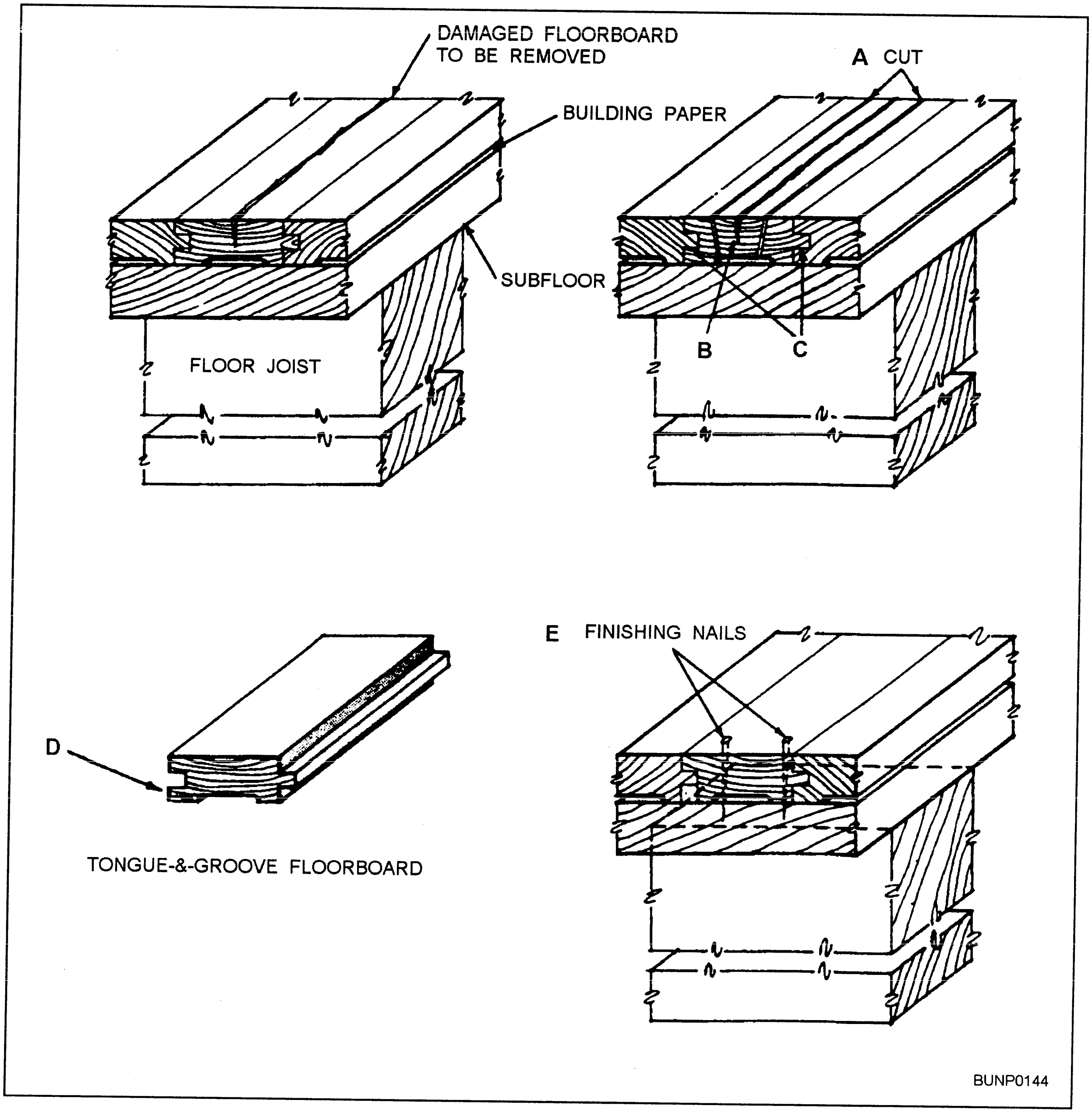


Figure 7-2.—Method of replacing tongue-and-groove flooring.

7. Dress the new portion to the level of the adjacent floor by sanding both areas to a continuous, smooth plane.

8. Dry sweep the area to remove all particles of dust.

9. On open-grained woods, brush on a paste filler. After the filler has partially dried, rub it into the pores of the wood with a circular motion. Wipe the surface lightly to remove any surplus filler. Inadequate filling is indicated by pockmarks and results from wiping off too much of the filler or from unusual absorption by the wood. Eliminate such deficiencies by repeating the filler application.

10. Seal and wax the floor (two coats).

Concrete Floors

Concrete floors should be inspected annually for dusting, spalling, cracking, and settling. Concrete floors of proper composition, installation, and curing require comparatively little maintenance unless they are exposed to conditions, such as the following:

- Severe abrasion and heavy vehicle loads from industrial traffic.
- The deteriorating effect of grease, oils, and food acids encountered in galleys, sculleries, and similar food-preparation spaces.
- To caustic soaps and solutions.

The corrosive agents in highly acid or alkaline liquids attack concrete floors and cause spalling and pitting. Where trucking is done over concrete floors, such as warehouses, trucks should be fitted with wide-faced wheels; if vehicle abrasion and shock continue to raise maintenance demands, the application of a heavy-duty topping to the concrete should be considered.

CAUTION

> Do NOT paint concrete floors for functional requirements, such as marking safety lanes or similar areas. Painting for appearance is unjustified and impractical; traffic areas on painted floors will wear first, making the floor unsightly and presenting a difficult cleaning problem.

One of the more common problem areas with concrete floors is the development of unsightly cracks. Cracks in concrete floors maybe caused by shrinkage, temperature changes, settlement, or lack of rigidity of supporting beams or other structural members. When such movements are recurrent and can be eliminated only by major structural changes, little can be done except to keep the cracks filled with a mastic material. In many cases comparatively small cracks may be filled with varnish or resin. Although the cracks will remain visible, they will not leak or gather dirt. When the cause of larger cracks has been determined and corrective measures taken to eliminate further cracking, the cracks can be permanently repaired by filling them with nonshrinking cement mortar.

Patching will not permanently correct cracks in slabs on grade caused by vertical movement resulting from exceeding the design load of the slab, inadequacy of the base, or insufficient bearing capacity of the soil. Slab failure under these circumstances can be corrected only by a major maintenance operation, such as mud-jacking. The procedures applicable to the repair of concrete floors are covered in detail in the section of this chapter that deals with the maintenance and repair of waterfront structures.

Terrazzo Floors

Terrazzo floors should be inspected annually for loose or broken segments and damage from improper cleaning. Terrazzo appears to be dense and very hard, but the cement is sensitive to harsh soaps and cleaners, which can cause pitting, roughen the surface, and make the floor permanently susceptible to dusting and dirt trapping. Repairs to a terrazzo floor should be made according to the specification for new floors. Only floor specialists who are capable of the class of workmanship necessary should be entrusted with the work.

Clay Tile Floors

Clay tile floors should be inspected annually for missing loose, or broken tiles; open joints; and damage from improper cleaning. If floor damage requires replacement of broken or badly stained tiles or resetting loose tiles, the steps for the procedure are as follows:

1. Remove the damaged or loose tiles.

2. Clean the mortar from the edges of the surrounding tile.

3. Roughen the concrete underbed to provide a good bond for the new setting cement.

4. Dampen the underbed and edges of the surrounding tile and place the setting mortar mixed in the proportion of 1 part portland cement to 3 parts sand.

5. Set the tile, tamping it to the level of the finished floor.

6. Fill the joints with grout or pointing mortar, matching the color and finish of the joints of the original floor as closely as possible. If the mortar in the existing joints has deteriorated, cracked, or crumbled, thoroughly clean the joints of all loose mortar and re-point them with grout or pointing mortar as follows:

- Grout joints one-eighth inch or less in width with neat portland cement grout of the consistency of thick cream.
- Point joints one-eighth inch to one-fourth inch in width with pointing mortar, consisting of one-part portland cement to one-part screened sand.
- Point joints wider than one-fourth inch with pointing mortar consisting of one-part portland cement to two-parts screened sand.

7. In locations, such as galleys and food-preparation areas, where the floor is directly exposed to the effects of corrosion agents, you should use acid-resistant joint material to fill the joints. The acid-resistant mortars are proprietary products and should be mixed according to the manufacturer's recommendations.

Resilient Floor Coverings

Resilient floor coverings generally used include linoleum, vinyl plastic tile, vinyl asbestos tile, and asphalt tile. Linoleum should be inspected annually for loose seams, buckling, serious indentation, and damage from improper cleaning. Resilient tile should be inspected annually for the following:

- Missing, loose, or broken tiles
- Open joints
- Serious indentations
- Burns
- Damage from improper cleaning

LINOLEUM is repaired by laying out the area along rectangular lines and laying an oversize section of new linoleum over the damaged area. Cut through the two layers simultaneously to ensure a tight fit. Remove the damaged section and clean the exposed underfloor of adhesive, dust, and dirt. Replace the damaged felt lining. Apply a linoleum adhesive to the exposed surface and fit the new linoleum in place. Roll the area with a linoleum roller and place weights of suitable size on the patch to assure proper adhesion.

RESILIENT TILE is repaired by removing the damaged section and replacing it with new material. Tile is more easily replaced than linoleum because of its smaller size. After the damaged tile is removed, scrape the exposed area level and clean off all mastic, dust, and dirt. Replace the damaged felt lining. Install the new tile in suitable cement or mastic according to the manufacturer's recommendations.

Stairways

Stairways should be inspected at least quarterly for adequacy of support and safe condition of components. A good inspection of stairways includes a check for the following conditions:

- Cracked, weathered, or rotted wood framing.
- Settled, cracked, or spalled concrete.
- Rusted or loose metal supports.
- Treads should be inspected for loose or broken tread nosing; excessive wear; paint or tread covering deterioration; and loose, eroded, or slippery tread surfaces. Exterior treads should be sloped (or drilled) to drain properly.
- Handrails should be inspected for loose fastenings and material deterioration.
- Newel posts and balusters should be checked for looseness and missing parts.

Maintenance on interior wood stairs usually involves treads. Squeaks indicate loose treads that can be corrected by driving finishing nails through the treads into the riser or carriages or by removing the molding under the tread overhang, driving wood wedges between the tread and riser, renailing the tread tightly, and replacing the molding. In open-string stairs, a tread that is worn but not split or broken may be removed and reversed. Split, broken, or otherwise seriously damaged treads should be replaced with new boards. Housed treads that cannot be removed maybe repaired by leveling the worn surface with asphaltic mastic or other suitable plastic materials and covering the tread with a suitable floor covering. Plain and nonslip nosing of steel, brass, bronze, aluminum, and molded hard rubber is commercially available and should be applied according to the manufacturer's recommendations.

EXTERIOR WALLS

Exterior walls fall into three structural categories: load-bearing walls (carrying structural loads); nonbearing walls (carrying only their own weight); and supported or enclosed walls, sometimes called curtain walls (with their weight supported by structural members).

Exterior walls are made of a wide variety of materials, such as the following:

- Wood (shingles, weather-board siding, plywood)
- Concrete and masonry (brick, concrete or cinder block, reinforced or nonreinforced concrete, structural clay tile, stone, stucco)
- Metal (corrugated iron or steel, aluminum, enamel-coated steel, protected metals)
- Mineral products (asbestos shingles, asbestos-cement sheets, and glass block)

Wood Exteriors

Wood exteriors should be regularly inspected for damage from wear, accidents, and the elements. They should also be inspected for damage resulting from insect pests. This may be done by tapping the wood with an object. A dull or hollow sound is an indication of damaged wood, which may be the result of insect pests. Painting and surface treatments should be inspected quarterly for deterioration; exteriors should be inspected for loose, warped, cracked, or broken boards or shingles.

Moisture is the most prevalent cause of failure of exterior walls. Stains, paint deterioration, and rot are usual signs of moisture damage. Condensation within and behind walls is a less obvious but equally damaging factor. Insufficient, loose, or displaced nailing produces separations and cracks that admit moisture and reduce the stability of wood walls.

Foundation settlement or displacement may cause misalignment of framing members and consequent damage to walls, including cracks in siding and breaking or displacement of boards or shingles. Make a careful check to determine that existing structural, functional, and material conditions warrant repair to the existing wall, rather than complete residing, insulating, or other overall repair or rehabilitation. Where existing situations are satisfactory, replace damaged material with like material. Cut back sufficient areas beyond the damaged part to obtain good jointing and sound nailing. Tighten nails in existing material to be left in place. Be sure that material receiving the new nailed pieces of sections are sound and true. Cover replacement wood with treatment and/or paint matching the original design. When "as-built" plans are available, it is well to examine the original construction detail for assurance that out-of-vision construction and utilities will not be damaged. Warped, split, or curled shingles should be removed with a ripper and replaced in a similar manner as roofing shingles. Panel siding should be periodically checked for looseness and faulty caulking. It is usually more economical and satisfactory to replace damaged or deteriorated panels than to attempt patching.

Concrete and Masonry Exteriors

Concrete and masonry exteriors, such as concrete block, cinder block, and brick, require less frequent maintenance than most outside materials, but some failures are common. Exteriors should be inspected quarterly for structural cracks, open-mortar joints, condensation in weep holes, settlement, efflorescence, stains, and deterioration of paint or other surface covering.

The most common fault found in block and brick walls is defective mortar joints. These defective joints can be corrected by re-pointing. The steps for the procedure are as follows:

1. Cut out cracked open-mortar joints to a depth of at least one-half inch. (Cutting can be done by hand, but if large areas are involved, it is usually cheaper to use power tools.) Take care not to damage brickwork during the cutting process.

2. Remove all dust and loose material with brushes, compressed air, or a water jet. If water is used, no further wetting of the joints may be needed unless the work is delayed.

3. Repair the joints by tuck pointing.

4. Use mortar of about the same density as the original mortar, if it can be determined; otherwise, use a prehydrated mortar mix in the following proportions by volume: 1 part of portland cement, 1 part of lime putty or hydrated lime, and 6 parts of sand.

5. Be sure the joints are damp, and then apply the mortar by placing it tightly into the joints in thin layers.

6. Tool the joints to smooth, compact, concave surfaces.

Another problem area easily detected during a routine inspection is efflorescence. Efflorescence usually appears as a light powder or crystallization caused by water-soluble salts, deposited as water evaporates within the mortar or the masonry unit. Aside from detracting from the appearance of a wall, efflorescence may indicate the penetration of moisture into the wall to an extent that could cause deterioration of interior wall coverings and finishes. Efflorescence may be removed by vigorous and repeated scrubbing with a stiff fiber or wire brush and clean water. An inspection should be made, however, to determine the source of the stain. If efflorescence appears at the edges and not near the center of the masonry unit, the mortar is probably at fault; if it appears near the center of the unit only, the masonry unit is at fault. The most immediate remedy to prevent recurrence of efflorescence is to check causes of excessive moisture that contacts the wall, such as defective flashings, gutters, downspouts, copings, and mortar joints.

Leakage through concrete walls is caused by cracks in the concrete and, in rare cases, porosity of the concrete. As with brick walls, the cracks may be caused by foundation settlement, excessive floor loadings, temperature settlement, contraction in structural members, or poor materials and poor workmanship in the original construction. The types of cracks encountered include horizontal movement cracks, vertical and diagonal movement cracks, and shrinkage cracks. An engineering investigation of the causes of structural defects should govern the nature and extent of major repairs.

HORIZONTAL MOVEMENT CRACKS are usually long, wide cracks in the mortar joints that occur along the line of the floor or roof slab or along the line of lintels over the window. Where these cracks turn the corner of a building, they frequently rack down, as discussed later. Figure 7-3 shows a typical horizontal movement crack and racked-down corner.

VERTICAL AND DIAGONAL MOVEMENT CRACKS generally occur near the ends or offsets of buildings. They may also be found extending from a windowsill to the lintel or a door or window on a lower floor. They vary from one eighth to three eighths of an inch in width and follow the mortar joints, but in some instances, they may break through the bricks or other masonry. A diagonal movement crack is shown in figure 7-4.

SHRINKAGE CRACKS are the fine hairline cracks that are found in mortar as well as in concrete walls. The most noticeable ones are those running vertically, but a close examination of a section of a wall that leaks may also show them in the horizontal or bed joints of brick or block walls.

RACKED-DOWN CORNERS occur where the horizontal movement cracks along the side and end of a building meet. Frequently, the horizontal crack not only continues around the corner but forms part of a diagonal crack that takes a downward direction and meets a similar crack from the other side, forming a "V". The bricks inside this "V" are loosened and must be reset.

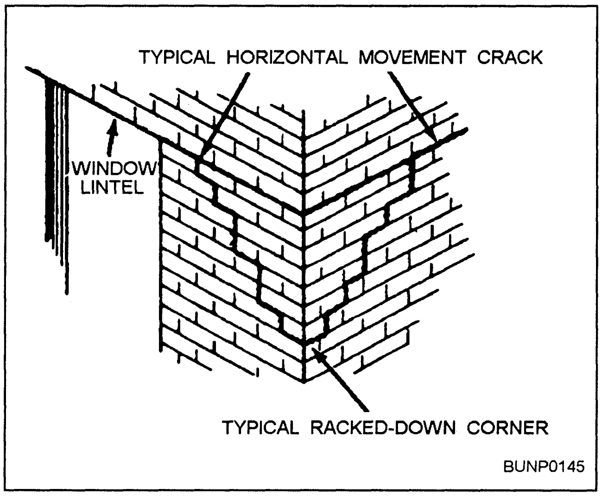


Figure 7-3.—Typical horizontal movement and racked-down corner cracks.

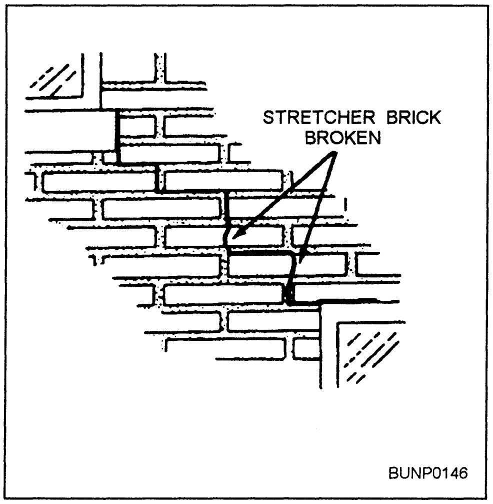


Figure 7-4.—Diagonal movement crack.

The steps you should follow to repair racked-down corners are as follows:

1. First remove all the bricks inside the V, including any bricks that have been broken (fig. 7-5). This forms irregular sides and helps to hold or key the brick in place.

2. After the bricks are removed, clean the sound bricks and obtain as many new matching ones needed to fill the opening. Relay the bricks in mortar up to and even with the horizontal crack running along the side and end of the building. If all joints are made the same width as the original joints and the mortar tends to match the old mortar, a very presentable job will result. As the bricks are built up, coat the backup bricks with mortar so that the newly laid bricks will be bonded to them.

3. Partly fill the top joint with mortar that is on line with the horizontal crack. This can be done by pushing the mortar into the joint with a narrow pointing trowel. When about half the depth of the joint is filled, fill the remainder with sealing compound. This system of mortaring only half the joint supports the brick above but forms a weak plane along the top of the racked-down areas. If movement takes place, the mortar joint breaks, but the relaid bricks remain in place. The sealing compound keeps the joint watertight.

INTERIOR WALLS, PARTITIONS, AND CEILINGS

Interior walls are usually made up of gypsum and plaster materials—the most common material being drywall. Other materials used are plywood, wood paneling, ceramic tile, or glazed-faced masonry. Partitions may be of plywood, drywall, hard-pressed fiberboard (particle board), structural clay tile, gypsum block, metal, and glass. Ceilings are usually made up of either drywall or acoustical materials. Another material commonly used to cover ceilings is plaster. Some of the major defects to look for when inspecting the more common types of interior walls, partitions, and ceilings are given in the following sections.

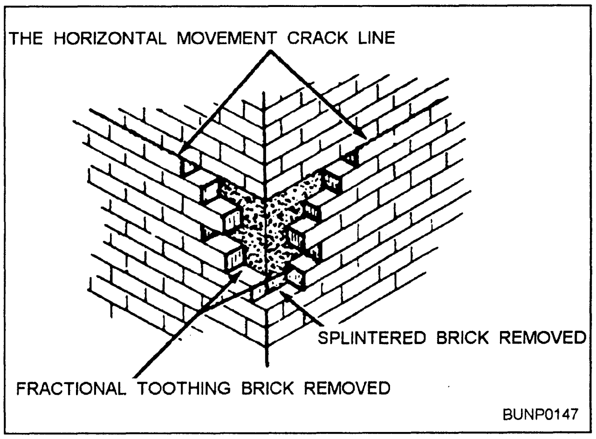


Figure 7-5.—Damaged brick removal.

Plastered Surfaces

Cracks, holes, and looseness in plastered surfaces are signs of excessive internal or external stresses. They may be caused by poor workmanship, such as improper proportions or application of the plaster, imperfect lathing, and poor atmospheric conditions during plastering; by moisture infiltration or an excess of moist air generated inside a building; or by the settling or other movement of some part of the building frame. External stresses that cause plaster damage should be investigated and corrected before repairs are made to the plastered surfaces themselves.

STRUCTURAL CRACKS are easily identified because they are usually large and well-defined, extending across the surface and entirely through the plaster. They generally develop during the first year after completion of construction and, in most cases, can be successfully and permanently repaired. However, before repairs are initiated, the cause of the failure should be determined from an engineering standpoint and necessary precautions taken to prevent recurrence of the failure. Structural cracks may extend diagonally from the corners of door and window openings, run vertically in corners where walls join, run horizontally along the junction of walls and ceilings, or occur in walls where two unlike materials join.

To repair a structural crack, use a linoleum knife or chisel to cut out and remove loose material. The crack must be formed to a V-shape to provide adequate keying action by making the surface opening narrower than the bottom of the crack. Care should be exercised to widen the crack only enough to ensure a good bond between patching plaster, old plaster, and lath. Expanded metal or wire lath should be cleaned and the mesh opened, so when patching plaster is forced into the opening, a good key is formed. Break out the key between wood lath so that a new key can be formed when patching material is forced into place. Thoroughly wet wood lath before applying patching plaster. Brush out all loose material, remove all grease or dirt from surrounding surface areas, and wet the edges of the groove. Press the first coat of patching plaster firmly into place, filling the groove nearly to the surface; allow it to set until nearly dry but not hard; then complete the patch by applying a coat of finished plaster, strike off flush, and trowel smooth. If the edges of the old plaster and the wood lath are not thoroughly wetted, they serve as a wick to draw the water from the fresh plaster, causing it to dry out, remain chalky, and crack around the edges of the patch. In applying the patching plaster, you should give special attention to the edges of the patch to ensure a firm, solid bond between old and new plaster.

LOOSE PLASTER is indicated by building and cracking of large areas of the plaster surface. The extent of loosened plaster can be determined by lightly tapping the surface with a small hammer, with the resultant sounds indicating the extent of the loose area. Loose plaster may result from excessive moisture caused by leaks in the roof, seepage through an exterior wall, plumbing leaks, or heavy condensation. This excessive moisture causes the plaster to become soft, which destroys the bond to the base, causing the plaster to loosen. In some cases, the plaster may bulge or sag but continue to hang in this condition quite a long time before falling, being held together only by the hair or fiber in the base coat. Occasionally, moisture causes the fastenings holding the lath to the structural frame to corrode, permitting both the lath and plaster to bulge or sag. Another cause of bulging plaster is the use of incompletely hydrated lime in the plaster mix. In localities where high humidity is prevalent, moisture causes a continued hydration of the lime that weakens the plaster and destroys the bond between plaster and base. This condition usually occurs in the spring and summer months, starting from the first to third year after plastering and continuing indefinitely.

Before the damaged plaster is repaired, it is necessary to locate and eliminate any source of moisture. Temporary repair to prevent loose plaster from falling until permanent repair can be done may be made by securing the loose plaster with a section of wallboard nailed securely to the wall or ceiling over the area effected. Nails should be of sufficient length to penetrate through the plaster and obtain a firm bearing in the studs or joists. Repairs of a permanent nature should be made as soon as possible. Remove all loose plaster around the break, working well back in the surrounding area to a point where solid plaster (well keyed to the lath, which, in turn, is solidly secured to the structural frames) is obtained. Remove the defective lath and replace it with suitable plaster backing, such as metal lath or plasterboard, and securely refasten all lath that has become loosened.

Dry Walls and Partitions.

Maintenance and repair of interior wallboard generally requires that nails, screws, and other fasteners be kept in a secure condition. Cracks in gypsum type of boards may be repaired similarly to cracks in plaster. Joints in drywall construction that fail must be re-cemented and taped. Broken sections of interior wallboard are generally best corrected by replacement of an entire panel. Wood paneling that develops cracks may be sealed with plastic wood or putty. Broken panels or siding usually are best repaired by replacement of a complete section, panel, or board. When repairs are completed, the repaired area should be finished to match the adjoining area. All fastening, such as nailing, screwing, or gluing, must be at least equal to the “as-built” construction. Nonload-bearing partitions should be inspected periodically for marks, dents, scratches, cracks, or other surface damage. Nonload-bearing partitions may be repaired or replaced without regard to the structural frame or ceiling and may be relocated to provide other interior arrangements of space.

Doors

Exterior doors are more subject to abuse and to weathering than interior doors. In general though, defects encountered in inspecting both exterior and interior doors are similar.

Doors should be inspected quarterly for defects, such as the following:

- Poor fitting
- Deteriorated or damaged frames
- Paint deterioration
- Material damage, such as cracked or broken glass, split or cracked wood panels, warped or dented metal, and warped or broken screening
- Broken or inoperative hardware, such as locks, hinges, and slides.
- Check all doorstops, thresholds, and weather-stripping for cracks, looseness, and workability, where applicable.

WOOD DOORS.— Mechanical injury to mullions, headers, jambs, or hardware usually causes trouble with LARGE WOOD FRAMED and BRACED DOORS. Decay, resulting from exposure to weather or shrinkage of door members, also causes distortion or failure. Frequently, the free edge of the door sags and causes the door to bind at the bottom and to open at the top. When inspecting these doors, you should check the following:

- The jamb opening to ensure that the hinge and lock sides are plumb and parallel.
- The doorhead to ensure that it is level.
- The anchorage of the jamb and the hinges.
- The lock face plates for projection beyond the face of the door.

Settling of the foundation or shrinkage and deflection of framing members often causes trouble at door openings. When the greatest settlement is on the hinge side of a door, the door will tend to become floor bound at the lock side. When settlement is greatest on the lock side, the door will bind at the head jamb. As a result, the bolt in the lock will not be in alignment with the strike plate, making it impossible to lock the door securely. Vertical settlement and horizontal deflection will cause the jamb opening to become out of square.

On most wood doors the simple correction is to plane as required at either the top or bottom for proper clearance. When the door itself has shrunk or is warped, swollen, or sagged, the procedures for corrective action are as follows:

1. When a door shrinks, remove the hinge leaves and install a filler (cardboard or metal shim) at the outer edge of the jamb and hinge mortise. This forces the door closer to the jamb at the lock edge; and if the hinge pins do not bend, the door should then operate satisfactorily. Each hinge should be shimmed equally to prevent the door from becoming hinge bound. When the door has swelled, place shims in the inner edge of the hinge mortise, as shown in figure 7-6.

2. Restore a warped door to its normal shape by removing it and laying it flat. Weighing it down may also be necessary. If it is still warped after a reasonable length of time, battens can be screwed to the door to restore it to true plane. Screw eyes, rods, and turnbuckles help straighten a door by gradually pulling it into place.

3. Install a diagonal batten brace from the top of the lock side to the bottom of the hinge side to repair a sagging door permanently. The diagonal brace must cover the joint between the rail and the stile and be securely fastened to both members, at the top and bottom, and other intermediate rail members. Temporary repair can be made by installing a wire stay brace equipped with turnbuckles and placed diagonally in the reverse direction from a batten brace.

4. Doors or door members may require rebuilding because of neglect or abuse. Remove the door to a flat surface and replace the damaged member. Carpenter's clamps assist in holding door members square while nails or screws are driven.

5. Trim the door when the preceding methods fail to correct the trouble. However, do not cut the doors immediately following rain or damp weather. When the door is dry, it may fit too loosely.

Failures in PANEL DOORS are similar to those in large wood doors. In addition, panel doors are subject

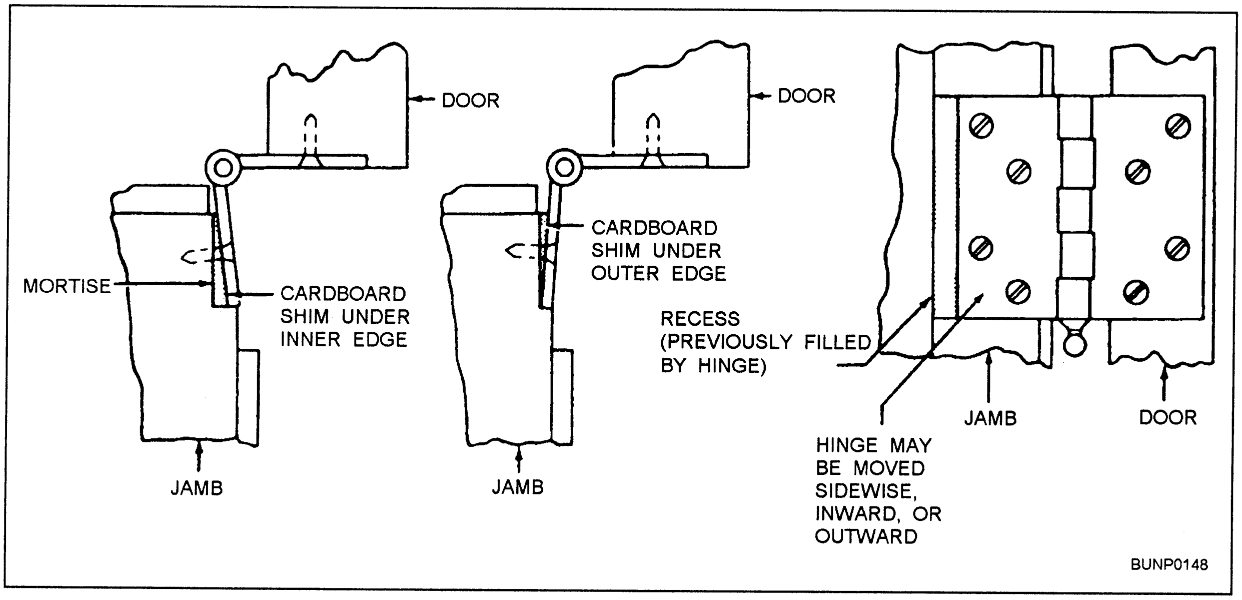


Figure 7-6.—Hinge adjustment for binding or sticking doors.

to binding at the hinge edge, as well as friction between the dead bolt and strike plate or between the latch bolt and strike plate.

METAL DOORS.— Metal doors, commonly used in warehouses, hangars, stockrooms, galleys, and other areas where hard service or other operations require them, are of various types: metal clad, hollow metal, and solid metal, with variations including interchangeable glass and screen panels.

Because most metal and fittings are shop-designed and fabricated, it can be assumed that they will maintain their shape and mechanical operating ability provided hinges, locks, and other fittings remain secure in their fastenings. This is done by checking screens, nuts and bolts, and special fasteners and operating devices regularly, keeping them tight and in good order. Building settlement, mechanical failure, and collision may require investigation and corrective measures for a basic cause of misalignment in the structure framing itself. Frames must be plumb and corners square, so the door fits the opening with proper clearances. Weatherproofing and caulking must be maintained in a workmanlike manner. Mechanically operated doors must be removed and straightened, repaired, or replaced. Repair material and finishing should match the existing material. Shop repair of metal doors should meet acceptable standards for welding, riveting, and sightliness. Replacement of surface metal on fireproof, metal-clad wood doors must be weathertight and of material of the same gauge as originally provided. Service doors in galleys, stockrooms, and other areas where personnel pass in and out frequently with arms loaded should be provided with kickplates and with bumper protection to prevent slamming against walls.

Windows

Both wood and metal windows are found in structures at Navy activities, and the inspector should be alert to detect any defects present in either type. Windows should be inspected quarterly, as appropriate, for loose-fitting or damaged frames, ill-fitting or broken sash, cracked or broken glass, deteriorated putty or caulking, broken or worn sash balances, and missing or broken hardware.

Window failures may result from various causes—the most common of which is weathering. Weathering causes loss of putty, paint, and caulking and this leads to deterioration and rotting in wood windows and rusting in metal windows. If atmospheric conditions cause ordinary putty to deteriorate quickly, plastic glazing compound should be substituted. Caulking around window frames must be maintained in good order to prevent leakage of moisture and air (fig. 7-7). Rust spots on metal sash and frames should be wire brushed or sanded, cleaned with a rag saturated with mineral spirits, and then painted. Problems of alignment caused by building settlements must be adjusted in conjunction with overall corrective measures, that may involve stabilizing the foundation and framing.

ROOFS

Roof structures can be classified according to their shapes and structural limitations. They can be flat, pitched, sloped (such as shed or lean-to types), curved (such as provided by bow-string trusses or circular arches), or mansard, which is a combination of a steep pitched and a shallow pitched roof. Roofs that are supported on exterior walls and at a ridge or bearing at some intermediate point are usually referred to as frame roofs. Those that are truss or arch supported only at the exterior walls or other trusses or columns are referred to as trussed roofs. Rafters are the structural members of a frame roof.

Frame Roofs

Rafters are generally more accessible to inspection than other structural members of a frame building. They are usually uncovered on the underside, so defects and failures can be visually detected. Warped, twisted, or broken rafters can be replaced or, if the roof surface is sound, they may be repaired. Warped and twisted rafters can be straightened by the addition of solid bridging and bracing; broken pieces can be scabbed without harm to the roof covering. Railers, sheathing, and other roof-framing members that are damaged by decay must be replaced. A prevalent cause of the need for extensive roof maintenance is failure of the roof covering. Leaky roofs no longer protect the framing, thus allowing weathering and eventual decay.

Trussed Roofs

Trusses should be inspected at least once a year to check for the existence of problems such as the following:

- Failure in upper and lower chord or web members

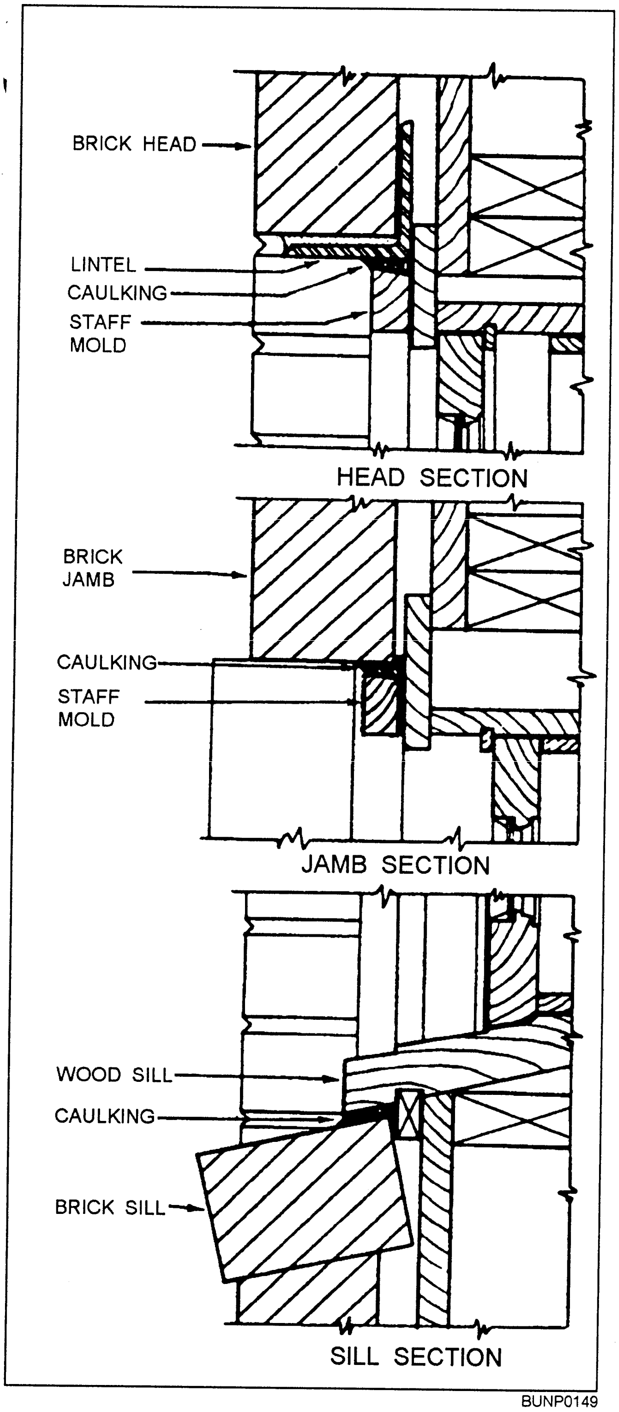


Figure 7-7.—Required caulking around window frames.

- Bowing of overstressed compression members
- Evident separation of joints caused by shrinkage
- Development of splits along lines of bolts
- Development of splits in ends of web members and chord splices
- Pronounced sagging of trusses

Normally, if an actual failure has occurred in a chord member, that member should be replaced. To do this, shore the truss at the panel points along the bottom chord and the remove the damaged member. Using the damaged member as a template, you can fabricate and install the new member. The replacements should be of the same material as the truss and of the same moisture content, if possible. To replace any truss member is usually a costly operation; unless the building is for permanent use, the member should be repaired or augmented rather than replaced.

Checking and splitting are normal reactions in most timber as it dries out. The checking and splitting are more pronounced when unseasoned lumber is used. If the split passes through the bolt holes and continues beyond into the member, it will require attention. The recommended remedy for splitting and checking is the installation of STITCH BOLTS. Figure 7-8 shows the use of stitch bolts in repairing scabs in which end splits have developed; also shown is stitch bolt repair to wood columns in which splitting and deep checking along the grain have occurred. The bolts used for this purpose are 1/2-inch bolts, threaded on both ends. To repair scabs, drill 1/2-inch holes 2 or 4 inches from the end of the split member and perpendicular to the axis of the member. The bolt is then inserted, a 2-inch square-cut washer placed at each end, and the nuts tightened. Installing the stitch bolts before tightening the bolted connection is advisable.

ROOFING

Failure to inspect, recognize, and correct minor defects and deterioration in its earliest stages is probably the greatest cause of premature roof failure. All roofing materials deteriorate on exposure to weather, and the rate of deterioration is affected largely by the kind of material involved and the conditions of exposure.

In inspecting structures, you will probably inspect different types of roofing, such as built-up, asphalt-shingle, wood, metal, tile, and slate. No attempt is made here to cover in detail the many types of roofing materials and their component accessories produced by numerous manufacturers, but rather to discuss, in general terms, the inspection and preventive maintenance procedures peculiar to built-up and metal roofing.

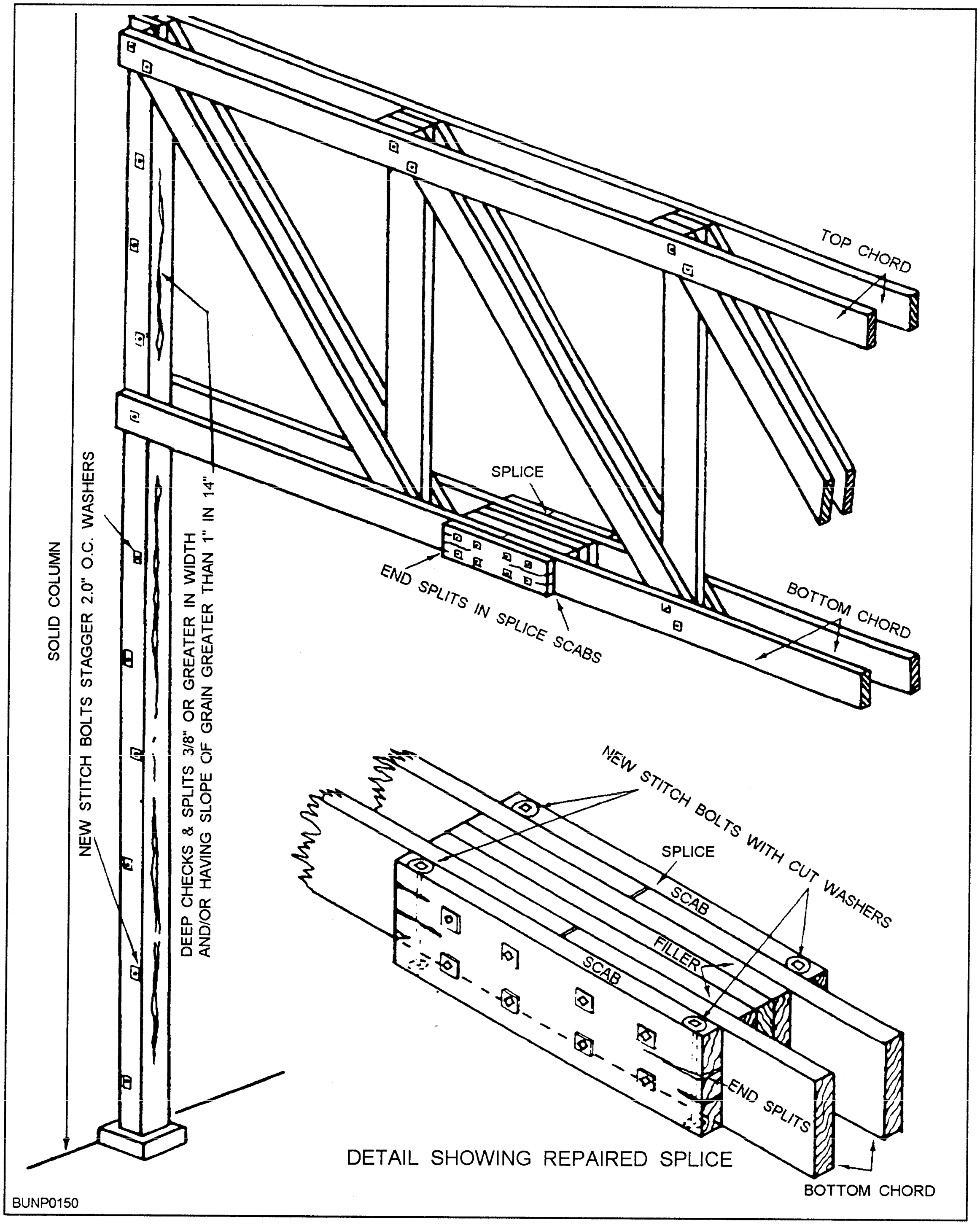


Figure 7-8.—Repair of minor splits using stitch bolts.

Built-Up Roofing

Built-up roofing is exactly what the name implies—a membrane built up on the job from alternate layers of bituminous-saturated felt and bitumen. The bitumen used to saturate the felt and used as a plying cement and coating for the saturated felts may be asphalt or coal-tar pitch. These can usually be distinguished by their odors. Asphalt has a distinctly oily odor and coal-tar pitch a somewhat pungent odor. These odors can be detected best with freshly broken specimens or from fumes of specimens that have been ignited and freshly extinguished. It is important that you determine the type of the existing bituminous material before making or recommending repairs because asphalt and coal-tar pitch are not compatible and contact between the two should be avoided. If you are in doubt, perform a volubility test.

The SOLUBILITY TEST is performed by pouring white gasoline into a container to which a small amount of unknown bituminous material is added. The amount that will stick to the head of a nail will be sufficient. The mixture is then agitated to determine the volubility of the unknown material. If the material mixes readily, giving a homogeneous mixture, it is an asphalt cement. If a mixture with stringy particles in suspension results, it is a tar, since tars are insoluble. If the unknown material is not readily soluble but forms black globules (balls), it is an asphalt emulsion. Built-up roofing should be inspected semiannually for cracking, alligatoring, low spots, and water pending; exposed bituminous coatings; and exposed, disintegrated, blistered, curled, or buckled felts.

CRACKING AND ALLIGATORING.— Smooth-surfaced, asphalt built-up roofs on which the surface mopping is relatively thin usually show definite alligatoring of the surface coating within 3 to 5 years. Alligatoring is always most severe where the asphalt coating is thickest. If allowed to proceed, alligatoring will develop into cracking, as shown in figure 7-9. Once the surface coating is cracked, water penetrates the membrane; and the roof deteriorates rapidly. Consequently, maintenance is necessary to prevent cracking.

The type and extent of maintenance depend on the future use of the structure. On smooth-surfaced, organic felt roofs of relatively brief expected use (4 years or less), remove all dust and dirt by sweeping, vacuuming, or air blasting and apply a thin coat of asphalt primer. After the primer is dry, one or two coating materials (asphalt or asphalt emulsion) may be applied by brushing or spraying at a rate of 3 gallons per square (100 square feet).

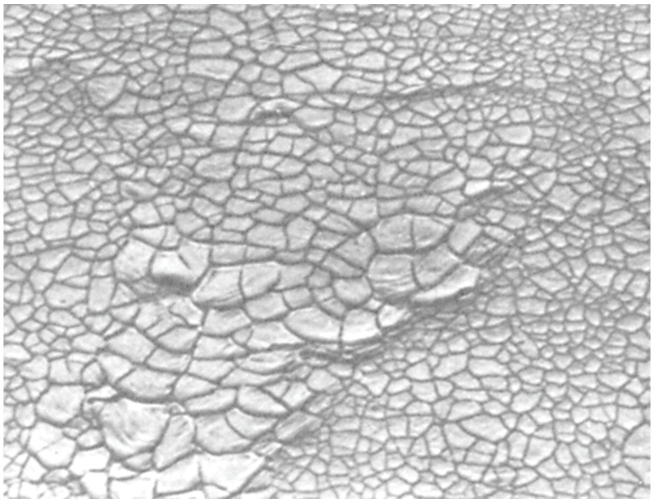


Figure 7-9.—Cracking and alligatoring.

If the asphalt coating is alligatored but not cracked and the felts are not exposed, the primer may be omitted. If an asphalt emulsion coating is to be applied to such surfaces, dust and dirt maybe washed off with a stream of water from a hose. The emulsion can be applied to a damp but not a wet surface.

On organic (rag) felt roofs intended for prolonged use (over 4 years), the cleaning and priming requirements are the same as for roofs of relatively brief expected use. After the primer has dried, apply one coat of asphalt emulsion at a rate of 2 gallons per square. Immediately after applying the emulsion while it is still wet, embed strips of fibrous glass mesh (woven or nonwoven) in the emulsion, lapping the strips 2 inches. While the first coat of emulsion is still wet, apply a second coat of emulsion at a rate of 1 gallon per square over the fibrous glass strips. After the second coat of emulsion has set firmly, apply a final coat of emulsion at a rate of 2 gallons per square. If the asphalt surface is alligatored but not cracked and the felts are not exposed, the primer may be omitted.

EXPOSED BITUMINOUS COATING.— When the bituminous coating on a mineral-surfaced built-up roof is exposed, as shown in figure 7-10, brush loose gravel or slag from the bare area. Cover the bare area with hot bitumen poured at a rate of 70 pounds per square, and embed fresh gravel or slag. Old gravel or slag may be reapplied when the dirt and dust have been screened from it.

EXPOSED FELTS.— Smooth-surfaced, asbestos-felt built-up roofs may be surfaced originally with hot asphalt or with a cold-applied asphalt emulsion. After 4 or 5 years of exposure (sometimes earlier with cold-applied coatings), light gray or even white areas appear, indicating that the felts are partly exposed. Because the asbestos felts are constructed mainly of

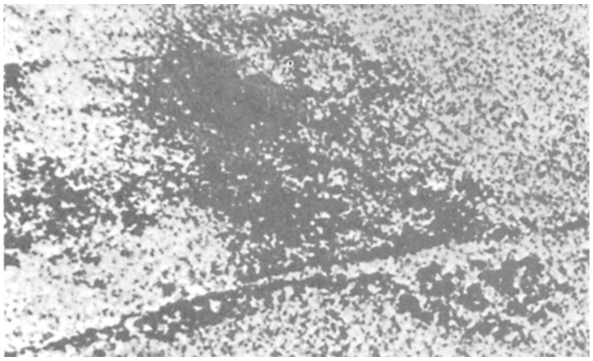


Figure 7-10.—Exposure of bituminous coating.

inorganic materials, exposure to the weather is much less serious than with organic felts. For an expected use of not more than 4 years, no treatment is necessary. Manufacturers of asbestos felts usually do not recommend recoating asbestos-felt roofs at any time. However, recoating of these roofs with asphalt emulsion at a rate of 3 gallons per square, at intervals of 4 or 5 years, will prolong their usefulness indefinitely.

On mineral-surface built-up roofs, exposed felts are repaired by first removing all dust and dirt from the exposed area and, in the case of asphalt roofs, applying one thin coat of asphalt primer. When the primer is dry, treat as described for exposed bituminous coating. Coal-tar pitch roofs are treated similarly, except that no primer is required before the coal-tar pitch is applied.

On organic felt, smooth-surfaced built-up roofs, repairs to exposed felts should be made as described for those on mineral-surfaced roofs, except that 20 or 25 pounds of asphalt should be mopped per square and the mineral surfacing omitted.

DISINTEGRATED FELTS.— To repair felts that have been exposed and partially disintegrated, scrape off all surfacing material to at least 2 1/2 feet beyond the area of disintegrated felts. Remove disintegrated felt layers and replace them with new 15-pound, bituminous-saturated felts of approximately the same size, mopped in place with hot bitumen. Apply at least two additional layers of 15-pound saturated felt, mopped on with hot bitumen and extending at least 12 inches beyond the area covered by the replacement felts. Apply a pouring of hot bitumen to the repaired area at a rate of 70 pounds per square; and while hot, embed fresh gravel or slag into it.

As mentioned earlier, asphalt and coal-tar pitch are not compatible. Asphalt and asphalt-saturated felt should always be used in the maintenance of asphalt built-up roofs and coal-tar pitch and coal-tar saturated felt in the maintenance of coal-tar pitch built-up roofs.

Metal Roofing

Galvanized-steel and aluminum roofing should be inspected semiannually for holes, looseness, punctures, broken seams, inadequate side and end laps, inadequate expansion joints, rust or corrosion, and damage resulting from contact of dissimilar metals. Because the different metal roofing materials normally require different preventive maintenance, they are considered separately in this manual. However, copper, terne, and aluminum roofs have one thing in common. When they have been well applied and adequately maintained, reroofing is seldom required.

GALVANIZED-STEEL ROOFING.— Corrugated, galvanized roofing is the lowest in cost of all types of metal roofing; and when properly applied and maintained, it renders satisfactory service. This type of galvanized roofing is used most frequently on warehouses and sheds. It is representative of the galvanized-metal roofings. The most frequent causes of failure in galvanized roofs are improper application and lack of maintenance painting. Leaks at seams and fasteners are evidence of improper application.

Inadequate laps in galvanized-steel roofing may be repaired by caulking or, in severe cases where caulking is not possible, by covering the laps with a membrane, such as asphalt-saturated cotton fabric or lightweight, smooth-surfaced roll roofing. When making repairs, the procedure requires that you adhere to the following steps:

1. Apply an asphalt roof coating to the seams in strips approximately 6 inches wide. Use approximately 1 gallon of coating material to 80 linear feet of seam.

2. Cut the roll roofing or saturated fabric into 4-inch strips approximately 12 feet long. Embed the membrane strip in the asphalt roof coating, pressing it firmly into the coating until it lies flat without wrinkles or buckles; the center of the strip must be directly over the exposed edge of the roofing.

3. Then apply another coating directly over the membrane strip so that the membrane is completely covered and the first and second coatings are continuous.

Roof coating materials vary considerably in consistency, composition, and setting time. In some cases, it may be desirable to allow the first coating to become tacky before applying the membrane material or to allow the first coating with the membrane embedded in it to remain for some time before applying the second coating.

You should realize that repairs of this kind cannot be expected to last as long as the galvanized sheets. Seams treated by this method should be maintained by recoating them periodically with an asphalt coating of the type used in the original treatment. [n warm humid locations, recoating will probably be necessary after

18 months to 2 years; in other locations, after 2 1/2 to 3 years.

ALUMINUM ROOFING.— Aluminum roofing, properly applied, does not normally require maintenance. Failures in aluminum roofing that result from improper application are essentially the same as those encountered with galvanized-steel roofing and are repaired similarly.

Flashing

Failures to roofs are usually attributed to the roofing material; however, frequently caused failures are actually due to improper installation of the flashing material. These areas should be the first to be inspected when leaks in a structure are reported. A good procedure to follow is to make a careful inspection of the roofing material near the flashings for signs of moisture. Punctures, broken laps or seams, separation of flashing from vertical surfaces, and deterioration from weather are causes of failure.

If a separation occurs between the base flashing and a wall, refasten the base flashing to the vertical surface by nailing or cementing. Recoat it with a plastic flashing cement and replace with the correct counter-flashing.

Leaks sometime occur around vent flashing. The majority of vents are constructed of metal and, consequently, are subject to expansion and contraction. For this reason, it is poor practice to attempt to flash up the sides of such projections because this type of flashing is subject to early failure. Vents are usually of two types: the flat flange vent and the curb flange vent. The flat flange vent is placed directly upon the last ply of roofing, whereas the curb vent is constructed to fit over a wooden or concrete curb. When exposed nails that hold a flashing flange to a roof work loose, as shown in figure 7-11, raise the flashing flange high enough to force plastic cement beneath it and replace the loose nails. Apply two plies of felt or fabric cemented to each other and to the flange with asphalt, pitch, or plastic cement. The outer edge of the first ply of felt or fabric should extend not less than 3 inches beyond the flange and that of the second ply of felt or fabric not less than 6 inches. Apply the finished surfacing similar to existing roof surfacing.

Drainage Systems

It is important that drainage areas be kept free from debris that will interfere with proper drainage. Many roof failures can be traced to inadequately maintained drainage systems. If during a semiannual roof inspection you notice the accumulation of debris in gutters and around drains, take action to make sure that all debris is removed to prevent subsequent roof failure.

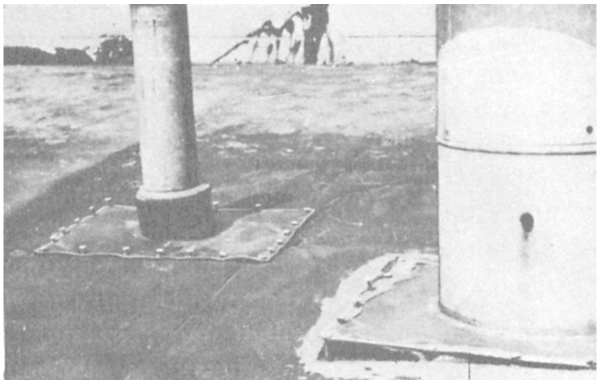


Figure 7-11.—Separation of metal flashing flanged from roof-caused by exposed nails that have worked loose.

PAINTED SURFACES

Paints are not indestructible. Even properly selected protective coatings properly applied on well-prepared surfaces will gradually deteriorate and eventually fail. The rate of deterioration under such conditions, however, is slower than when improper painting operations are carried out. Inspectors and personnel responsible for maintenance painting must be familiar with the signs of various stages of deterioration to establish an effective and efficient system of inspection and programmed painting. Repainting at the proper times prevents the problems resulting from painting either too soon or too late. Painting scheduled before it is necessary is uneconomical and eventually results in a heavy film buildup leading to abnormal deterioration of the paint system. Painting scheduled too late results in costly surface preparation and may cause damage to the structure, which then may require expensive repairs.

Inspection of Painted Surfaces

All painted surfaces should be inspected at definite intervals. They should be inspected semiannually in exterior and corrosive environments, in areas where heavy traffic may cause rapid wear (floor finishes), and in areas where sanitation is important. Other areas should be inspected annually. The inspector should observe their condition for the type and stage of deterioration and make recommendations for spot painting, repainting, or more frequent inspection. The frequency of repainting can be determined by periodic inspection of all coatings. It is important to check on a systematic basis so that painting can be scheduled in advance, at a time when the coating is thin enough, yet has not degraded to the point of disintegration. Thus little surface preparation will be required, and only one or two coats of paint may be necessary.

Stages of Paint Deterioration

Paints which are exposed outdoors normally proceed through two stages of deterioration; generally, a change in appearance followed by a gradual degradation. If repainting is not done in time, disintegration of the paint then takes place followed ultimately by deterioration of the substrate (basic surface). Interior coatings generally change slowly in appearance with time but do not usually degrade to any significant extent otherwise.

The first stage of deterioration shows up as a change in appearance of the coating with no significant effect on its protective qualities. This change in appearance may result from soiling, fading, or flattening, depending on the type and color of the paint used and the conditions of exposure.

The second stage of normal deterioration occurs after continued exposure. The coating begins to break down, first at the surface, then, unless repainted, gradually through the coating and down to the substrate. There are two types of degradation that may take place—either chalking or checking and cracking—the degree of either depends on the type of paint and the severity of exposure. When large areas of substrate become exposed, the coating has reached the point of complete deterioration and is in a state of neglect. Such surfaces require extensive and difficult preparation before repainting. All of the old coating may have to be removed for you to ensure that it does not create problems by continuing to lose adhesion, taking the new coating with it. Furthermore, complete priming of the exposed substrate will also be required, thus adding to cost and time. Continued neglect may also lead to deterioration of the structure, resulting in expensive repairs in addition to paint costs.

It is assumed that, through study and experience, you are familiar with the defects resulting from the various stages of deterioration mentioned above and can readily identify them. Therefore, the defects are not described here.

WATERFRONT STRUCTURES

As with buildings, the maintenance inspection of waterfront structures should be designed to include the following: (1) the prompt detection of deficiencies or damages and (2) the expeditious performance of repairs, consistent with requirements, in an economical and workmanlike manner.

Deterioration of waterfront structures is caused by the destructive forces to which they are exposed, such as the following:

- Attack by marine organisms
- Rust, corrosion, and decay
- Mechanical damage, including the impact and pressure of ships, and the abrasive action of sand and debris
- Wave action and erosion

To determine the extent of maintenance and repair work required, an inspection should be made annually of all basic structures (piers, wharves, quay walls, bulkheads, and retaining walls) and semiannually for fenders and movable equipment, such as brows and camels. More frequent inspections than those specified may be necessary under certain circumstances, such as tidal waves, high tides, earthquakes, and action by destructive forces of nature. Inspections may be made from the structures, from a boat or afloat, or from below the waterline by divers. Cameras are often used in visual inspections.

Some of the major defects that can be seen by visual inspection are as follows:

- Spans, cracks, and breaks in concrete work.
- Rusting of structural steel and exposed reinforcingsteel in concrete.
- Decay in wood.
- Mechanical damage, resulting in broken or bentstructural members.
- Damage by wave action and water erosion, including thewashing out of fill through defective sheetpiling.
- Shrinkage of timbers around bolts and cracks aroundloose bolts that allow water to enter. These conditions areusually found in pier curb rails, stringers, wales, pile caps, and other members above the tidal range.
- Deterioration of decking.

- Loose spikes and bolts; worn, cracked or broken rails, and deteriorated ties.
- Deterioration of service lines, terminal boxes, outlets, broken brackets, loose insulation, corroded piping, andbroken seals.

CONCEALED DAMAGES are often overlooked in a visual inspection. It is often necessary to resort to special methods or tests. When underwater damage is suspected, divers are generally required. Some of the methods used to discover concealed damages are tapping with a hammer and probing with a chisel, a screwdriver, or a sharp-pointed instrument to detect deterioration or decay. This type of inspection will usually indicate whether further examination is necessary. Any evidence of damage or deterioration affecting the structural stability of any structure should be the subject of an immediate engineering study.

Waterfront structures, for the most part, contain one or more of the following materials: concrete, metal, wood, stone, earth, or masonry units. Therefore, the following sections describe the maintenance and repair procedures unique to each of these materials, in general, with specific procedures when they apply to certain types of structures.

CONCRETE STRUCTURES

Concrete is a fairly permanent construction material, but local conditions can produce defects that require corrective measures. You should be familiar with common types of defects that occur in concrete and know what measures to take to correct these defects.

Repairing Concrete

When concrete that covers reinforcing steel is deteriorated, spalled, or cracked, the reinforcing steel begins to rust and repairs should be made promptly to avoid excessive damage. All loosened materials must be removed and the concrete cut back to sound material. Cut the areas to be patched a minimum of 1 inch and at right angles to the surface. If the reinforcing steel is seriously damaged by rust, cut the concrete back far enough to replace the damaged steel with new reinforcing. New reinforcing bars should match the original bars in size and grade of steel and should be lapped at each end for a length of not less than 30 diameters of the original bars or as directed by higher authority. The new bars must be securely wired or welded to the old before patching. Exposed reinforcing steel that is not seriously damaged by rust should be cleaned by brushing or sandblasting to make a firm bond with the new concrete. Reinforcing steel should be covered by a minimum of 3 inches of concrete if at all possible.

Superstructure Repairs

Repairs to superstructures will include filling surface cracks, replacing structural members, cutting and filling expansion joints, and resurfacing decks.

SURFACE CRACKS that are not structural defects must be promptly filled to avoid the entrance of water. Thoroughly clean the crack with a high-pressure water jet to remove all foreign matter. Edges of the crack should be moistened, but not wet. Fill the crack with a thin grout of cement and water or a epoxy-based material, using a brush, if necessary, to push the grout in the crack. For wider cracks, use a mortar of cement, sand, and water instead of cement grout. If such cracks are of insufficient width to permit placement of filler material, they should be cut out before cleaning. After filling the crack, cover with burlap or sand and keep the covering moist for at least 3 days. Asphalt, tar, and certain other materials may also be used with satisfactory results for sealing random cracks in concrete decks and curbs.

PATCHING AND REPLACEMENT forms are usually required except for minor patches on top of a slab and for pressure-applied concrete or epoxy-based material. Forms may be of pipe, sheet metal, or wood and either left in place or stripped. They should be strong, well-braced and, if they are to be stripped, designed so they can be removed without damaging the concrete. Pressure-applied concrete is generally used to repair spalling on the underside of a deck or beam. Cut back the spalled area to sound concrete, and replace reinforcement as described earlier. Then repair or rebuild to the original section with pressure-applied concrete. Slabs or other structural members that are broken or severely damaged must be replaced. The assistance of qualified engineers should be obtained to analyze such cases to determine the cause of failure and to furnish an adequate design of replacement members. Methods of patching deck slabs of reinforced concrete piers are shown in figures 7-12 and 7-13. Slabs may be broken through by overloading. If this is a relatively small area and near the center of a span, it can be repaired by cutting out the deck and reconcreting, as shown in figure 7-13. To repair a hole, you can bevel the concrete as shown

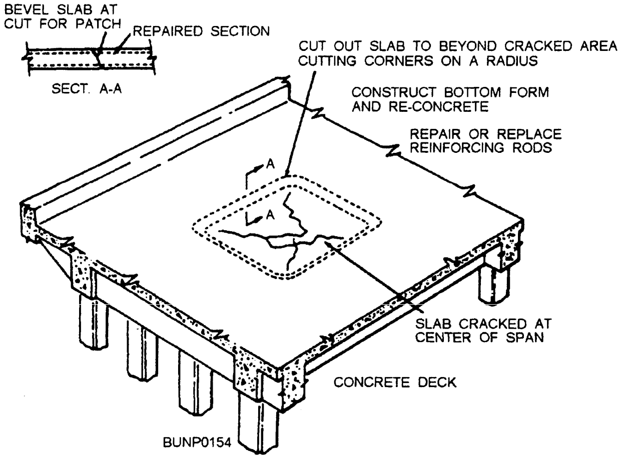


Figure 7-12.—Repair of deck at center of span.

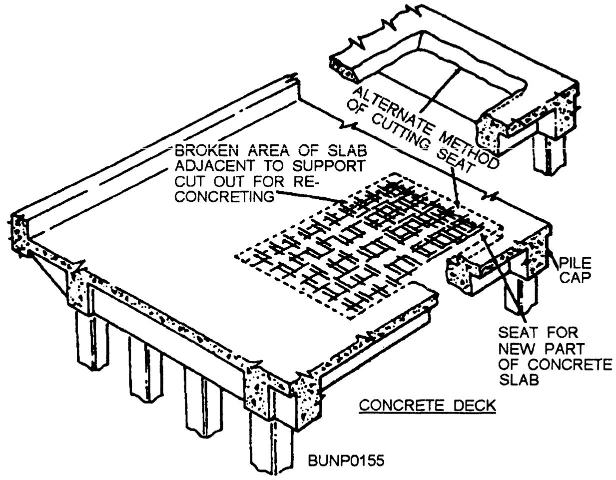


Figure 7-13.—Repair to damaged edge of slab.

in figure 7-14; or in addition to beveling, the area to be removed may first be scored along the break line, using a saw, to a depth of 1 1/2 inches. The depth is to be adjusted where reinforcing is encountered. No joint in the slab should be made either adjacent to or at the edge of a supporting beam or at or near the ends of reinforcing bars. If the slab must be cut back to the supporting beams or replaced, a seat should be cut into the beam to the depth of the slab and one quarter to one third of the width of the beam. If deck slabs have been damaged by heaving (lateral or upward movement resulting from freeze/thaw cycles), they must be replaced. Make provisions for an adequate expansion joint in the new slab. If two or more adjacent slabs have heaved, you will often find that piles have been pulled up with the slabs. When this condition occurs, the piles should be re-driven to a firm bearing and necessary repairs made to concrete caps. (See fig. 7-15.)

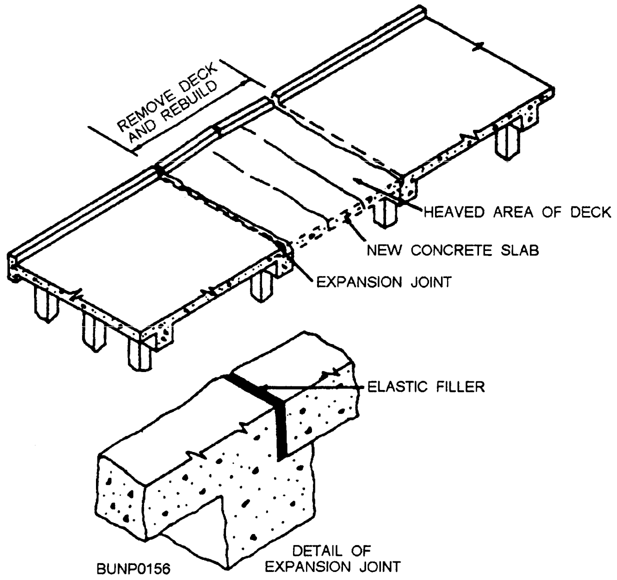


Figure 7-14.—Heaving of concrete deck.

If EXPANSION JOINTS have proven inadequate in number or are not functioning properly, heaving will result. Where joints are too far apart, cut additional joints with a concrete saw and fill them with an approved type of joint sealer. Asphalt, tar, and certain other materials may be used with satisfactory results for sealing joints. Sealing material should adhere to the concrete and should remain plastic at all temperatures. It should not become hard and brittle in low temperatures or so soft that it flows from-the joint during intense heat or so tacky that it is picked up by vehicle tires.

RESURFACING concrete pier decks that have widespread surface deterioration may be restored by resurfacing with asphalt. The existing slab must be properly prepared before placement of the new asphalt surface course. Clean all loose, scaled, and foreign matter down to sound concrete, using power wire brooms and compressed air. Flush with high-pressure fresh water to remove salt if near seawater. All cracks must be cut to a clean rectangular trench, usually not less than 1/2 inch wide by 1 1/2 inches deep (adjust depth to suit reinforcing steel). Fill the trench to within one-half inch of the top with a high-softening point asphalt mastic or joint-filling compound. Paint the surface of the concrete for 3 to 4 inches on both sides of the trench with asphalt emulsion and cover with 30-pound asphalt-impregnated felt 4 inches wider than the trench. It is very important to seal the cracks

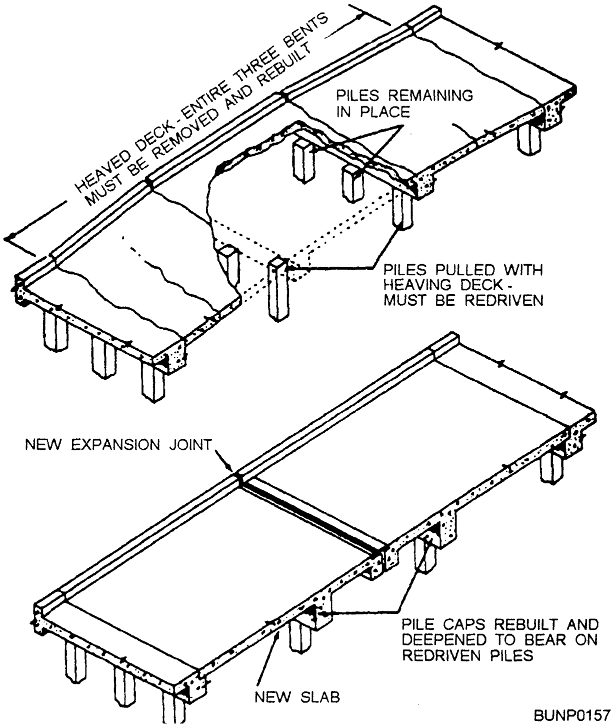


Figure 7-15.—Piles pulled by heaving deck.

properly to eliminate reflection cracking and subsequent premature failure of the new asphalt surface cover. Liquid asphalt is applied to the surface of the portland cement surface as a primer, and a dense graded mix of asphalt concrete or sheet asphalt is laid as a surface according to a predetermined design. A partial remedy to protect concrete from chemical deterioration is to apply a layer of dense impervious concrete properly anchored to the old work or some of the newer materials, such as epoxy resin formulations.

Substructure Repair

Free standing components of structures damaged or deteriorated by such means as spalling or longitudinal or horizontal cracks in tiles and bracing can be repaired above the waterline. Pressure-applied mortar, epoxy formulations, normal portland cement concrete, or grout are the materials used. Encasement of damaged portions in reinforced concrete is the conventional method of repairing piling. It is always preferable to place concrete in air if economical and feasible; however, this requires the use of cofferdams, and it is not always an economical solution. When the solution dictates, concrete can be placed under water. Forms may be used, as shown in figures 7-16 and 7-17.

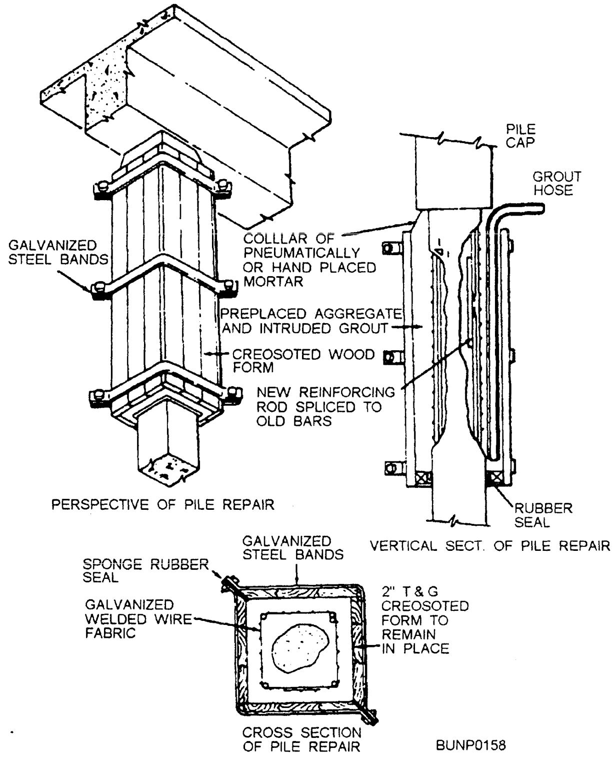


Figure 7-16.—Encasement of damaged piles (wood form).

Additional reinforcing in the form of rods or mesh is placed around the damaged pile, and sectional forms are used to hold the concrete in place until it cures. Forms may be made of pipe, sheet metal, or wood and are split in half vertically so that they can be placed around the tile and bolted together above the water. Each section is then slid into place and new sections added until the desired length is obtained. The form is then filled with concrete. Forms may be left in place or removed for reuse. Where only a section of the pile is to be encased in concrete and the forms do not extend to the mud line, the lowest section of the forms must be closed to hold the concrete or aggregate and grout in place. (See fig. 7-17.) Pressure-applied concrete may be used to make sectional forms. These are built upon cylinders of expanded metal laths shaped to fit around the pile. Wire mesh reinforcement may be used outside of the metal lath where additional strength is required. Pressure-applied concrete is used to make a sectional form 1 or 2 inches thick, and the concrete is allowed to set. This form is then dropped into place and filled with concrete.

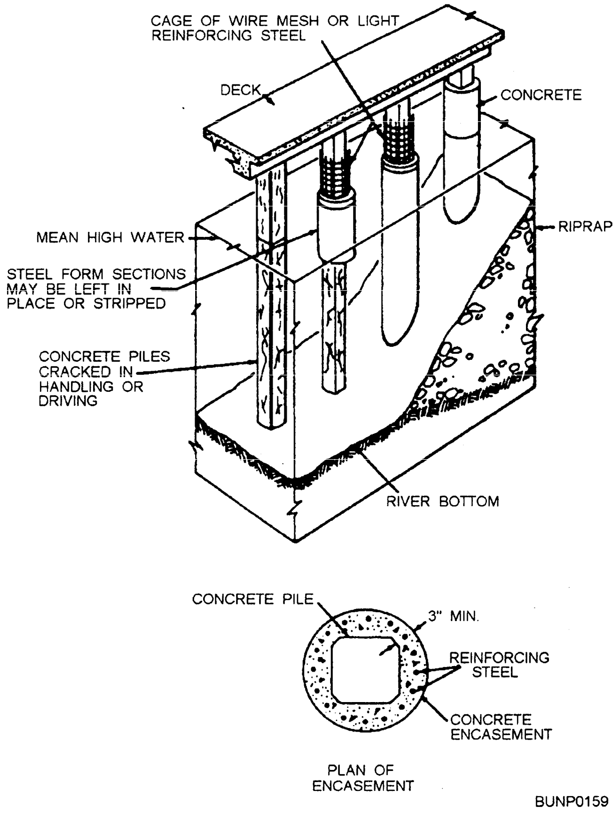


Figure 7-17.—Encasement of damaged piles (metal form).

STEEL STRUCTURES

Inspections of corroded. weakened, or damaged areas are essential for determining the best methods or needs for repair coating or replacement of steel members in the various structures. Main members are normally replaced when 30 percent or more of the section has been removed by corrosion or when seriously deformed. In the planning of replacements, consideration must be given to the rate of corrosion or actual decrease in section. If adjacent members show signs or serious deterioration, it may be best to replace whole frames or bents. Never remove a stressed member until the stress has been relieved by temporary bracing, shoring, or jacking because, if the stress is not removed, the member may sprint out of place when loosened, making it very difficult to replace the member. In the replacement of piles, the load should be shifted temporarily to adjacent piles by means of temporary beams or jacks. The replacement of wales on bulkheads may require the excavation of the fill to relieve the lateral loads. The structures must retain their structural stability at all times. In most cases, the maintenance and repair of metal structures will be handled by the SWs. At times, though, the BUS may be working with the SWs in these operations, so let us consider some of the common methods of maintenance and repair.

New members must be accurately fabricated to match the old work. Special care must be taken to be sure that all bolt-and-rivet holes line up with original members. Before the placement of the new member, all old rivets or bolts must be removed in the most expeditious manner by using hand or pneumatic chisels, saws, and wrenches, or by burning them off before removing the old member. Place the new member in position and line up all holes by adjusting the jacks or the bracing as necessary. Place a few bolts to hold the member, then fasten securely in place by riveting, placing additional bolts or welding.

In the replacement of bearing piles, the new pile is generally driven alongside the old one at a slight angle. It is then cut off at the proper elevation, capped, usually by welding on a steel plate, and pulled into position by block and tackle. If the old pile is pulled and a new one driven, care must be taken to transfer the load temporarily until the new pile can assume the load. Care must be taken to bore or punch the bolt holes in the cap to conform with the holes in the floor beam or stringer.

Precautions may be necessary when replacing wales and sheet metal bulkheads because they often retain materials that have a low angle of repose. The old wales are left in place or at least until new wales are installed just above or below the originals. Occasionally, they can be connected to existing tie rods; however, in most cases, new tie rods and deadmen should be installed.

Badly deteriorated sheet pile is generally protected by new sheetpiling being driven outside the old piling and provided with new wales, rods, and deadmen. The space between the piles must be filled with well-tamped earth, sand, gravel, or concrete, depending upon conditions at the site.

Steel members that have corroded in only limited areas may be repaired by welding fishplates onto the flanges and the web. The corroded area should be first thoroughly cleaned and featheredges burned off back to a point where the metal is of sufficient thickness to hold a weld. Fishplates should be of sufficient cross-sectional areas to develop the full strength of the original section and should extend beyond the top and bottom of the corroded zone. Another method is to encase the corroded section in reinforced concrete.

After cleaning the corroded area and cutting back the corroded edges, you weld the reinforcing bars to the flanges and the web. A form is then placed around the corroded section and filled with concrete. Figure 7-18 shows this procedure for a steel H-pile. The same system can be used for other structural members.

Sheetpiling Repair

Sheetpiling usually serves as a bulkhead to retain earth or other fill. Holes in the bulkhead will result in loss of materials and settlement behind the bulkhead. Local damage or holes can be repaired by welding on plates or more sections of steel sheetpiling. If the holes are small, wooden plugs can be used to fill the holes. Usually, it is necessary to install new sheetpiling in the deteriorated areas; however, it may be economically feasible to protect the damaged sheetpiling with a concrete facing, as shown in figure 7-19. Remove all rust, scale, and marine growth before placing concrete. Concrete covers, when applied to the exposed exterior face of the piling, should be at least 6 inches in thickness and extend well beyond the area of corrosion, damage, or deterioration. Formwork should be of wood, supported in place by stud bolts that are welded to the sheetpiling. Use heavy zinc-coated bolts and nuts. It is preferable that the wood forms be left in place because they will provide protection against damage from floating debris and erosion for some time. Where the back of the bulkhead can be easily exposed, it may be advisable to encase the sheetpiling completely in concrete. Minimum thickness of concrete facing where the piling is completely encased in concrete should be 3 inches. Care must be taken in replacing the backfill when the sheet pile has been encased. GRANULAR materials are preferable. Fill should be placed in layers and well compacted.

Tie Rod Repair

Deteriorated tie rods will allow the top of a bulkhead to move outward. Remove the fill to expose the tie rods and turnbuckles by starting the excavation at the back face of the bulkhead, and progress to the shore in as narrow a trench as possible along the tie

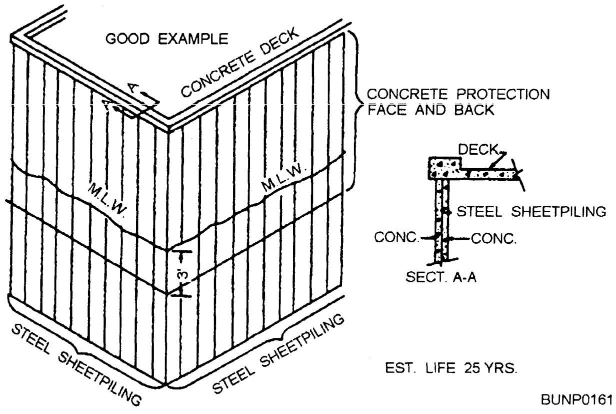


Figure 7-19.—Concrete encasement of steel sheet pile.

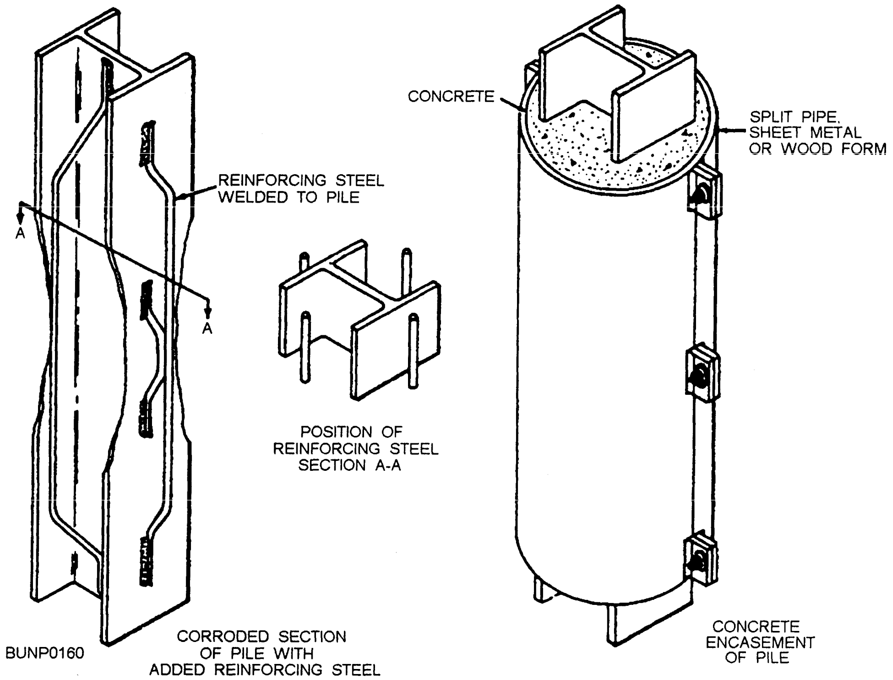


Figure 7-18.—Concrete encasement of steel pile.

rod to the deadmen. Thoroughly clean the tie rods and turnbuckle by removing rust and corrosion. Repairs may be made by welding new rods onto the corroded area (fig. 7-20) or by installing new rods from the turnbuckle to the face of the wall or outside of the wales. Check the condition of the deadmen and either make necessary repairs or strengthen them as required. Tie rods should be replaced or repaired one at a time. Coat new work with bituminous material, wrap with fabric tape, apply another coating of bituminous material over the tape, and then backfill the trench.

WOOD STRUCTURES

Wood pile and timber structures in a marine environment are susceptible to infestation and attack by marine organisms or wood rot spores. Therefore, treated piles and timbers should be used in the repair or replacement of such members in structures, unless there is a specific reason for doing otherwise, on the basis of the economic expected life. Southern yellow pine, Douglas fir, and oak have been found to be most suitable for waterfront structures; however, hemlock, larch, spruce, cedar, and tamarack can be used. Bolts, washers, spikes, driftpins, and other hardware used in repair of timber members must be heavily galvanized.

Decking

The use of creosote-treated lumber for wood “decking” is not recommended. Deck surfaces drain rapidly and, being well ventilated, dry rapidly so that the principal concern is not the same as it is for the covered, inaccessible structural framing. Usage and wear from traffic is generally the cause of deck repair and replacement. Top surface decking over which vehicular and pedestrian traffic passes should be replaced when the top surface becomes excessively uneven, hazardous, or worn to a point of possible failure of the decking. Replacement should be with edge-grain timber, surfaced on four sides. Decking should be laid with 1/2-inch to 3/8-inch spaces between each plank to permit ventilation and drainage. The top surface should be reasonably smooth and level, particularly where repaired areas meet existing decking. End joints should be staggered where existing and new decking meet. Decking should be nailed securely at every stringer with 6-inch spikes for 3-inch decking and 7- or 8-inch spikes for 4-inch decking. Spikes should be driven flush with the top deck planking. Care should be taken to rebuild the openings or access for underpier fire-fighting nozzles or sprayers and for access to piping, valves, and fittings into the repaired decking area. Decking for relieving platforms that have an earth fill should be a double layer of pressure-treated lumber laid without spacing between planks.

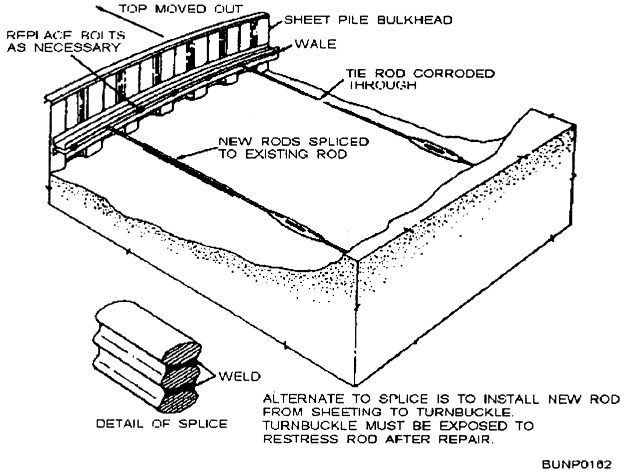


Figure 7-20.—Repair of tie rods.

Stringers

Stringers that have rotted or have been damaged should be replaced. Replacement stringers should be tightly bolted where they lap with existing stringers that are to remain, and they should be pinned or bolted down to caps. Stringers that extend continuously for the length of the pier may be replaced in part by splicing to sound parts of the timber. Splices should be placed directly over pile caps, and the splices in adjacent stringers should be staggered where possible. A typical splice for a 12-inch by 12-inch stringer or cap is shown in figure 7-21.

Pile Caps

Pile caps that require replacement because of rot or damage should be completely replaced between the splices of the original structure. Bolt holes in new caps should be carefully made to align properly with bolt holes in existing caps. It is preferable to use new fishplates, particularly if they are of timber.

Braces

Diagonal and sash braces that have rotted, have been broken, or have been weakened by marine borer attack should be replaced. Each brace should be replaced completely, rather than spliced. Bolt holes should be carefully placed for proper alignment. When wood braces are fastened to piling, the pile should not be cut to obtain a flush fit. The braces should be bolted, if possible, above the high waterline. After bolt holes have been drilled, they should be treated with preservative, preferably with a specially designed bolt hole that forces the preservative into the hole under pressure. Where decking has been removed for repairs, it is often possible to drive brace piles to provide lateral stiffness. This eliminates all bolt holes except at the top of the structure immediately under the decking.

Fire Curtain Walls

Fire curtain walls that have rotted or that have been damaged or severely attacked by marine borers should be restored to the original condition. When damaged timbers are replaced, they may be spliced out. Splices should not be made in the same location on both sides of the wall because an open crack would remain. The curtain wall should be as airtight as possible after repairs are completed. Wood fire curtains are usually made of two layers of timber—the joints in one layer running diagonally to the joints in the other. It is important that the joints be tight and that both sides of the wall be completely repaired.

Wood Piles

The decayed top of wood-bearing piles can be repaired by cutting off the damaged portion and building up to the proper height with sound timber (fig. 7-22). Driftpins should be driven through the cap and down through the new section of pile. This involves the removal of some of the deck planking. In every case, fishplates of metal or treated wood should be used to hold the new section in place. Fasten the fishplates securely with spikes, lag screws, or bolts. Where all the piles in a bent have decayed tops but there is less than a foot of unsound piling, the method shown in figure 7-23 maybe used. The top of each pile in the bent is cut off to allow the installation of an additional 12-inch by 12-inch cap under the existing cap. Drive the driftpins through the caps into the piles to hold the tops in place. In most cases, the connection of the caps to the piles should be further strengthened by bolting them together with 1-inch bolts and 12 1/2-inch by 3/8-inch steel straps. Use 1-inch bolts for bolting the two caps together.

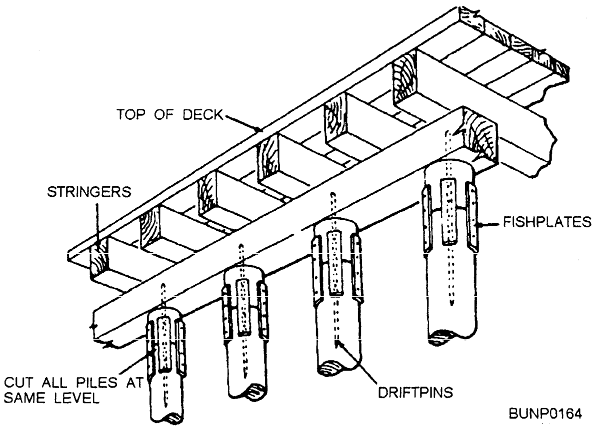


Figure 7-22.—Replacing top of piles.

Piles that are broken or badly damaged should be replaced (fig. 7-24). The old pile should be pulled and a new one driven in its place. Where old piles cannot be pulled or where they break off, the old pile must be

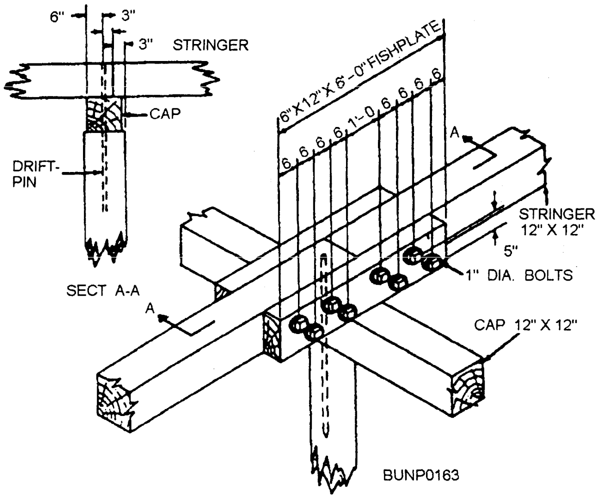


Figure 7-21.—Stringer splice.

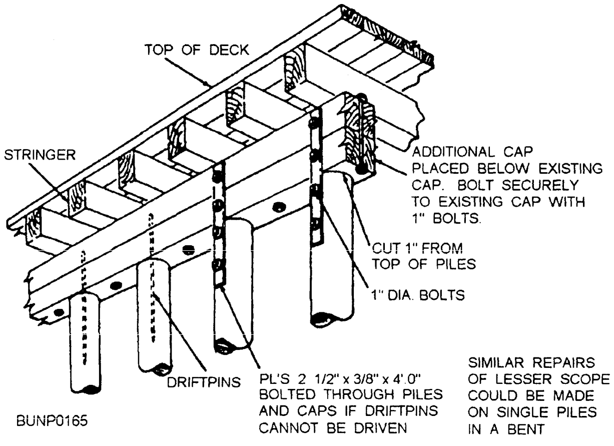


Figure 7-23.—Repair of top of piles.

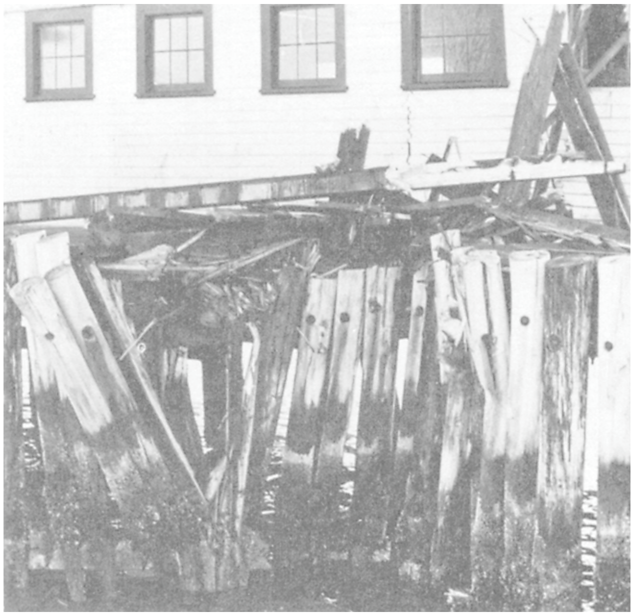


Figure 7-24.—Broken wood piles.

cut off as far down as possible and a new pile driven alongside of it. After driving, the head of the new pile is pulled into place and fastened to the cap with a driftpin or with the use of fishplates (fig. 7-25). Treated replacement piles should be used for all structural pier piles; however, on major operations and supply piers, where the life expectancy of the fender system is relatively short because of its continued exposure to the berthing of major ships, the use of untreated, unskinned piles may be considered structurally suitable and economically sound.

Piles that have been weakened by marine borers can be strengthened and protected by encasing them in concrete jackets. Steel reinforcing can be used in the concrete jacket either in the form of bars or wire mesh. Concrete encasement may be used to cover a short section of the pile where damage is limited, as shown in figure 7-26, or may be extended well below the waterline, as shown in figure 7-27. The damaged surface of the pile must be scraped to sound wood. Either metal or wood forms may be used. If wood forms are used, a 2-inch creosoted tongue-and-groove material should be used and left in place. Fender piles that are broken between the top and bottom wales, as shown in figure 7-28, can be repaired by cutting off the pile just below the break and, then installing a new section of pile and fitting. Place and bolt a pile section or timber section directly behind the fender pile from the top to the bottom wales. A metal wearing strip should be spiked to the wearing edge of the pile.

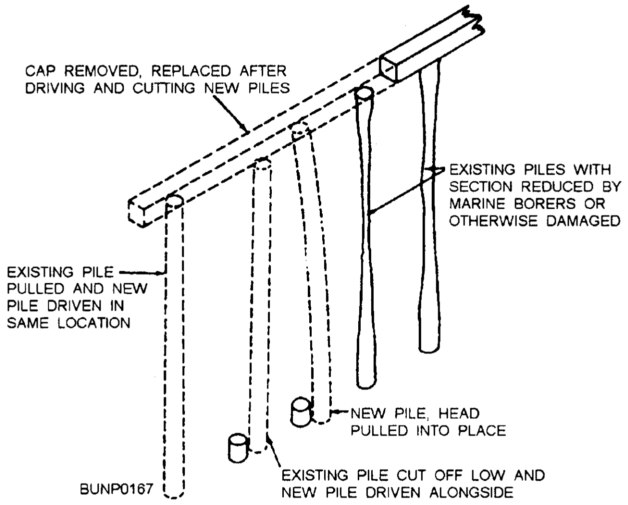


Figure 7-25.—Wood pile replacement.

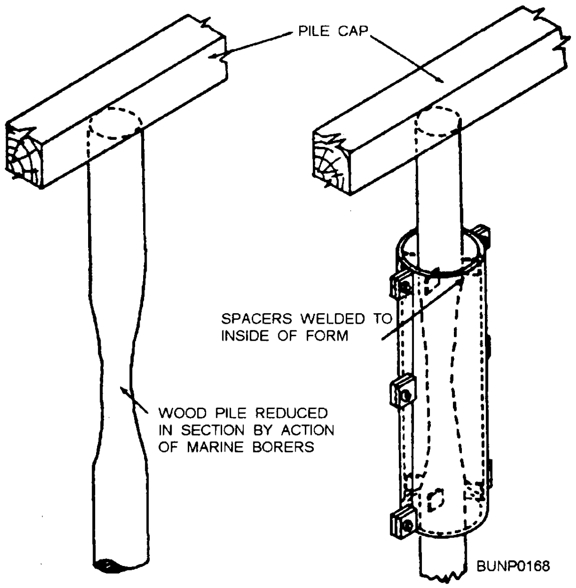


Figure 7-26.—Concrete encasement of short section of wood pile.

Sheeting

Piers and quay walls may have a bulkhead of wood sheet pile to retain the fill on the shoreside. Riprap is usually placed at the foot of the sheeting for strengthening. Extensive deterioration of the bulkhead will result in the loss of fill and settlement above the affected area. Repairs usually require the driving of sheetpiling to form a new bulkhead a minimum of 1 foot inside the old one to avoid the driving frames or wales attached to the old bulkhead. New sheetpiling may be pressure-treated wood, concrete, or sheet steel. Steel sheetpiling is normally used for the new bulkhead because oftentimes the work must be done inside a pier shed. In this case, steel piling is driven in maximum lengths possible and additional lengths welded on successively. The new sheet pile should

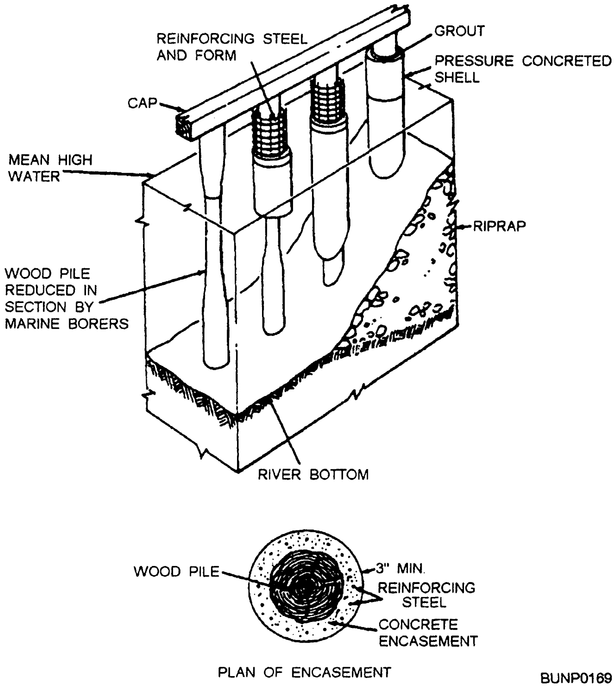


figure 7-27.—Extensive concrete encasement of wood pile.

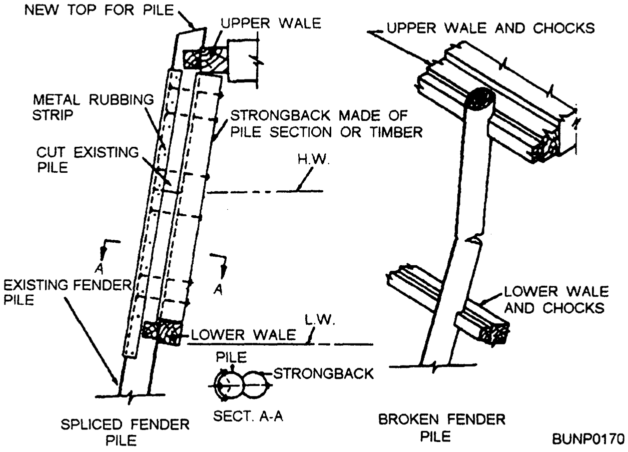


Figure 2-28.—Fender pile repair.

extend to a minimum of 3 feet below the top of the deteriorated wood sheeting. The fill at the inside edge of the old bulkhead is normally removed before driving the new sheetpiling. When this is done, a concrete cap should be placed over the new sheeting to form a seal with the existing construction.

Dolphins

Maintenance of dolphins includes the replacement of fastenings and any wire rope wrapping that has become ineffective through corrosion or wear. If dolphins are connected by a catwalk, maintenance of the catwalk includes the replacement of damaged or deteriorated timbers or the cleaning and painting or the replacement of the steel members. Repairs of dolphins include replacement of piles, wire rope wrappings, and blocking. If any piles have to be replaced, the fastenings should be removed only as far as necessary to release the piles that are damaged. Care should be taken to drive the new piles at the proper angle so they will not have to be “pulled” too far to fit them in place. The size of piles to be replaced should be carefully noted, particularly at the head or intermediate point where they are fitted together with the other piles. Much trouble in cutting and fitting the replacement piles can be avoided by selecting piles with the proper size head. All replacement piles should be driven before any are brought together. After all are driven, the center cluster should be brought together first and should be fitted, chocked, bolted, and pinned; they are then wrapped with wire rope. All cuts in piles for fittings, bolts, and wrappings should be thoroughly field-treated with creosote. Frequently, it is more economical to build a new dolphin, rather than to repair an existing one.

STONE, MASONRY, AND EARTH STRUCTURES

Some structures, such as breakwaters and seawalls, depend upon their mass for stability against wave action and currents. Materials commonly used for such structures are stone, blocks of concrete, cast-in-place concrete, and earth. Earth structures are usually converted with a protective coating, such as riprap, to hold them in place.

The most common cause of deterioration and damage to mass structures is wave action particularly during storm conditions. Severe wave action may move stones out of place when built into a wall or move others by washing out sections of a breakwater or causeway. This damage makes the structure more susceptible to additional damage. Repairs should be made as soon as possible.

Stone Structures

Stone structures are considered to be those constructed of stone, blocks of concrete, or special concrete shapes, such as tetrahedrons, piled up or distributed in a random fashion. Some structures may have an earth core retained in place by stone, composing the area that is exposed to wave action. In repair of the damage, consideration must be given to the cause of damage, such as an unusually severe storm, need for strengthening of structure, and too steep side slopes. Unless it is evident after study by design engineers that changes in design are required, the structural damage should be repaired with the same materials used in the original to restore the structure to its original strength, elevation, and cross section. Depressions washed out of the bottom in the vicinity of structures should be replaced with sand or GRANULAR materials up to the original level before replacing stone. You can do this either by dumping from the undamaged part of the structure or by placing the materials from a barge from a floating derrick.

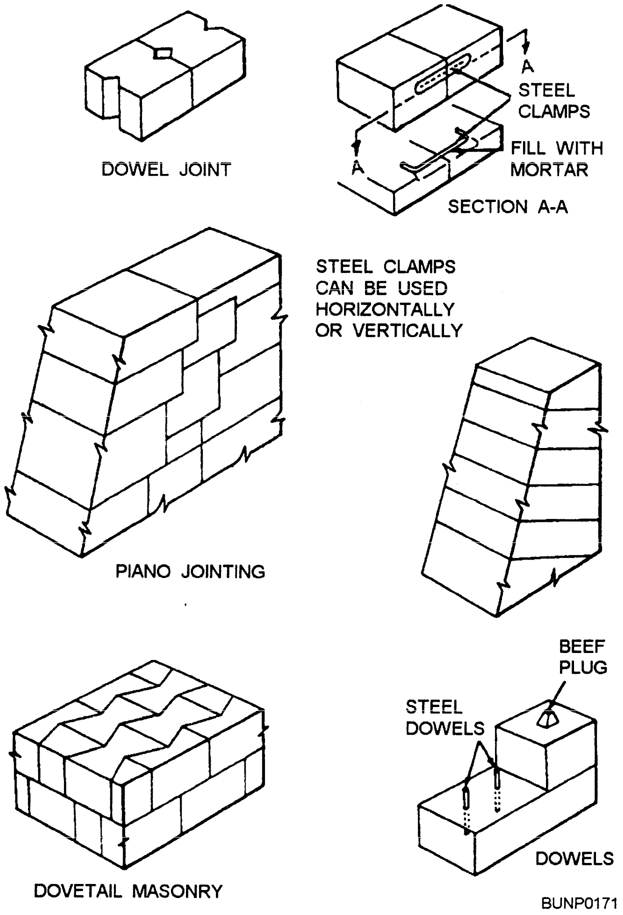


Figure 7-29.—Anchoring masonry blocks.

Masonry Structures

Structures, made of cut stone and cast concrete, made into shapes and fitted up tightly together, or laid up with mortar or similar material, are considered masonry structures. Units may be bonded together by overlapping, by metal clamps, dowels, or bed plugs, or by shapes of the blocks (fig. 7-29). All metal fastenings should be zinc-coated and well bedded in mortar. Sections of masonry that have washed out or have been damaged should be completely rebuilt, bonding the units to each other or using metal fastenings as necessary. Masonry walls that have cracked because of unequal settlement can be rebuilt, adding reinforcing bars, as shown in figure 7-30. Repair of cracked walls should be delayed until settlement is complete if possible. Where sections of walls have been displaced by sliding, an investigation should be made to determine the cause before it is rebuilt. If water builds up back of the walls, the weep holes should be cleaned and new ones installed to relieve the pressure. Walls that fail because they are inadequate should be redesigned before they are rebuilt. It is advisable to provide clamps for reinforcement where the displacement of a wall is minor. If it is not necessary to rebuild the wall, it can be reinforced by drilling holes down through the wall at the rear of displacement and a short distance beyond, inserting steel rods in the holes and filling the holes with cement mortar (fig. 7-31).

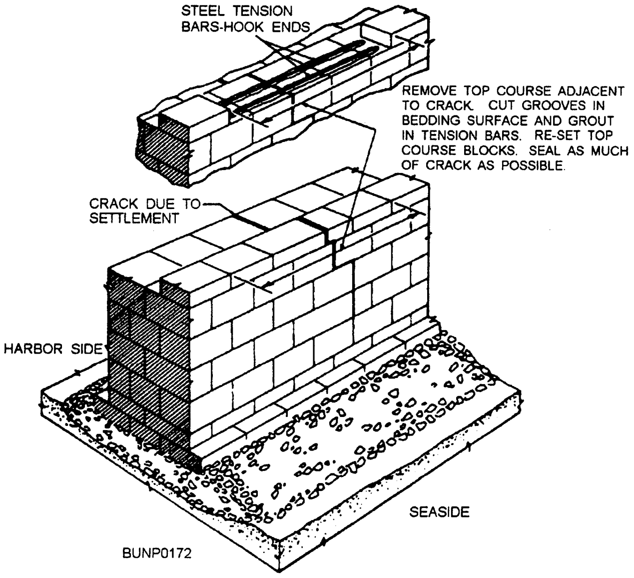


Figure 7-30.—Repair to cracked masonry walls.

Earth Structures

The use of earth for waterfront structures is confined largely to dikes and levees. It is also used for the interior of such structures as causeways, moles, and breakwaters; as backfill for quay walls and similar

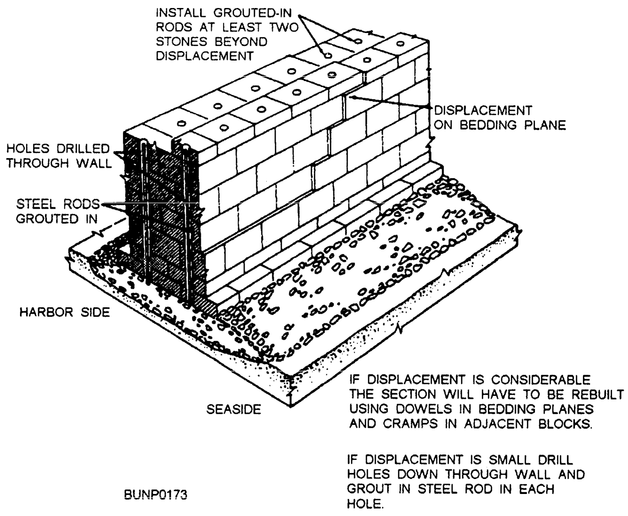


Figure 7-31.—Reinforcing vertical walls.

structures; and for fill for caissons and cellular structures. Earth that is exposed to wave action must usually be protected by riprap, cut stones, concrete blocks, or similar materials. The washing away of this protection exposes the earth to erosion by rain, waves, and currents. When the earth is eroded, it should be replaced and well compacted before replacing the protecting material. Where earth fill is supported by a bulkhead, cell, caisson, or similar structure, the supporting structure should be repaired and the fill replaced in layers with the coarser materials next to the bulkhead and the finer materials inboard. Layers must be compacted and consolidated. All materials for dikes and levees should be impermeable to prevent water from working through the structure. Vegetative covering is usually grown on the sides and top of earth structures to prevent erosion. Areas where vegetation has died or been damaged should be replanted.

This chapter does not attempt to give you all the tools necessary to inspect facilities and structures, but the information given you and the references listed below are what you need to provide proper maintenance procedures in the construction industry.

CHAPTER 8

HEAVY CONSTRUCTION

LEARNING OBJECTIVE: *You will be able to describe the procedures for erecting heavy timber bridges, shoring, pile construction, waterfront structures, timber fasteners and connectors, and steel frame structures. Identify the different types of pile-driving equipment, types of piles, and understand the many safety hazards associated with pile driving.*

As a Builder, you may perform various construction operations involving heavy structures. This chapter describes equipment, terminology, methods, and techniques of heavy construction. Since heavy construction is hazardous work, the use of safe working practices at all times can prevent injuries to personnel and damage to equipment. This chapter explains the methods of constructing heavy timber structures and waterfront structures in terms of contingency operations vice commercial or industrial construction.

As a general rule, the term *heavy construction* refers to the type of construction in which large bulks of materials (over 5 inches thick) and extra-heavy structural members are used, such as steel, timber, concrete, or a combination of these materials. In the Naval Construction Force (NCF), heavy construction includes the construction of bridges, shoring operations, waterfront structures, and steel frame structures.

BRIDGE CONSTRUCTION

A bridge is a structure used to carry traffic over a depression or an obstacle, and it generally consists of two principal parts as follows: the lower part, or SUBSTRUCTURE and the upper part, or SUPERSTRUCTURE. When a bridge is supported only at its two end supports, or abutments, it is called a single-span bridge. A bridge with one or more intermediate supports, as shown in figure 8-1, is known

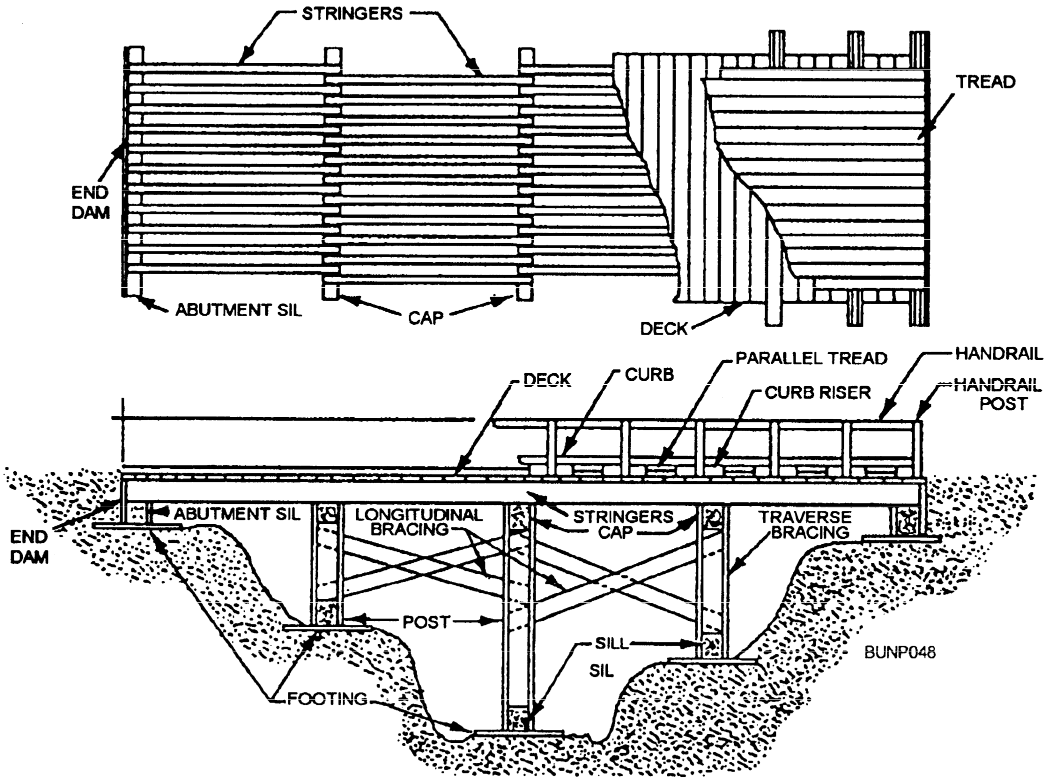


Figure 8-1.—A multispan (trestle-bent) bridge.

as a multispan bridge. Although bridges may be either fixed or floating, only fixed bridges are covered in this training manual (TRAMAN). The following information covers the components of a fixed bridge.

SUBSTRUCTURE

The substructure supports the superstructure and consists of abutments, footings, sills, posts, bracing, and caps.

Abutments

There are different types of fixed-bridge abutments. First, let's cover the footing type of abutment. In figure 8-2, views (A) and (C) show two types of footing abutments. View (A) shows a timber-sill abutment, and view (C) shows a timber-bent abutment. By studying both of these views, you will see that three elements are common to a footing type of abutment. Specially each type has a footing, a sill, and an end dam.

Notice that the timber-sill abutment shown in figure 8-2, view (A), is the same footing type of abutment shown for the bridge in figure 8-1. In this type of abutment, loads are transmitted from the bridge stringers to the sill which distributes the load to the footing. The footing then distributes the combined load over a sufficient area to keep the support from sinking into the ground. The end dam is a wall of planks that keeps the approach-road backfill from caving in between the stringers. The timber-sill abutment should not be more than 3 feet high. It can be used to support spans up to 25 feet long,

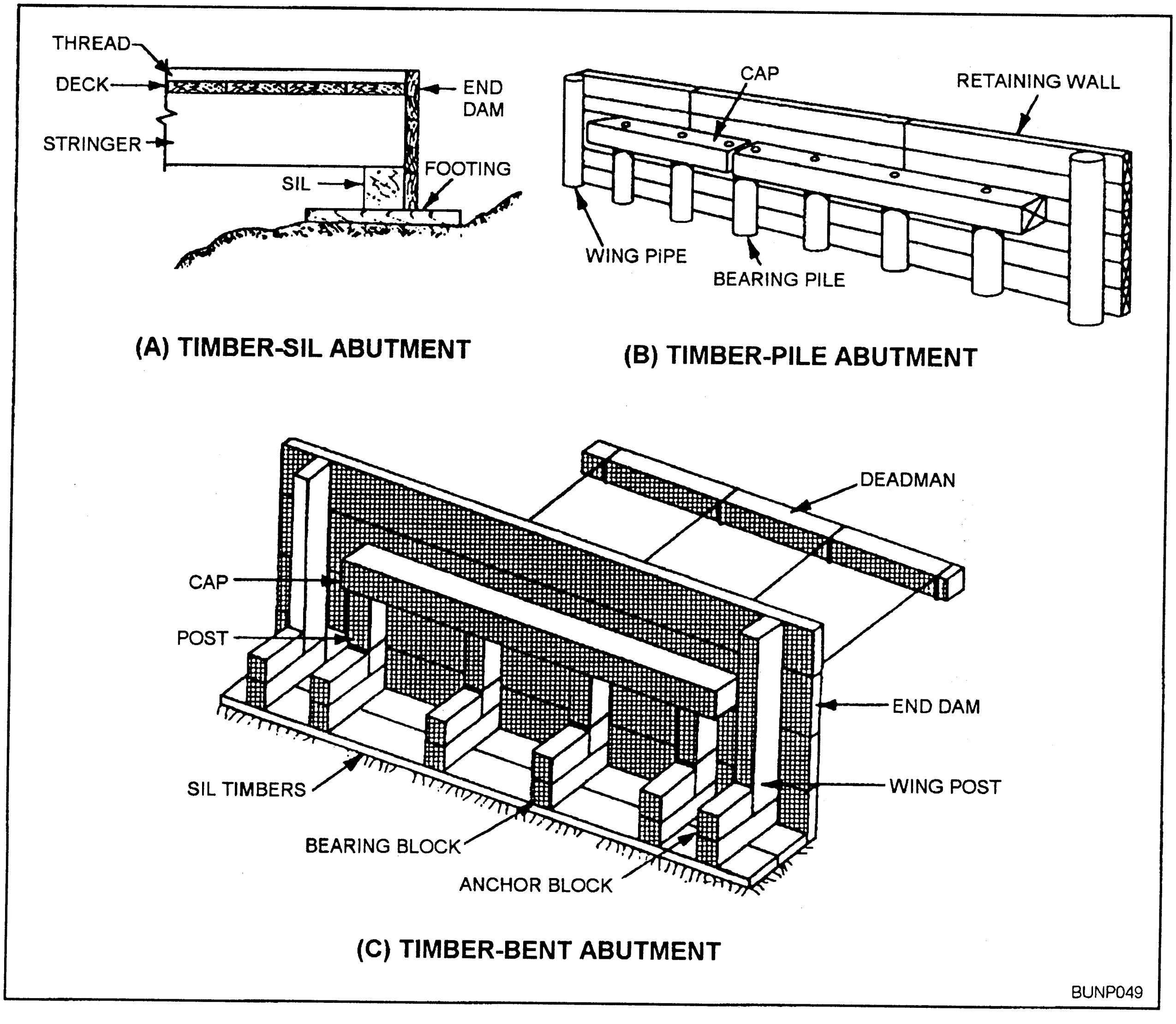


Figure 8-2.—Types of fixed-bridge abutments.

The timber-bent abutment shown in figure 8-2, view (C), can be used with timber or steel stringers on bridges with spans up to 30 feet. The DEADMAN is used to provide horizontal stability. These abutments do not exceed 6 feet in height.

Other types of fixed-bridge abutments are PILE abutments and CONCRETE abutments. Timber or steel pile abutments can support spans of any length, can be used with steel or timber stringers, and can reach a maximum height of 10 feet. A timber-pile abutment is shown in figure 8-2, view (B). Concrete abutments are the most permanent type. They may be mass or reinforced concrete, may be used with spans of any length, and may be as high as 20 feet. Use these abutments with either steel or timber stringers.

Foundations

That part of a building or structure located below the surface of the ground is called the FOUNDATION. Its purpose is to distribute the weight of the building or structure and all live loads over an area of subgrade large enough to prevent settlement and collapse.

In general, all foundations consist of the following three essential parts: the foundation bed, which consists of the soil or rock upon which the building or structure rests; the footing, which is normally widened and rests on the foundation bed; and the foundation wall, which rises from the foundation to a location somewhere above the ground. The foundation wall, contrary to its name, may be a column or a pedestal instead of a wall. However, when it is a wall, it forms what is known as a continuous foundation. Figure 8-3 shows common types of wall and column foundations.

The continuous foundation is the type most commonly used for small buildings. The size of the footing and the thickness of the foundation wall are specified on the basis of the type of soil at the site. Most building codes also require that the bottom of the footing be horizontal and that any slopes be compensated for by stepping the bottom of the footing.

Another type of foundation is the grade-beam foundation. A GRADE BEAM is a reinforced concrete beam located at grade level around the entire perimeter of a building, and it is supported by a series of concrete piers extending into undisturbed soil. The building loads are supported by the grade beam, which distributes the load to the piers. The piers then distribute the load to the foundation bed.

A spread foundation, as shown in figure 8-4, is often required where heavily concentrated loads from columns, girders, or roof trusses are located. This type of foundation maybe located under isolated columns or at intervals along a wall where the concentrated loads occur. Spread footings are generally reinforced with steel. They may be flat, stepped, or sloped, as shown in figure 8-3.

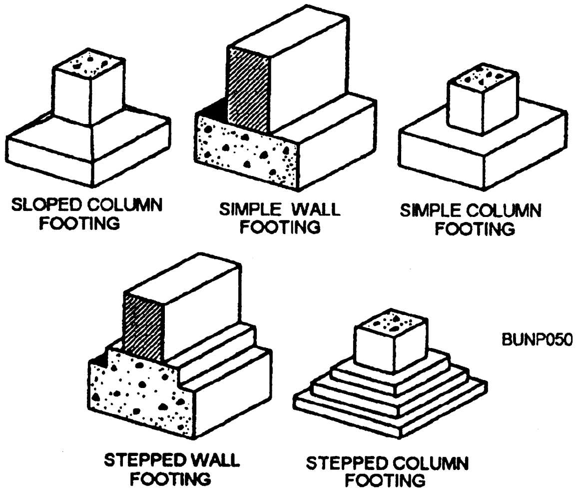


Figure 8-3.—Common wall and column foundations.

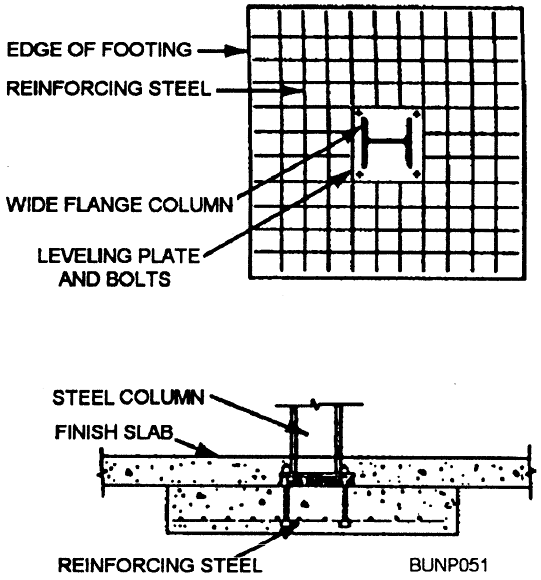


Figure 84.—P1an and section of a typical spread footing.

Figure 8-5 shows the plan and section of a typical mat foundation. In this type of foundation, a heavily reinforced concrete slab extends under the entire building and distributes the total building load over the entire site. This minimizes problems created by unequal settlement when the subsoil conditions are uneven.

Intermediate Supports

BENTS and PIERS provide support for the bridge superstructure at points other than the bank ends. A BENT consists of a single row of posts, or piles, while a PIER consists of two or more rows of posts, or piles. The following text covers some of the different types of bents and piers.

The PILE BENT shown in figure 8-6 consists of the bent cap, which provides a bearing surface for the bridge stringers, and the piles, which transmit the load to the soil. The support for the loads may be derived either from column action, when the tip of the pile bears on firm stratum, such as rock or hard clay, or from friction between the pile and the soil into which it is driven. In both cases, earth pressure must provide some lateral support, but traverse bracing is often used to brace the bent laterally.

A TIMBER PILE BENT consists of a single row of piles with a pile cap. Brace it to the next bent or to an abutment to reduce the unbraced length and to provide stability. This bent will support a combined span of 50 feet.

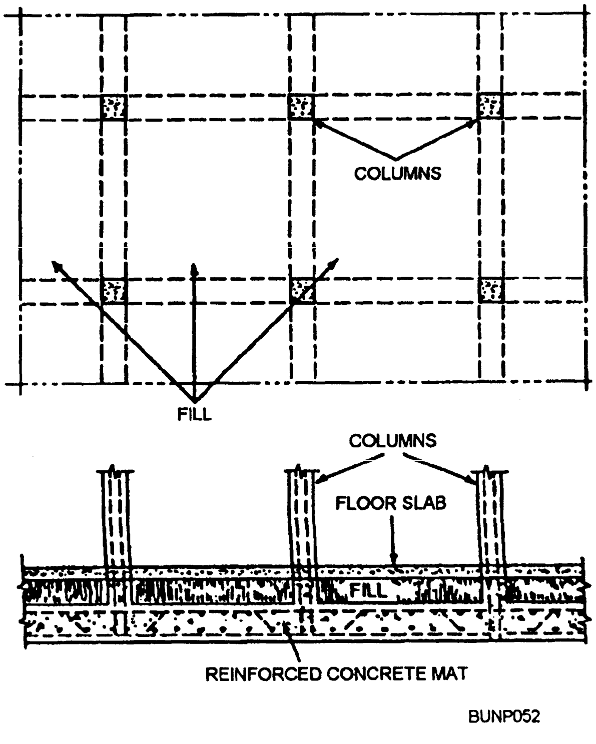


Figure 8-5.—Plan and section of a mat foundation.

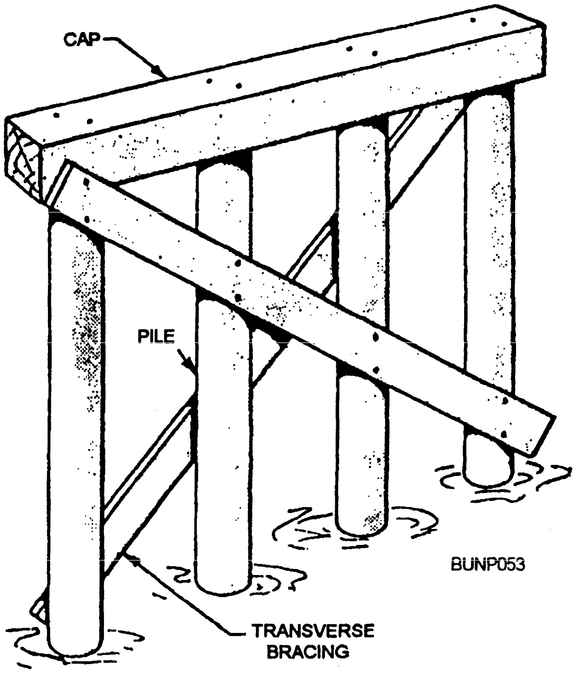


Figure 8-6.—Typical pile bent.

The TRESTLE BENT shown in figure 8-7 is similar to the pile bent, except the post takes the place of the piles, and transmits the load from the cap to the sill. The sill transmits the load to the footings, and the footings transmit the load to the soil. Timber trestle bents are normally constructed in dry, shallow gaps where the soil is firm. They are not suitable for use in soft soil or swift or deep streams. The bent can support a combined span length of up to 30 feet and can be 12 feet high.

The PILE BENT PIER (fig. 8-8) is composed of two or more pile bents. In this figure, notice the common cap. The cap transmits the bridge load to the CORBELS which transmits the combined load to the individual bent caps. Piers are usually provided with cross bracing that ties the bents together and provides rigidity in the longitudinal direction.

A TRESTLE BENT PIER is the same as the pile bent pier, except it has sills and footings to transmit the load to the soil, as shown in figure 8-7. This bent is designed to carry vertical loads only and is used to support spans up to a combined 60 feet and for ground-to-grade heights of up to 18 feet.

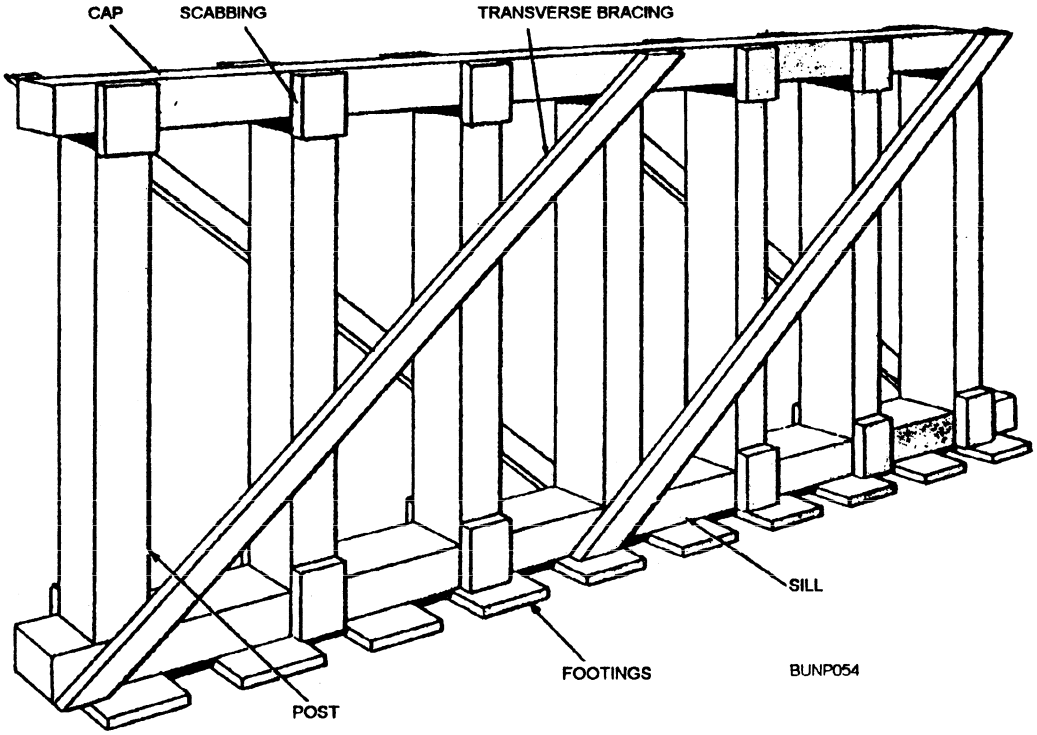


Figure 8-7.—Timber trestle bent.

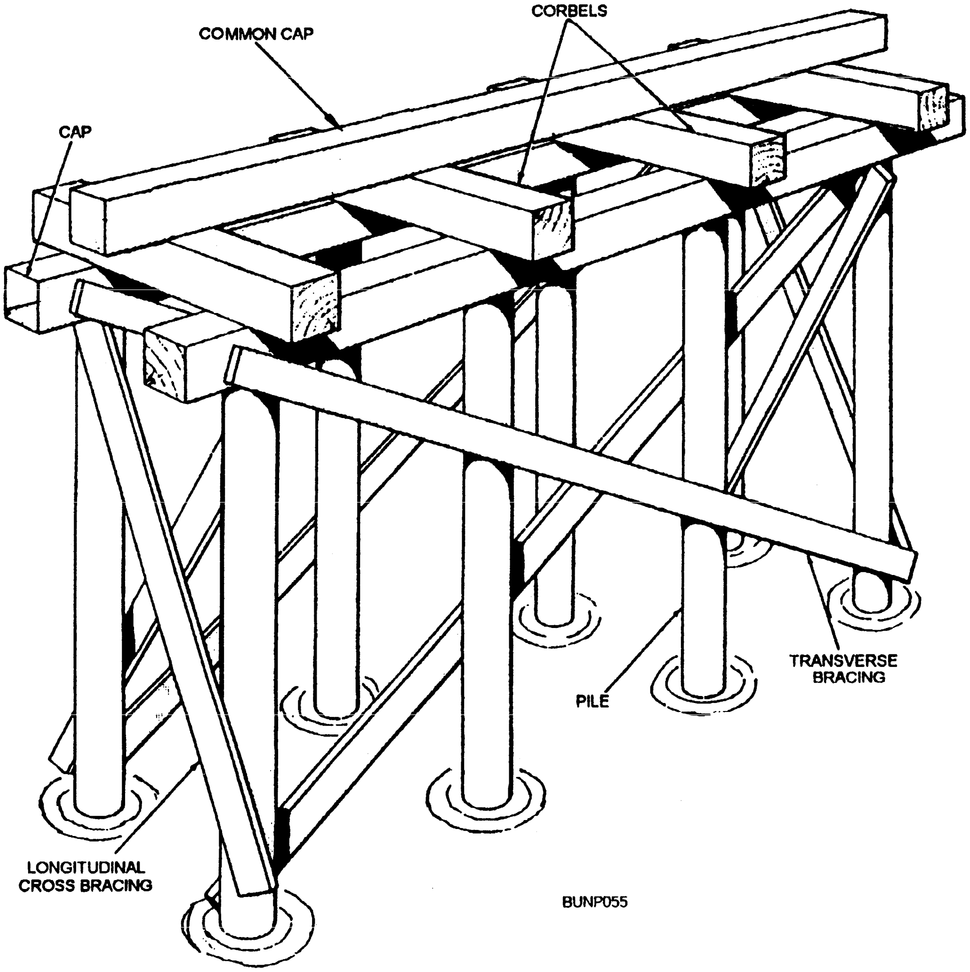


Figure 8-8.—Typical pile pier.

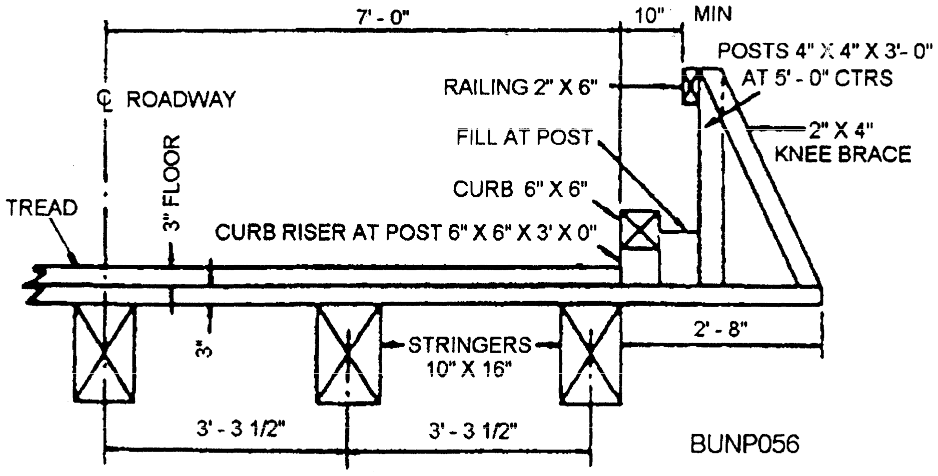


Figure 8-9.—Details of a superstructure of a timber trestle.

Bracing

LONGITUDINAL BRACING and TRANSVERSE BRACING are the two types commonly used to support the substructure in heavy timber construction, as shown in figure 8-8. Longitudinal bracing is used to provide stability in the direction of the bridge center line. Transverse bracing, sometimes called lateral bracing, provides stability at right angles to the center line.

Sometimes a third type of bracing, called a DIAPHRAGM, is used. This bracing is used between the stringers to prevent BUCKLING (deflecting laterally under load).

SUPERSTRUCTURE

The SUPERSTRUCTURE of a bridge consists of the stringers, flooring (decking and treads), curbing, walks, handrails, and other items that form the part of the bridge above the substructure. Figure 8-9 is an illustration of a superstructure.

As shown in figure 8-9, those structural members that rest on and span the distance between the intermediate supports or abutments are called STRINGERS. The stringers are the main load-carrying members of the superstructure. They receive the load from the flooring and transmit it to the substructure. Although the figure shows both steel and timber stringers, in practice, only one type is normally used.

The flooring system includes the deck; the wearing surface, or tread, that protects the deck; and the curb and handrail system. The plank deck is the simplest to design and construct, and it provides considerable savings in time compared to other types of decks. Plank decking is normally placed perpendicular to the bridge center line (direction of traffic) for ease and speed of construction. A better arrangement, however, is provided when the decking is placed at about a 30- to 60-degree skew to the center line. Provide space of approximately one-quarter inch between the planks to allow for swelling, to provide water drainage, and to permit air circulation. The minimum thickness of decking is 3 inches in all cases; however, when the required thickness of plank decking exceeds 6 inches, then use a laminated type of decking.

SHORING EXCAVATION

One of the inherently hazardous parts of construction operations is excavating. The main hazards of excavation work areas follows:

1. Collapse or failure of excavation walls burying workers and equipment

2. Materials, tools, and equipment falling into holes and striking workers below

3. Hazards involving public utilities, such as electricity, water, gas, or natural gases and oxygen deficient atmosphere

4. Wet, muddy conditions, causing slips, trips, or falls, complicated by limited spaces in which personnel work

Take precautions to make sure the excavation banks do not collapse and cause injury or death to persons working in the excavation. The method used to protect excavation banks from collapsing depends on the type of soil in the area, the depth of the excavation, the type of foundation being built, and the space around the excavation.

Before beginning the excavation, the Builder must secure all possible information regarding any,

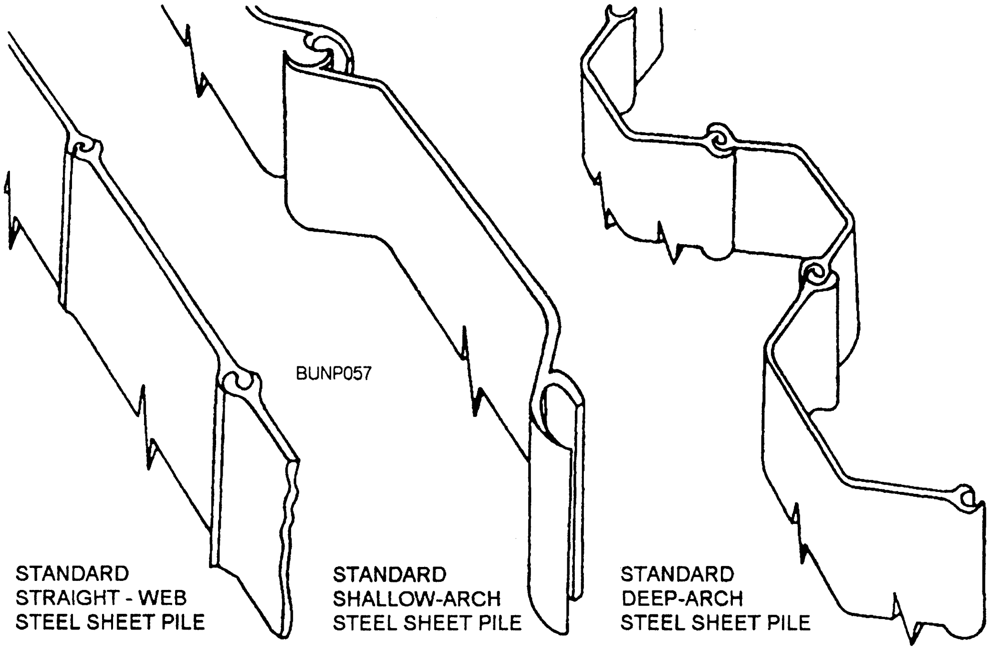


Figure 8-10.—Types of interlocking sheet piles.

underground installations in the area including sewer, water, fuel, and electrical lines. A Builder must also take precautions NOT to disturb or damage any utility while digging and to provide adequate protection after any such exposed. Make sure you have a digging permit on the jobsite and that you follow its guidelines.

Many safety codes also require that the excavation be inspected by a qualified person (ROICC or safety officer) after a rainstorm or any other hazardous natural occurrence. Avert earth bank cave-ins or landslides by increasing the amount of shoring and other means of protection.

Provide convenient and safe access to excavated areas for your crew. Such access may consist of stairways, ladders, or securely fastened ramps.

During excavation some soil types pose greater problems than others. Sandy soil is always considered dangerous even when it is allowed to stand for a period of time after a vertical cut. The instability can be caused by moisture changes in the surrounding air or changes in the water table. Vibration from blasting, traffic movement, and material loads near the cut can also cause earth to collapse in sandy soil.

Clay soils present less risk than sand; however, soft clay can also be dangerous. You can do a simple test of clay conditions by pushing a 2 by 4 into the soil. If the 2 by 4 is easily pushed in the ground, it indicates that the clay is soft and may collapse. Silty soils (a combination of sand and clay) are also unreliable and require the same precautions as sand.

SLOPING

When there is sufficient space around the construction site, slope the earth banks as necessary to prevent collapse. The *Occupational Safety and Health Administration* (OSHA) code regulations for the construction industry recommends a 45-degree slope for excavations with average soil conditions. Solid rock, shale, or cemented sand and gravel may require less slope. Compacted sharp sand or well-rounded loose sand may require more than a 45-degree slope.

SHORING VERTICAL WALLS

Shoring (supporting) the vertical walls of an excavation is required when sloping is considered unsafe or inadequate. Soil types, such as clays, silts, loams, or non-homogenous soils, usually require shoring. Shoring may also be required where there is insufficient room for sloped banks. This is particularly true in industrial and commercial areas where new construction is right next to existing buildings. In addition to preventing injury from collapse of excavation banks, stability of the foundation walls of adjoining buildings must be protected. Shoring for high vertical walls is supervised by a civil engineer, and the installation is supervised by qualified personnel. Do not remove the shoring system until the construction in the excavated area is completed and all the necessary steps are taken to safeguard workers. Two methods commonly used to shore high vertical excavation banks are the use of interlocking sheetpiling, as shown in figure 8-10 and soldier piles, as shown in figure 8-11.

INTERLOCKING SHEET PILES consist of steel pilings that can be reused many times and offer the additional advantage of being watertight. Each individual sheetpiling is lowered by crane into a template that holds it in position. Then the piling is driven into place with a pile driver. Install braces to help support the metal sheets.

SOLDIER PILES are H-shaped piles that are driven into the ground with a pile driver and are spaced between 3 and 10 feet apart. Refer to the plans and specifications for spacing requirements. Three-inch-thick wood planks, called **lagging,** are placed between the flanges or directly against the front of the piles. You may use 2-inch blocks for spacing between each plank or butt the planks together depending on the specifications. Soil conditions and the depth of the excavation may require **tie-backs** that consist of steel strand cables placed in holes drilled horizontally into the banks of the excavation. The holes are drilled into the banks of the excavation with a power auger and are often 50 feet or more in length. The tie-back cables are inserted through an opening in the pile and are secured in the earth by power grouting the hole.

After the grout has set up, a strand-gripping device, consisting of a gripper and gripper casing, is placed over the cables. A hydraulic tensioning jack is used to tighten the cables. When the jack releases the cables, the gripping device holds them and maintains the required tension against the pile. The number of tie-backs required should be determined by an engineer whose decision will be based on soil conditions and the depth of the excavation. Some soldier pile systems may also include a heavy horizontal steel waler held in place with tie-backs. This technique is similar to constructing a single waler system for concrete—same basic principle.

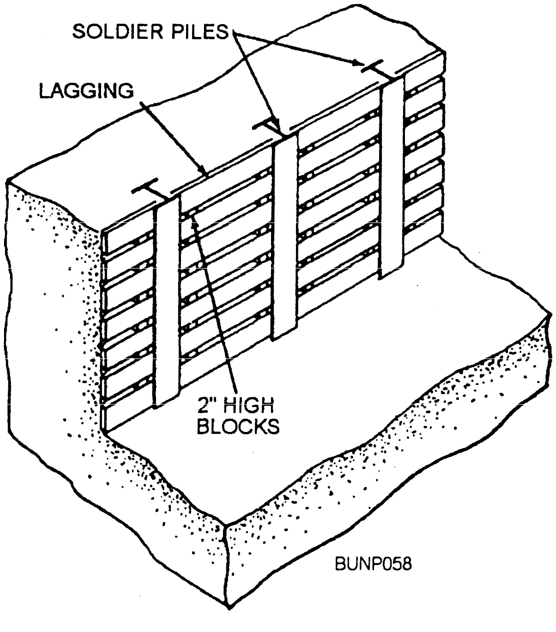


Figure 8-11.—Soldier pile systems.

In many instances, it is necessary for the excavation for a new building to be carried right up to the foundation of an existing one. This presents a problem if the new excavation is to be deeper than the footings of the existing building. Part of the support for those footings will be removed, and it is the BU's responsibility to protect the building against movement caused by settlement during and after construction of the new building. Temporary support may be provided by SHORING or NEEDLING, while permanent support is provided by UNDERPINNING—extending the old foundation to the level of the new one.

A common method of support for adjacent structures is by the use of 12 by 12 timbers, called SHORES, inclined against the wall to be supported and extending across the excavation to a temporary FOOTING consisting of a framework or mat of timbers laid on the ground. Fit the upper ends of the shores into openings cut in the wall, or butt them against a timber bolted to the wall. Place steel SADDLES in openings cut in concrete or masonry walls to support lifting or to steady shores.

As a good practice, set shores as vertical as possible to reduce lateral thrust against the wall. Whenever possible, locate the heads at floor level to minimize the danger of pushing the wall in.

Make the provision for inducing a lift or thrust in the shores by inserting jacks between the bases of the shores and the footing. Use a standard steel screw jack with the capabilities to lift as much as 100 tons for shores. When a single screw jack is used with a shore, a hole is bored in the base of the shore to admit the threaded portion of the jack, and the arrangement is called a PUMP. For a larger lifiing effect, a pair of jacks are attached to a short timber called a CROSSHEAD. An advantage of crosshead arrangements is that after the lift has been applied, the crosshead can be blocked and the jacks removed for use elsewhere.

PILE CONSTRUCTION

As a Builder, you will coordinate and direct pile-driving operation crews. Piles include many different types and materials. The more common types are covered next.

BEARING PILES

TIMBER BEARING PILES are usually straight tree trunks with the limbs and bark removed, and all timber will be PRESSURE-TREATED. These piles, if kept continuously wet, will last for centuries; however, they are used for low-design loads because of their vulnerability to damage while they are being driven into the ground. The small end of the pile is called the tip; the larger end is called the butt. Timber piles range from 16 to 90 feet in length with a tip diameter of at least 6 inches. The butt diameter is seldom less than 12 inches.

STEEL BEARING PILES are usually H-pile (having an H-shaped cross section). These piles are usually used for driving through bedrock or until refusal. A steel pile can also be a pipe pile with a circular cross section. A pipe pile can be either an open-end pile or a closed-end pile, depending on whether the bottom end is open or closed.

CONCRETE PILES, as shown in figure 8-12, may be either precast or cast in place. Most precast piles used today are pretensioned and are manufactured in established plants. These piles are made in square, cylindrical, or octagonal shapes. When driven into soil or mucky soil, they are usually tapered. Cast-in-place piles are cast on the jobsite and are classified as shell type or shell-less type. The shell type is formed when the hollow steel tube (shell) with a closed end is driven into the ground and it is filled with concrete. The shell-less type is formed when first a casing and core are driven to the required depth. The core is removed, and the casing is filled with concrete. The casing is then removed, leaving the concrete in contact with the earth.

SHEET PILES

Sheet piles, made of wood, steel, or concrete, are equipped or constructed for edge-joining, so they can be driven edge-to-edge to form a continuous wall or bulkhead. A few common uses of sheet piles are as follows:

1. To resist lateral soil pressure as part of a temporary or permanent structure, such as a retaining wall
2. To construct cofferdams or structures built to exclude water from a construction area
3. To prevent slides and cave-ins in trenches or other excavations

The edges of steel sheetpiling are called INTERLOCKS (fig. 8-10), because they are shaped for locking the piles together edge-to-edge. The part of the pile between the interlocks is called the WEB.

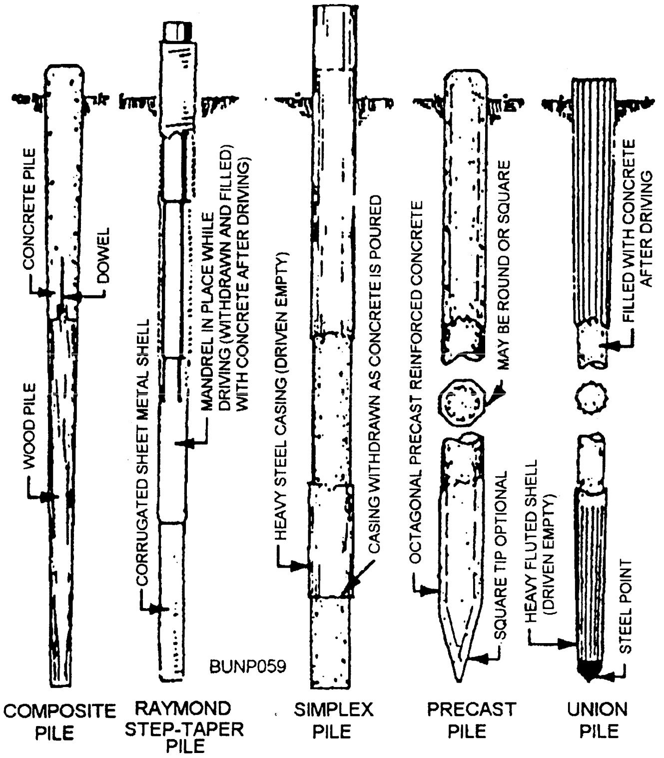


Figure 8-12.—Types of concrete piles.

PILE-DRIVING OPERATION

Almost all pile driving is done with a crawler or with truck-mounted cranes rigged with pile-driving attachments, as shown in figure 8-13. The main parts of pile-driving attachments are as follows:

1. The LEADS come in 10-, 15-, and 20-foot sections bolted together to form various lengths.

2. The CATWALKS, also called the LEAD BRACE or SPOTTERS, can be extended or telescoped to various lengths. These can be set to hold the leads vertical for driving bearing piles or to hold them at an angle for driving batter piles.

Steps in rigging pile-driving attachments on a crane are as follows:

1. The lead sections are assembled on the ground, as shown in figure 8-14. The crane is lined up with the leads, and the boom is lowered until its head is in line with the tops of the leads, as shown in the same figure.

2. The cotter pins on the ends of the boom point pin are removed, the adapters are installed, and the cotter pins are reinstalled.

3. The adapters are bolted to the ends of the leads, as shown in figure 8-15. To avoid trouble, bolt on one adapter, and swing the boom enough to align the bolt holes with the adapter and leads. The tops of the leads are now attached to the head of the boom.

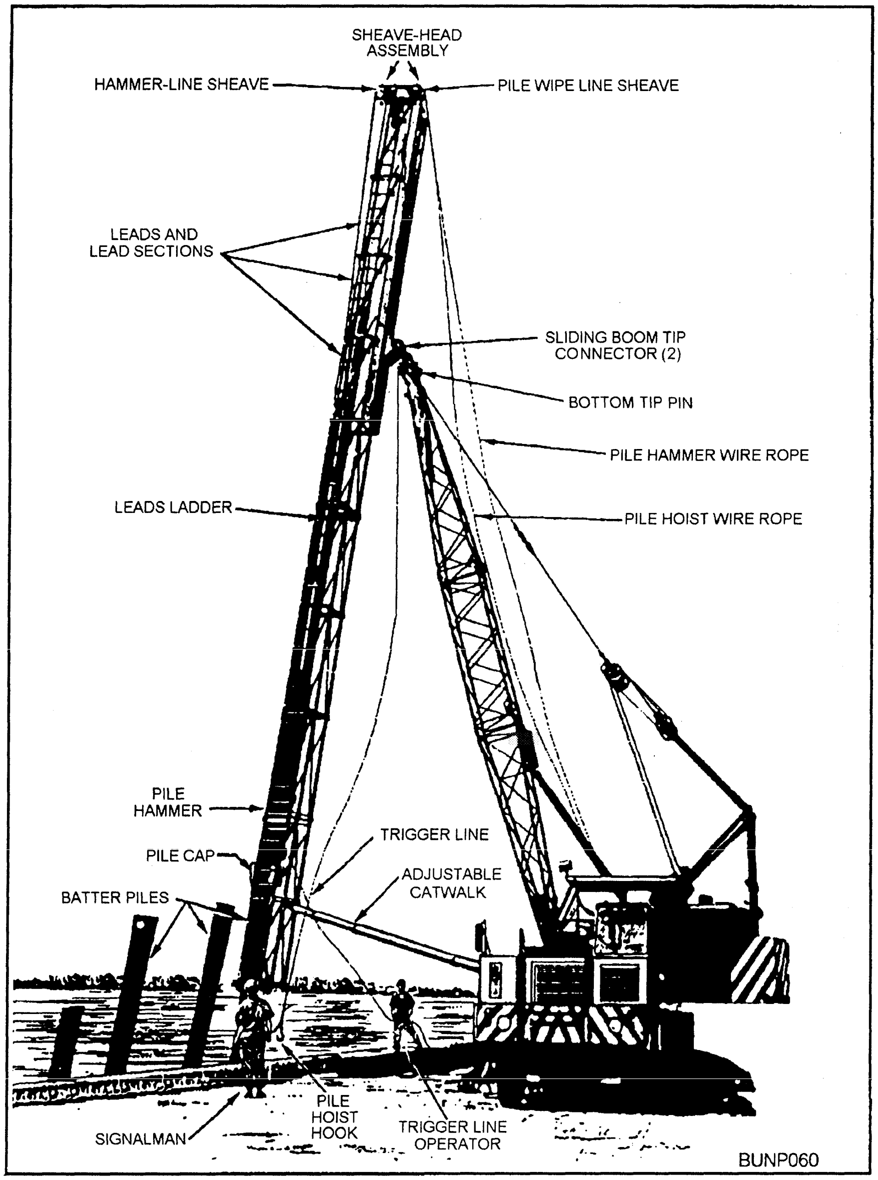


Figure 8-13.—Typical pile-driving operation.

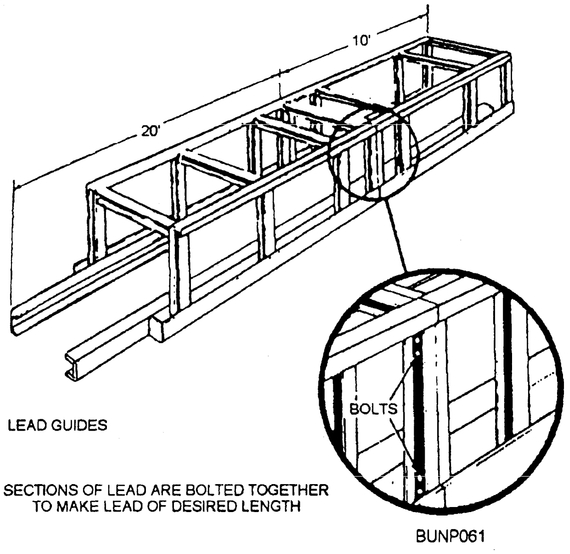


Figure 8-14.—Assembly of 10- and 20-foot sections.

4. The lines that handle the piles and the hammer (called the PILE WHIP and the HAMMER WHIP) are reeved (passed) over the sheaves at the head of the boom, and the ends are brought down to the foot of the leads and lashed. Enough slack in each whip is reeved through to ensure that the boom can be topped up to the vertical height of the leads without also straining the sheaves.

5. The leads are raised by topping up the boom.

6. When the leads are raised to the vertical position, lead braces or spotters (catwalks) are then attached.

7. The hammer is placed in the leads, as shown in figure 8-16. The leads are raised off the ground by topping the boom; the hammer is placed under them; the leads are lowered onto the hammer; and the hammer whip line is attached to the pin on top of the hammer.

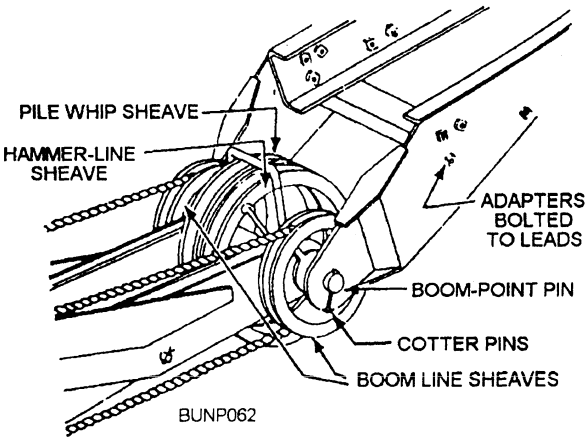


Figure 8-15.—Lead adapters connected to the boom tip.

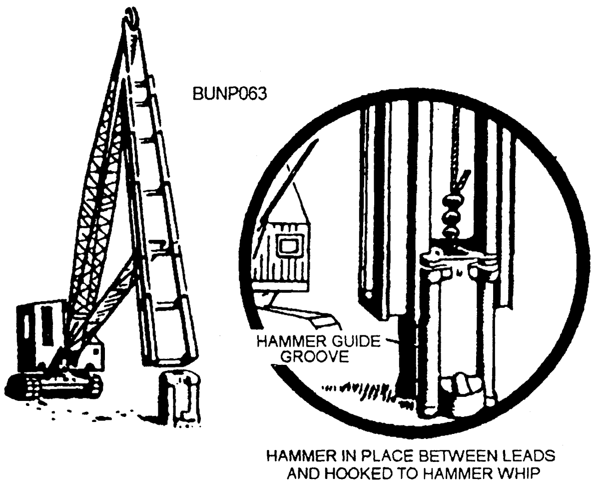


Figure 8-16.—Placing hammer in leads.

8. The driving cap or follower block is a cap that rests on the top of the pile being driven. It slides freely in the leads to steady the pile and to receive and transmit the impact of the hammer. The cap, as shown in figure 8-17, has a sling of wire rope, so the cap and the hammer may be drawn to the top of the leads out of the way when a pile is being positioned for driving.

Pile-Driving Hammers

The three main types of pile-driving hammers are the DROP hammer, the STEAM, or PNEUMATIC, hammer, and the DIESEL hammer. A drop hammer is a block of metal run up to a specified height and then dropped on a cap placed on the butt or head of the pile. Drop hammers weigh from 1,200 to 3,000 pounds.

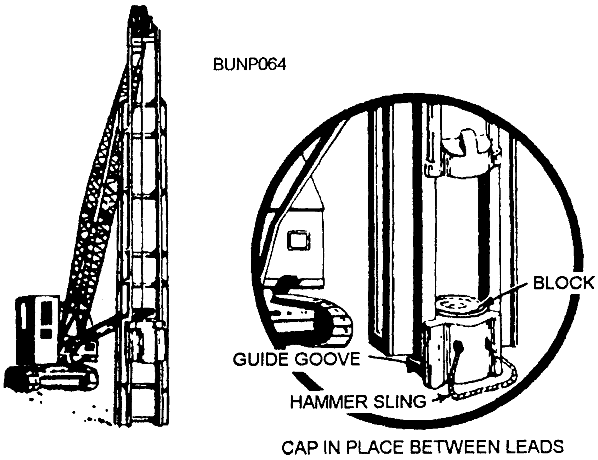


Figure 8-17.—Placing pile cap in leads.

The steam, or pneumatic, hammer has basically replaced the drop hammer. This hammer (fig. 8-18) consists of a cylinder that contains a steam-driven or air-driven RAM. The ram consists of a PISTON equipped with a STRIKING HEAD. The hammer is rested on the butt or head of the pile for driving.

With a SINGLE-ACTION steam, or pneumatic, hammer, the power drive serves only to lift the ram; the downward blow of the ram results from the force of gravity only. In a DOUBLE-ACTION hammer, the ram is both lifted and driven downward by the power drive. A double-action hammer weighs from 5,000 to 14,000 pounds and a single-action hammer weighs about 10,000 pounds.

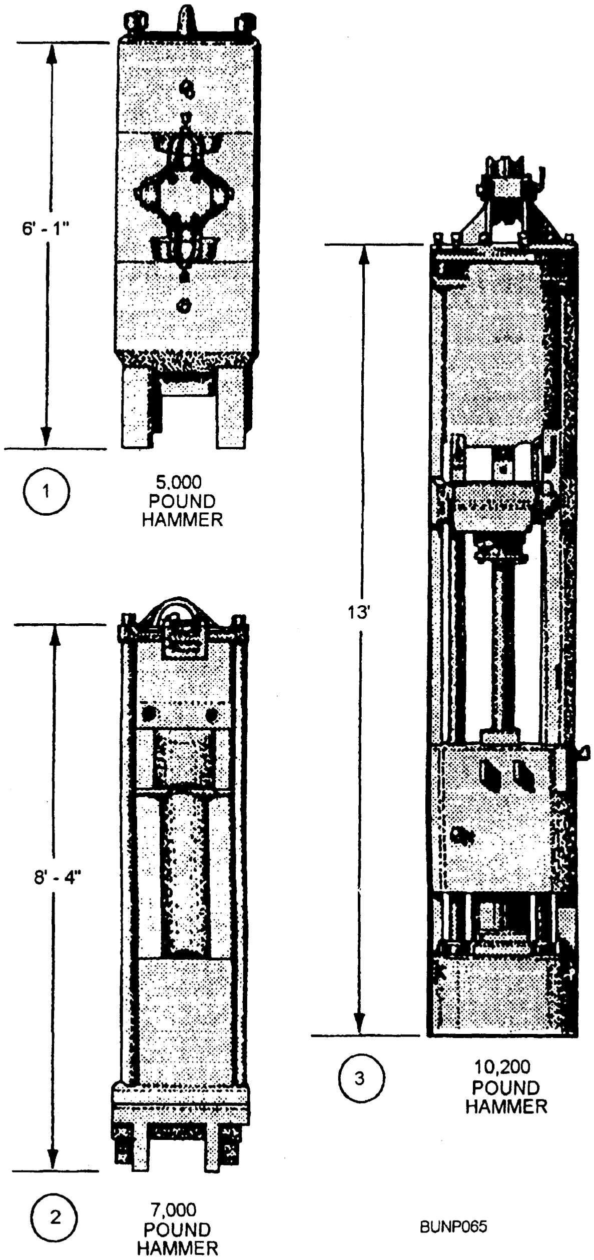


Figure 8-18.—Steam, or pneumatic, pile hammers.

The blow of the double-action hammer is lighter, but more rapid than that of the single-action hammer. The double-action hammer generally drives lightweight or average weight piles into soils of average density; its rapid blows tend to keep the pile in motion and thereby reduces the resistance of inertia and friction. For heavy piles in hard or dense soil, however, the resistance from inertia and friction, together with the rapid, high-velocity blows of the double-action hammer, tend to damage the butt or head of the pile.

The single-action hammer generally drives heavy piles into hard or dense soil; its heavy ram, striking at lower velocity, allows more energy to be transferred into the motion of the pile, reducing impact and damage to the butt or head of the pile.

The diesel pile hammer shown in figure 8-19 is the most common hammer used in the NCF. This hammer

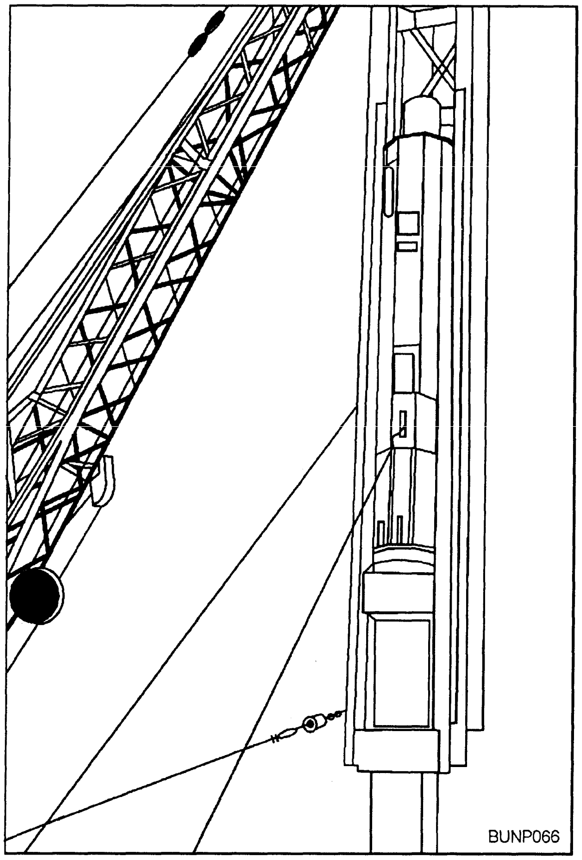


Figure 8-19.—Diesel pile hammer.

is made up of a cylinder, a ram piston, a fuel pump, a built-in fuel tank, a lubricant oil tank, and an inertia oil pump that lubricates mechanically during operation.

The diesel pile hammer is about twice as fast as a conventional pneumatic, or steam, hammer of like size and weight. A conventional pneumatic hammer requires a 600-cubic-foot-per minute compressor to operate, while the diesel is a self-contained unit constructed in sizes that deliver up to 43,000 foot-pounds of energy per blow.

Pile-Driving Caps

A pile-driving CAP is a block (usually a steel block) that rests on the butt or head of the pile and protects it against damage by receiving and transmitting the blows of the hammer or ram. In the steam, or pneumatic, hammer, the cap is a part of the hammer. The cap with a drop or diesel hammer is a separate casting, with the lower part recessed to fit the head or butt of the pile, and the upper part recessed to contain a hardwood block which receives the blows of the hammer. The cap is fitted with a wire-rope sling so that the cap, as well as the hammer, may be raised to the top of the leads when positioning a pile in the leads. Pile CAPS are available for driving timber, concrete, sheet, and H-beam piles. Figure 8-20 shows an example of a steel H-pile and a special cap for driving.

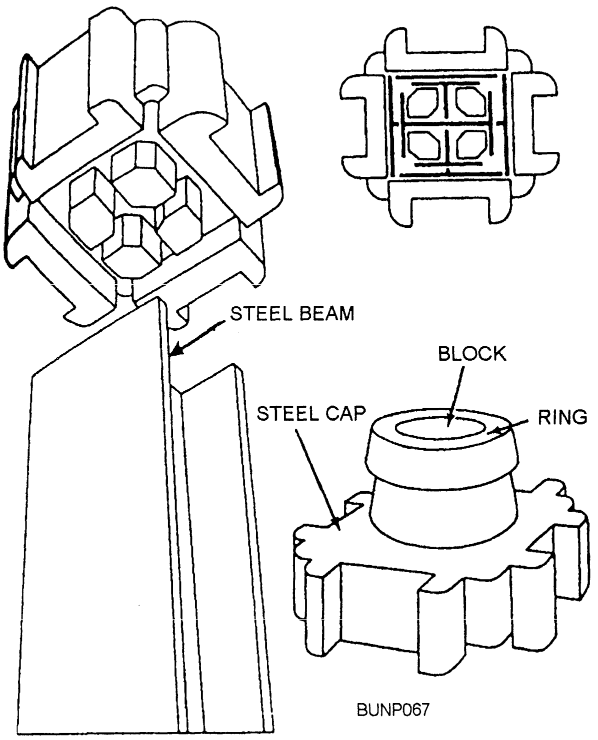


Figure 8-20.—H-beam pile-driving cap.

Crane Safety

As the project supervisor of a pile-driving operation, you must be aware of the safety precautions and procedures involved when working with and around cranes.

Statistics on accidents show that a free moving power crane is one of the most destructive machines used in the Navy, as well as in private industry. Over one third of the victims of crane accidents are operators; more than one fourth are crew members other than operators. Ironically, the people who sustain the most injuries from cranes are the very ones who can do the most to prevent injuries. Most crane accidents are preventable simply because they are caused by situations, conditions, or actions under the control of the operating crew. The term *preventable accident* is illogical; if an accident were preventable, it would not be an accident, but an act of omission or commission by somebody.

Most crane work is, or should be, a coordinated activity of a team of skilled technicians and workers. The lives and well-being of the whole team are in the hands of each member of the team during a continually shifting scene requiring constant judgment and responsibility. The pile-driving crew is usually made up of the following personnel:

- Rig operator
- Signalman
- Loftman
- Hoisting engineer
- Hook-on person

During any pile-driving operation, the SIGNALMAN is the boss of the rig and is normally the only person giving signals to the operator. The only signal any other person may give that the operator will obey is the EMERGENCY STOP SIGNAL. Refer to the *Equipment Operator Basic,* NAVEDTRA 12535, for more information regarding crane safety.

Pile-Driving Safety

Standard safety and accident prevention procedures developed to govern general construction operations apply also to pile-driving operations. Pile driving is hazardous, and personnel should take adequate care to be protected from injury. Close cooperation between the Equipment Operators and crew members (Builders/Steelworkers) is essential to avoid accidents.

Apply normal safety precautions to hand power tools used to prepare piles for driving and in cutting off, straightening, and aligning piles after they are driven.

Wearing safety shoes is required. Be sure you and all your crew are wearing hard hats. Mill scale may fly from a steel pile while it is being driven.

During the first few feet of driving a pile, keep personnel out of the way as much as possible so that if the tip of the pile were to strike an obstacle and slide out of line, no one would be struck by the pile.

During actual pile driving, protect your ears. When working over water, wear life jacket and make sure crew members do likewise. Use safety belts as required.

Characteristics of Different Piles

As a Builder, you will be most concerned with timber piles. Steel piling ranks next in importance, especially where the construction must accommodate heavy loads or the foundation is expected to be used over a long period of time. Steel is best suited for use as bearing piles where piles must be driven under the following conditions:

- Piles are longer than 80 feet.
- Column strength exceeds the compressive strength of timber.
- To reach bedrock for maximum bearing surface through overlying layers of partially decomposed rock.
- To penetrate layers of coarse gravel or soft rock, such as coral.
- To attain greater depth of penetration for stability.

Concrete and composite piles are seldom used because they require material and equipment that is not normally available through military supply channels. They are likely to be used in cases where local materials are readily available, whereas standard military piling would have to be received in large quantities from CONUS. Interlocking steel sheetpiling is often used in military construction, but concrete-steel piling can be manufactured in the field when local material is available.

Precautions during Pile Driving

Be careful during driving to avoid damage to the pile, the hammer, or both. If the pile driver shifts position during driving, the blows of the hammer will be out of line with the axis of the pile and both the pile and the hammer may be damaged.

Watch the piles carefully for any sign of a split or break below ground. When you are driving pile and it suddenly becomes easier to drive or the pile suddenly changes direction, a break or split has probably occurred. When this happens, pull the pile as soon as possible, because further driving is useless.

“SPRINGING” means that the pile vibrates too much laterally. Springing may occur when a pile is crooked, when the butt has not been squared off properly, or when the pile is not in line with the fall of the hammer. In all pile driving, make sure the fall of the hammer is in line with the pile axis; otherwise, the head of the pile and the hammer may be damaged severely and much of the energy of the hammer blow lost.

Excessive BOUNCING may come from a hammer that is too light. However, it usually occurs when the butt of the pile has been crushed or broomed, when the pile has met an obstruction, or when it has penetrated to a solid footing. When a double-acting hammer is being used, bouncing may result from too much steam or air pressure. With a closed-end diesel hammer, if the hammer lifts on the upstroke of the ram piston, the throttle setting is probably too high. Back off on the throttle and control just enough to avoid this lifting. If the butt of the timber pile has been crushed or broomed more than an inch or so, cut it back to sound wood before you drive it any more.

When a pile has reached a level where 6 blows of a drop hammer, 20 blows of a steam or air hammer, or 10 blows of a-diesel hammer per inch will not drive it more than an average of one-eight inch per blow, the pile has either hit an obstruction or has been driven to REFUSAL. In either case, further driving is likely to break or split the pile. If the lack of penetration seems to be caused by an obstruction, try 10 or 15 blows of less than maximum force; they may cause the pile to displace or penetrate the obstruction. For obstructions which cannot be disposed of in this manner, it is often necessary to PULL (extract) the pile (see next section) and blast out the obstruction with an explosive lowered to the bottom of the hole.

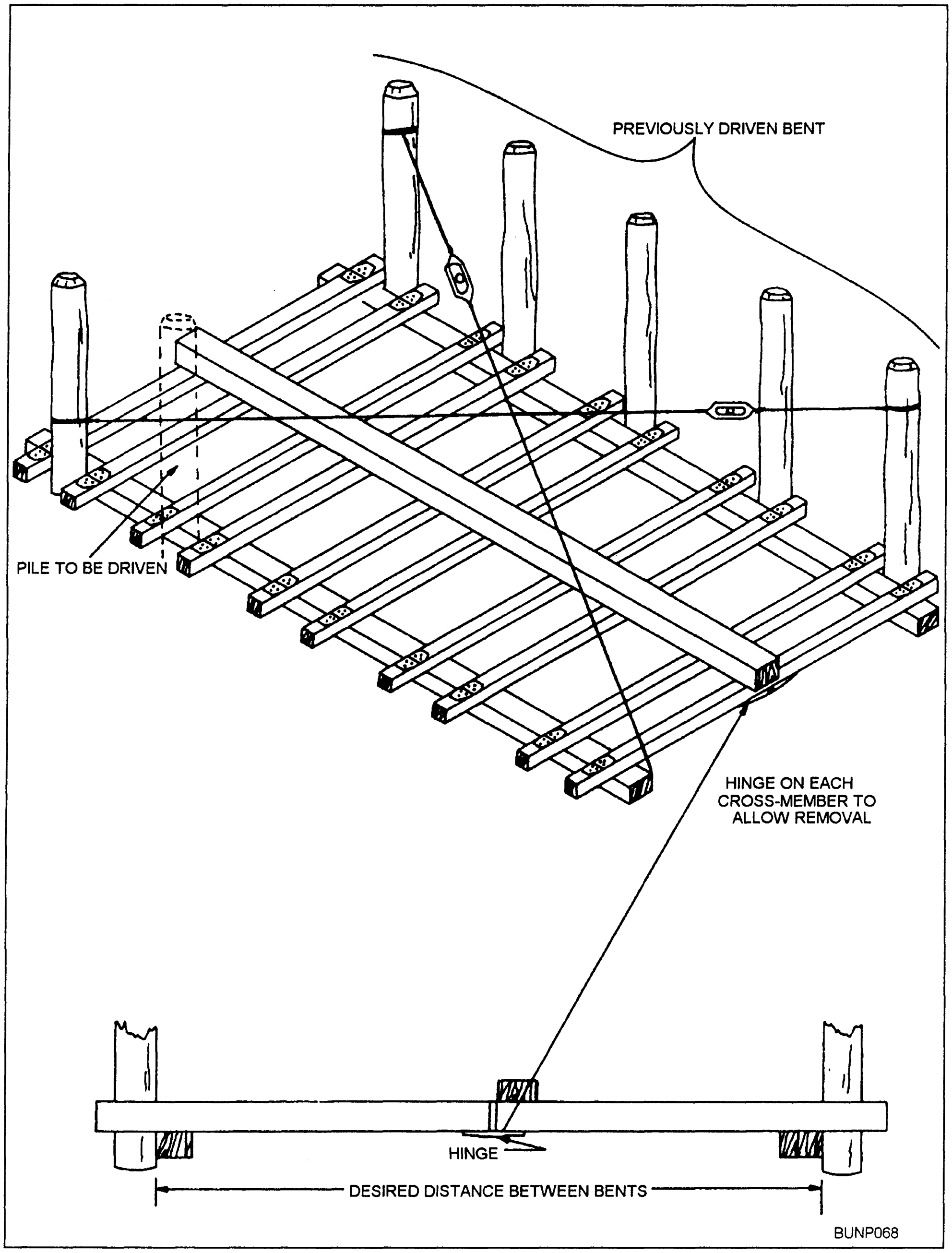


Figure 8-21.—Floating template for positioning piles.

A pile is at the point of refusal when it has been driven to a depth where deeper penetration is prevented by friction. A pile supported by skin friction alone is called a FRICTION pile. A pile supported by bedrock or an extra dense layer of soil at the tip is called an END-BEARING pile. A pile supported partly by skin friction and partly by substratum of extra dense soil at the tip is called a COMBINATION END-BEARING and FRICTION pile.

It is not always necessary for you to drive a friction pile to refusal; such a pile needs to be driven only to the depth where friction develops the required load-bearing capacity.

When bearing piles are driven on land, the position of each pile is usually located by the Engineering Aid and marked with a stake. A common method of locating the positions of a series of pile bents driven in water is by use of a wire rope long enough to stretch between the abutments and marked with pieces of tape, spaced according to the prescribed or calculated distance between bents.

After the first bent is driven, a floating TEMPLATE is used when driving subsequent bents like the one shown in figure 8-21. Pairs of BATTENS are spaced according to a specified spacing between piles in a bent and are nailed across each pair of timbers. The parts of each batten lying beyond the timbers are hinged for raising. The template is lashed to the outer piles in the bent already driven by means of a pair of wire ropes, equipped with turnbuckles as shown. After the piles in the new bent are driven, the hinged parts of the battens are raised, the wire ropes are let go, and the template is floated out from between the bents.

Piles can be driven either tip or butt down; they may be driven butt first if a large bearing area is required or if the pile is to resist an upward force.

Lagging

Lagging is used to increase the resistance of a friction pile. Before the pile is driven, long, narrow strips of wood or steel are lag-screwed to the pile, as shown in figure 8-22. These are attached to the lower part of the pile from approximately 12 inches above the tip to the limits of the depth that the pile is expected to penetrate. The extra surface area increases the load-carrying capacity of the pile but tends to make it more difficult to drive.

Figure 8-22.—Lagging of a timber friction pile.

CONSTRUCTING A PILE BENT

After the piles in a pile bent have been driven, the remaining steps in constructing the bent are ALIGNING, CUTTING, CAPPING, and BRACING the piles.

Aligning Piles in a Bent

Piles in a bent are straightened with tackles and brought into alignment with an ALIGNING FRAME, as shown in figure 8-23. After the frame has been put on, a working platform, like the one shown in figure 8-21, is usually erected to support the personnel who will cut, cap, and brace the piles.

Cutting Piles in a Bent

A timber pile selected for a bent should be long enough to leave 2 or 3 feet extending above the specified elevation of the bottom of the cap after the pile has been driven to the specified penetration. The piles are then cut to the specified elevation with a chain saw or a crosscut saw.

Because the cap must bear evenly on all the piles in the bent, it is important that they all be cut exactly the same elevation. Ensure this by the use of the CUTTING GUIDE or the SAWING GUIDE, as shown in

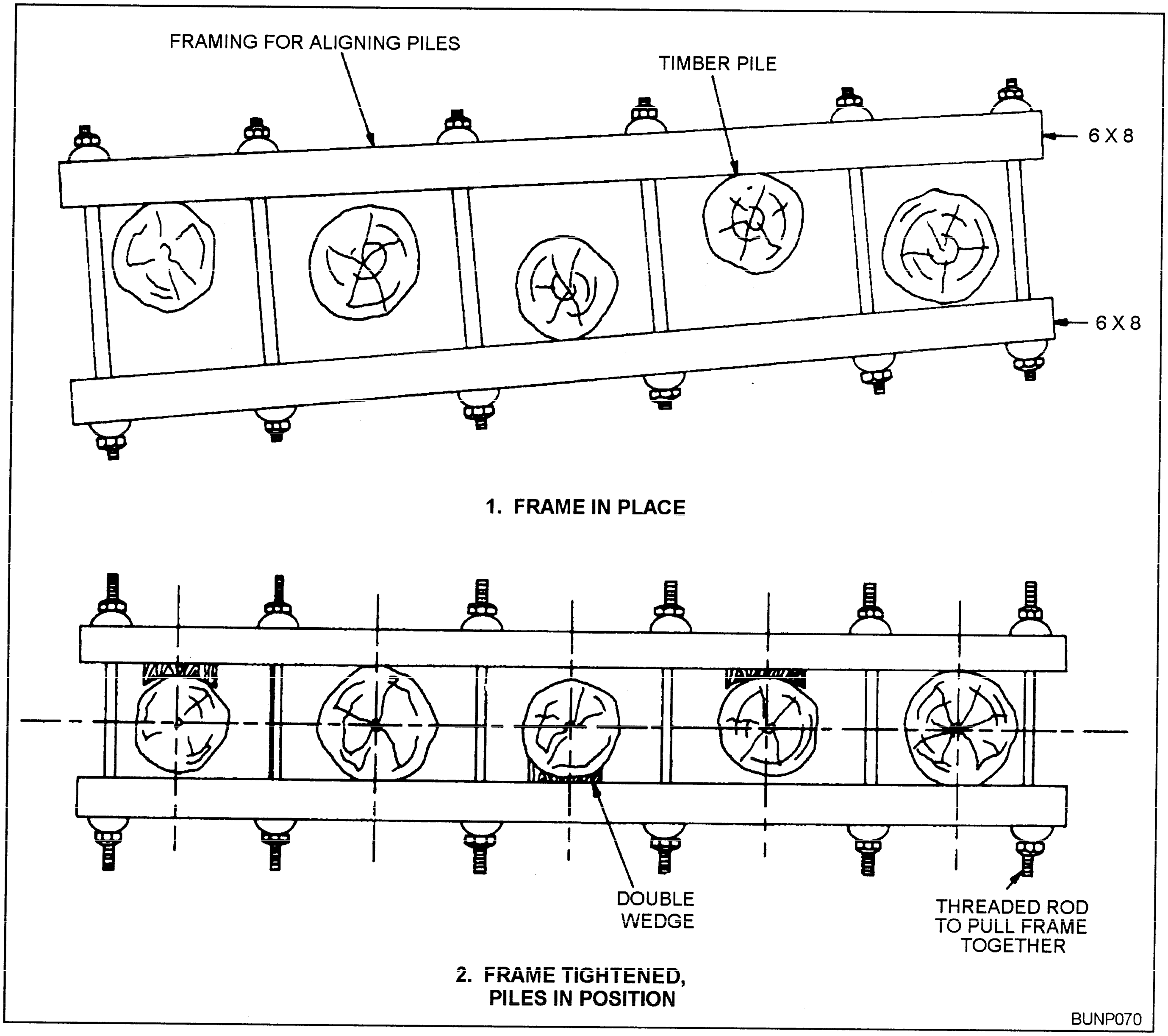


Figure 8-23.—Straightening frame.

figure 8-21. Determine the position for the cutting guide by locating the correct elevation of the bottom of the cap and by an engineer's level on the two outside piles in the bent.

Capping Piles in a Bent

After timber piles in a bent are straightened, aligned, and cut, the piles are usually capped. The cap

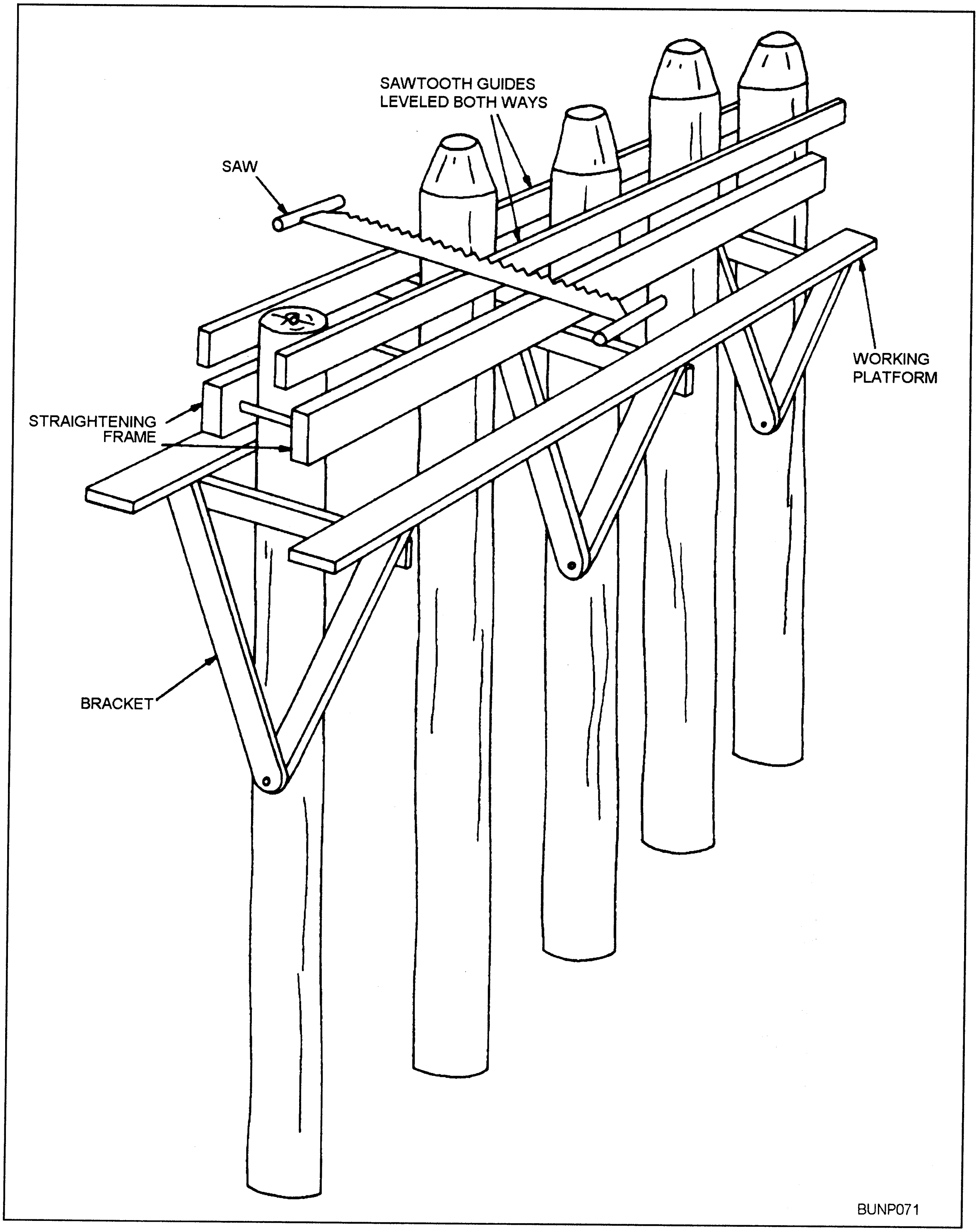


Figure 8-24.—Cutting timber pile bent to final height.

is set in place, a hole for a driftbolt is bored through the cap into the top of each pile, and the driftbolts are driven. The transverse and longitudinal bracing is then put on. Sometimes, however, the bracing may be installed before the piles are capped.

PLACING PILES BY JETTING

Jetting often makes pile-penetration easier. Jetting is the process of forcing water under pressure around and under the pile to lubricate and/or displace the surrounding soil, as shown in figure 8-25. In soils other

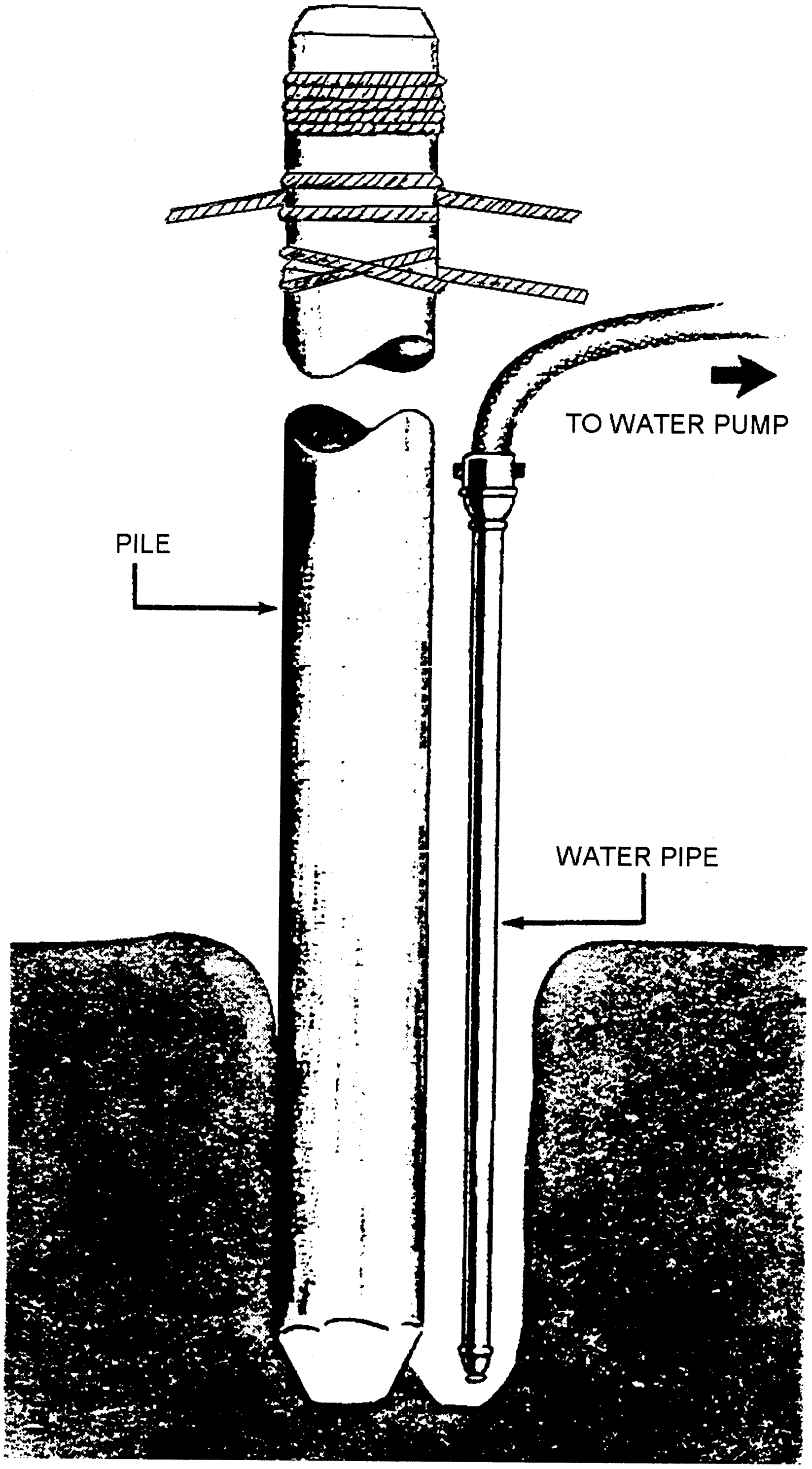


Figure 8-25.—Jetting with a single jet pipe,

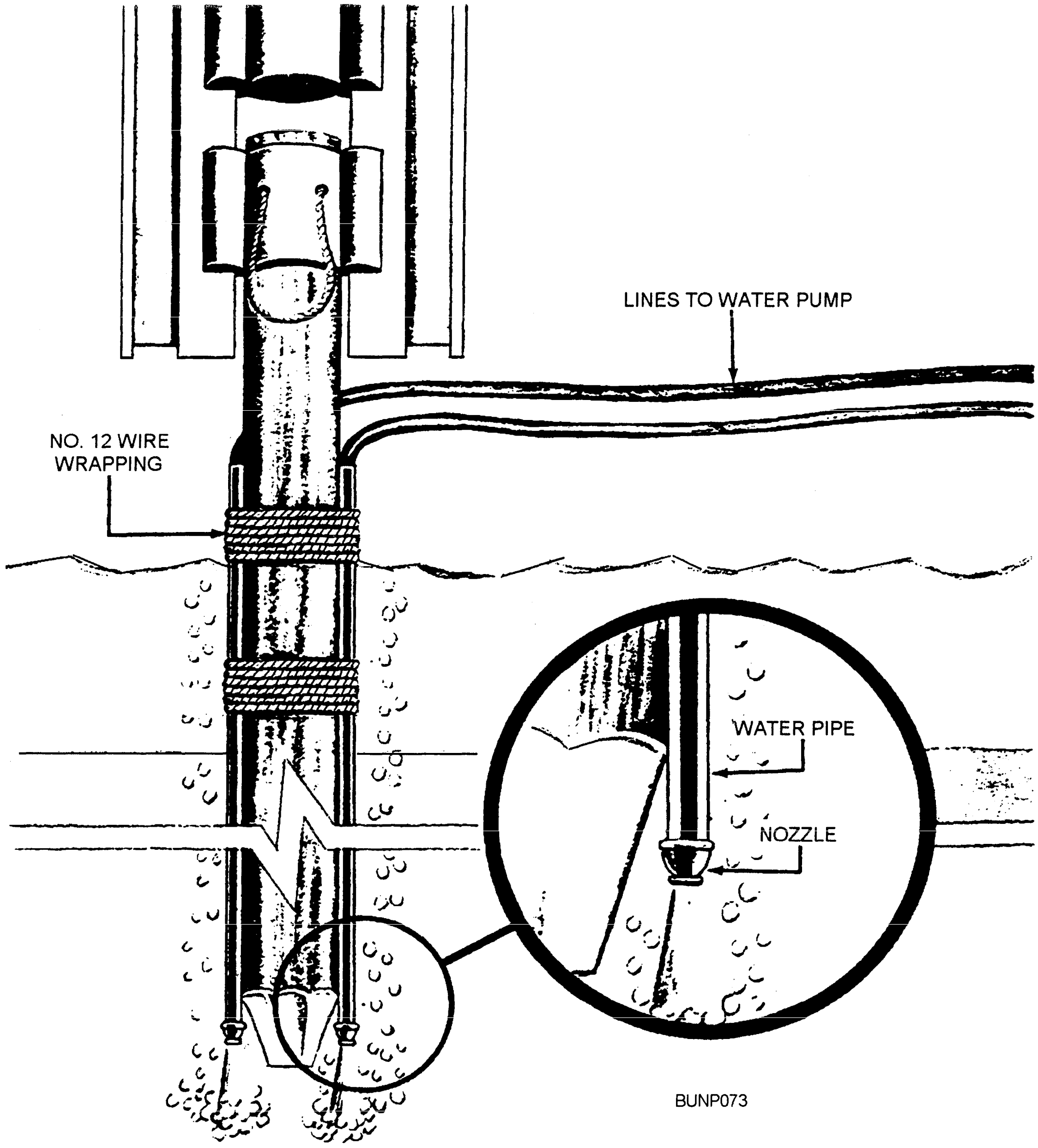


Figure 8-26.—Jetting with two jet pipes.

than fairly coarse, dense sands, jetting is not necessary or advisable. Jetting equipment consists of a water pump, a length of flexible hose, and a metal JET PIPE; jet pipes run from 2 1/2 to 3 inches in diameter.

A single jet pipe is used as follows. The pile is set in position with the hammer resting on it for extra weight, and the jet pipe is manipulated to loosen and wash away the soil from under the tip, as shown in figure 8-31. As the soil is washed away, the pile sinks under its own weight and that of the hammer. A few hammer blows are struck occasionally to keep the pile moving downward. When it is 3 feet above the final tip elevation, the jet pipe is withdrawn and the pile is driven the rest of the way with the hammer.

The action of a single jet pipe on one side of a pile tends to send the pile out of plumb. Whenever possible, two pipes are used and lashed to the pile on opposite sides, as shown in figure 8-26.

EXTRACTING PILES

A pile that has met an obstruction or that has split or broken in driving or that is to be salvaged (steel sheet piles are frequently salvaged for reuse) is usually PULLED (extracted). Pull the pile as soon as possible after driving it; the longer the pile stays in the soil, the more compact the soil becomes, and the greater will be the resistance to pulling. Methods of pulling piles are as follows:

In the DIRECT LIFT method, a crane is used to pull the pile. The crane whip is slung to the pile, and a gradually increased pull is applied up to just a little less than the amount that is expected to start it. Lateral

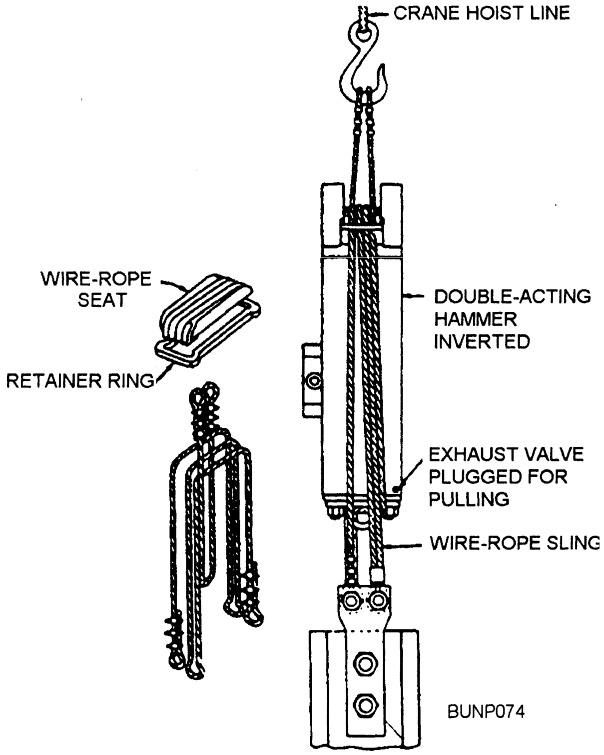


Figure 8-27.—Wire-rope sling used with 5,000-pound airstream hammer to pull piles.

blows from a HEADACHE BALL (heavy steel ball, swung on a crane whip to demolish walls) or a few light blows on the butt or head with a driving hammer are given to break the skin friction. The crane pull is then increased to maximum capacity. If the pile still will not start, it maybe loosened by jetting or the lift of the crane may be supplemented by the use of hydraulic jacks.

The 5,000-pound double-acting hammer may be used in an inverted position to pull piles. The hammer is turned over, and a wire-rope sling is passed over it and attached to the pile (fig. 8-27). The hammer whip is heaved taut, and the upward blows of the hammer ram on the sling plus the pull of the hammer whip are usually enough to pull the pile.

TIDAL LIFT is used often to pull piles driven in tidewater. Slings on the piles are attached to barges or pontoons at low tide; the rising tide pulls the piles as it lifts the barges or pontoons. To avoid the danger of tipping barges over, place a barge on each side of the pile with the lifting force transmitted by girders extending across the full width of both barges.

PLANNING AND ESTIMATING PILE-DRIVING OPERATIONS

So far, you have a thorough understanding of the materials used, and the principles of, and the capabilities of driving pile. Preparing estimates, such as man-days, and equipment, are usually left up to the Equipment Operators (EOs), but should not present any real problem for you.

Manpower estimates (fig. 8-28) for bearing piles are based on a typical crew consisting of the following members:

- One crew leader.
- One crane operator.

Work Element Description	Unit	Man-Hours Per Unit
25 FT Wood Piling	Each	3.5
50 FT Wood Piling	Each	6.5
75 FT Wood Piling	Each	9.6
25 FT Steel Piling	Each	4.0
50 FT Steel Piling	Each	7.2
75 FT Steel Piling	Each	12.0
40 FT Precast Concrete Piling	Each	13.2
60 FT Precast Concrete Piling	Each	18.0
80 FT Precast Concrete Piling	Each	24.0
Steel Sheetpiling	1,000 SF	102.0
Assemble and Rig Leads and Hammer	Each	48.0
Dismantle Leads and Hammer	Each	32.0

SUGGESTED CREW SIZE: Two EOs, and two EAs, six to ten BUs.

NOTES:

1. Manhour figures are preliminary estimate only. The many variables of this work require on-site determinations for accurate estimates.
2. Factors of importance are: Design, soil, equipment and method used, tides, access to site, currents, materials storage, etc.
3. For concrete filled, fluted hollow steel piling and pipe piling for spudding pontoon small craft finger piers, use the steel bearing pile figures.

Figure 8-28.—Table from P-405.

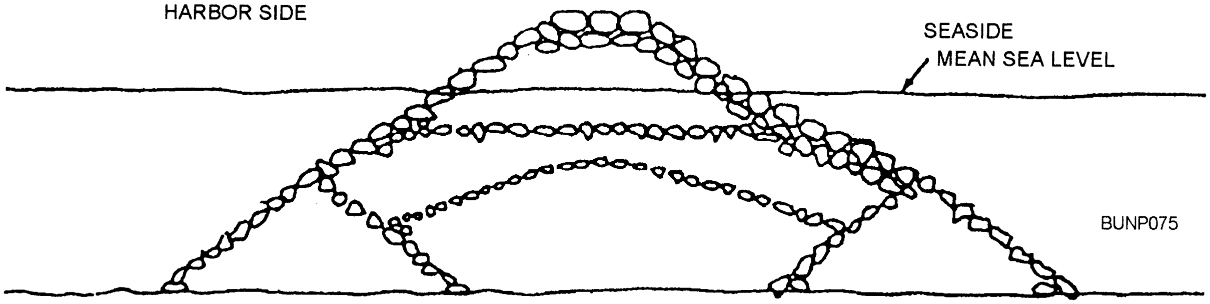


Figure 8-29.—Rubble-mound breakwater or jetty.

- Four crew members to place the piles in the leads.
- One or two crew members to prepare the piles. This is based on the further assumption that the pile driver can pick up and place the piles in the leads. If this cannot be done because of the location of the undriven piles, you must allow for an additional crane and increase the total man-days required by 15 percent.

The time in man-days required to drive each pile depends on the type of pile and its length. Precast concrete bearing piles drive slower than wood or steel ones; and logically, the use of a longer pile usually means that you plan to drive it deeper, which will take more time. Under average conditions, it takes 3.0 man-hours to drive a 25-foot wood pile, but for a steel pile, it takes 4.0 man-hours, and for a precast concrete pile, it takes 13.2 man-hours. These estimates take into account pile preparation, placing it in the leads, driving, and cutoff, if required.

When estimating the man-days required to complete a pile-driving operation, you cannot forget to include time for the assembly of the leads and hammer, preparing the equipment for driving, cutting holes in steel piling to facilitate handling, and disassembly of the equipment upon completion, if required. You must also allow time for pile extraction if it is a required part of the project.

WATERFRONT STRUCTURES

Waterfront structures may be broadly divided into three types as follows: (1) harbor-shelter structures, (2) stable-shoreline structures, and (3) wharfage structures.

HARBOR-SHELTER STRUCTURES

Harbor-shelter structures are offshore structures that are designed to create a sheltered harbor. Various types of these structures are covered next.

A BREAKWATER is an offshore barrier, erected to break the action of the waves and thereby maintain an area of calm water inside the breakwater. A JETTY is a similar structure, except its main purpose is to direct the current or tidal flow along the line of a selected channel.

The simplest type of breakwater or jetty is the rubble-mound (also called rock-mound) type shown in figure 8-29. The width of its cap may vary from 15 to

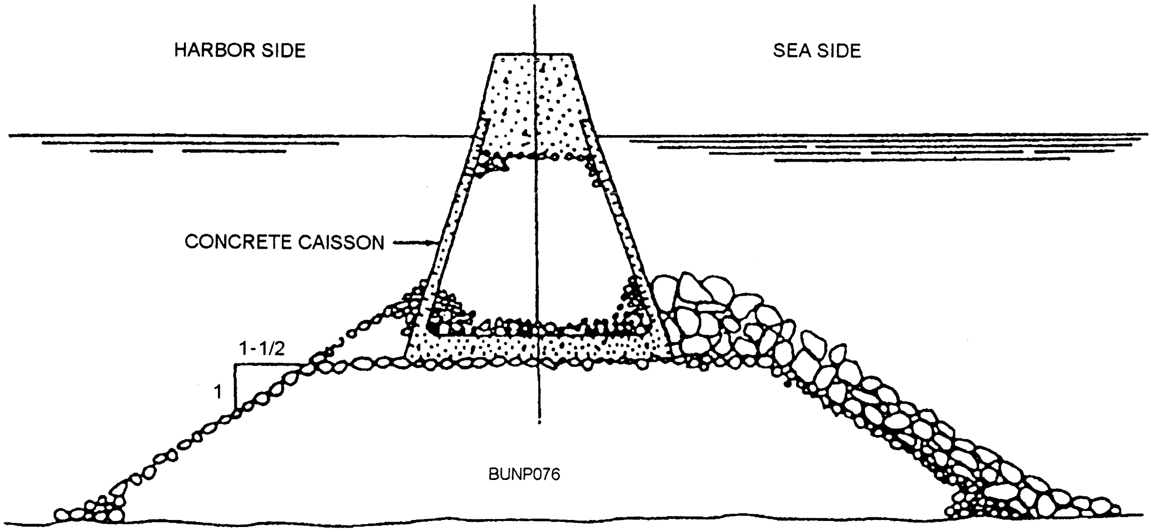


Figure 8-30.—Composite breakwater or jetty.

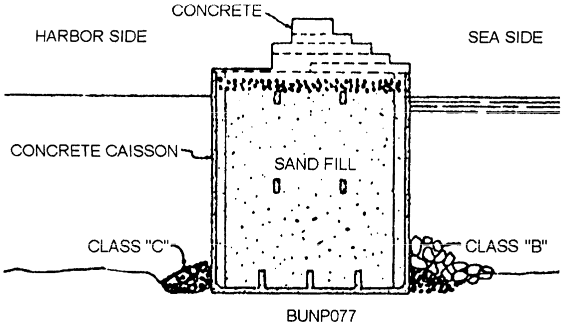


Figure 8-31.—Caisson breakwater or jetty.

70 feet. The width of its base depends on the width of the cap, the height of the structure, and the slopes of the inner and outer faces. For a deepwater site or for one with an extra-high tide range, a rubble-mound breakwater may be topped with a concrete cap structure, as shown in figure 8-30. A structure of this type is called a composite breakwater or jetty. In figure 8-30, the cap structure is made of a series of precast concrete boxes called caissons, each of which is floated over its place of location and then sunk into position. A monolithic (single-piece) concrete cap is then cast along the tops of the caissons. Sometimes, breakwaters and jetties are built entirely of caissons, as shown in figure 8-31.

A GROIN is a structure similar to a breakwater or jetty, but it serves a third purpose. A groin is used in a situation where a shoreline is subject to along shore erosion, caused by wave or current action parallel or oblique to the shoreline. The groin is run out from the shoreline (usually there is a succession of groins at intervals) to check the along shore wave action or deflect it away from the shore.

A MOLE is a breakwater that is paved on the top for use as a wharfage structure. To serve this purpose, it must have a vertical face on the inner side, or harborside. A jetty may be similarly constructed and used, but it is still called a jetty.

STABLE-SHORELINE STRUCTURES

These structures are constructed parallel with the shoreline to protect it from erosion or other wave damage. They are covered as follows.

A SEAWALL is a vertical or sloping wall that offers protection to a section of the shoreline against erosion and slippage caused by tide and wave action. A seawall is usually a self-sufficient type of structure, such as a gravity type retaining wall. Seawalls are classified according to the types of construction. A seawall may be made of riprap or solid concrete. Several types of seawall structures are shown in figure 8-32.

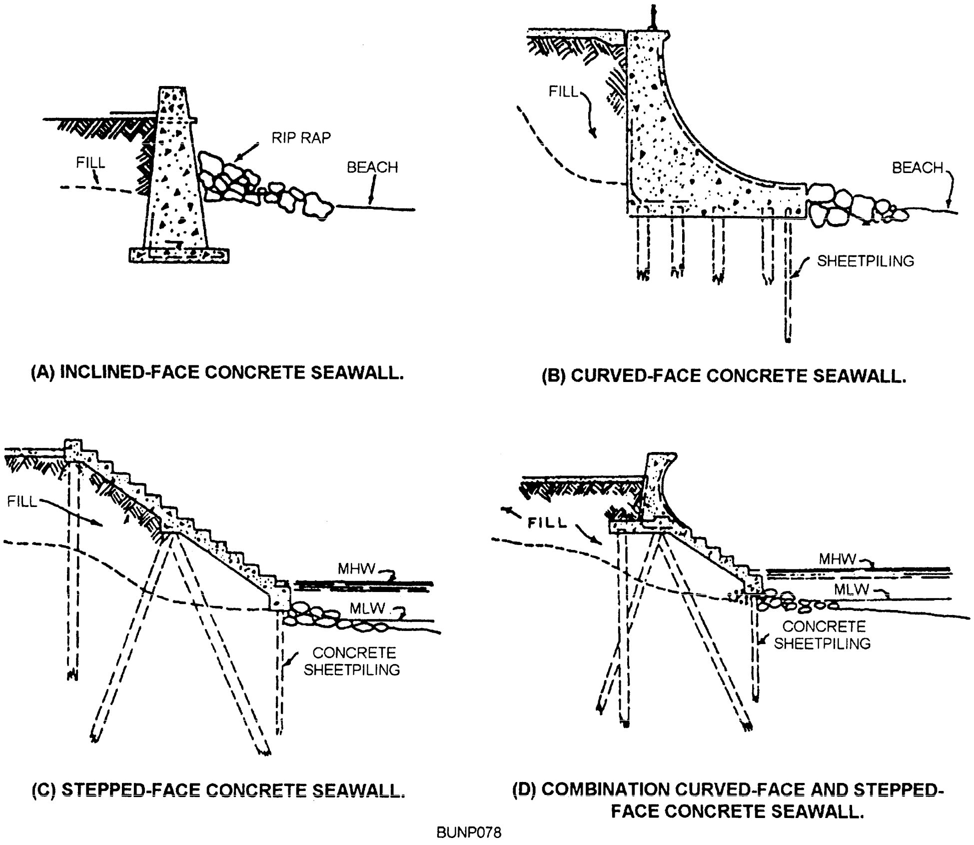
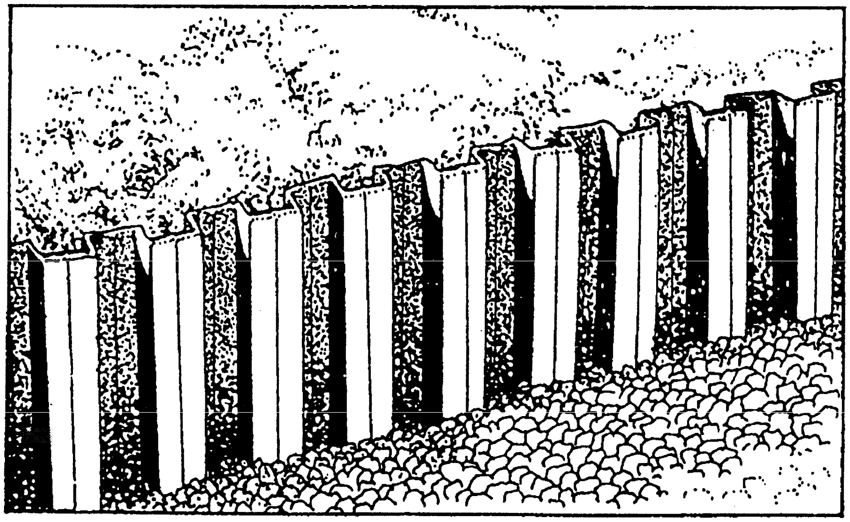


Figure 8-32.—Various types of seawalls.



BUNP079

Figure 8-33.—Steel sheet-pile bulkhead.

A BULKHEAD serves the same general purpose as a seawall, namely, to establish and maintain a stable shoreline. However, while a seawall is self-contained, relatively thick, and is supported by its own weight, the bulkhead is a relatively thin wall. Bulkheads are classified according to types of construction, such as the following:

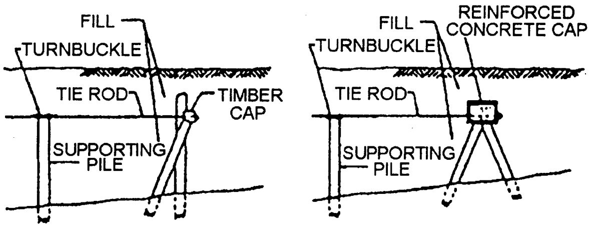
1. Pile-and-sheathing bulkhead
2. Wood sheet-pile bulkhead
3. Steel sheet-pile bulkhead
4. Concrete sheet-pile bulkhead

Most bulkheads are made of steel sheet piles, as shown in figure 8-33, and are supported by a series of tie wires or tie rods that are run back to a buried anchorage (or deadman). The outer ends of the tie rods are anchored to a steel wale that runs horizontally along the outer or inner face of the bulkhead. The wale is usually made up of pairs of structural steel channels that are bolted together back to back.

In stable soil above the groundwater level, the anchorage for a bulkhead may consist simply of a buried timber, a concrete deadman, or a row of driven and buried sheet piles. A more substantial anchorage for each tie rod is used below the groundwater level. Two common types of anchorages are shown in figure 8-34. In view A, the anchorage for each tie rod consists of a timber cap, supported by a batter pile, which is bolted to a bearing pile. In view B, the anchorage consists of a reinforced concrete cap, supported by a pair of batter piles. As shown in the figure, tie rods are supported by piles located midway between the anchorage and the bulkhead.

Bulkheads are constructed from working drawings like those shown in figure 8-35. The detail plan for the bulkhead shows that the anchorage consists of a row of sheet piles to which the inner ends of the tie rods are anchored by means of a channel wale.

The section view shows that the anchorage will lie 58 feet behind the bulkhead. This view also suggests the order of construction sequence. First, the shore and bottom will be excavated to the level of the long, sloping dotted line. The sheet piles for the bulkhead and anchorage will then be driven. The intervening dotted lines, at intervals of 19 feet 4 inches, represent supporting piles, which will be driven to hold up the tie rods. The piles will be driven next, and the tie rods then set in place. The wales will be bolted on, and the tie rods will be tightened moderately (they are equipped with turnbuckles for this purpose).

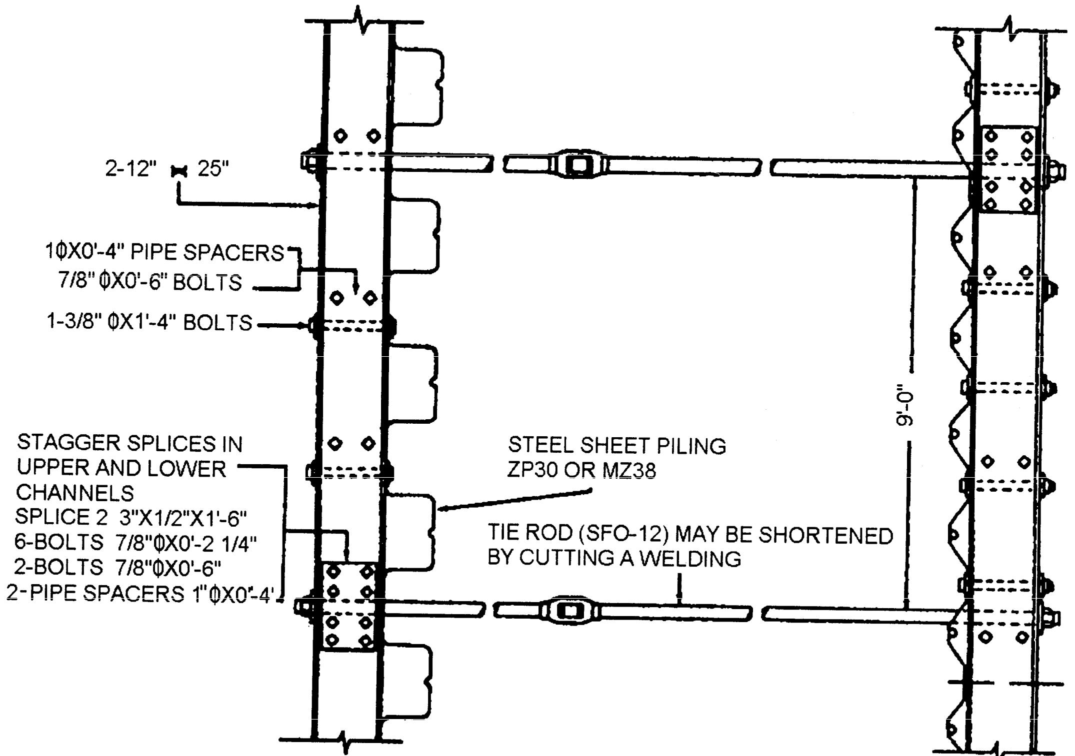


A. BATTER PILE ANCHORAGE WITH TIMBER CAP

B. A-FRAME PILE ANCHORAGE WITH REINFORCED CONCRETE CAP

BUNP080

Figure 8-34.—Two types of tie-rod anchorages for bulkheads.



DETAIL PLAN OF BULKHEAD

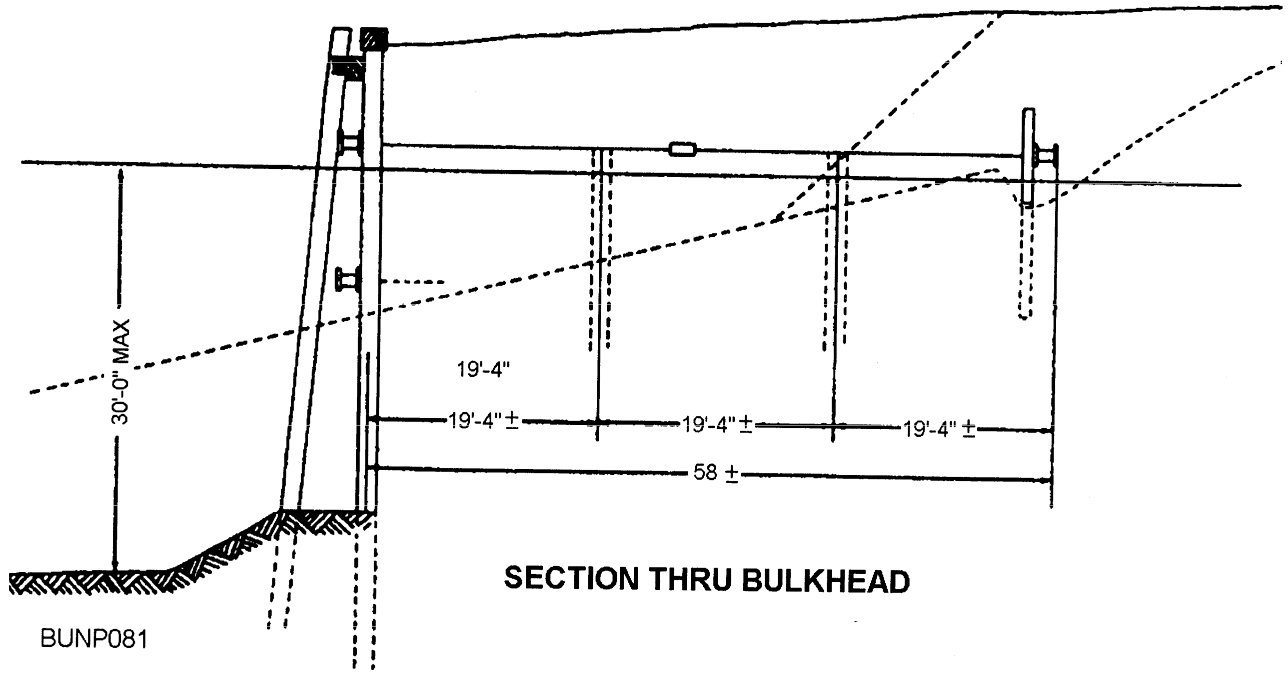


Figure 8-35.—Working drawings for steel sheet-pile bulkhead.

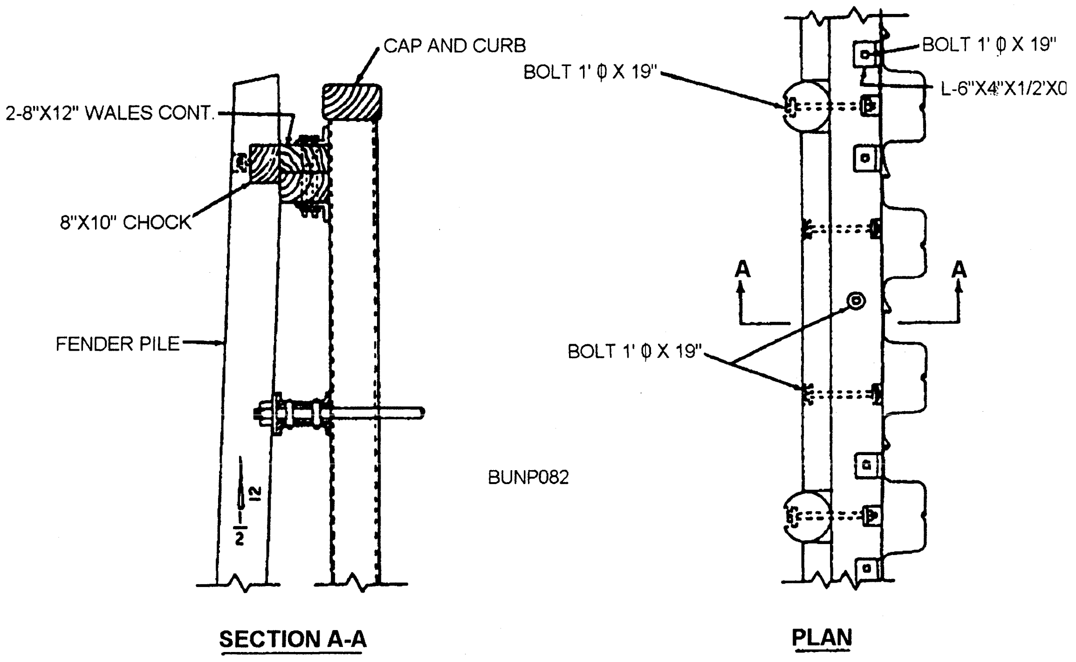


Figure 8-36.—Cap and fender pile for bulkhead.

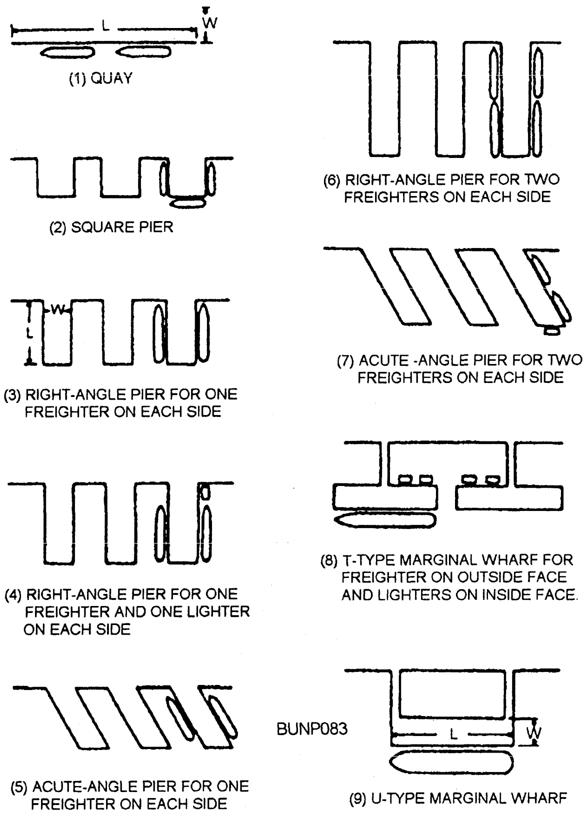
Backfilling to the bulkhead will then begin. The first backfilling operation will consist of filling over the anchorage out to the sloping dotted line. The turnbuckles on the tie rods will then be set up to bring the bulkhead plumb. Then the remaining fill, out to the bulkhead, will be put in. Finally, outside the bulkhead, the bottom will be dredged to a depth of 30 feet.

As shown in figure 8-36 the fender piles will be fitted with a timber cap to make it possible for the ships to come alongside the bulkhead. These piles, installed at proper intervals, will provide protection against the impact of ships and will protect the hulls of ships from undue abrasion.

WHARFAGE STRUCTURES

Wharfage structures are designed to allow ships to dock alongside then for loading and discharge. Figure 8-37 shows various plan views of wharfage structures. Any of these may be constructed of fill material, supported by bulkheads. However, a pier or marginal wharf usually consists of a timber, steel, or concrete superstructure, supported on a substructure of timber, steel, or concrete pile bents.

Working drawings for advanced-base piers are contained in the *Facilities Planning Guide,* volume 1, NAVFAC P-437. Figures 8-38, 8-39, and



W = WHARF WIDTH L = WHARF LENGTH
NOTE: NOT TO SCALE. FOR EXPLANATION OF LAYOUT TERMINOLOGY ONLY

Figure 8-37.—Types of wharfage structures.

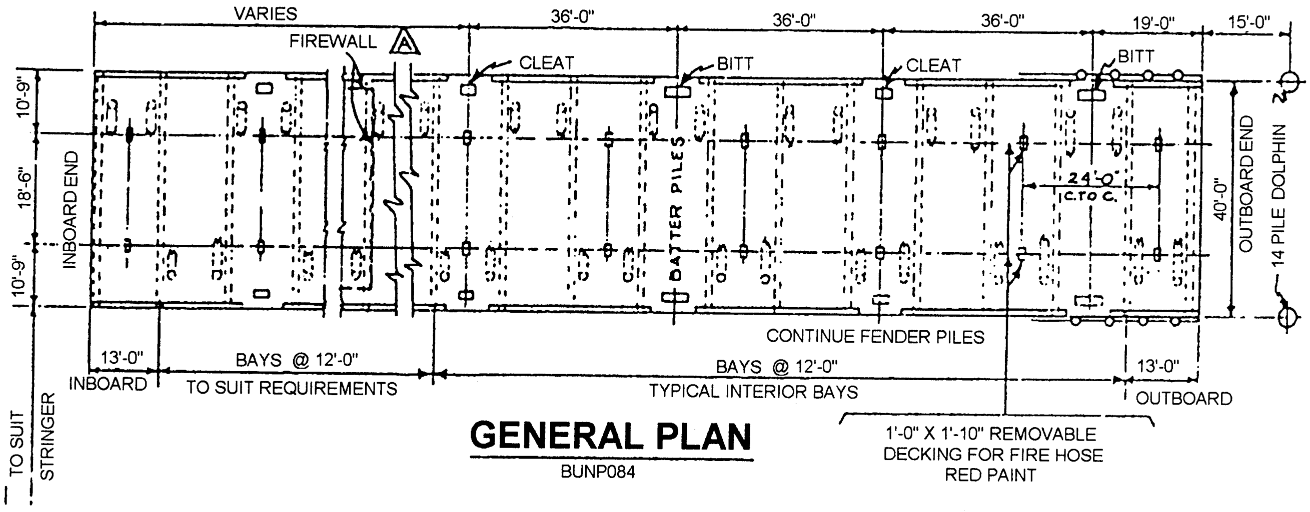


Figure 8-38.—General plan of an advanced-base 40-foot timber pier.

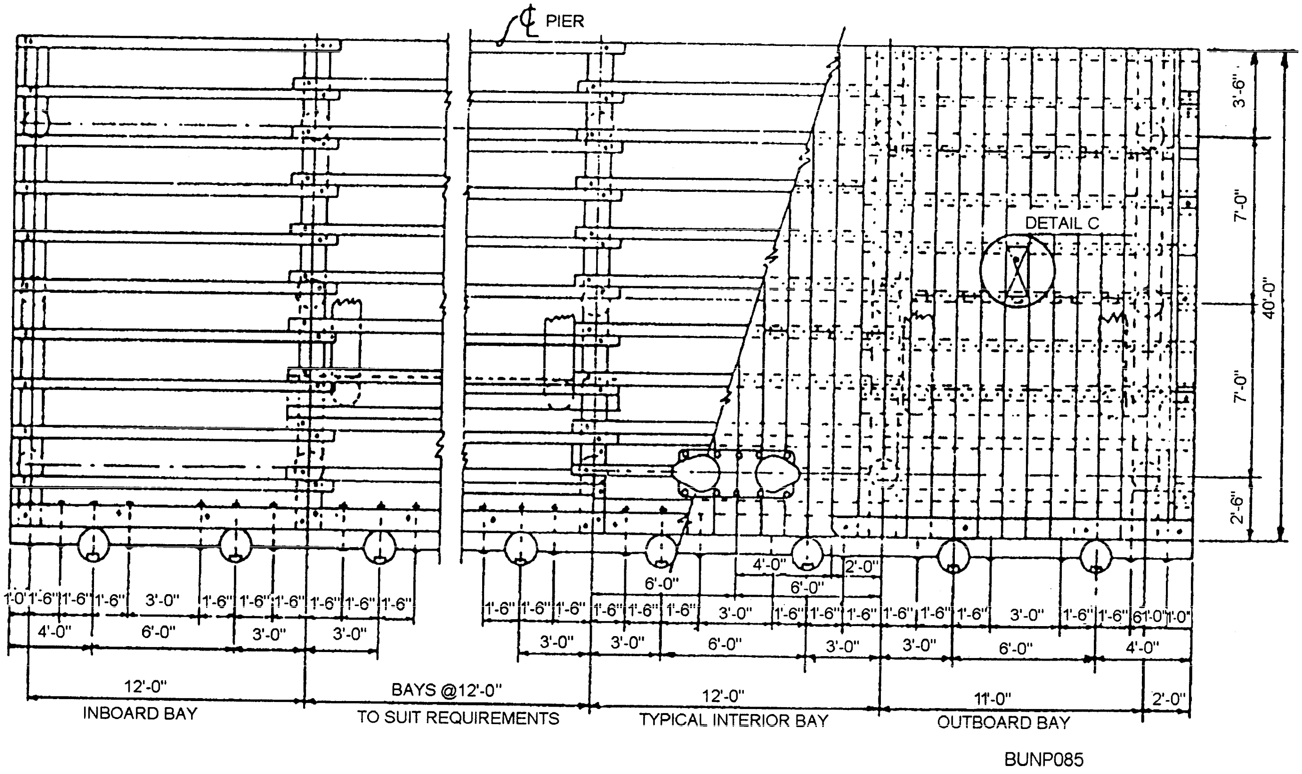


Figure 8-39.—Part plan of an advanced-base timber pier.

8-40 are portions of the advanced-base drawing for a 40-foot timber pier. Chapter 10 provides further information on the advanced base functional components (ABFC).

Each part of a pier lying between adjacent pile bents is called a BAY, and the length of a single bay is equal to the on-center spacing of the bents. In the general plan shown in figure 8-39, you can see that the 40-foot pier consists of one 13-foot outboard bay, one 13-foot inboard bay, and as many 12-foot interior bays as needed to meet the length requirements for the pier.

The cross section shown in figure 8-40 shows that each bent consists of six bearing piles. The bearing piles are braced transversely by diagonal braces. Additional transverse bracing for each bent is provided by a pair of batter piles. The batter angle is specified as 5 in 12. One pile of each pair is driven on either side of the bent, as shown in the general plan. The butts of the batter piles are joined to 12-inch by 12-inch by 14-foot longitudinal batter-pile caps, each of which is bolted to the undersides of two adjacent bearing-pile caps in the positions shown in the part plan. The batter-pile caps are placed 3 feet inboard of the center lines of the outside bearing piles in the bent. They are backed by 6- by 14-inch batter-pile cap blocks, each of which is bolted to a bearing-pile cap. Longitudinal bracing between bents consists of 14-foot lengths of 3- by 10-inch planks, bolted to the bearing piles.

The superstructure (fig. 8-40) consists of a single layer of 4 by 12 planks laid on 19 inside stringers measuring 6 inches by 14 inches by 14 feet. The inside

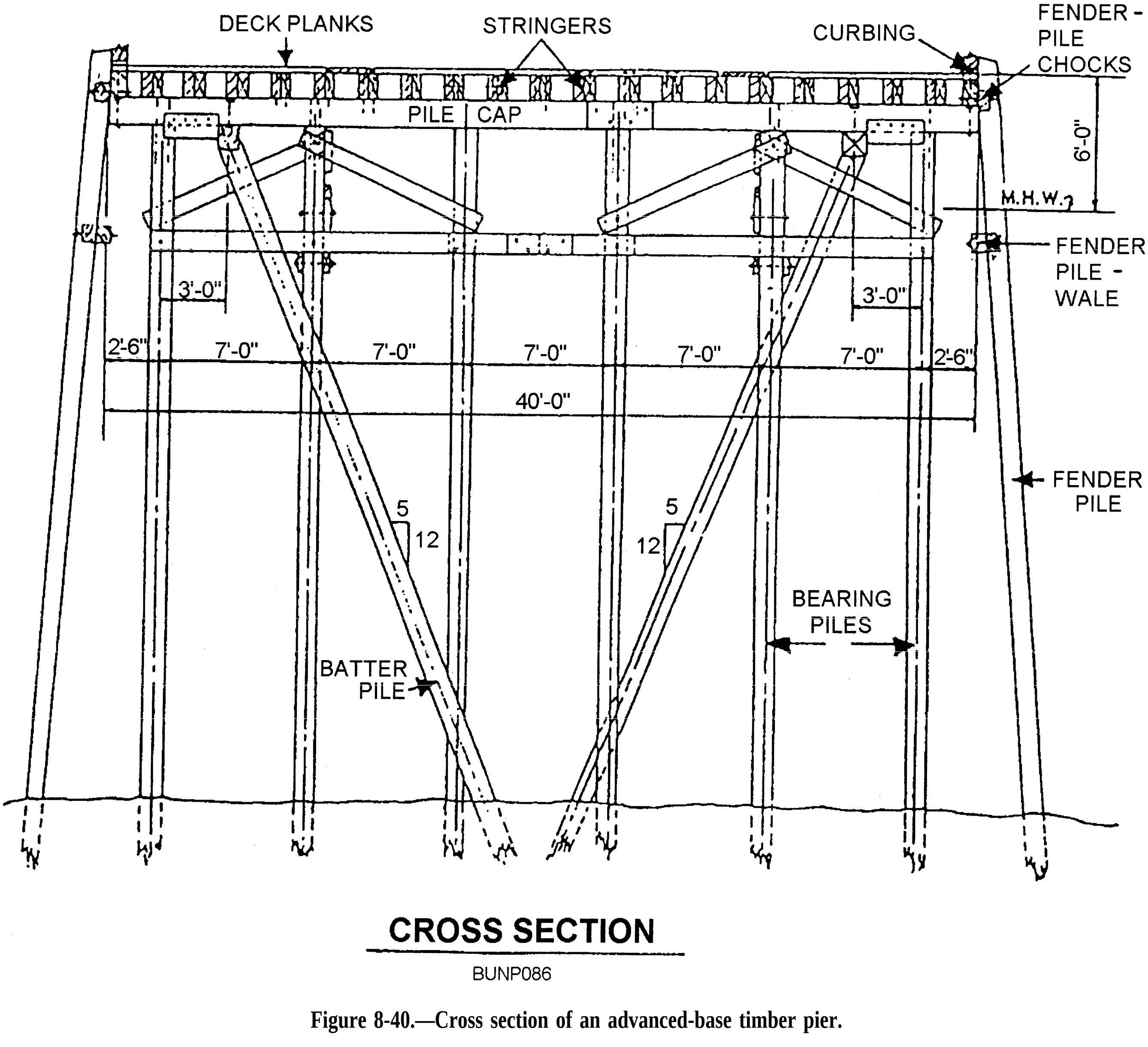


Figure 8-40.—Cross section of an advanced-base timber pier.

stringers are fastened to the pile caps with driftbolts. The outside stringers are fastened to the pile caps with bolts. The deck planks are fastened to the stringers with 3/8-by 8-inch spikes. After the deck is laid, 12-foot lengths of 8 by 10 are laid over the outside stringers to form the curbing. The lengths of curbing are distributed as shown in the general plan. The curbing is bolted to the outside stringers.

The pier is equipped with a fender system to protect it against shock, caused by contact with vessels coming or docked alongside of it. Fender piles, spaced as shown in the part plan, are driven along both sides of the pier and bolted to the outside stringers. The heads of these bolts are countersunk below the surfaces of the piles. An 8- by 10-fender wale is bolted to the backs of the fender piles. Lengths of 8- by 10-fender-pile chocks are cut to fit between the piles and bolted to the outside stringers and the fender wales. The spacing for these bolts is shown in the part plan. As shown in the general plan, the fender system also includes two 14-pile dolphins, located 15 feet beyond the end of the pier. A **dolphin** (fig. 8-4 1) is an isolated cluster of piles,

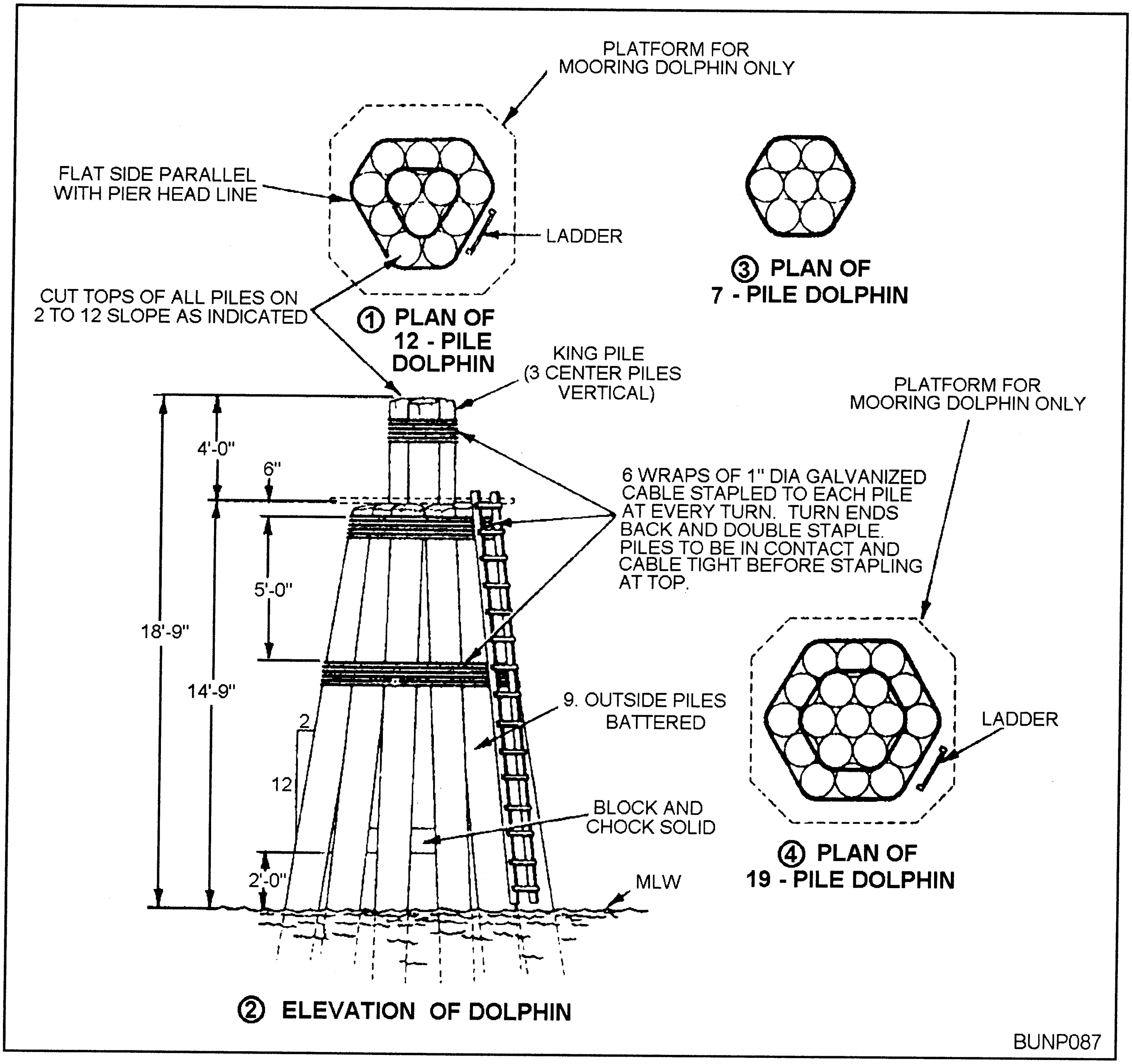


Figure 8-41.—Typical Dolphin Plan.

TIMBER FASTENERS AND CONNECTORS

As a Builder, be aware that it is usually unnecessary to call out in working drawings the types of fasteners used for light frame construction. However, this is not the case, for heavy timber construction. To prepare drawings or estimate materials for timber structures, you need a working knowledge of timber fasteners and connectors and the manner in which they are used. The following text covers the more common types.

TIMBER FASTENERS

Bolts used to fasten heavy timbers usually come in 1/2-, 3/4-, and 1-inch diameters and have square heads and nuts. In use, the bolts are fitted with round steel washers under both the bolt head and the nut. The bolts are then tightened until the washers bite well into the wood to compensate for future shrinkage. Bolts should be spaced a minimum of 9 inches on center and should be no closer than 2 1/2 inches to the edge or 7 inches to the end of the timber.

Driftbolts, also called driftpins, are used primarily to prevent timbers from moving laterally in relation to each other, rather than to resist pulling apart. They are used more in dock and trestle work than in trusses and building frames. A drifibolt is a long threadless rod that is driven through a hole bored through the member and into the abutting member. The hole is bored slightly smaller than the bolt diameter and about 3 inches shorter than the bolt length. Driftbolts are from 1/2 to 1 inch in diameter and 18 to 26 inches long.

Butt joints are customarily connected using driftbolts; however, another method of making butt-joint connections is to use a scab. A scab is a short length of timber that is spiked or bolted to the adjoining members, as shown in figure 8-42.

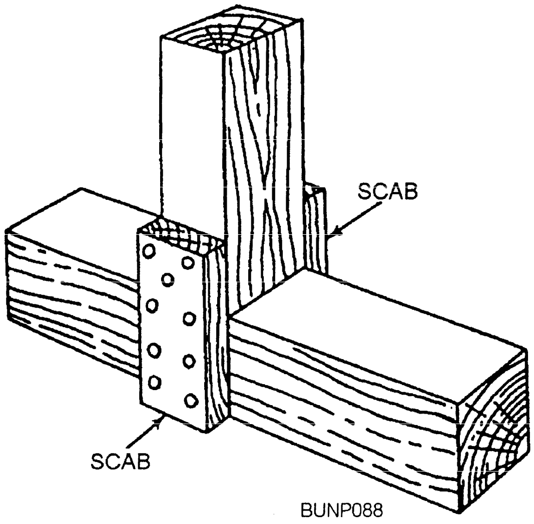


Figure 8-42.—Scabs.

TIMBER CONNECTORS

A timber connector is any device used to increase the strength and rigidity of bolted lap joints between heavy timbers. For example, the split ring (fig. 8-43) is embedded in a circular groove. These grooves are cut with a special bit in the faces of the timbers that are to be joined. Split rings come in diameters of 2 1/2 and 4 inches. The 2 1/2-inch ring requires a 1/2-inch bolt, and the 4-inch ring uses a 3/4-inch bolt.

Shear plates are shown in figure 8-44. These connectors are intended for wood-to-steel connections, as shown in view(B). But, when used in pairs, they may be used for wood-to-wood connections as shown in view (C). When making a wood-to-wood connection, the fabricator first cuts a depression into the face of each of the wood members. These depressions are cut to the same depth as the shear plates. Then a shear plate is set into each of the depressions so that the back face of the shear plate is flush with the face of the wood members. Finally, the wood members are slid into place and bolted together. Because the faces are flush, the members easily slide into position, which reduces the labor necessary to make the connection. Shear plates are available in 2 5/8- and 4-inch diameters.

For special applications, **toothed rings** and **spike grids** are sometimes used. The toothed ring connector (fig. 8-45) functions in much the same manner as the split ring but can be embedded without the necessity of cutting grooves in the members. The toothed ring is embedded by the pressure provided from tightening a

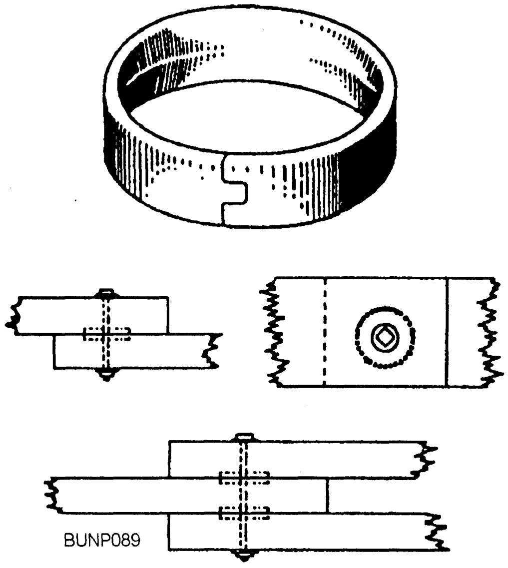
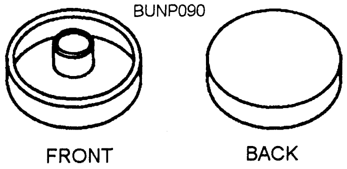
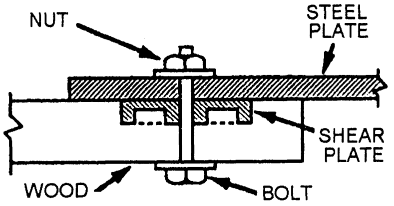


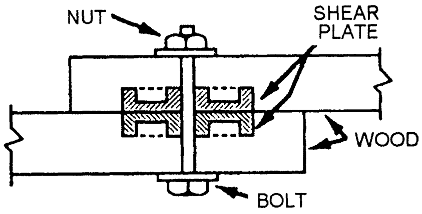
Figure 8-43.—Split ring and split-ring joints.



(A) SHEAR PLATE



(B) SHEAR PLATE CONECTION (WOOD-TO-STEEL)



(C) SHEAR PLATE CONNECTION (WOOD-TO-WOOD)

Figure 8-44.—Shear plate and shear-plate joints.

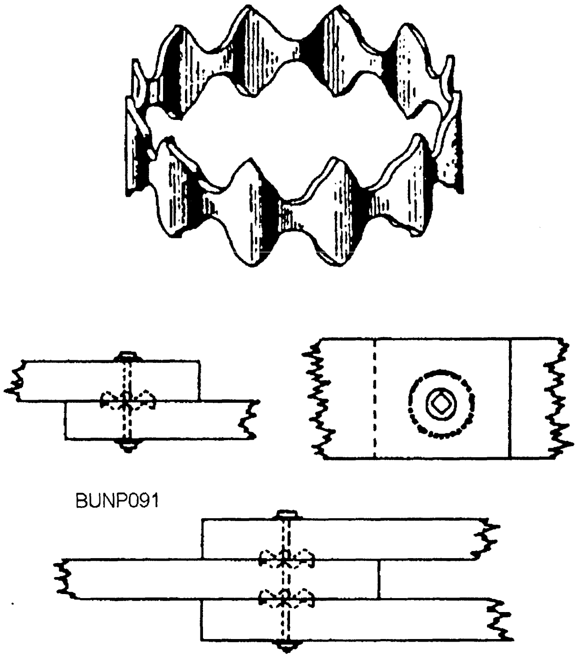


Figure 8-45.—Toothed ring and toothed-ring joints.

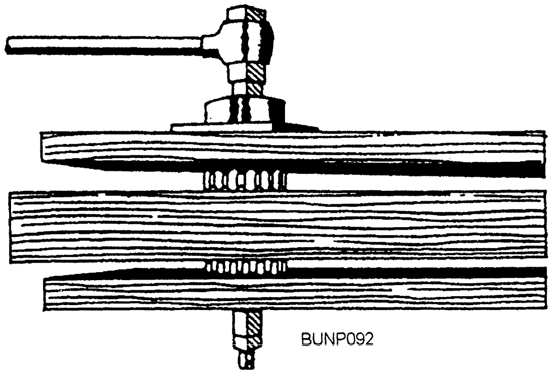


Figure 8-46.—Embedding toothed rings.

high-tensile strength bolt, as shown in figure 8-46. The hole for this bolt is drilled slightly larger than the bolt diameter so that the bolt may be extracted after the toothed ring is embedded. The spike grid is used as shown in figure 8-47. A spike grid may be flat (for joining flat surfaces), single-curved (for joining a flat and a curved surface), or double-curved (for joining two curved surfaces). A spike grid is embedded in the same manner as a toothed ring.

Tools used in heavy construction are covered in the Use *and Care of Hand Tools and Measuring Tools,* NAVEDTRA 12085. In the Table of Allowance (TOA), you will find certain kits that can be used such as the following:

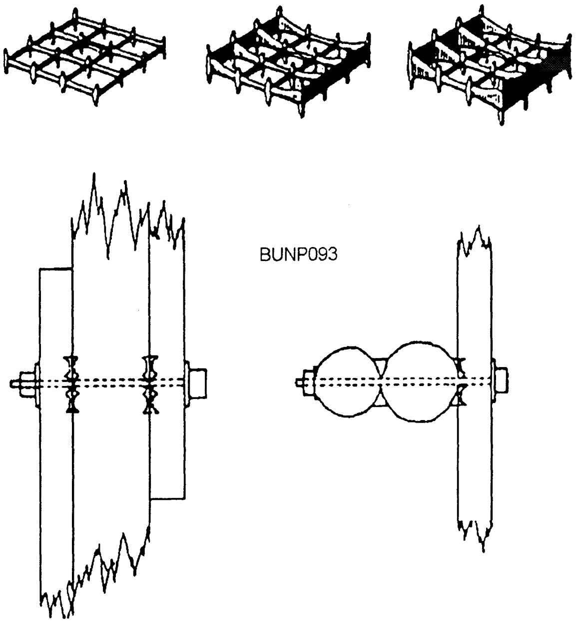
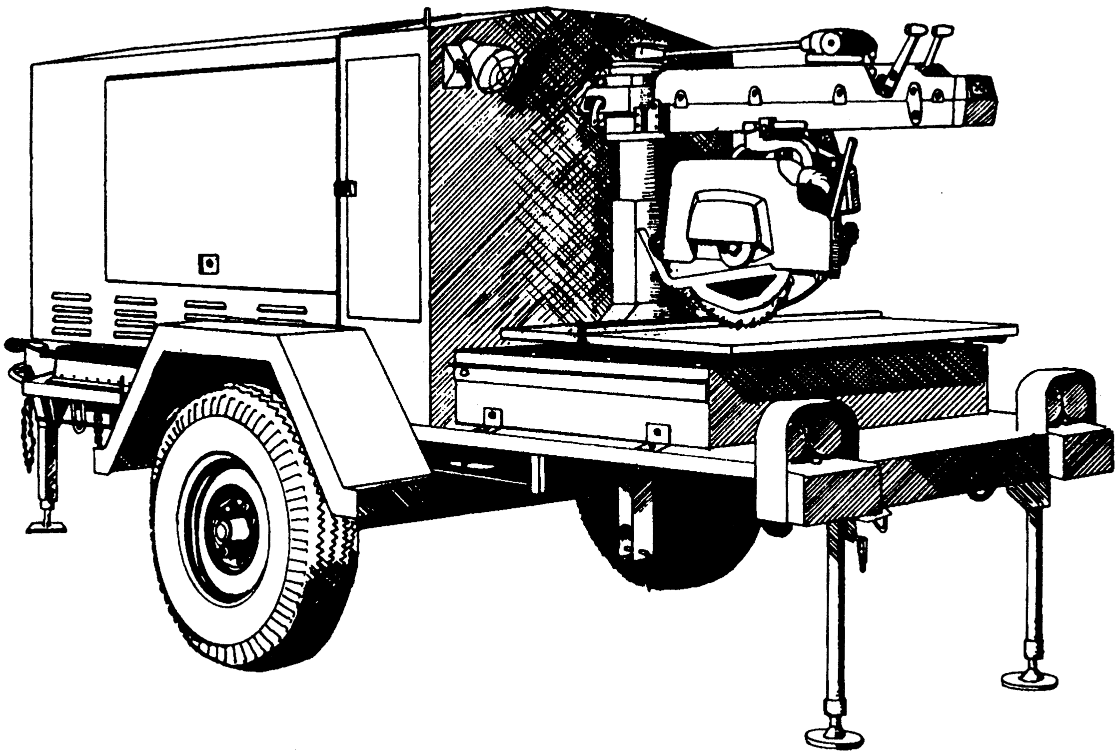
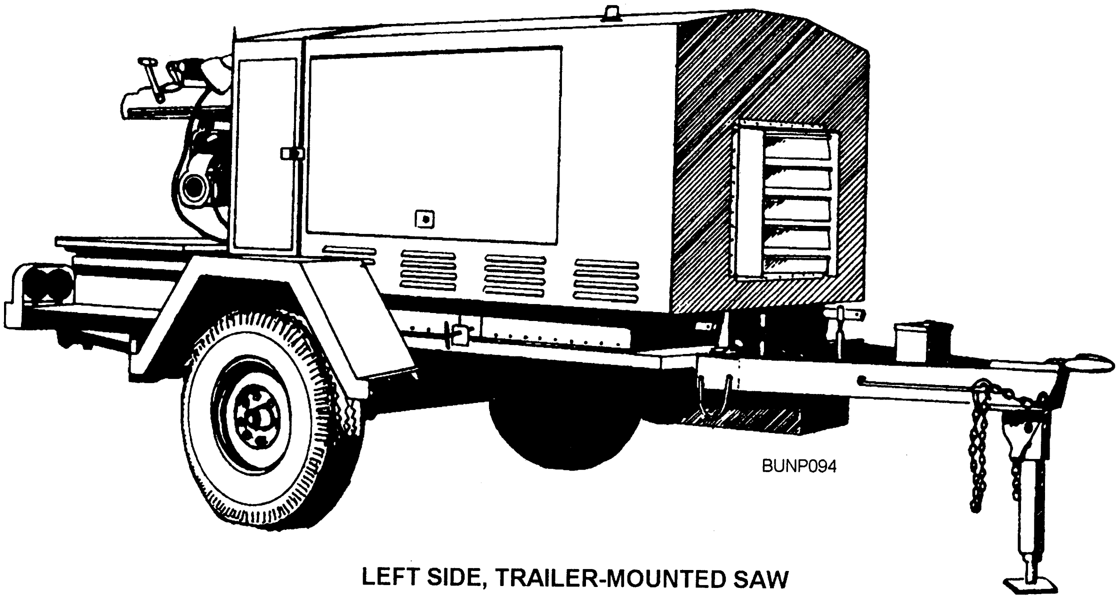


Figure 8-47.—Spike grids and spike-grid joints.



RIGHT SIDE, TRAILER-MOUNTED SAW



LEFT SIDE, TRAILER-MOUNTED SAW

Figure 8-48.—Trailer-mounted radial overarm field saw (front view and side view).

- Kit assembly 80041 – Heavy Const. Tools F/4
- Kit assembly 82072 – Saw, Radial Arm (Field) (fig. 8-48)
- Kit assembly 85025 – Saw, Chain 36N, GEN, 2 man
- Kit assembly 80019 – Carpenters Tools F/4

These are just a few of the kits that can be used from the TOA. Refer to the NAVFAC P-405 for a list of kit assemblies by number.

STEEL FRAME STRUCTURES

The construction of a framework of structural steel involves two principal operations: fabrication and erection. Fabrication involves the processing of raw materials to form the finished members of the structure. Erection includes all rigging, hoisting, or lifting of members to their proper places in the structure and making the finished connections between members.

A wide variety of structures are erected using structural steel. Basically, they can be listed as buildings, such as PEBs, bridges, and towers; most other structures are modifications of these three.

STEEL BUILDINGS

Three basic types of steel construction are used today. These may be designated as wall-bearing construction, skeleton construction, and long-span construction.

In wall-bearing construction, exterior and interior masonry walls are used to support structural members, such as steel beams and joists, which carry the floors and roof. Note that while this section of your TRAMAN covers steel structures, wall-bearing construction is applicable to nonsteel structures as well. Wall-bearing construction is one of the oldest and most common methods in use. Although modem developments in reinforced concrete masonry make the use of this method feasible for high-rise structures, wall-bearing construction is normally restricted to relatively low structures, such as residences and light industrial buildings.

A tall building with a steel frame, as shown in figure 8-49, is an example of skeleton construction. In this

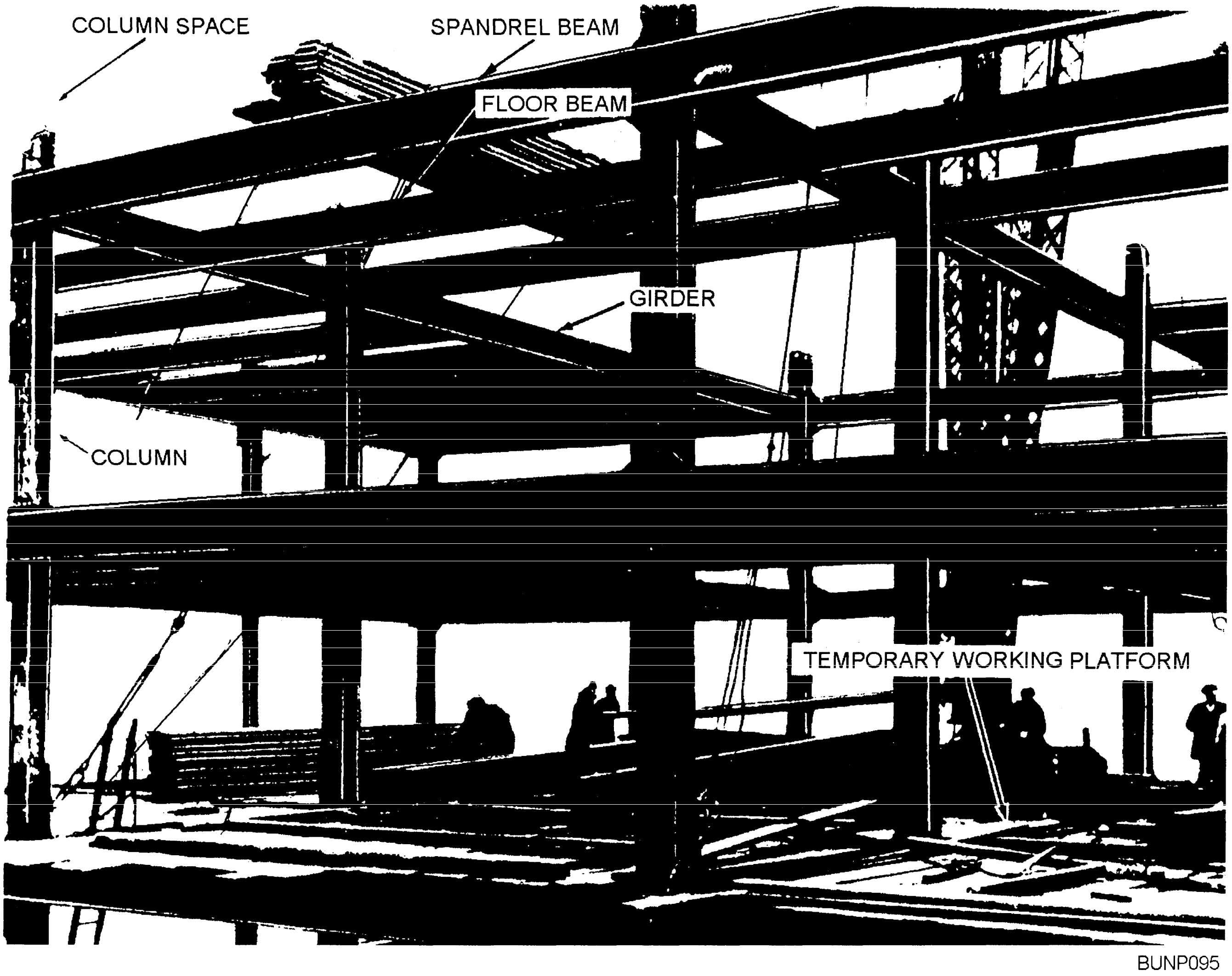


Figure 8-49.—Structural steel skeleton construction.

type of construction, all live and dead loads are carried by the structural-frame skeleton. For this reason, the exterior walls are nonbearing curtain walls. Roof and floor loads are transmitted to beams and girders, which are, in turn, supported by columns. The horizontal members or beams that connect the exterior columns are called spandrel beams. If you add additional rows of columns and beams, there is no limitation to the area of floor and roof that can be supported using skeleton construction. However, one limitation of using skeleton construction is the distance between columns.

Oftentimes, large structures, such as aircraft hangars, may require greater distances between supports than can be spanned by the standard structural steel shapes. In this case, one of several methods of long-span steel construction is used. One method uses built-up girders to span the distances between supports. Two types of built-up girders are shown in figure 8-50. As shown in the figure, the built-up girder consists of steel plates and shapes that are combined together to meet the necessary strength. The individual parts of these girders are connected by welding or riveting.

Another method, usually more economical, is the use of a truss to span large distances. A TRUSS is the framework of a structural member consisting of a top chord, bottom chord, and diagonal web members that are usually placed in a triangular arrangement. Figure 8-51 shows many different types of trusses that can be fabricated to conform to the shape of nearly any roof system.

A third long-span method, although not as versatile as trusses, is the use of bar joists. BAR JOISTS are much lighter than trusses and are fabricated in several different types. One type is shown in figure 8-52. Prefabricated bar joists, designed to conform to specific load requirements, are obtainable from commercial companies. Other long-span construction methods

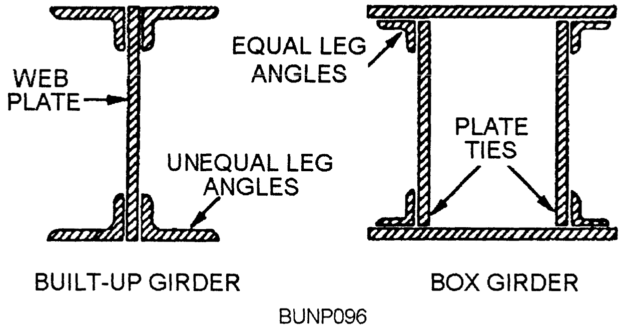


Figure 8-50.—Typical built-up girders.

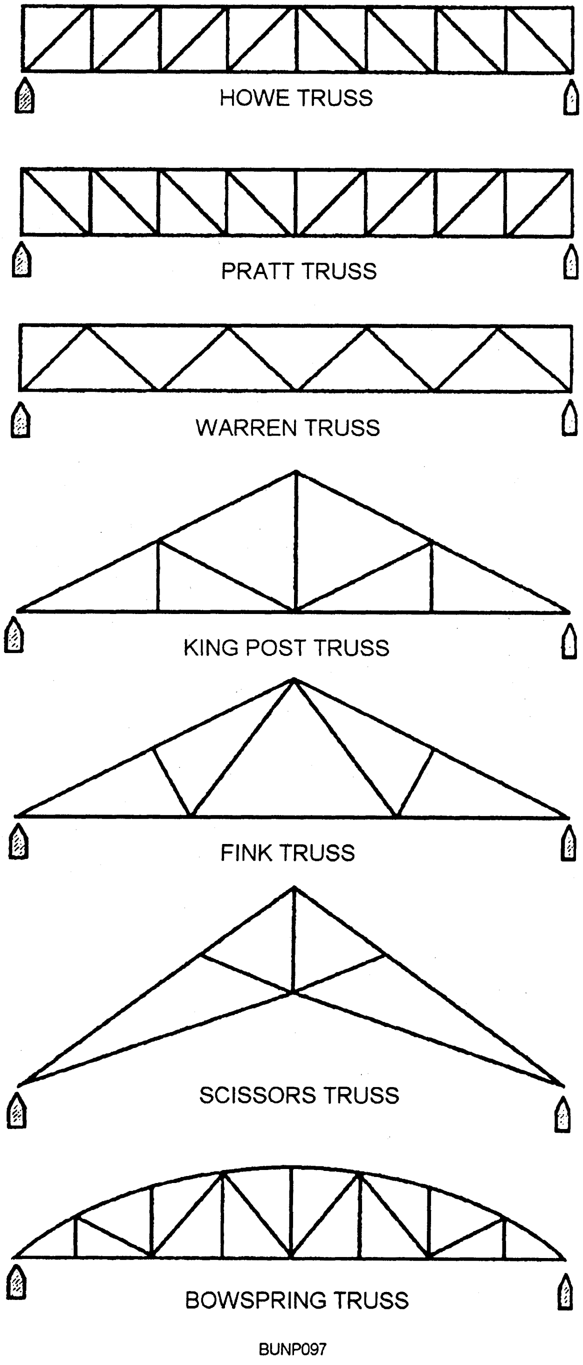


Figure 8-51.—Typical steel trusses.

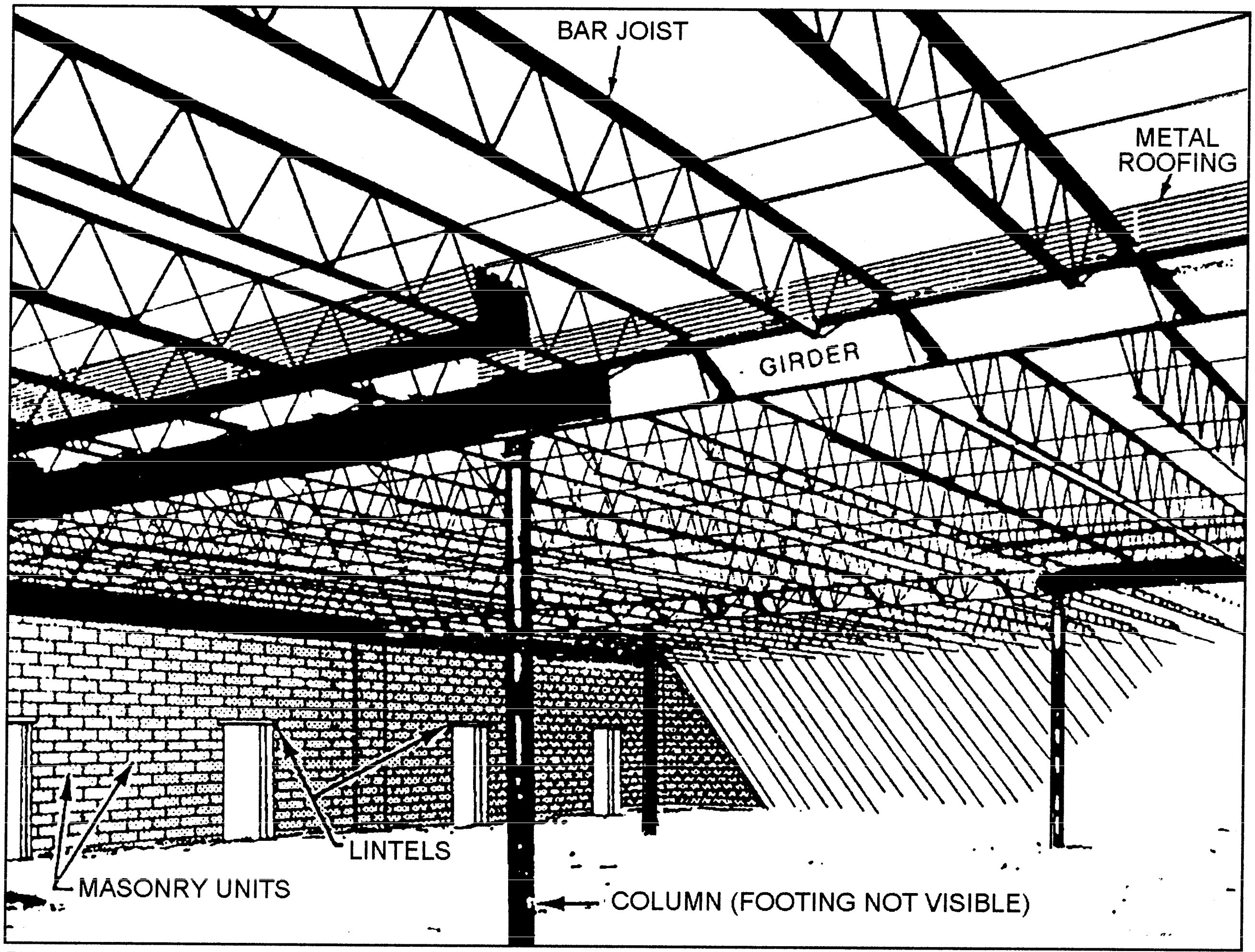


Figure 8-52.—Clear span bar joists.

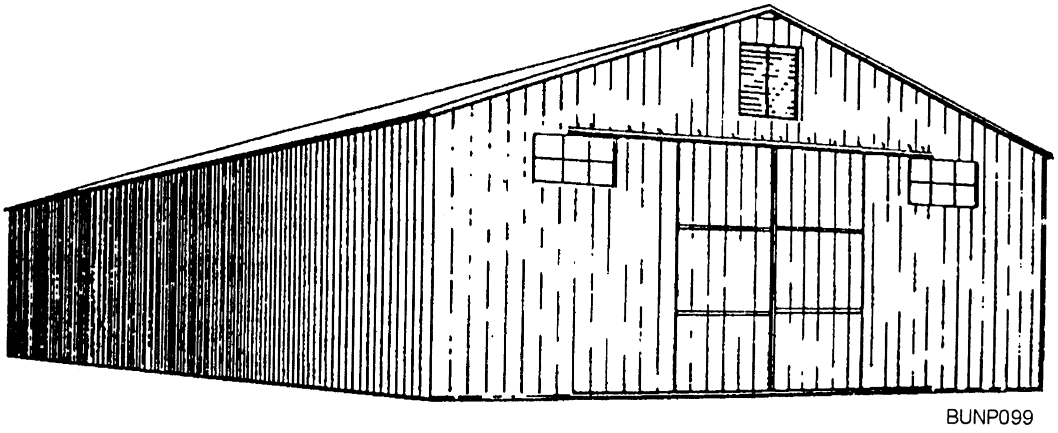


Figure 8-53.—Completed 40' x 100' x 14' pre-engineered metal building.

involve several different types of framing systems, which include steel arches, cable-hung frames, and other types of systems. These methods are beyond the scope of this TRAMAN.

PRE-ENGINEERED METAL STRUCTURES

Pre-engineered metal structures are commonly used in military construction. These structures are usually designed and fabricated by civilian industry to conform with specifications set forth by the military. Rigid-frame buildings, steel towers, communications antennas, and steel tanks are some of the most commonly used structures, particularly at overseas advanced bases. Pre-engineered structures offer an advantage in that they are factory-built and designed to be erected in the shortest amount of time possible. Each structure is shipped as a complete kit, including all the materials and instructions needed to erect it.

Of the pre-engineered metal structures available, the one that is perhaps most familiar to the Seabees is the pre-engineered metal building (PEB) shown in figures 8-53 and 8-54. Figure 8-53 shows the nomenclature of the various parts of the PEB. For definition of this nomenclature, erection details, and other important information regarding the PEB, you should refer to the *Steelworker*, NAVEDTRA 12530.

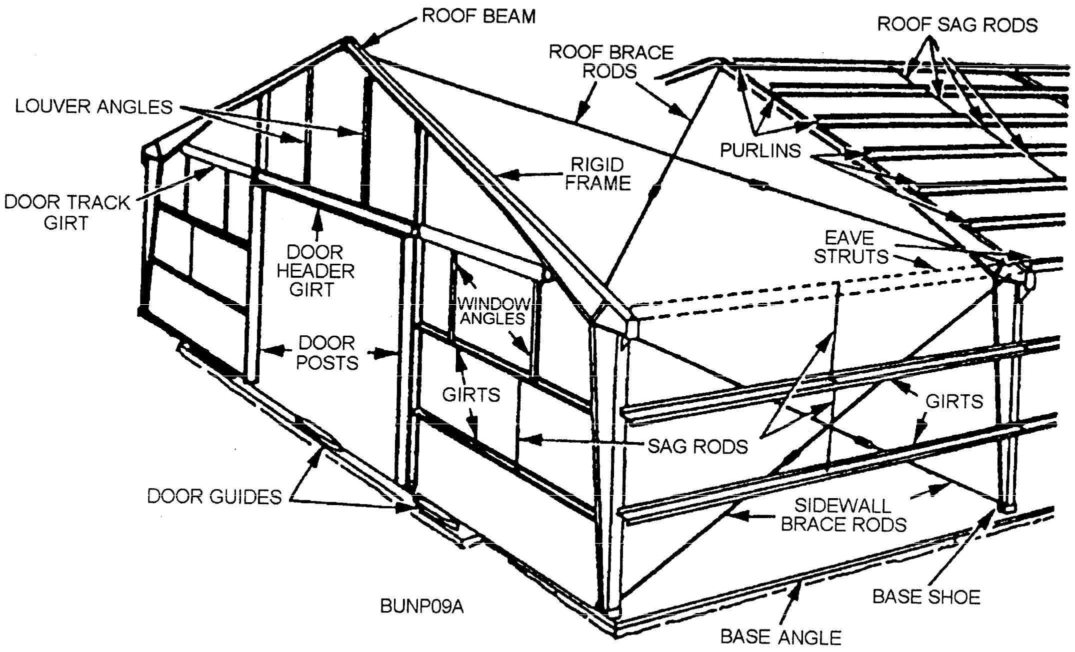


Figure 8-54.—Structural members of a pre-engineered metal building.

CHAPTER 9

ADVANCED BASE PLANNING AND FIELD STRUCTURES

LEARNING OBJECTIVE: *Recognize the principles involved in the use of the Facilities Planning Guide, and identify procedures used to construct field structures and repair war damaged structures during contingency operations.*

As a Seabee in the Naval Construction Force (NCF), your primary mission is to support the Navy and Marine Corps during contingency operations. You, as the Builder, are usually the prime contractor on any vertical construction project, as covered in chapter 3. This means you have to be knowledgeable of contingency operations. REMEMBER, the primary reason Seabee's exist is to provide construction support in any contingency operation and to TRAIN everyone accordingly.

"Contingency" means an amount included in the construction budget to cover the cost of **UNFORESEEN** factors related to construction. Contingency operations, such as the Vietnam War, Persian Gulf War, Operation Restore Hope in Somalia, peace-keeping mission in Bosnia, Typhoon O'Mara in Guam, Hurricane Andrew in Florida, Mt. Pinatubo eruption in Philippines, and many more humanitarian assignments, are what Seabees are trained to do.

As crew leaders and project managers, the need to understand *how* the Advanced Base Functional Component (ABFC) system works and what types of field structures you will be dealing with is critical to contingency operations.

ADVANCED BASE FUNCTIONAL COMPONENT SYSTEM

The ADVANCED BASE FUNCTIONAL COMPONENT (ABFC) system provides support facilities to the constantly changing tactical and strategic situations. A modular or building block concept was developed. Components were needed to incorporate personnel, materials, equipment, and facilities. These components were designed and developed to fulfill specific functions, no matter where the components were placed. The Navy ABFC system is based on early experiences in advanced base planning and shipment used in World War II. Additional improvements were adopted from experiences learned in Korea, Vietnam, and the Persian Gulf and many other small conflicts.

ABFCs are normally complete entities. The basic groupings of the ABFC system are (1) **component,** a complete unit; (2) **facility,** a portion of a complete component; and (3) **assembly,** a portion of a facility. ABFCs, though normally complete, may not be supplied with housing, messing, medical facilities, maintenance facilities, defensive ordnance, communication equipment, and utilities with each component. These service components or facilities are to be integrated into an overall base development or augmentation plan. The ABFC system consists of the following two general-purpose publications: *Table of Advanced Base Functional Components with Abridged Initial Outfitting Lists*, OPNAV 41P3A, and *Facilities Planning Guide,* volumes 1 and 2, NAVFAC P-437.

ABFCs are assigned descriptive names to indicate their functions and alphanumeric designators to facilitate reference. A detailed advanced base initial outfitting list (ABIOL) is an itemized line-item printout of the material in each ABFC. Each command or bureau of the system is responsible for maintaining a detailed listing of that part of the ABIOL assigned to it.

FACILITIES PLANNING GUIDE

When you are tasked to assist in planning the construction of an advanced base, consult the *Facilities Planning Guide.* This guide identifies the structures and supporting utilities of the Navy ABFC system. This system was developed to make pre-engineered facility designs and corresponding material lists available to planners at all levels. While these designs relate primarily to the expected needs at advanced bases and to the Navy ABFC system, they also can be used to satisfy peacetime requirements. Facility, logistic, and construction planners will find the information required to select and document the materials necessary to construct facilities.

The NAVFAC P-437 consists of two volumes. Volume 1 contains reproducible engineering drawings and is now available on CD-ROM, which is organized as follows:

- Part 1, Component Site Plans, is indexed by component and ABFC designation.
- Part 2, Facility Drawings, is indexed by facility number and DoD category code.
- Part 3, Assembly Drawings, contains assembly information and is indexed by assembly number.

Each drawing is a detailed construction drawing that describes and lists the facilities, the assemblies, or the line items required to complete it. A summary of logistic, construction, and cost data is provided for each component, facility, and assembly of the ABFC system. A "component" is defined as a grouping of personnel and material that has a specific function or mission at an advanced base. Whether it is located overseas or in CONUS, a component is supported by facilities and assemblies.

A construction network is included in each facility of the ABFC system as part of the design package in the NAVFAC P-437 (fig. 9-1). The network includes such information as tool kits, equipment, and PRCP skills required for each facility. Time and effort are saved by use of the construction networks that were developed for each facility in the ABFC system. To benefit from the construction networks, you must have an understanding of the basic principles and assumptions upon which the networks are based. Network analysis procedures for precedence diagraming are covered in chapter 5 of the *Seabee Planner's and Estimator's Handbook,* NAVFAC P-405, and chapter 2 of this TRAMAN.

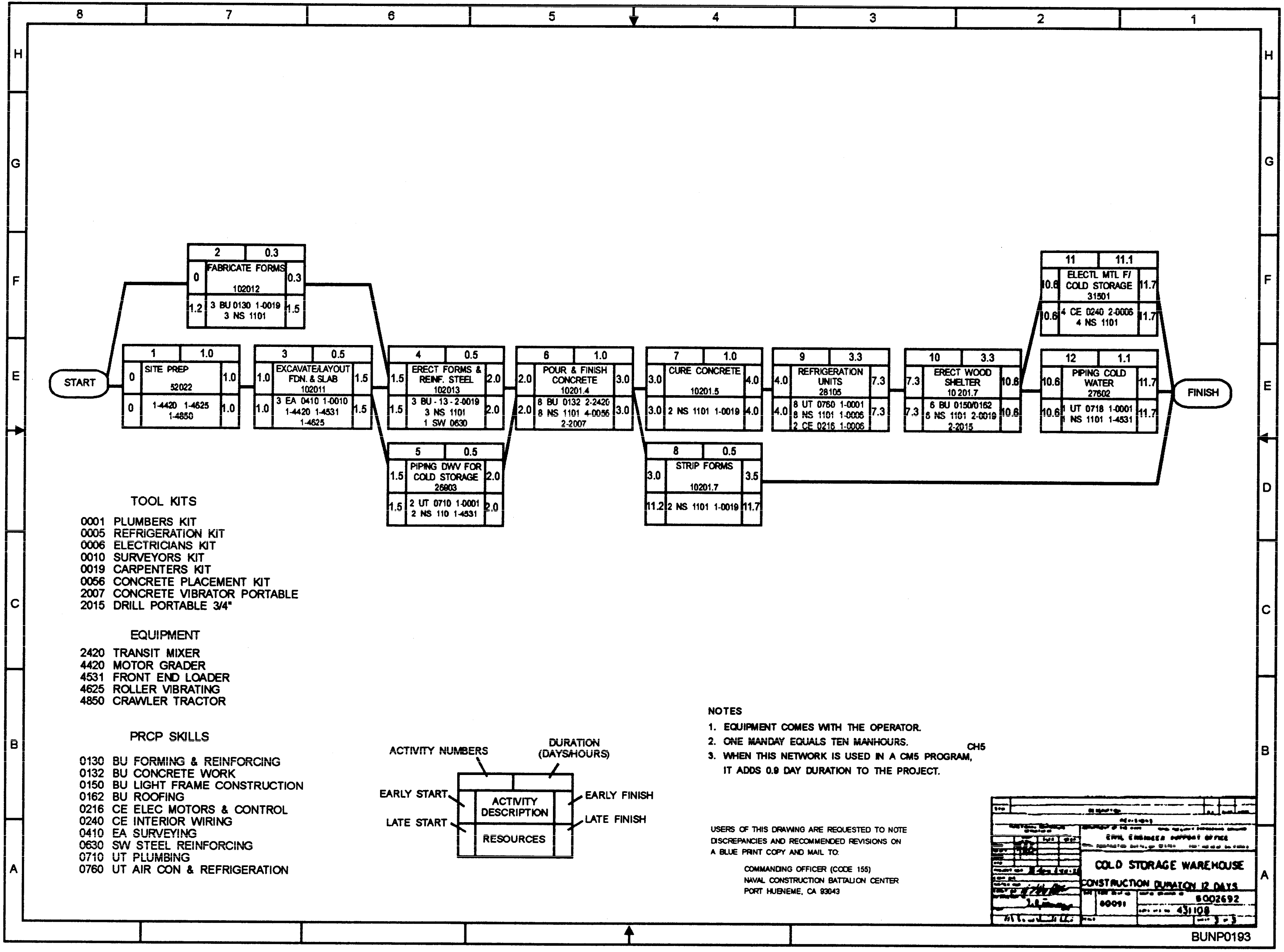
Volume 2 of NAVFAC P-437 contains the detailed data display for each component, facility, and assembly and is available on a hard disk. (Except for earthwork, material lists in volume 2 are complete bills of material.) The volume is also arranged in three parts.

- Part 1 lists and describes by DoD category code the facilities requirement for each component.
- Part 2 lists and describes by assembly number the assembly requirement for each facility.
- Part 3 lists line-item requirements by national stock number (NSN) for each assembly.

The P-437 also contains other useful information for planners, such as crew sizes; man-hours by skill; land areas; amounts of fuel necessary to make a component, facility, or assembly operational; and information about predesigned facilities and assemblies that are not directly related to components shown in the ABFC table (OPNAV 41P3A). These predesigned facilities and assemblies give the planner alternatives for satisfying contingency requirements when the callout of a complete component is not desired. To make the P-437 compatible with other DoD planning guides, *Category Codes Facilities,* NAVFAC P-72, a related publication, establishes the category codes, the nomenclature, and the required units of measure for identifying, classifying, and quantifying real property. The cardinal category codes are as follows:

100	Operations and Training
200	Maintenance and Production
300	Research, Development, and Evaluation
400	Supply
500	Hospital and Medical
600	Administrative
700	Housing and Community Support
800	Utilities and Ground Improvement
900	Real Estate

If a facility is required for enlisted personnel quarters, for example, it will be found in the 700 series (Housing and Community Support). The assemblies within each facility consist of a grouping of line items at the NSN level which, when assembled, will perform a specific function in support of the facility. An assembly is functionally grouped in such a way that the



TOOL KITS

0001	PLUMBERS KIT
0005	REFRIGERATION KIT
0006	ELECTRICIANS KIT
0010	SURVEYORS KIT
0019	CARPENTERS KIT
0056	CONCRETE PLACEMENT KIT
2007	CONCRETE VIBRATOR PORTABLE
2015	DRILL PORTABLE 3/4"

EQUIPMENT

2420	TRANSIT MIXER
4420	MOTOR GRADER
4531	FRONT END LOADER
4625	ROLLER VIBRATING
4850	CRAWLER TRACTOR

PRCP SKILLS

0130	BU FORMING & REINFORCING
0132	BU CONCRETE WORK
0150	BU LIGHT FRAME CONSTRUCTION
0162	BU ROOFING
0216	CE ELEC MOTORS & CONTROL
0240	CE INTERIOR WIRING
0410	EA SURVEYING
0630	SW STEEL REINFORCING
0710	UT PLUMBING
0760	UT AIR CON & REFRIGERATION

NOTES

1. EQUIPMENT COMES WITH THE OPERATOR.
2. ONE MANDAY EQUALS TEN MANHOURS.
3. WHEN THIS NETWORK IS USED IN A CM5 PROGRAM, IT ADDS 0.9 DAY DURATION TO THE PROJECT.

USERS OF THIS DRAWING ARE REQUESTED TO NOTE DISCREPANCIES AND RECOMMENDED REVISIONS ON A BLUE PRINT COPY AND MAIL TO:

COMMANDING OFFICER (CODE 155)
NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CA 93043

Figure 9-1.—Construction network.

assembly number relates to the Occupational Field 12 skill required to install it. The groupings are numbered, as shown in table 9-1.

Table 9-1.—Assembly Sequence Numbers

Description	Number Start	Sequence Stop
Builder (BU) oriented	10,000	19,999
Utilitiesman (UT) oriented	20,000	29,999
Construction Electrician (CE) oriented	30,000	39,999
Steelworker (SW) oriented	40,000	49,999
Equipment Operator (EO) oriented	50,000	54,999
Waterfront equipment	55,000	57,999
Underwater construction and diving equipment	58,000	59,999
Operational supplies	60,000	62,499
Operating consumables	62,500	64,999
NBC warfare	65,000	67,499
Personnel-related supplies	67,500	69,999
Unassigned at present	70,000	79,999
Shop equipment including maintenance tools	80,000	80,999
Unique ABFC tool kits	81,000	81,999
Naval Construction Force (NCF) Table of Allowance (TOA) construction tools and kits (power tools)	82,000	82,099
NCF TOA construction tools and kits (electrical)	82,500	82,599
NCF TOA construction tools and kits (miscellaneous)	83,000	83,199
NCF TOA construction tools and kits (rigging)	84,000	84,099
Shop equipment (ABFC unique)	85,000	87,499

Tailoring Components and Facilities

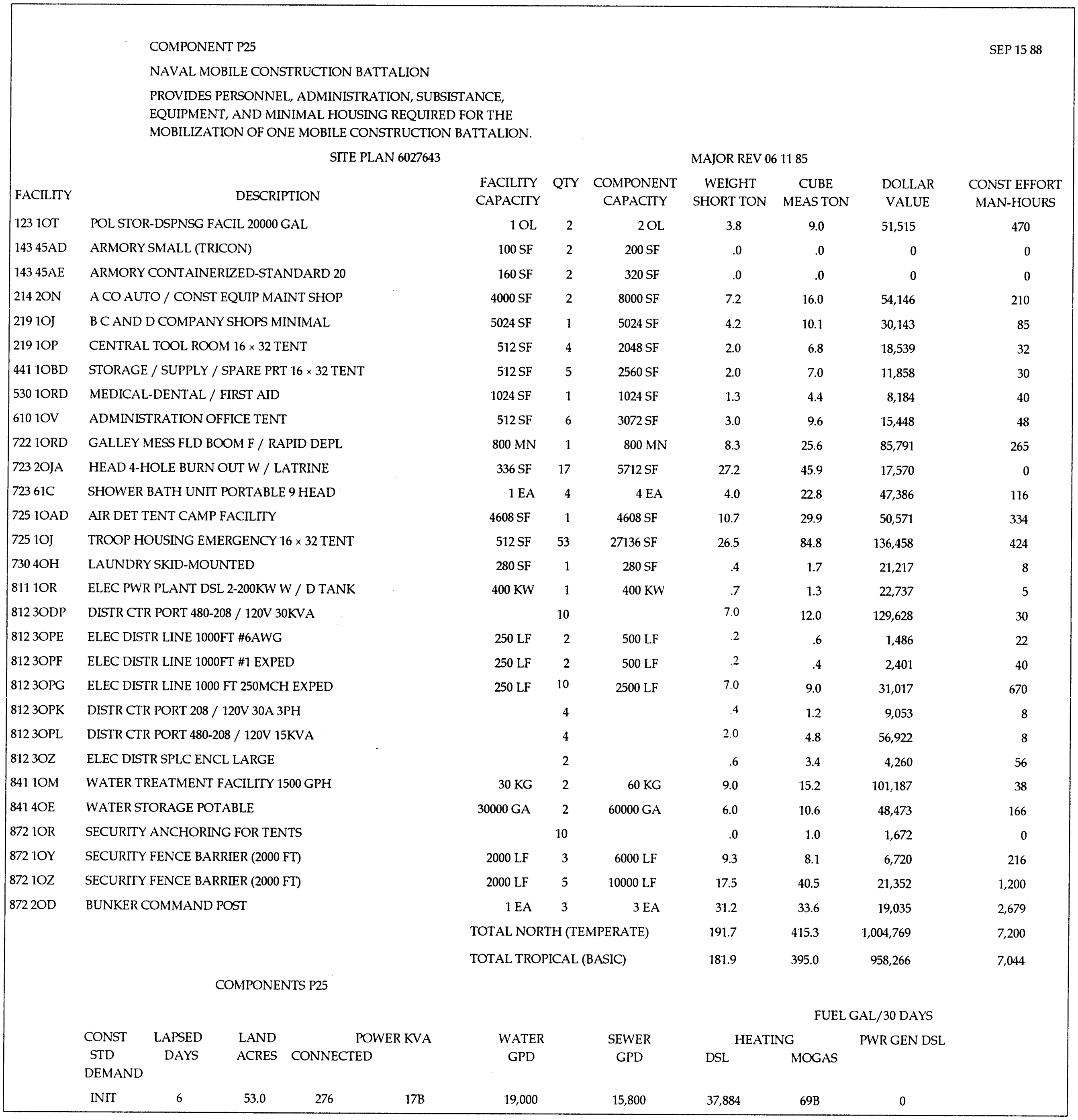
When you use the ABFC system, remember to tailor it to your specific needs. Know your exact mission and its requirements. Choose the components, the facilities, or the assemblies that best fit or can be tailored to meet your desired goals. Develop modular elements to serve similar functions in various locations. The exact requirements for a specific base cannot be defined, economically designed, nor supported within the general system. However, the base development planner knows the specific location, mission, unit composition, and availability of other assets. The planner can then select from the ABFC system the components or facilities that satisfy these specific requirements. Tailoring is then applied to the preplanned ABFC assets to come up with what is needed.

Tailor components or facilities by either (1) deleting or adding facilities or assemblies and (2) specifying requirements for the Tropical or North Temperate Zone. Assemblies required only in Tropical installations are coded with the letter *T* in the zone column to the right of the assembly description. Assemblies required only in North Temperate installations are coded with the letter *N.* Uncoded assemblies are common to both zones.

Use and Application of the *Facilities Planning Guide*

Although a listing in the P-437 may help you order individual items in general supply, it does NOT replace stock lists of systems commands or bureaus, offices, single managers, or inventory control points. Stock numbers and descriptions can be verified through appropriate stock lists. You are responsible for verifying stock numbers when ordering a component, a facility, or an assembly.

COMPONENT.— Figure 9-2 shows a typical component breakdown of the P-25. A brief header describes the mission and capabilities of the component. The site plan, pertaining to each component, is shown by a NAVFAC drawing number. However, drawings in volume 1, part 1, are indexed by component designation, not drawing numbers. The word *NONE* appears for components that have no site plans. The facilities required to make the component operative are listed in numerical sequence by DoD category code. The alpha suffix for each facility designator indicates differences between sizes, types, or layouts of facilities with the same functional purpose. Facility capacity is expressed in terms of the units of measure used in the *Category Codes Facilities,* NAVFAC P-72. The component capacity is figured by multiplying the facility capacity and the quantity. Weight and cube are measured in normal units for export packing.



COMPONENT P25 SEP 15 88

NAVAL MOBILE CONSTRUCTION BATTALION

PROVIDES PERSONNEL, ADMINISTRATION, SUBSISTANCE,
EQUIPMENT, AND MINIMAL HOUSING REQUIRED FOR THE
MOBILIZATION OF ONE MOBILE CONSTRUCTION BATTALION.

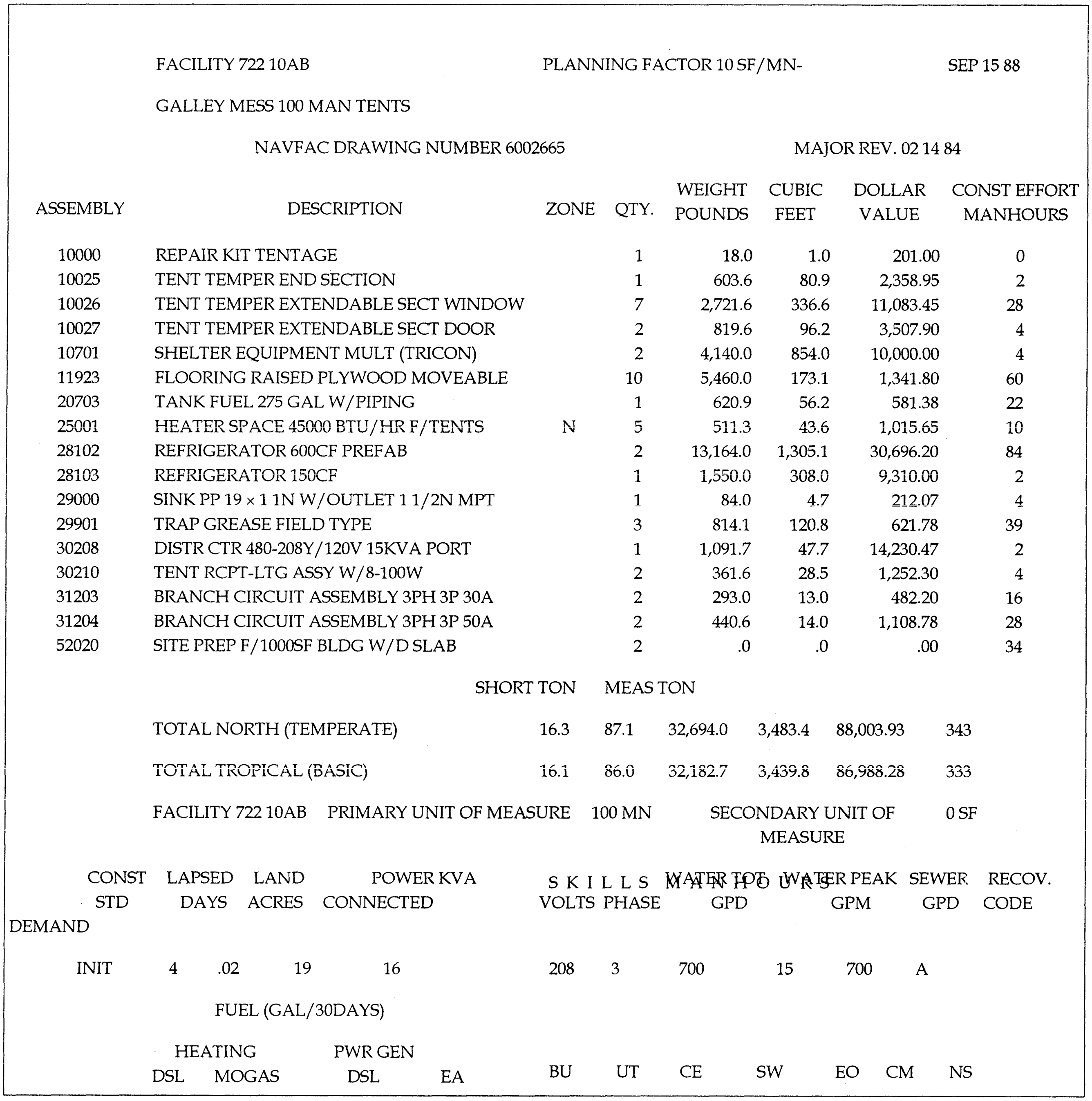
SITE PLAN 6027643 MAJOR REV 06 11 85

FACILITY	DESCRIPTION	FACILITY CAPACITY	QTY	COMPONENT CAPACITY	WEIGHT SHORT TON	CUBE MEAS TON	DOLLAR VALUE	CONST EFFORT MAN-HOURS
123 1OT	POL STOR-DSPNSG FACIL 20000 GAL	1 OL	2	2 OL	3.8	9.0	51,515	470
143 45AD	ARMORY SMALL (TRICON)	100 SF	2	200 SF	.0	.0	0	0
143 45AE	ARMORY CONTAINERIZED-STANDARD 20	160 SF	2	320 SF	.0	.0	0	0
214 2ON	A CO AUTO / CONST EQUIP MAINT SHOP	4000 SF	2	8000 SF	7.2	16.0	54,146	210
219 1OJ	B C AND D COMPANY SHOPS MINIMAL	5024 SF	1	5024 SF	4.2	10.1	30,143	85
219 1OP	CENTRAL TOOL ROOM 16 × 32 TENT	512 SF	4	2048 SF	2.0	6.8	18,539	32
441 1OBD	STORAGE / SUPPLY / SPARE PRT 16 × 32 TENT	512 SF	5	2560 SF	2.0	7.0	11,858	30
530 1ORD	MEDICAL-DENTAL / FIRST AID	1024 SF	1	1024 SF	1.3	4.4	8,184	40
610 1OV	ADMINISTRATION OFFICE TENT	512 SF	6	3072 SF	3.0	9.6	15,448	48
722 1ORD	GALLEY MESS FLD BOOM F / RAPID DEPL	800 MN	1	800 MN	8.3	25.6	85,791	265
723 2OJA	HEAD 4-HOLE BURN OUT W / LATRINE	336 SF	17	5712 SF	27.2	45.9	17,570	0
723 61C	SHOWER BATH UNIT PORTABLE 9 HEAD	1 EA	4	4 EA	4.0	22.8	47,386	116
725 1OAD	AIR DET TENT CAMP FACILITY	4608 SF	1	4608 SF	10.7	29.9	50,571	334
725 1OJ	TROOP HOUSING EMERGENCY 16 × 32 TENT	512 SF	53	27136 SF	26.5	84.8	136,458	424
730 4OH	LAUNDRY SKID-MOUNTED	280 SF	1	280 SF	.4	1.7	21,217	8
811 1OR	ELEC PWR PLANT DSL 2-200KW W / D TANK	400 KW	1	400 KW	.7	1.3	22,737	5
812 3ODP	DISTR CTR PORT 480-208 / 120V 30KVA		10		7.0	12.0	129,628	30
812 3OPE	ELEC DISTR LINE 1000FT #6AWG	250 LF	2	500 LF	.2	.6	1,486	22
812 3OPF	ELEC DISTR LINE 1000FT #1 EXPED	250 LF	2	500 LF	.2	.4	2,401	40
812 3OPG	ELEC DISTR LINE 1000 FT 250MCH EXPED	250 LF	10	2500 LF	7.0	9.0	31,017	670
812 3OPK	DISTR CTR PORT 208 / 120V 30A 3PH		4		.4	1.2	9,053	8
812 3OPL	DISTR CTR PORT 480-208 / 120V 15KVA		4		2.0	4.8	56,922	8
812 3OZ	ELEC DISTR SPLC ENCL LARGE		2		.6	3.4	4,260	56
841 1OM	WATER TREATMENT FACILITY 1500 GPH	30 KG	2	60 KG	9.0	15.2	101,187	38
841 4OE	WATER STORAGE POTABLE	30000 GA	2	60000 GA	6.0	10.6	48,473	166
872 1OR	SECURITY ANCHORING FOR TENTS		10		.0	1.0	1,672	0
872 1OY	SECURITY FENCE BARRIER (2000 FT)	2000 LF	3	6000 LF	9.3	8.1	6,720	216
872 1OZ	SECURITY FENCE BARRIER (2000 FT)	2000 LF	5	10000 LF	17.5	40.5	21,352	1,200
872 2OD	BUNKER COMMAND POST	1 EA	3	3 EA	31.2	33.6	19,035	2,679
		TOTAL NORTH (TEMPERATE)			191.7	415.3	1,004,769	7,200
		TOTAL TROPICAL (BASIC)			181.9	395.0	958,266	7,044

COMPONENTS P25

CONST STD DEMAND	LAPSED DAYS	LAND ACRES	POWER KVA		WATER GPD	SEWER GPD	FUEL GAL/30 DAYS		
							HEATING		PWR GEN DSL
			CONNECTED				DSL	MOGAS	
INIT	6	53.0	276	17B	19,000	15,800	37,884	69B	0

Figure 9-2.—Component.



FACILITY 722 10AB PLANNING FACTOR 10 SF/MN- SEP 15 88

GALLEY MESS 100 MAN TENTS

NAVFAC DRAWING NUMBER 6002665 MAJOR REV. 02 14 84

ASSEMBLY	DESCRIPTION	ZONE	QTY.	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE	CONST EFFORT MANHOURS
10000	REPAIR KIT TENTAGE		1	18.0	1.0	201.00	0
10025	TENT TEMPER END SECTION		1	603.6	80.9	2,358.95	2
10026	TENT TEMPER EXTENDABLE SECT WINDOW		7	2,721.6	336.6	11,083.45	28
10027	TENT TEMPER EXTENDABLE SECT DOOR		2	819.6	96.2	3,507.90	4
10701	SHELTER EQUIPMENT MULT (TRICON)		2	4,140.0	854.0	10,000.00	4
11923	FLOORING RAISED PLYWOOD MOVEABLE		10	5,460.0	173.1	1,341.80	60
20703	TANK FUEL 275 GAL W/PIPING		1	620.9	56.2	581.38	22
25001	HEATER SPACE 45000 BTU/HR F/TENTS	N	5	511.3	43.6	1,015.65	10
28102	REFRIGERATOR 600CF PREFAB		2	13,164.0	1,305.1	30,696.20	84
28103	REFRIGERATOR 150CF		1	1,550.0	308.0	9,310.00	2
29000	SINK PP 19 × 1 1N W/OUTLET 1 1/2N MPT		1	84.0	4.7	212.07	4
29901	TRAP GREASE FIELD TYPE		3	814.1	120.8	621.78	39
30208	DISTR CTR 480-208Y/120V 15KVA PORT		1	1,091.7	47.7	14,230.47	2
30210	TENT RCPT-LTG ASSY W/8-100W		2	361.6	28.5	1,252.30	4
31203	BRANCH CIRCUIT ASSEMBLY 3PH 3P 30A		2	293.0	13.0	482.20	16
31204	BRANCH CIRCUIT ASSEMBLY 3PH 3P 50A		2	440.6	14.0	1,108.78	28
52020	SITE PREP F/1000SF BLDG W/D SLAB		2	.0	.0	.00	34

	SHORT TON	MEAS TON				
TOTAL NORTH (TEMPERATE)	16.3	87.1	32,694.0	3,483.4	88,003.93	343
TOTAL TROPICAL (BASIC)	16.1	86.0	32,182.7	3,439.8	86,988.28	333

FACILITY 722 10AB PRIMARY UNIT OF MEASURE 100 MN SECONDARY UNIT OF MEASURE 0 SF

DEMAND	CONST STD	LAPSED DAYS	LAND ACRES	POWER KVA CONNECTED	VOLTS	PHASE	WATER TOT GPD	WATER PEAK GPM	SEWER GPD	RECOV. CODE
INIT	4	.02	19	16	208	3	700	15	700	A

FUEL (GAL/30DAYS)

S K I L L S M A N H O U R S

HEATING		PWR GEN								
DSL	MOGAS	DSL	EA	BU	UT	CE	SW	EO	CM	NS

Figure 9-3.—Facility listing for 100-man galley mess, ABFC facility 722-10AB.

FACILITY.— Figure 9-3 shows a typical facility entry in part 2 of volume 2; for example, facility #722-10AB, the 100-man galley. Adjacent to the facility number, the heading shows the JCS planning factor applied (1 O SF/MN), which means 10 square feet per person. This planning factor is based on *Planning Factors for Military Construction in Contingency Operations,* Joint Staff Memorandum (MJCS) 235-86. The header also describes the basic capability of the facility. The NAVFAC drawing number follows the facility capability description. The drawing number is shown for reference purposes. All drawings in volume 1, part 2, are indexed by facility number.

The ASSEMBLIES required to make the facility functionally operational are listed in assembly-number-sequence. These numbers were derived from the prime trade involved in the construction. The 10,000 series indicates the Builders.

A brief description appears next, followed, when appropriate, by the code "N" for the North Temperate Zone or "T" for the Tropical Zone. Only assemblies required for arctic operation are designated code "N." Other facilities or assemblies are designed for use in both North and South Temperate Zones and Tropical Zones. The quantity given is used as a multiplier, indicating the number of assemblies to be ordered.

Weight and cubic feet are measured in normal terms for export packing. Weight, cubic feet, and dollar value reflect totals for each line.

Construction estimates are computed in the same manner as components except for the addition of the primary facility capacity and the secondary capacity, as described in the NAVFAC P-72. This is used, for example, in the 700 series of facilities where the primary capacity is expressed in personnel and the secondary, in square feet.

Summary data, located below the component facility listings, provide information on the following:

1. Construction standards (CONST STD), taken from *Joint Chiefs of Staff (JCS)*, publication 3, are grouped into two classifications: initial and temporary. Initial (INIT) is a duration requirement of less than 6 months. Temporary (TEMP) is a duration requirement of 6 to 60 months.

2. Days of construction duration (LAPSED DAYS) are based on job requirements, optimum construction crew size, and full-material availability.

3. Often the land requirements (LAND ACRES), based on the assumed plot plan, will not be followed exactly because of terrain or existing buildings. The idealized plot plan was developed to design supporting utility systems. The information contained in the utility facilities has been increased to allow for variation in terrain.

4. The connected electrical load (POWER kVA) has been computed based on knowledge of ABIOL or TOA contents. A load diversity factor has been applied to compute the kVA demand.

5. Water and sewer (GPD) are based on ABIOL or TOA contents and the utility systems designed to this criteria.

6. Fuel usage (FUEL GAL) is computed on 30-day requirements for installed engine-driven or fuel-fired equipment only. No allowance for automotive, construction, weight handling, and other jobsite support equipment fuel is included. Fuel is not provided when facilities or assemblies are shipped. NAVSUP provides fuel as a contribution when whole components are shipped.

7. The skill requirements (SKILLS MAN-HOURS) are designated by Seabee (OF- 13) ratings and are expressed in man-hours, as computed for each facility.

The recoverability code is a broad indication of the relocatability or recoverability. The code "A" indicates total recoverability, and "D" indicates a disposable facility. More details are found in table 9-2, Recoverability Code.

Table 9-2.—Recoverability Code

A. Relocatable:	Designed for the specific purpose of being readily erected, disassembled, stored, and reused. Includes tentage.
B. Pseudo-relocatable:	Not specifically designed to be dismantled and relocated, but could be, with considerable effort and loss of parts. Rigid-frame building included.
C. Nonrecoverable:	A structure not designed to provide relocatability features or one where the cost of recovery of the shelter exceeds 50% of the initial procurement cost. Bolted tanks and steel bridges included.
D. Disposable:	Those temporary structures having low acquisition and erection costs, which are not designed for relocation and reuse and may be left on site or destroyed, such as SEAHUTS.

ASSEMBLY.— Figure 9-4 shows a typical entry for an assembly; for example, Assembly 11923, flooring raised plywood moveable, provides the necessary material and estimated manpower required to build this assembly. Header information is the same as that for a facility. Assembly line-item requirements are listed by cognizance symbol and NSN. The unit of issue, weight, cubic feet, and dollar value are extracted from supply files once the requirement data is entered. This data changes often, but frequent changes are not made in the *Facilities Planning Guide* for stock numbers with minor price-level changes.

Figure 9-5 shows a typical entry for an assembly; however, this assembly is not associated with any facility. Assembly 11900 is an augment assembly tailored specifically for contingency operations. The 16-foot by 32-foot tent frame (strongback) is the most versatile tent assembly used throughout the NCF.

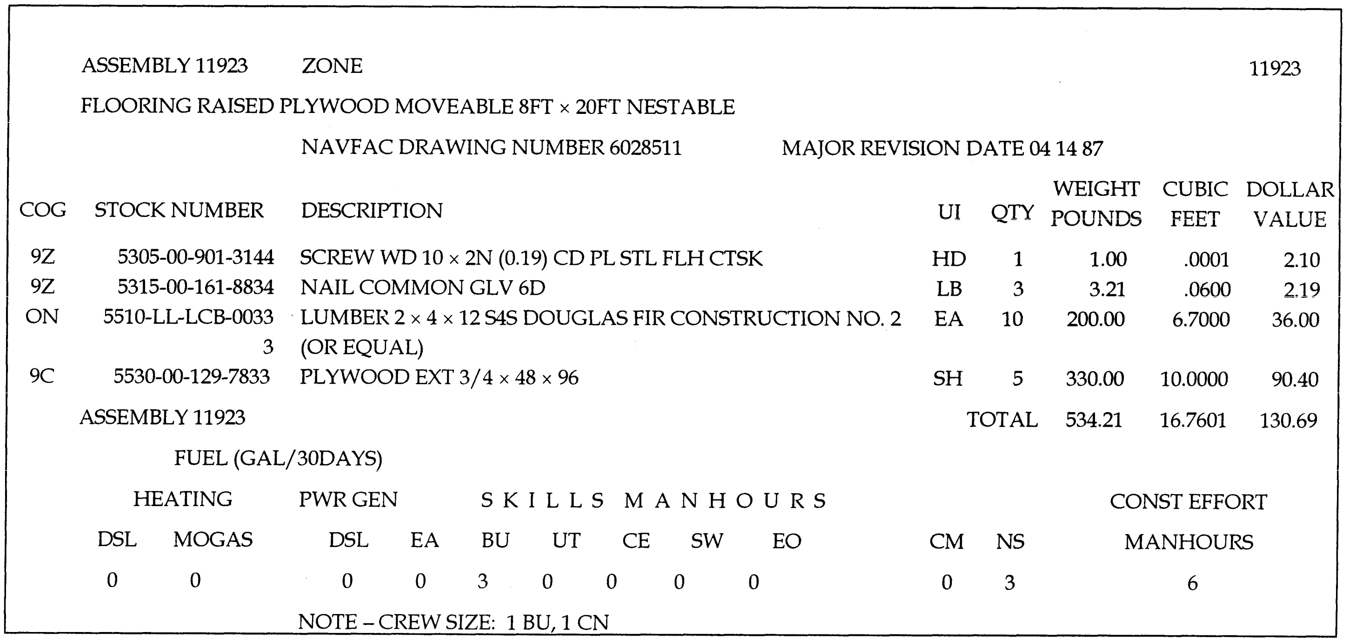
Index of Facilities

Suppose you have a requirement for an electrical distribution system underground. To determine what is available in the ABFC system to satisfy the requirement, look in P-437, volume 2, part 2, *Index of Facilities,* under the 800 series (Utilities and Ground Improvements), as shown in figure 9-6. If an approximate 11,000-foot system is needed, facility 812 30AB can be used. Figure 9-7 gives the information you need to fulfill the requirement for an underground electrical distribution system.

Certain installed equipment or collateral equipment, such as furniture and fixtures contributed by others, are not furnished with the facilities or the assemblies listed in the P-437. You must request this equipment separately. The assembly listings indicate what is installed or what NAVFAC collateral equipment is provided.

FIELD STRUCTURES

This section covers the procedures for the erection of the K-SPAN, the towers, and the bunkers. Other field structures commonly used are 40-foot by 100-foot P. E. B., the 20-foot by 48-foot P. E. B., the 16-foot by 32-foot strongback tent, and heavy timber structures, all of which are covered throughout this TRAMAN and in chapter 6.



ASSEMBLY 11923 ZONE 11923

FLOORING RAISED PLYWOOD MOVEABLE 8FT × 20FT NESTABLE

NAVFAC DRAWING NUMBER 6028511 MAJOR REVISION DATE 04 14 87

COG	STOCK NUMBER	DESCRIPTION	UI	QTY	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE
9Z	5305-00-901-3144	SCREW WD 10 × 2N (0.19) CD PL STL FLH CTSK	HD	1	1.00	.0001	2.10
9Z	5315-00-161-8834	NAIL COMMON GLV 6D	LB	3	3.21	.0600	2.19
ON	5510-LL-LCB-0033 3	LUMBER 2 × 4 × 12 S4S DOUGLAS FIR CONSTRUCTION NO. 2 (OR EQUAL)	EA	10	200.00	6.7000	36.00
9C	5530-00-129-7833	PLYWOOD EXT 3/4 × 48 × 96	SH	5	330.00	10.0000	90.40
	ASSEMBLY 11923			TOTAL	534.21	16.7601	130.69

FUEL (GAL/30DAYS)

HEATING		PWR GEN	SKILLS MANHOURS								CONST EFFORT
DSL	MOGAS	DSL	EA	BU	UT	CE	SW	EO	CM	NS	MANHOURS
0	0	0	0	3	0	0	0	0	0	3	6

NOTE – CREW SIZE: 1 BU, 1 CN

Figure 9-4.—Flooring raised plywood moveable, ABFC assembly #11923.

ASSEMBLY 11900 ZONE 11900

TENT DECK AND FRAME F/16 × 32

STRONGBACK, WOOD, F/16 × 32 TENT

NAVFAC DRAWING NUMBER 6271431 MAJOR REVISION DATE 01 12 88

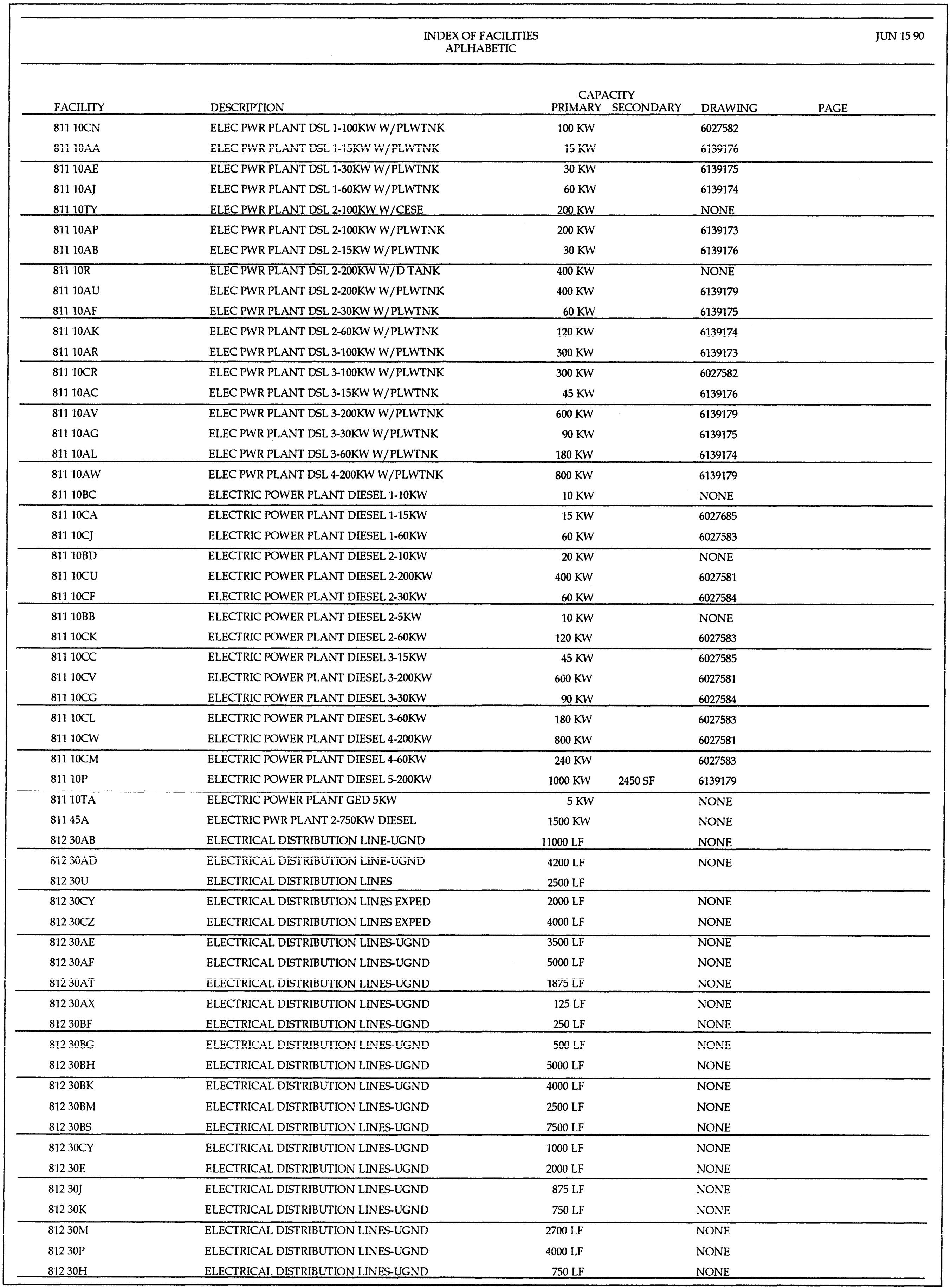
COG	STOCK NUMBER	DESCRIPTION	UI	QTY	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE
9Z	5315-00-164-5121	NAIL COMMON BRITE 20D	LB	20	21.40	.4000	9.00
9Q	5315-00-753-3882	NAIL COMMON BRITE 8D	PG	4	20.00	.8000	9.12
9Q	5315-00-753-3885	NAIL COMMON BRITE 16D	PG	4	20.00	.8000	8.96
9Q	5315-00-889-2605	STAPLE TACKER .455 × 1/2 (5000 PER BX)	BX	2	2.50	.0250	10.86
9Z	5340-00-229-4248	HINGE BUTT 3 1/2N × 3N – 6 STL BODY ZINC COATED	EA	4	1.40	.0280	5.76
	8	BRASS/STEEL PIN					
9Z	5340-00-622-9651	DOOR PULL LITE STL 4 3/4	EA	2	.12	.0024	.62
9Z	5360-00-292-6973	SPRING DOOR	EA	2	.50	.0040	1.28
9C	5510-00-220-6080	LUMBER 1 × 6 S4S	BF	200	400.00	16.6000	58.00
9C	5510-00-220-6194	LUMBER 2 × 4 S4S	BF	840	1,680.00	69.7200	226.80
9C	5510-00-220-6202	LUMBER 2 × 12 S4S	BF	160	320.00	13.2800	57.60
9C	5510-00-220-6226	LUMBER 4 × 4 S4S	BF	85	212.50	7.0550	29.75
9C	5530-00-129-7777	PLYWOOD EXT 1/2 × 48 × 96	SH	23	1,104.00	30.5900	307.05
9G	6840-00-229-3534	PENTACHLOROPHENOL 1GL	GL	1	9.00	.2000	3.30
9D	8305-00-559-5047	SCREEN INSECT 48 × 100FT	YD	40	48.00	1.6000	54.00
ASSEMBLY 11900			TOTAL		3,839.42	141.1044	782.10

FUEL (GAL/30DAYS)

HEATING PWR GEN SKILLS MANHOURS CONST EFFORT

DSL MOGAS DSL EA BU UT CE SW EO CM NS MANHOURS

Figure 9-5.—Strongback tent assembly.

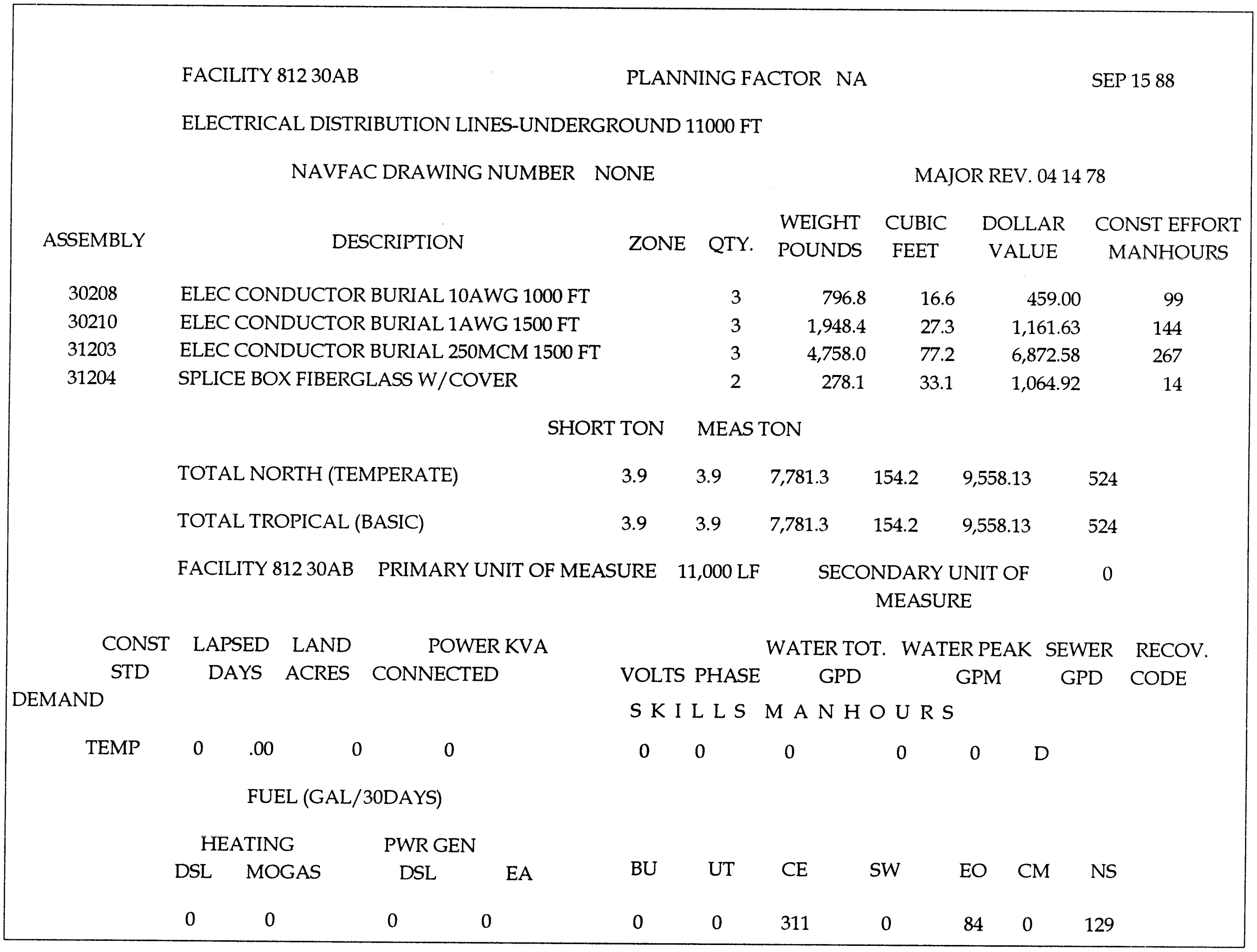


INDEX OF FACILITIES
APLHABETIC

JUN 15 90

FACILITY	DESCRIPTION	CAPACITY PRIMARY	SECONDARY	DRAWING	PAGE
811 10CN	ELEC PWR PLANT DSL 1-100KW W/PLWTNK	100 KW		6027582	
811 10AA	ELEC PWR PLANT DSL 1-15KW W/PLWTNK	15 KW		6139176	
811 10AE	ELEC PWR PLANT DSL 1-30KW W/PLWTNK	30 KW		6139175	
811 10AJ	ELEC PWR PLANT DSL 1-60KW W/PLWTNK	60 KW		6139174	
811 10TY	ELEC PWR PLANT DSL 2-100KW W/CESE	200 KW		NONE	
811 10AP	ELEC PWR PLANT DSL 2-100KW W/PLWTNK	200 KW		6139173	
811 10AB	ELEC PWR PLANT DSL 2-15KW W/PLWTNK	30 KW		6139176	
811 10R	ELEC PWR PLANT DSL 2-200KW W/D TANK	400 KW		NONE	
811 10AU	ELEC PWR PLANT DSL 2-200KW W/PLWTNK	400 KW		6139179	
811 10AF	ELEC PWR PLANT DSL 2-30KW W/PLWTNK	60 KW		6139175	
811 10AK	ELEC PWR PLANT DSL 2-60KW W/PLWTNK	120 KW		6139174	
811 10AR	ELEC PWR PLANT DSL 3-100KW W/PLWTNK	300 KW		6139173	
811 10CR	ELEC PWR PLANT DSL 3-100KW W/PLWTNK	300 KW		6027582	
811 10AC	ELEC PWR PLANT DSL 3-15KW W/PLWTNK	45 KW		6139176	
811 10AV	ELEC PWR PLANT DSL 3-200KW W/PLWTNK	600 KW		6139179	
811 10AG	ELEC PWR PLANT DSL 3-30KW W/PLWTNK	90 KW		6139175	
811 10AL	ELEC PWR PLANT DSL 3-60KW W/PLWTNK	180 KW		6139174	
811 10AW	ELEC PWR PLANT DSL 4-200KW W/PLWTNK	800 KW		6139179	
811 10BC	ELECTRIC POWER PLANT DIESEL 1-10KW	10 KW		NONE	
811 10CA	ELECTRIC POWER PLANT DIESEL 1-15KW	15 KW		6027685	
811 10CJ	ELECTRIC POWER PLANT DIESEL 1-60KW	60 KW		6027583	
811 10BD	ELECTRIC POWER PLANT DIESEL 2-10KW	20 KW		NONE	
811 10CU	ELECTRIC POWER PLANT DIESEL 2-200KW	400 KW		6027581	
811 10CF	ELECTRIC POWER PLANT DIESEL 2-30KW	60 KW		6027584	
811 10BB	ELECTRIC POWER PLANT DIESEL 2-5KW	10 KW		NONE	
811 10CK	ELECTRIC POWER PLANT DIESEL 2-60KW	120 KW		6027583	
811 10CC	ELECTRIC POWER PLANT DIESEL 3-15KW	45 KW		6027585	
811 10CV	ELECTRIC POWER PLANT DIESEL 3-200KW	600 KW		6027581	
811 10CG	ELECTRIC POWER PLANT DIESEL 3-30KW	90 KW		6027584	
811 10CL	ELECTRIC POWER PLANT DIESEL 3-60KW	180 KW		6027583	
811 10CW	ELECTRIC POWER PLANT DIESEL 4-200KW	800 KW		6027581	
811 10CM	ELECTRIC POWER PLANT DIESEL 4-60KW	240 KW		6027583	
811 10P	ELECTRIC POWER PLANT DIESEL 5-200KW	1000 KW	2450 SF	6139179	
811 10TA	ELECTRIC POWER PLANT GED 5KW	5 KW		NONE	
811 45A	ELECTRIC PWR PLANT 2-750KW DIESEL	1500 KW		NONE	
812 30AB	ELECTRICAL DISTRIBUTION LINE-UGND	11000 LF		NONE	
812 30AD	ELECTRICAL DISTRIBUTION LINE-UGND	4200 LF		NONE	
812 30U	ELECTRICAL DISTRIBUTION LINES	2500 LF			
812 30CY	ELECTRICAL DISTRIBUTION LINES EXPED	2000 LF		NONE	
812 30CZ	ELECTRICAL DISTRIBUTION LINES EXPED	4000 LF		NONE	
812 30AE	ELECTRICAL DISTRIBUTION LINES-UGND	3500 LF		NONE	
812 30AF	ELECTRICAL DISTRIBUTION LINES-UGND	5000 LF		NONE	
812 30AT	ELECTRICAL DISTRIBUTION LINES-UGND	1875 LF		NONE	
812 30AX	ELECTRICAL DISTRIBUTION LINES-UGND	125 LF		NONE	
812 30BF	ELECTRICAL DISTRIBUTION LINES-UGND	250 LF		NONE	
812 30BG	ELECTRICAL DISTRIBUTION LINES-UGND	500 LF		NONE	
812 30BH	ELECTRICAL DISTRIBUTION LINES-UGND	5000 LF		NONE	
812 30BK	ELECTRICAL DISTRIBUTION LINES-UGND	4000 LF		NONE	
812 30BM	ELECTRICAL DISTRIBUTION LINES-UGND	2500 LF		NONE	
812 30BS	ELECTRICAL DISTRIBUTION LINES-UGND	7500 LF		NONE	
812 30CY	ELECTRICAL DISTRIBUTION LINES-UGND	1000 LF		NONE	
812 30E	ELECTRICAL DISTRIBUTION LINES-UGND	2000 LF		NONE	
812 30J	ELECTRICAL DISTRIBUTION LINES-UGND	875 LF		NONE	
812 30K	ELECTRICAL DISTRIBUTION LINES-UGND	750 LF		NONE	
812 30M	ELECTRICAL DISTRIBUTION LINES-UGND	2700 LF		NONE	
812 30P	ELECTRICAL DISTRIBUTION LINES-UGND	4000 LF		NONE	
812 30H	ELECTRICAL DISTRIBUTION LINES-UGND	750 LF		NONE	

Figure 9-6.—Alphabetical index of facilities.



FACILITY 812 30AB PLANNING FACTOR NA SEP 15 88

ELECTRICAL DISTRIBUTION LINES-UNDERGROUND 11000 FT

NAVFAC DRAWING NUMBER NONE MAJOR REV. 04 14 78

ASSEMBLY	DESCRIPTION	ZONE	QTY.	WEIGHT POUNDS	CUBIC FEET	DOLLAR VALUE	CONST EFFORT MANHOURS
30208	ELEC CONDUCTOR BURIAL 10AWG 1000 FT		3	796.8	16.6	459.00	99
30210	ELEC CONDUCTOR BURIAL 1AWG 1500 FT		3	1,948.4	27.3	1,161.63	144
31203	ELEC CONDUCTOR BURIAL 250MCM 1500 FT		3	4,758.0	77.2	6,872.58	267
31204	SPLICE BOX FIBERGLASS W/COVER		2	278.1	33.1	1,064.92	14

	SHORT TON	MEAS TON				
TOTAL NORTH (TEMPERATE)	3.9	3.9	7,781.3	154.2	9,558.13	524
TOTAL TROPICAL (BASIC)	3.9	3.9	7,781.3	154.2	9,558.13	524

FACILITY 812 30AB PRIMARY UNIT OF MEASURE 11,000 LF SECONDARY UNIT OF MEASURE 0

DEMAND	CONST STD	LAPSED DAYS	LAND ACRES	POWER KVA CONNECTED	VOLTS	PHASE	WATER TOT. GPD	WATER PEAK GPM	SEWER GPD	RECOV. CODE
TEMP	0	.00	0	0	0	0	0	0	0	D

FUEL (GAL/30DAYS)				SKILLS MANHOURS						
HEATING		PWR GEN								
DSL	MOGAS	DSL	EA	BU	UT	CE	SW	EO	CM	NS
0	0	0	0	0	0	311	0	84	0	129

Figure 9-7.—Selection of facility from index.

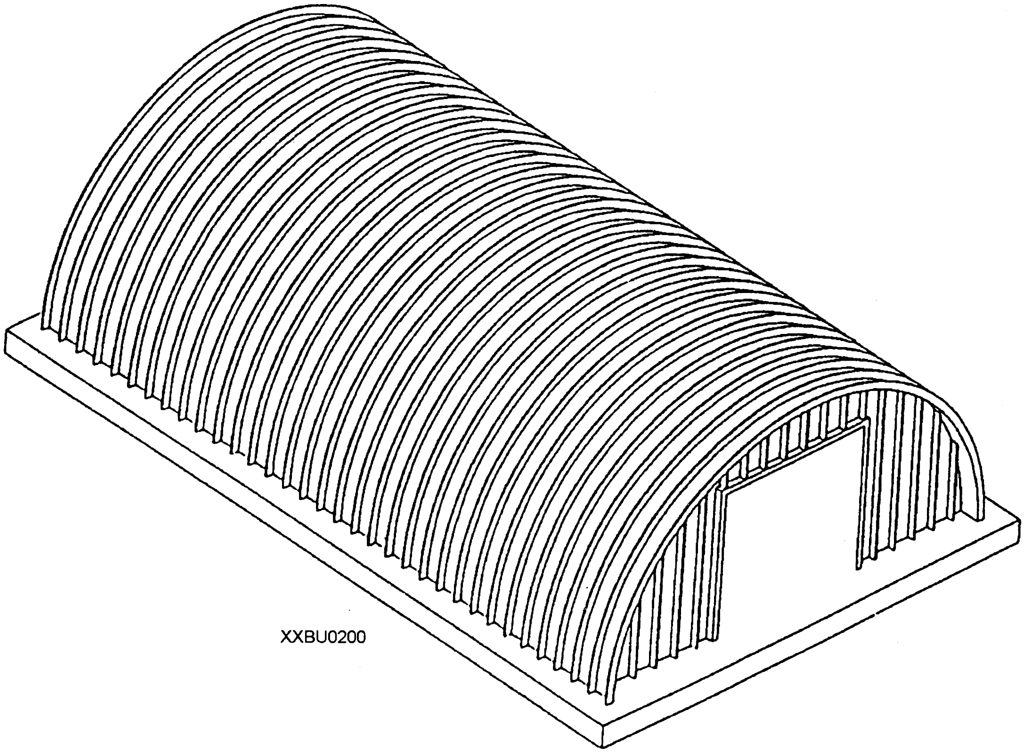


Figure 9-8.—Typical K-SPAN building.

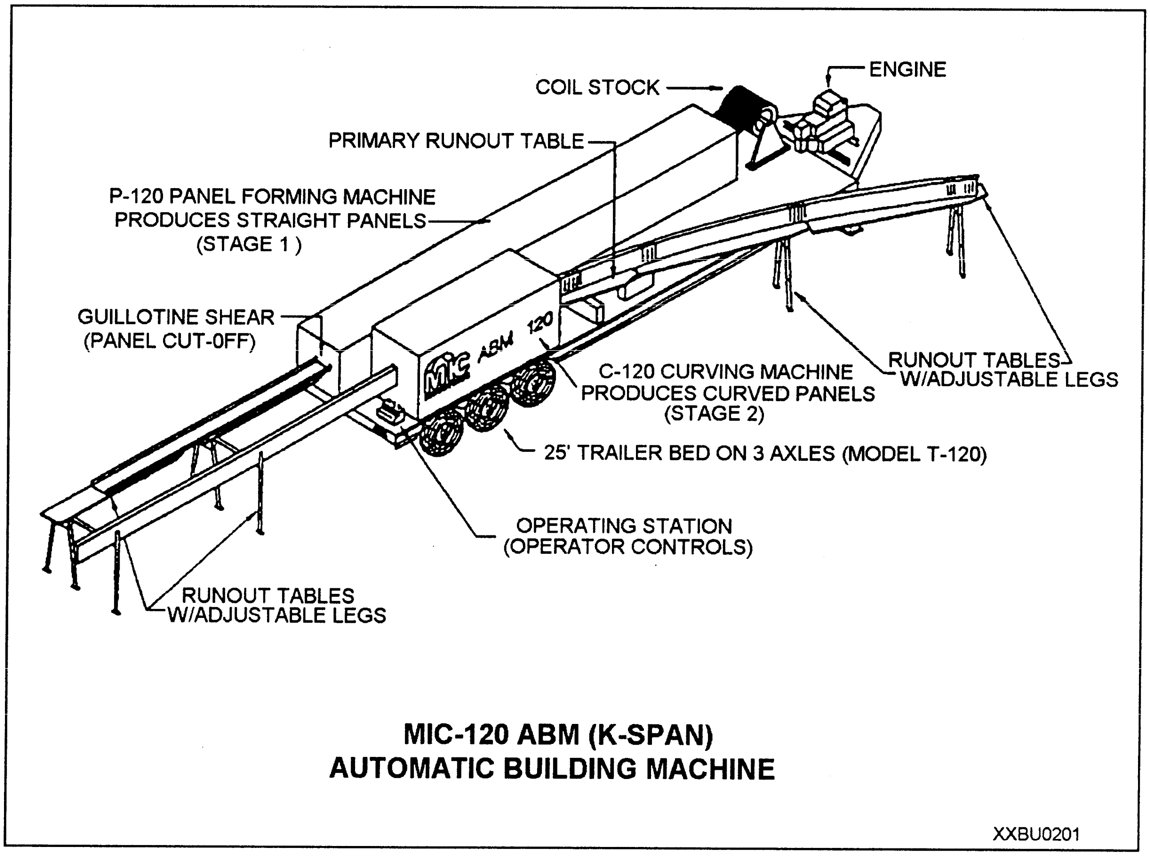


Figure 9-9.—Automatic Building Machine 120.

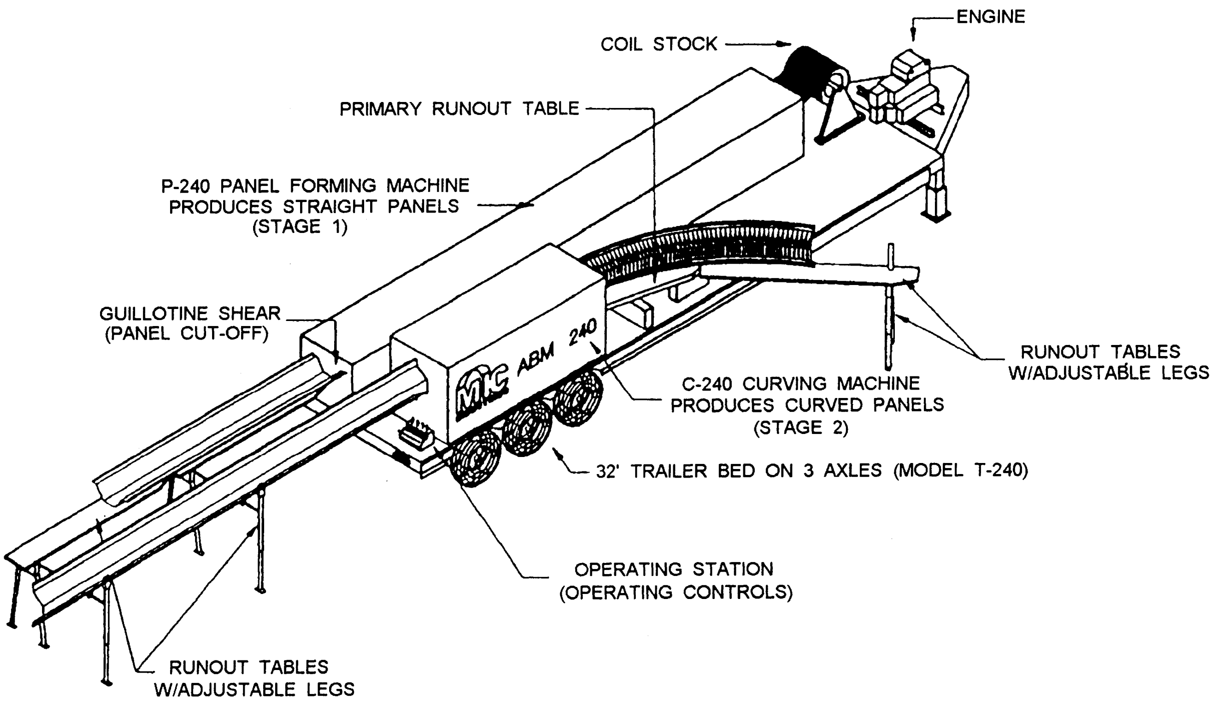
K-SPAN BUILDING

K-SPAN buildings (fig. 9-8) are a new form of construction within the Seabee community. The intended uses of these buildings are for open storage; however, these buildings can be designed for use as office spaces, hangars, supply buildings, medical facilities, and more permanent structures. It is a self-contained, metal building manufacturing plant (Automatic Building Machine) mounted on a trailer, forming a type of “mobile factory.” There are two types of K-SPAN building machines, as shown in figures 9-9 and 9-10: the MIC 120 and the MIC 240 (Super Span). An interesting aspect of this machine is that it can be easily transported by air anywhere in the world. The ABM System has already been certified for air transport by the U.S. Air Force in C- 130, C- 141, and C-5 aircraft.

Training

Training personnel in the operation of all related K-SPAN equipment is essential. The formal training of K-SPAN construction is held at both NCRs. Crew members and leaders, once trained, can instruct other members of the crew in the safe fabrication and erection of a K-SPAN. Each regiment has personnel certified by MIC Industries to instruct this training.

The training provided to you is not to be taken as the absolute and only way to construct the K-SPAN. As in the case of most construction procedures, there are several different ways to accomplish the task. Crew size, experience, and type of equipment available may alter the way you perform the task; however, you should



MIC-240 ABM (SUPER SPAN)
AUTOMATIC BUILDING MACHINE

XXBU0202

Figure 9-10.—Automatic Building Machine 240.

achieve the same end results. Table 9-3 shows the personnel and skills required to erect this building.

Operating Instructions

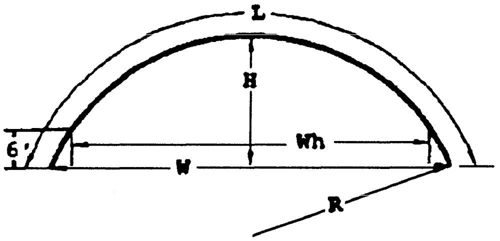
The main component of the K-SPAN system is the trailer-mounted building machine (fig. 9-12). This figure shows the main components of the trailer and general operating instructions. The primary position of the operator's station is located at the rear of the trailer. The crew member selected for this position must have a thorough understanding of the machine operations and manuals. From that position, the operator controls all the elements required to form the panels. The operator must remain at the controls at all times. From the placement of the trailer on site to the completion of the curved panel, attention to detail is paramount as with all aspects of construction.

As you operate the machine, you will be adjusting the various machine-operating components. Adjustments for the thickness, the radius, and the curving machine **MUST** be made according to the

DESIGN DATA
MIC-120

W = 50.0 feet

H = 20.0 feet



L = 69.2 feet
Wh = 45.7 feet
R = 25.6 feet
A = 745 sq ft
(end wall area)

LOADS		STEEL REQUIRED		MAX. FORCES IN ARCH		MAX. ARCH REACTIONS PER FOOT AT FOUNDATION					
LIVE	WIND	THICKNESS & GRADE		AXIAL	MOMENT	HORIZONTAL (LB)		VERTICAL (LB)		MOMENT (IN-LB)	
		TOP	END	(LB)	(IN-LB)	+	-	+	-	+	-
0	70	.035C	.023C	241	-13569	248	-61	184	-96	1313	-13569
0	80	.041D	.023C	323	-17876	329	-85	250	-113	1539	-17876
0	90	.045D	.023C	419	-22801	424	-116	331	-124	1689	-22801
0	100	-	-	-	-	-	-	-	-	-	-
10	70	.035C	.023C	-306	-13569	248	-201	184	-256	7250	-13569
10	80	.041D	.023C	323	-17876	329	-210	250	-273	7479	-17876
10	90	.045D	.023C	419	-22801	424	-216	331	-284	7625	-22801
10	100	-	-	-	-	-	-	-	-	-	-
20	70	.035C	.023C	-521	-13569	350	-350	184	-416	13186	-13569
20	80	.041D	.023C	-537	-17876	359	-359	250	-433	13418	-17876
20	90	.045D	.023C	-547	-22801	424	-365	331	-444	13562	-22801
20	100	-	-	-	-	-	-	-	-	-	-
30	70	.035D	.023C	-739	19125	500	-500	184	-576	19122	-19125
30	80	.041D	.023C	-754	19358	509	-509	250	-593	19358	-19347
30	90	.045D	.023C	-763	-22801	515	-515	331	-604	19498	-22801
30	100	-	-	-	-	-	-	-	-	-	-
40	70	.045D	.023C	-981	25442	664	-664	163	-764	25434	-25442
40	80	.045D	.023C	-981	25442	664	-664	242	-764	25434	-25442
40	90	.045D	.023C	-981	25442	664	-664	331	-764	25434	-25442
40	100	-	-	-	-	-	-	-	-	-	-

STEEL WEIGHTS (LB)						
thickness (inch)	.023	.026	.029	.035	.041	.045
arch weight (lb)	126	143	159	193	226	248
end wall weight (lb)	1367	1546	1724	2081	2437	2675

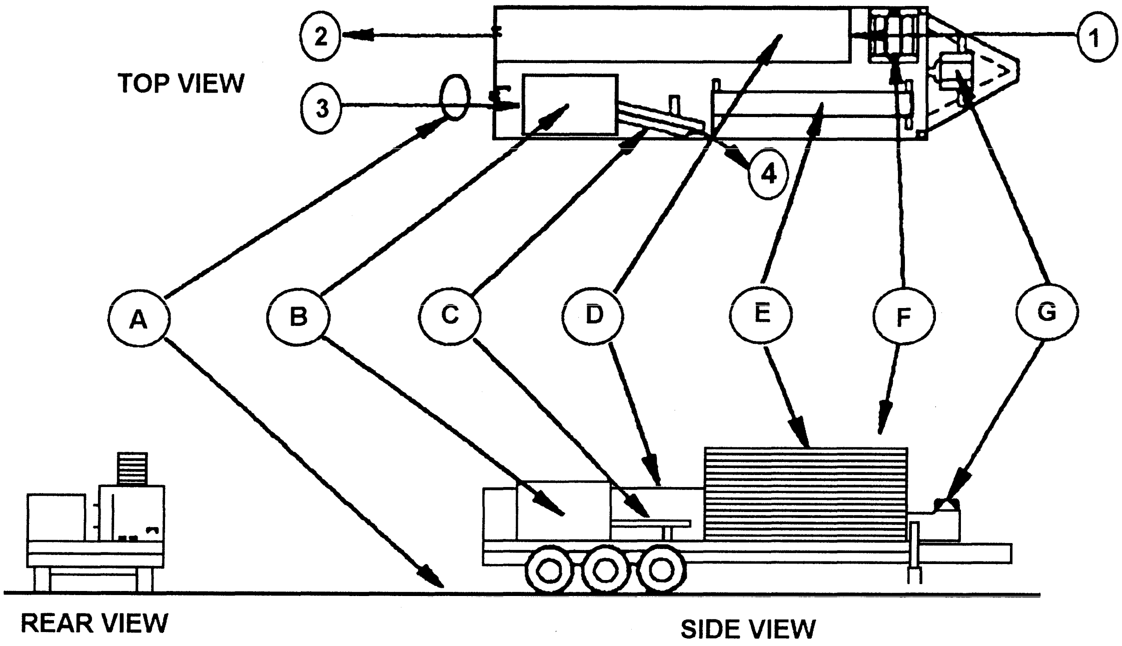
* NOTE: The "arch weight" shown above can be divided by 50 pounds (22.7 kg) carrying load per person to determine the number of workers required to transport each arch from the curved runout tables to the pre-staging area.

XXBU0203

Figure 9-11.—Chart for determining crew size for ABM 120.

Table 9-3.—Personnel and Skill Requirements

PERSONNEL	SKILL REQUIREMENTS
ENGINEER	(Not required on a full-time basis) May be required to engineer and design foundation and special applications.
PROJECT MANAGER OR CREW LEADER	Oversees all phases of construction including machinery transportation and operations. Maintains working knowledge of all tools, equipment, and building construction. Must also be familiar with the ABM machinery. Knows and enforces all SAFETY rules and regulations.
TRUCK/CRANE OPERATOR	Loads material onto machine and transport equipment. Places arched panels on foundations. Tows machinery between jobsites. Make sure machinery is in proper working order and is certified in crane operations. Complies with all SAFETY procedures.
WELDER	Must have a working knowledge of welding, cutting, and fabrication of light steel. Must be familiar with welder/generator operations and maintenance.
CONSTRUCTION MECHANIC	Successfully undergoes special training on the ABM machine (training should be conducted by either the REGIMENTs or by the MANUFACTURER). Must be thoroughly familiar with the "OPERATING MANUAL."
GENERAL LABORER	Should be familiar with general construction techniques. Must OBEY all safety rules and regulations. To determine the amount of laborers (fig. 9-11) required for the job, **divide the weight of steel by 50**.



XXBU0204

A. OPERATOR'S STATION
B. PANEL CURVING MACHINE
C. PRIMARY CURVING RUN-OUT TABLE
D. STRAIGHT PANEL ROLL FORMING MACHINE
E. RUN-OUT TABLES IN TRANSPORTING RACK
F. COIL STOCK PAY-OUT REEL AND STAND
G. ENGINE/HYDRAULIC PUMP PRIMARY POWER UNIT

GENERAL OPERATION (TOP VIEW)

1. COIL STOCK ENTERS PANEL FORMING MACHINE
2. FORMED STRAIGHT PANEL
3. STRAIGHT PANEL ENTRY TO PANEL CURVING MACHINE
4. CURVED BUILDING PANEL

Figure 9-12.—Trailer-mounted machinery.

manuals. **Do not permit shortcuts in adjustments.** Any variations in adjustments, or disregard for the instructions found in the operating manuals, will leave you with a pile of useless material or an inconsistent building.

Foundations

The design of the foundation for a K-SPAN building depends on the size of the building (MIC 120 or MIC 240), the existing soil conditions, and the wind load. <u>The foundation must be approved by a certified engineer.</u>

The foundations for the buildings are easy to construct when you have the right equipment and crew. The roof and wall loads are transferred to the foundation through the base of each arch. Therefore, all loads are uniformly carried down each sidewall by continuous strip footing. The foundations are more economical than foundations of more conventional buildings.

The concrete forms and accessories provide sufficient material to form the foundations for a building 100 feet long by 50 feet wide. When a different configuration is required, forms are available from the manufacturer.

The actual footing construction is based, as with all projects, on the plans and specifications. The location of the forms, the placement of steel, and the psi (pounds per square inch) of the concrete is critical. The building

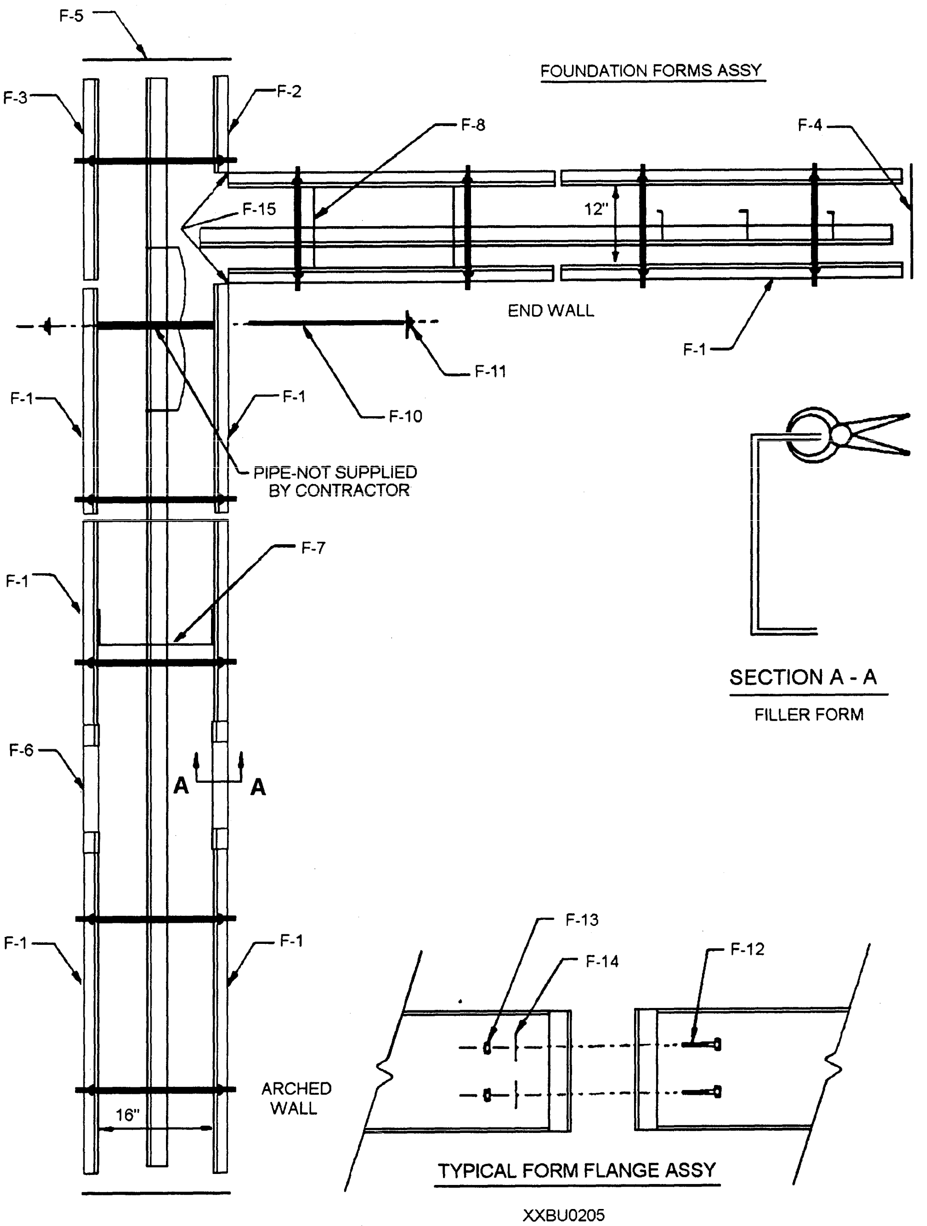


Figure 9-13.—Simple form assembly.

Table 9-4.—Concrete Forms Included in Kit

DESCRIPTION (Each set of forms is sufficient to erect a building 100 feet long by 50 feet wide)	PART NUMBER
Side form panels, 1' × 10', 12 gauge steel	F-1
Transition panels, 1' × 12", 12 gauge steel	F-2
Transition panels, 1' × 28", 12 gauge steel	F-3
End-wall caps, 1' × 15", 12 gauge steel	F-4
Side-wall caps, 1' × 19", 12 gauge steel	F-5
Filler form, 1' × 12', 12 gauge steel	F-6
Sidewall inside stop, 1' × 12", 12 gauge steel	F-7
End wall inside stop, 1' × 12", 12 gauge steel	F-8
Stakes, 1/4" diameter, bar steel	F-9
All-thread rod, 1/2-13 × 18"	F-10
Hex nuts, 1/2-13	F-11
Hex bolts, 1/8-16 × 1-1/2	F-12
Hex nuts, 3/8-16	F-13
Flat washers, 1/8" SAE	F-14
Corner angles, 2" × 2" × 12", steel angle	F-15

panels are welded to the angle in the footer before concrete placement. Because of this operation, all aspects of footer construction must be completely checked for alignment and squareness. Once concrete is placed, there is no way to correct errors.

As mentioned above, forms are provided for the foundation. Using table 9-4 as a guide, figure 10-13 gives you a simple foundation layout by parts designation. As noted in figure 9-13, the cross pipes are not provided in the kit. They must be ordered when the project is being planned and estimated.

Building Erection

With the placement of the machinery and forming of the building panels in progress, your next considerations are the placement and the weight-lifting capabilities of the crane. Check the weight-lifting chart of the crane for its maximum weight capacity. This dictates the number of panels (recommend 5/ABM 120 and 3/ABM 240) you can safely lift at the operating distance. As with all crane operations, attempting to lift more than the rated capacity can cause the crane to turn over.

Attaching the spreader bar (fig. 9-14) to the curved formed panels is a critical step; failure to clamp the

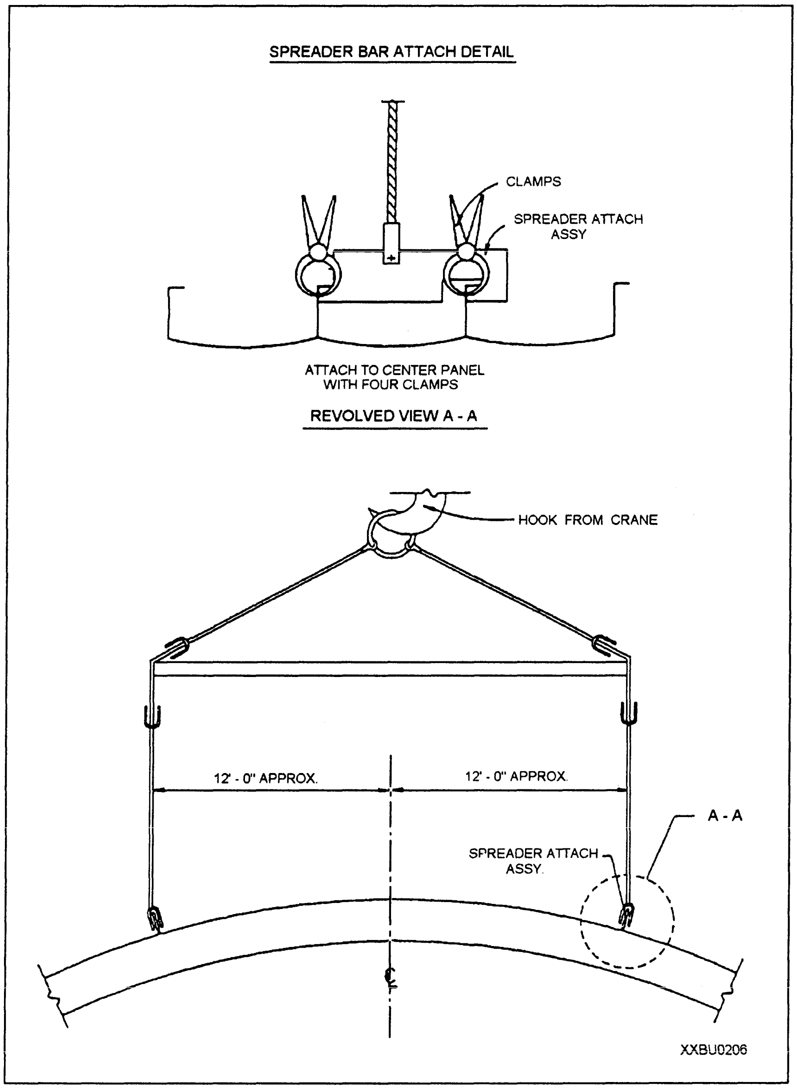


Figure 9-14.—Spreader bar attachment.

panels tightly can cause the panels to slip and fall with potential harm to personnel and damage to the panels. With the guide ropes attached (fig 9-15) and personnel manning these ropes, lift the panels for placement. When the panels are lifted, lift only as high as necessary, position two men at each free end to guide the panels in

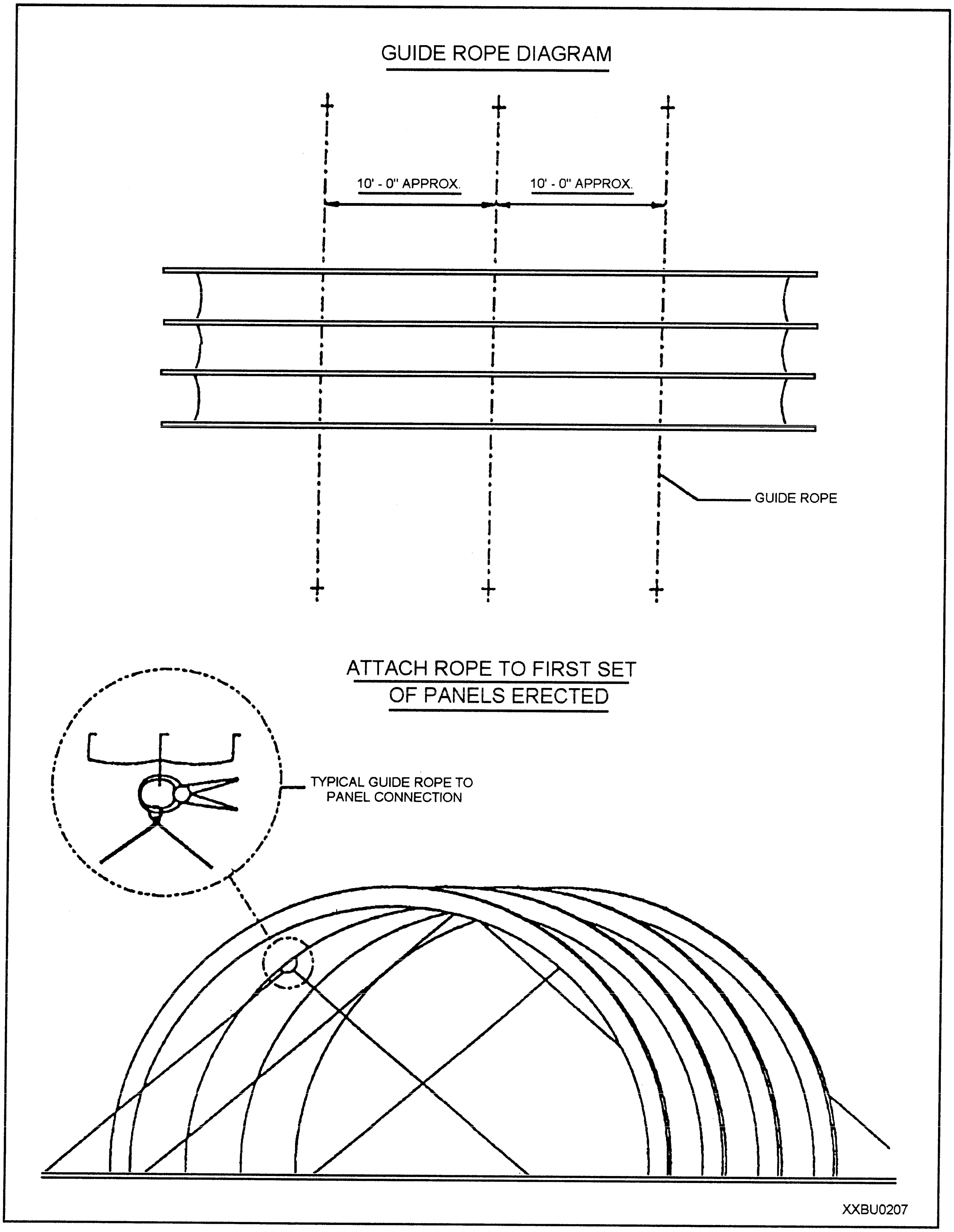


Figure 9-15.—Guide rope diagram.

place, and remind crew members to keep their feet from under the ends of the arches. You must never attempt to lift sets of panels in winds exceeding 20 mph.

Place the first set of panels on the attaching angle of the foundation and position them so there will be room for the end-wall panels. After the first set of panels are positioned, clamp them to the angle, plumb with guide ropes, and secure the ropes to previously anchored stakes. Detach the spreader bar and continue to place the panel sets. Seam each set to the standing panels before detaching the spreader bar.

After about 15 panels (three sets) are in place, measure the building length at both ends (just above forms) and at the center of the arch. This measurement will seldom be exactly 1 foot per panel (usually slightly more), but should be equal for each panel. Adjust the ends to equal the center measure. Panels are flexible enough to adjust slightly. Check these measurements periodically during building construction. Since exact building lengths are difficult to predict, the end wall attaching angle on the finishing end of the building should not be put in place until all panels are set.

After the arches are in place, set the longest end-wall panel in the form, then plumb and clamp it in place. Work from the longest panel outward and be careful to maintain plumb.

When all the building panels are welded to the attaching angle (fig. 9-16) at 12 inches on center, you are ready to place the concrete. When the concrete is placed, remember it is extremely important that it is well-vibrated. This helps eliminate voids under all embedded items. As the concrete begins to set, slope the top exterior portion of the concrete cap about

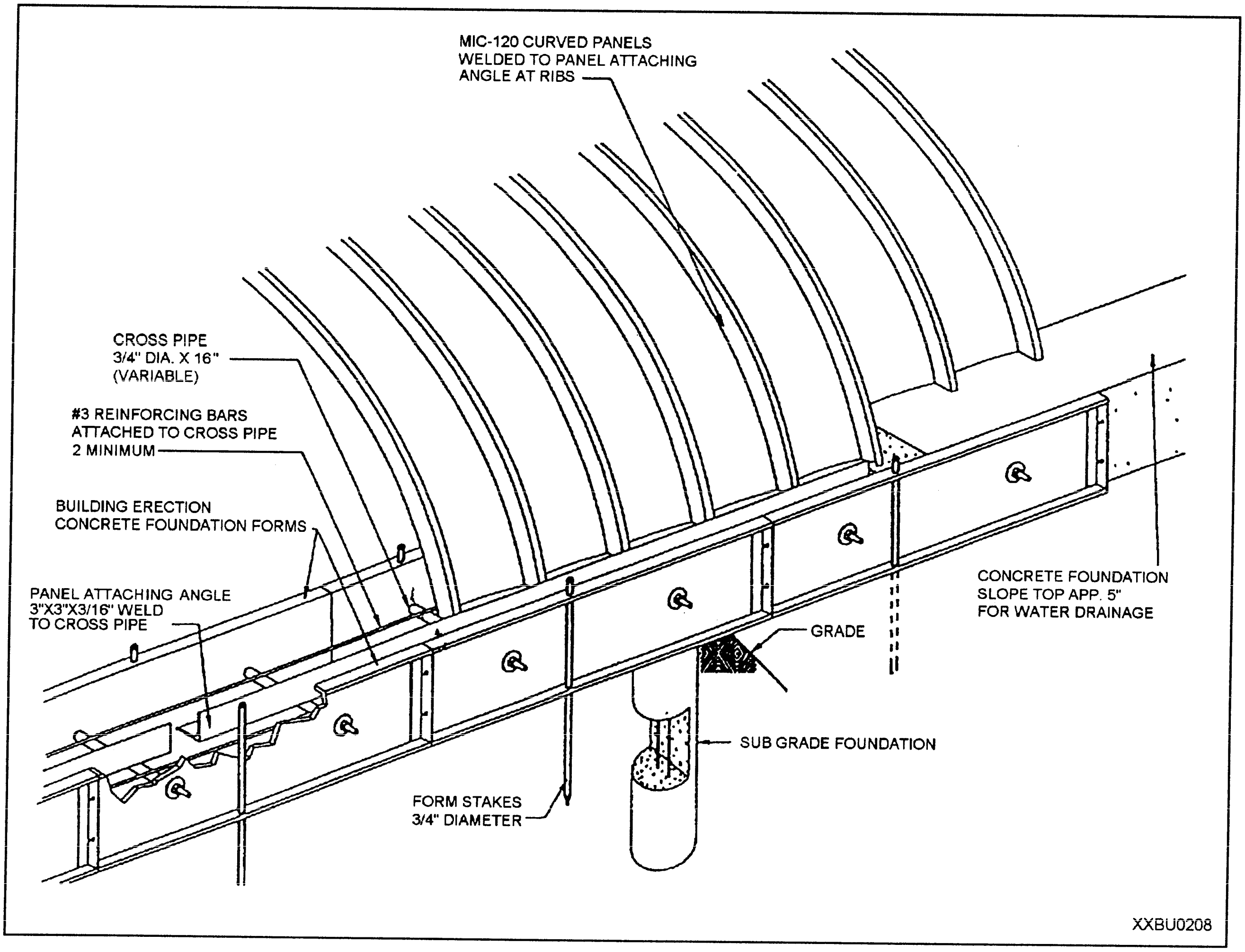


Figure 9-16.—Building foundation concept.

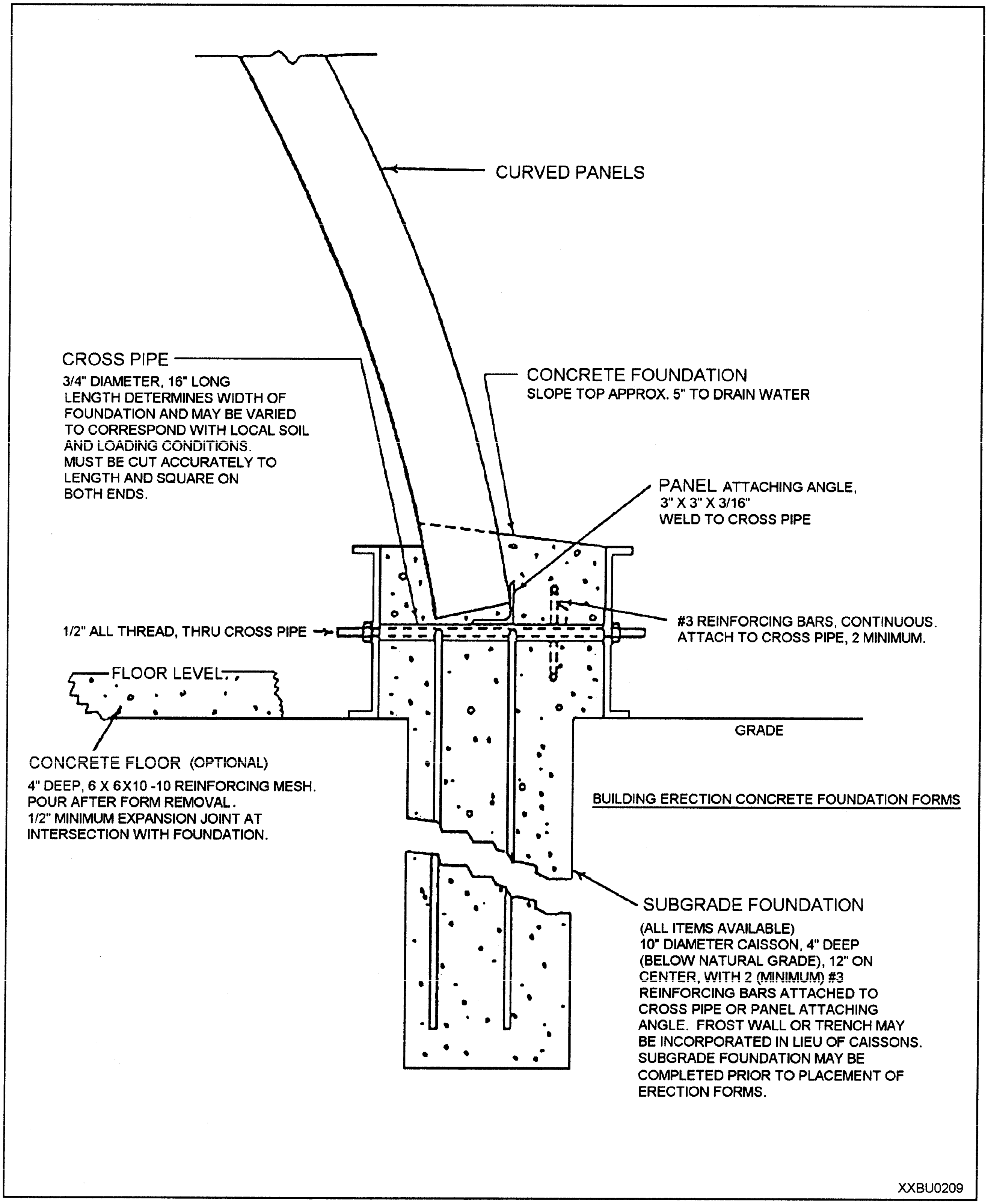


Figure 9-17.—Concrete foundation.

5 inches (fig. 9-17) to allow water to drain away from the building. The elevation and type of interior floor are not relevant as long as the finish of the interior floor is not higher than the top of the concrete cap.

Construction Details

The K-SPAN building system is similar to other types of pre-engineered or prefabricated buildings in that windows, doors, and roll-up doors can be installed only when erection is completed. When insulation of the building is required, insulation boards (usually 4 by 8 feet) maybe of any semirigid material that can be bent to match the radius of the building. The insulation is installed using clips, as shown in figure 9-18.

When the integrity of the end-wall panels is continuous from the ground to the roof line, the end

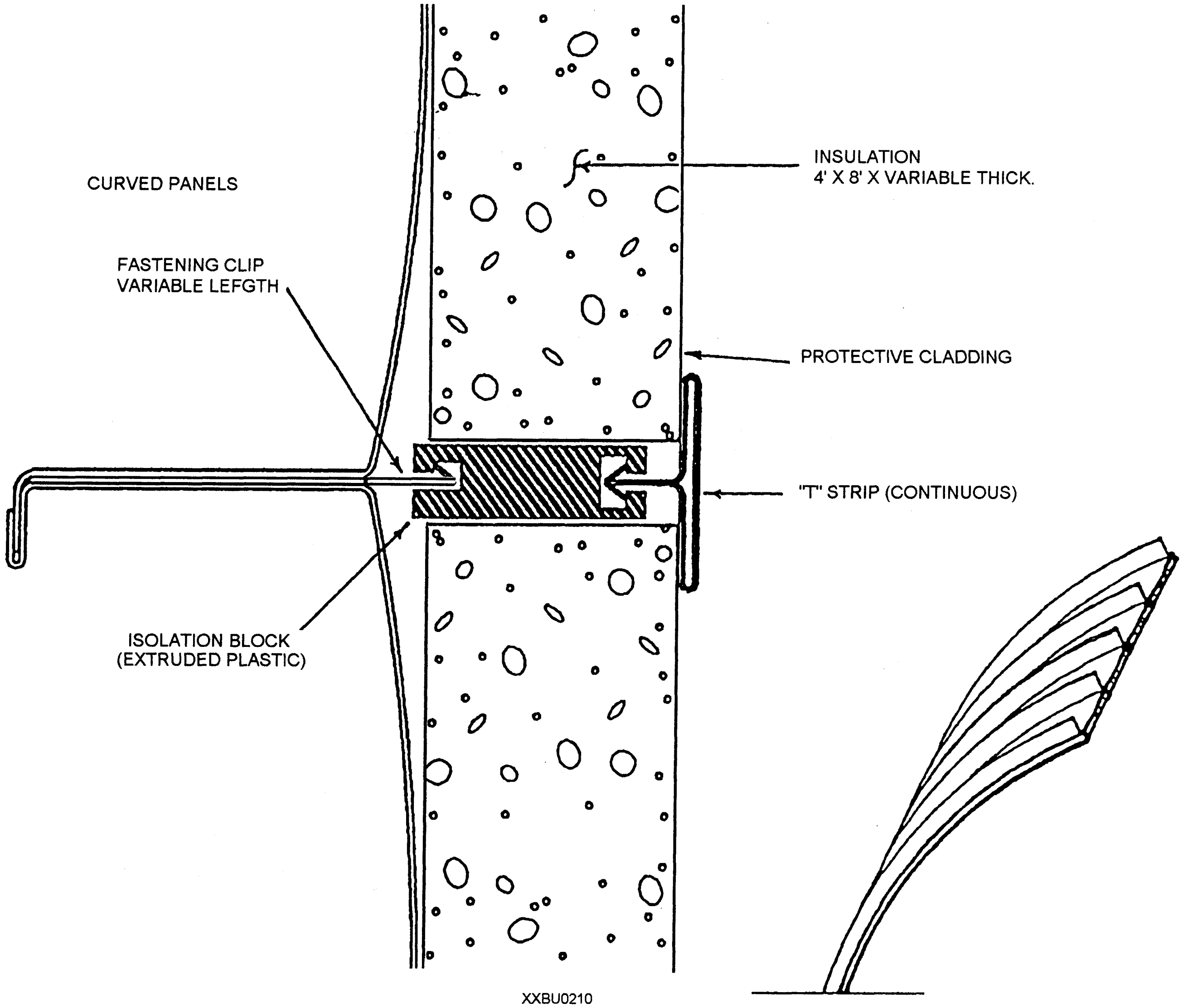
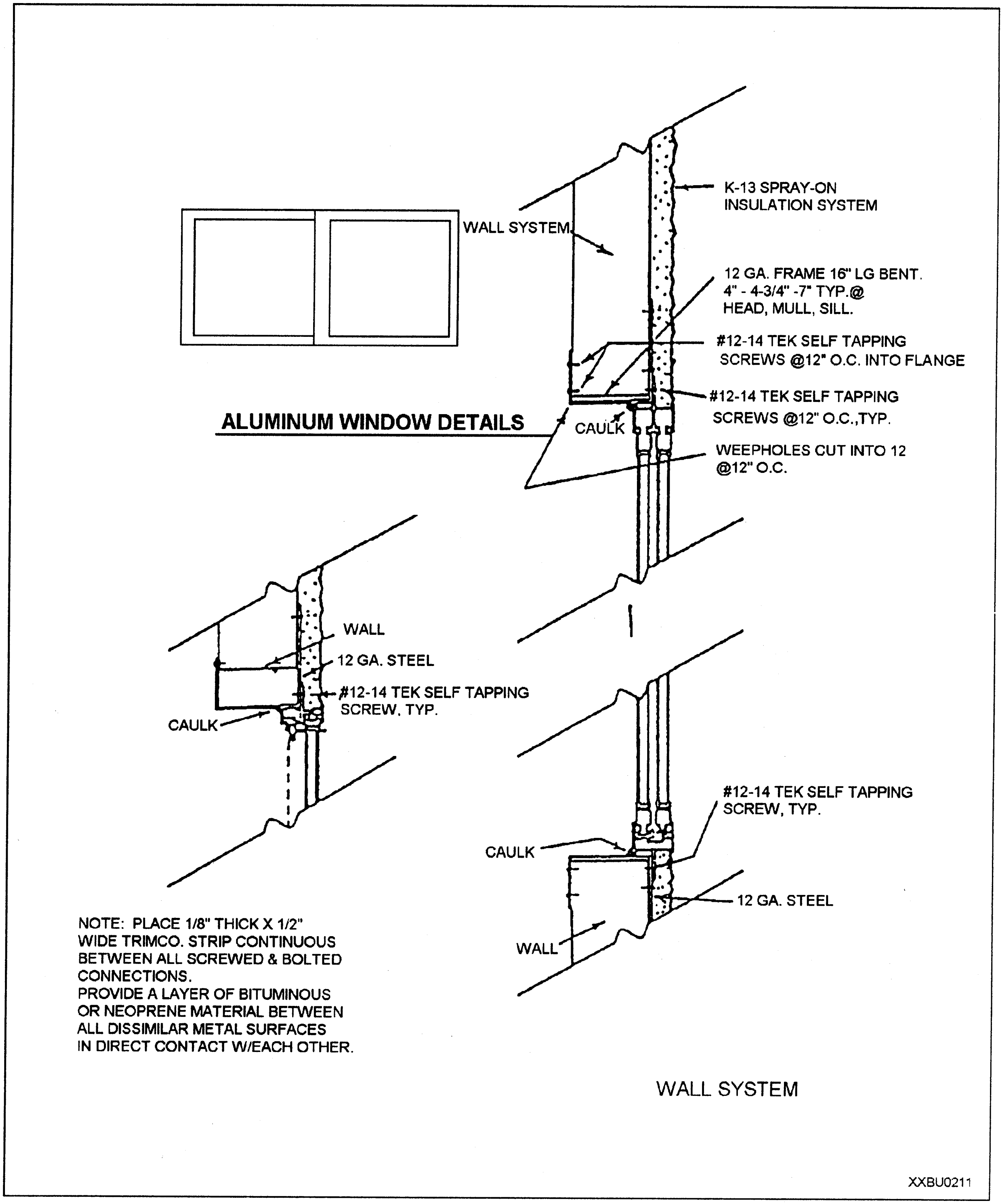


Figure 9-18.—Insulation.

walls become self-supporting. The installation of windows (fig. 9-19) and aluminum doors (fig. 9-20) presents no problem since the integrity of the wall system is not interrupted. The installation of the



NOTE: PLACE 1/8" THICK X 1/2" WIDE TRIMCO. STRIP CONTINUOUS BETWEEN ALL SCREWED & BOLTED CONNECTIONS.
PROVIDE A LAYER OF BITUMINOUS OR NEOPRENE MATERIAL BETWEEN ALL DISSIMILAR METAL SURFACES IN DIRECT CONTACT W/EACH OTHER.

Figure 9-19.—Aluminum window installation.

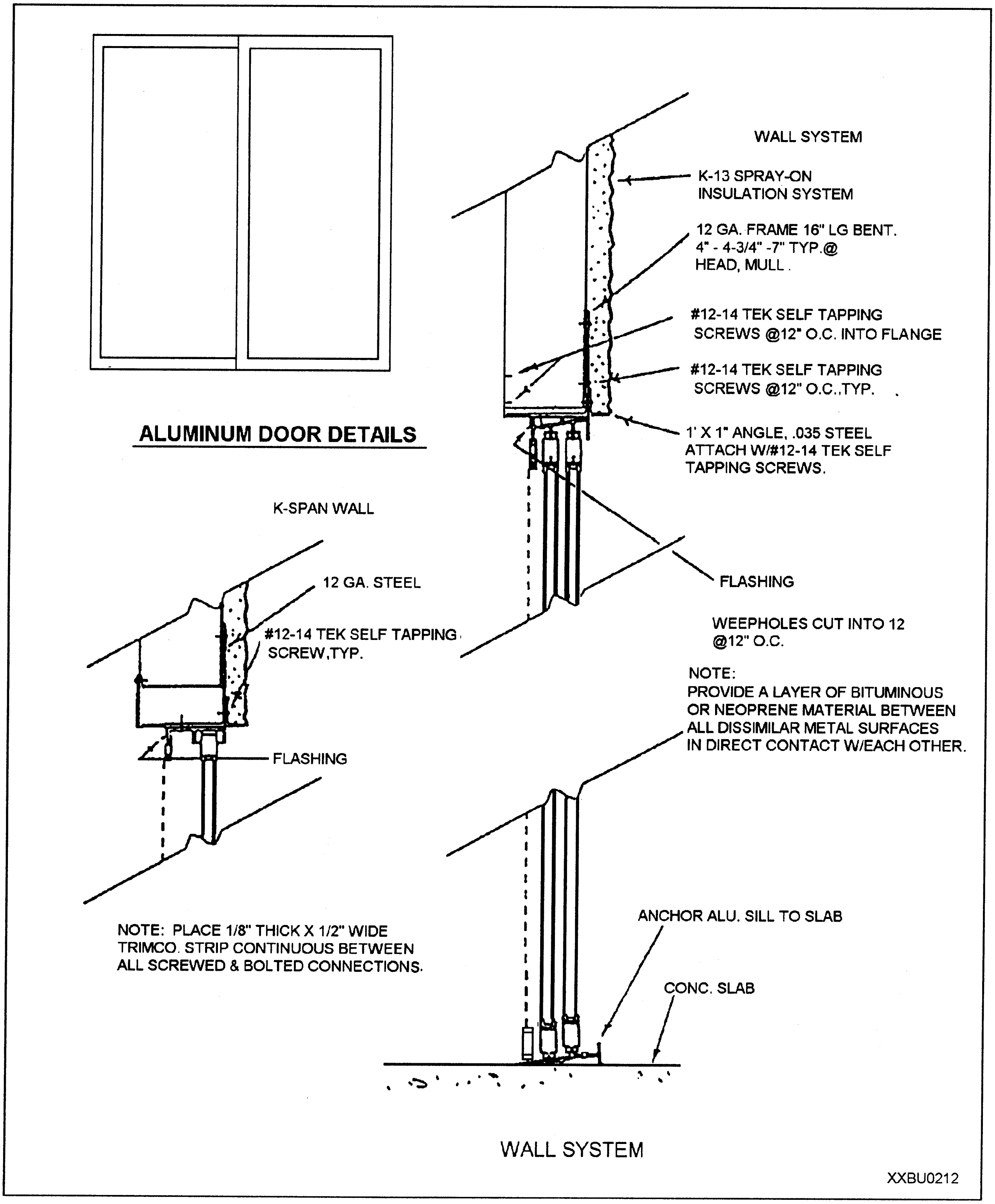


Figure 9-20.—Aluminum door installation.

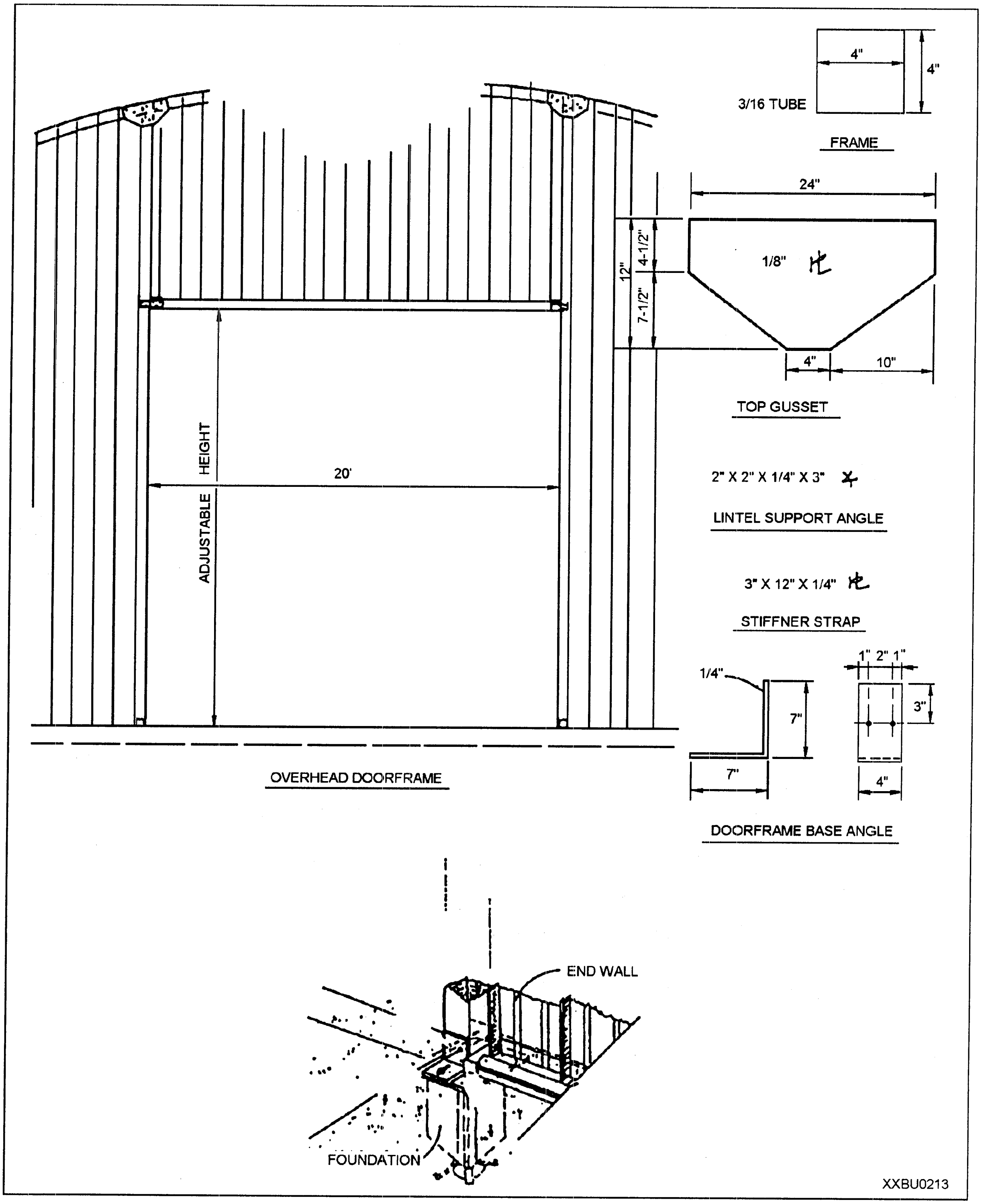


Figure 9-21.—Overhead doorframe.

overhead door (fig. 9-21) does present a problem in that it does interrupt the integrity of the wall system. This situation is quickly overcome by the easily installed and adjustable (height and width) doorframe package that supports both the door and end wal1. This doorframe package is offered by the manufacturer.

Finish of Project

When all the panels are in place and secured to the base angle, the next step is optional. Apply a rubberized coat of paint to the base of the panels (interior/exterior) to a height slightly above the finish concrete. This gives added protection to the metal panels exposed to the concrete.

Finally, place the concrete (fig. 9-22) into the above ground foundation forms. Take care not to slash excessive amounts of concrete above the rubberized paint line.

Figure 9-23 shows the fundamental steps in constructing a K-SPAN from start to finish.

ABM 240

There is another type of K-SPAN building, actually referred to as a Super Span by the manufacturer, the ABM 240. Actual construction of the ABM 240 is the same as that for the ABM 120 (K-SPAN). It can use heavier coil stock and is a larger version. Figure 9-24

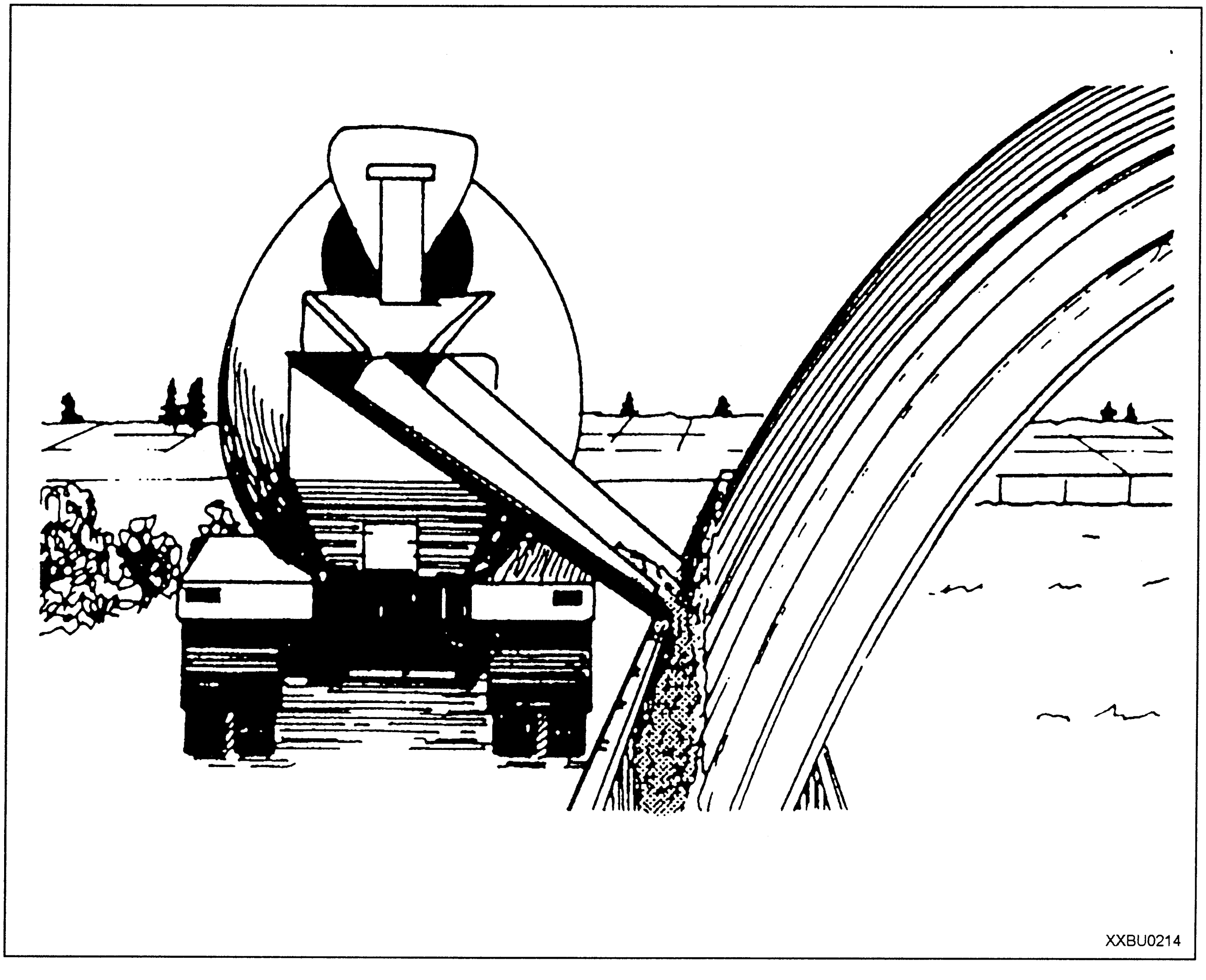


Figure 9-22.—Placement of concrete foundation.

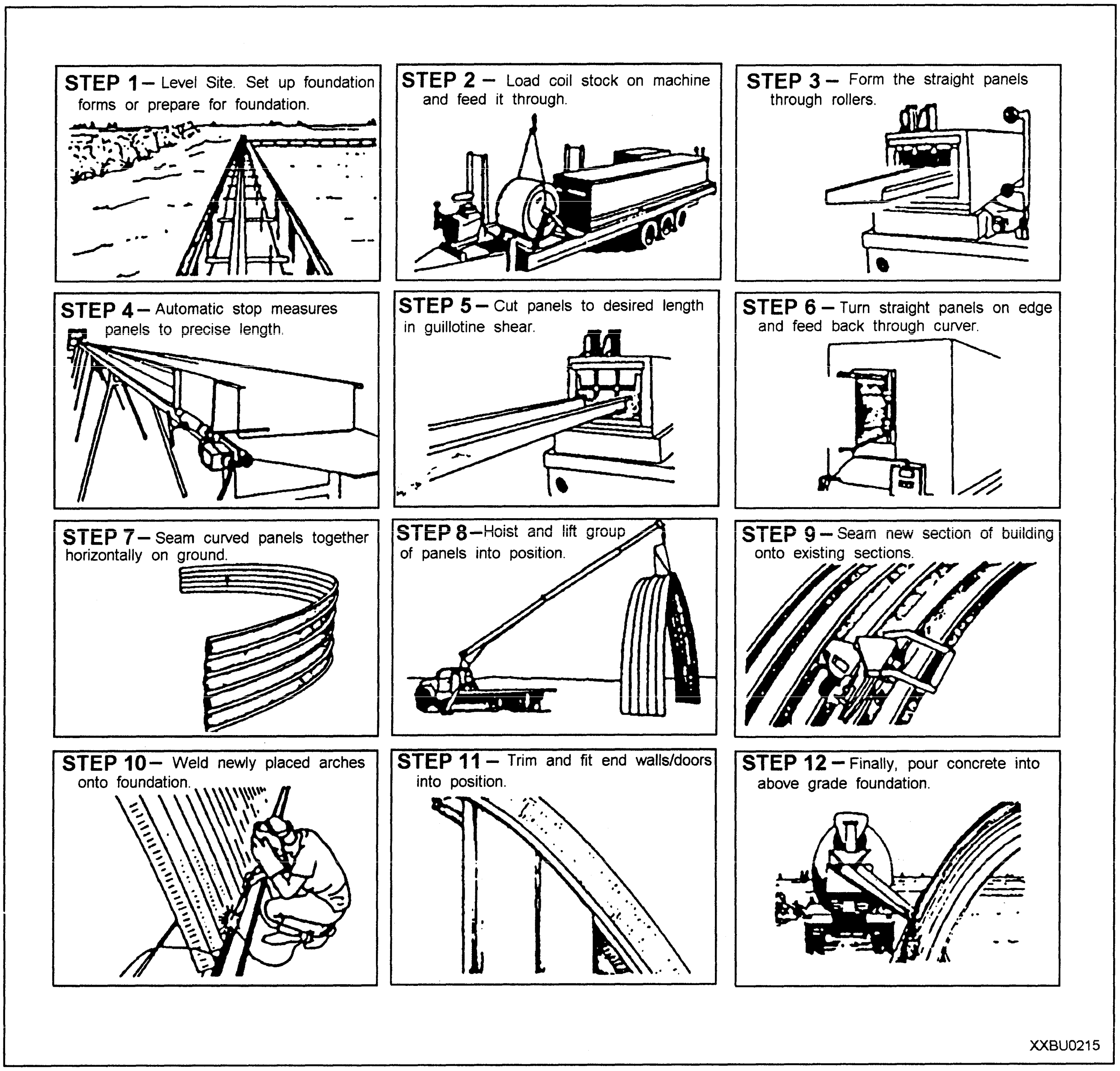


Figure 9-23.—Steps in K-SPAN construction.

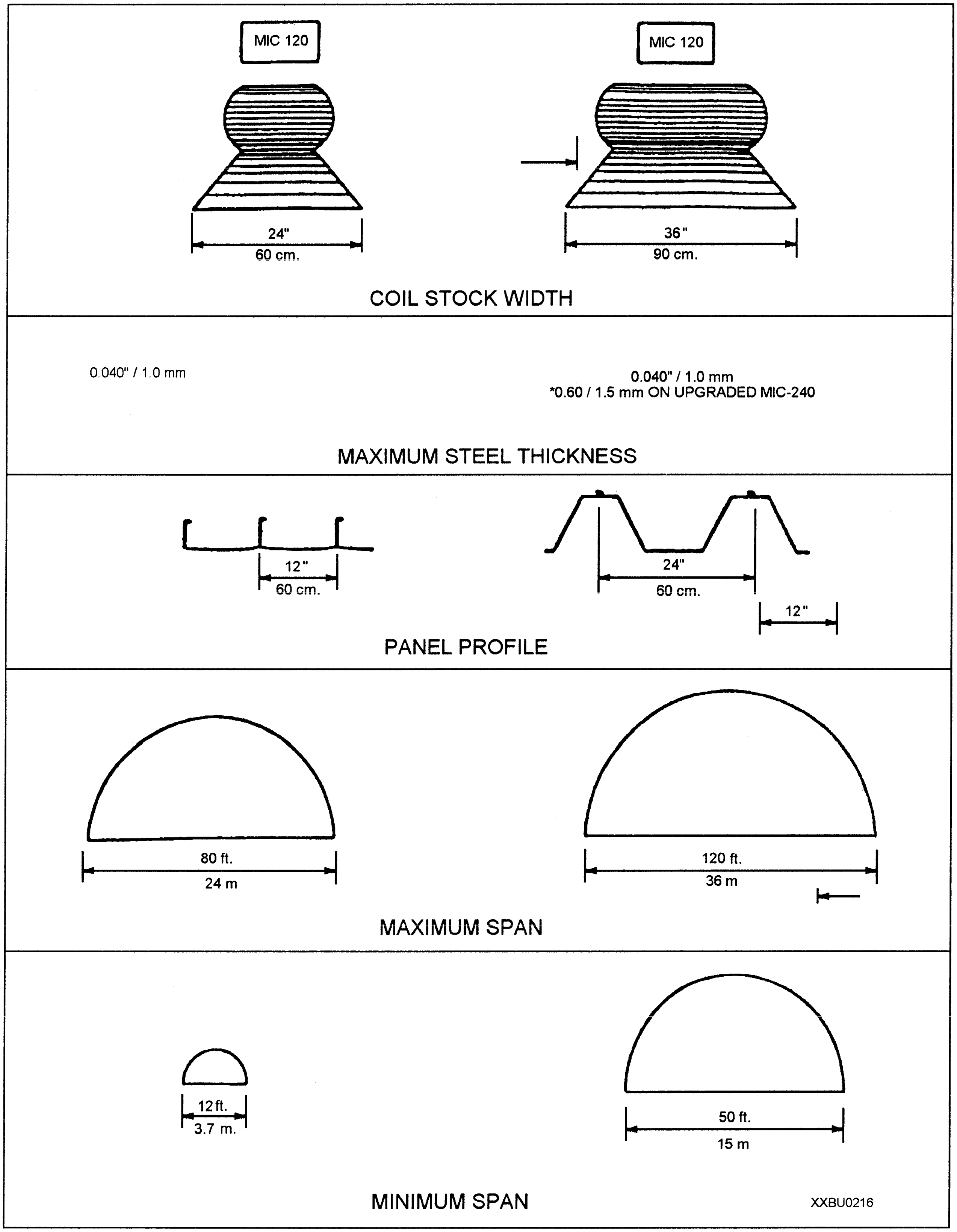


Figure 9-24.—ABM System 120 and 240 comparison chart.

shows the differences between the two. Figure 9-25 shows the differences in crew size due in large part to the heavier gauge steel required by the ABM 240.

Keep in mind that the information provided in this section on the K-SPAN building is basic. During the actual construction of this building, **you must consult the manufacturer's complete set of manuals.**

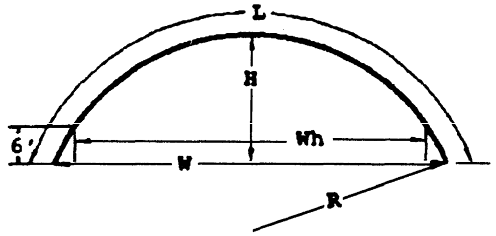
TOWERS AND BUNKERS

TOWERS are framework structures designed to provide vertical support. They may be used to support another structure, such as a bridge, or they may be used to support a piece of equipment, such as a communication antenna or for a lookout post or weapon mounts. Since the prime purpose of a tower is to provide vertical support for a load applied at the top, the compression members, providing this support, are the only ones that require high-structural strength. The rest of the structure is designed to stiffen the vertical members and to prevent bending under load. Primarily, the bracing members are designed to take loads in tension and are based on a series of diagonals. Atypical

DESIGN DATA
MIC-120

W = 60.0 feet

H = 20.0 feet



L = 76.4 feet
Wh = 53.4 feet
R = 32.5 feet
A = 867 sq ft
(end wall area)

LOADS		STEEL REQUIRED		MAX. FORCES IN ARCH		MAX. ARCH REACTIONS PER FOOT AT FOUNDATION					
LIVE	WIND	THICKNESS & GRADE		AXIAL	MOMENT	HORIZONTAL (LB)		VERTICAL (LB)		MOMENT (IN-LB)	
		TOP	END	(LB)	(IN-LB)	+	-	+	-	+	-
0	50	.023D	.023C	133	-7462	135	-47	94	-70	805	-7462
0	60	.029D	.023C	199	-10854	201	-74	145	-88	1015	-10854
0	70	.035D	.023C	280	-14868	280	-108	207	-106	1224	-14868
0	80	.045C	.023C	367	-19459	367	-143	273	-137	1576	-19459
10	50	.023D	.023C	-341	7800	252	-252	94	-250	7800	-7794
10	60	.029D	.023C	-360	-10854	265	-265	145	-268	8006	-10854
10	70	.035D	.023C	-380	-14868	280	-277	207	-287	8209	-14868
10	80	.045C	.023C	-414	-19459	367	-298	273	-317	8570	-19459
20	50	.035C	.023C	-649	15212	482	-482	66	-467	15195	-15212
20	60	.035C	.023C	-649	15212	482	-482	131	-467	15195	-15212
20	70	.035D	.023C	-649	15212	482	-482	207	-467	15195	-15212
20	80	.045C	.023C	-680	-19459	503	-503	273	-497	15565	-19459
30	50	.045D	.023C	-950	22559	708	-708	43	-678	22559	-22537
30	60	.045D	.023C	-950	22559	708	-708	108	-678	22559	-22537
30	70	.045D	.023C	-950	22559	708	-708	184	-678	22559	-22537
30	80	.045D	.023C	-950	22559	708	-708	273	-678	22559	-22537
40	50	-	-	-	-	-	-	-	-	-	-
40	60	-	-	-	-	-	-	-	-	-	-
40	70	-	-	-	-	-	-	-	-	-	-
40	80	-	-	-	-	-	-	-	-	-	-

STEEL WEIGHTS (LB)						
thickness (inch)	.023	.026	.029	.035	.041	.045
arch weight (lb)	140	158	176	213	249	274
end wall weight (lb)	1590	1798	2005	2420	2835	3112

* NOTE: The "arch weight" shown above can be divided by 50 pounds (22.7 kg) carrying load per person to determine the number of workers required to transport each arch from the curved runout tables to the pre-staging area.

XXBU0217

Figure 9-25.—Chart for determining crew size for ABM 240.

trestle tower used in bridge construction is shown in figure 9-26.

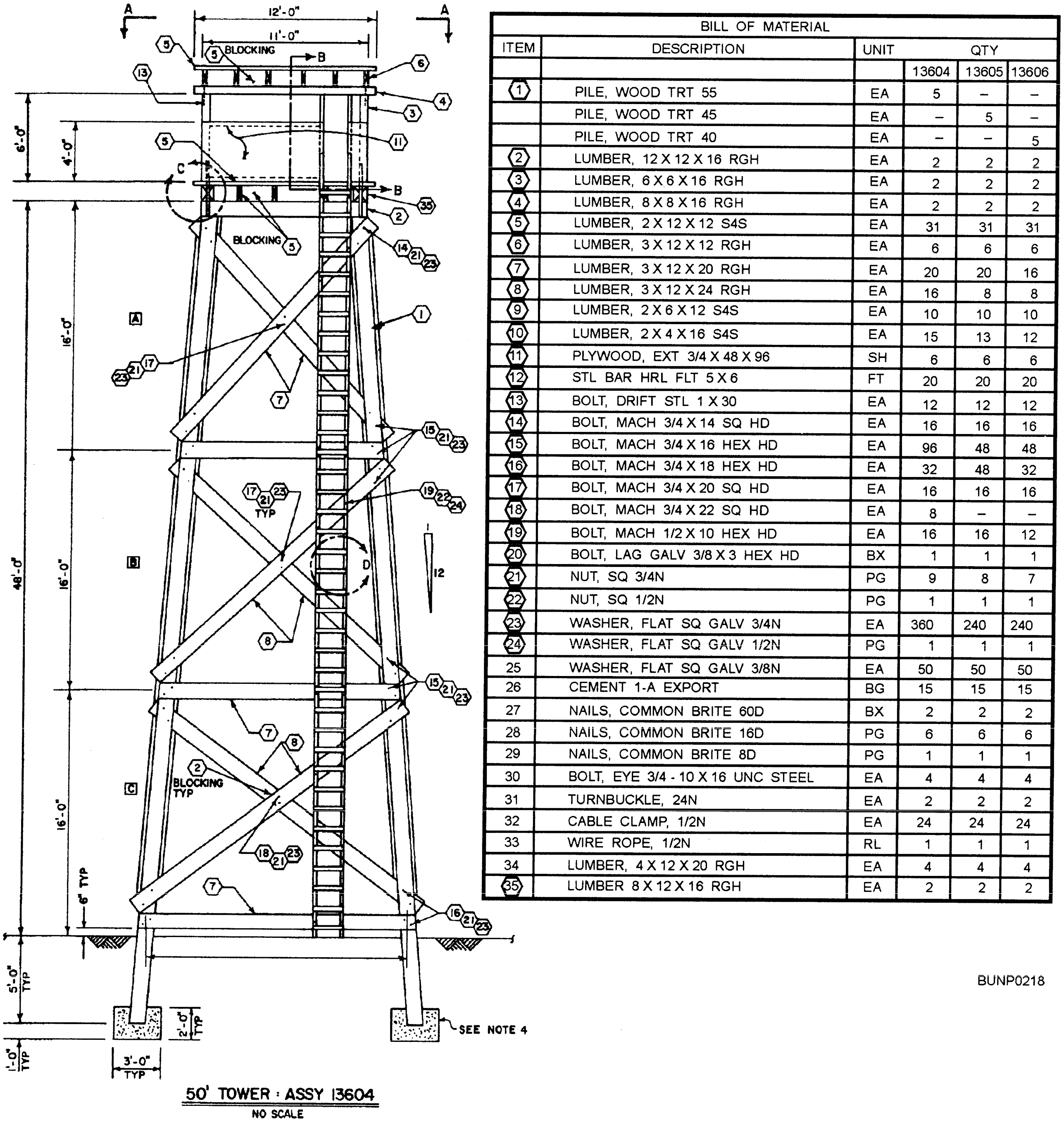
BUNKERS are fortified shelters built partly or entirely below ground. The framework of bunkers is designed to provide protection against certain incoming munitions. Figure 9-27 shows an example of a bunker from the P-437, which is a standard bunker constructed under contingency operations.

Training of the tower and bunker construction is provided by-each regiment during their CCCT.

NATURAL DISASTER RECOVERY OPERATIONS

The Seabees are also tasked to help in humanitarian operations, providing disaster control and recovery measures in the event of natural disasters, such as the following:

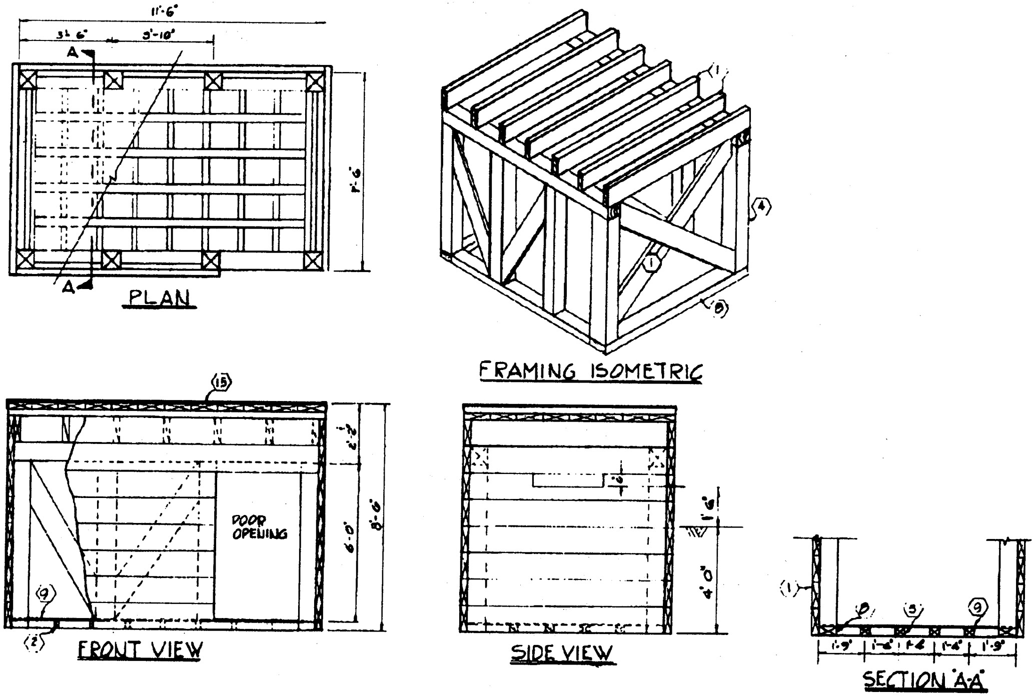
- Hurricane (Atlantic Region)/Typhoon (Pacific Region)
- Flood/Tsunami



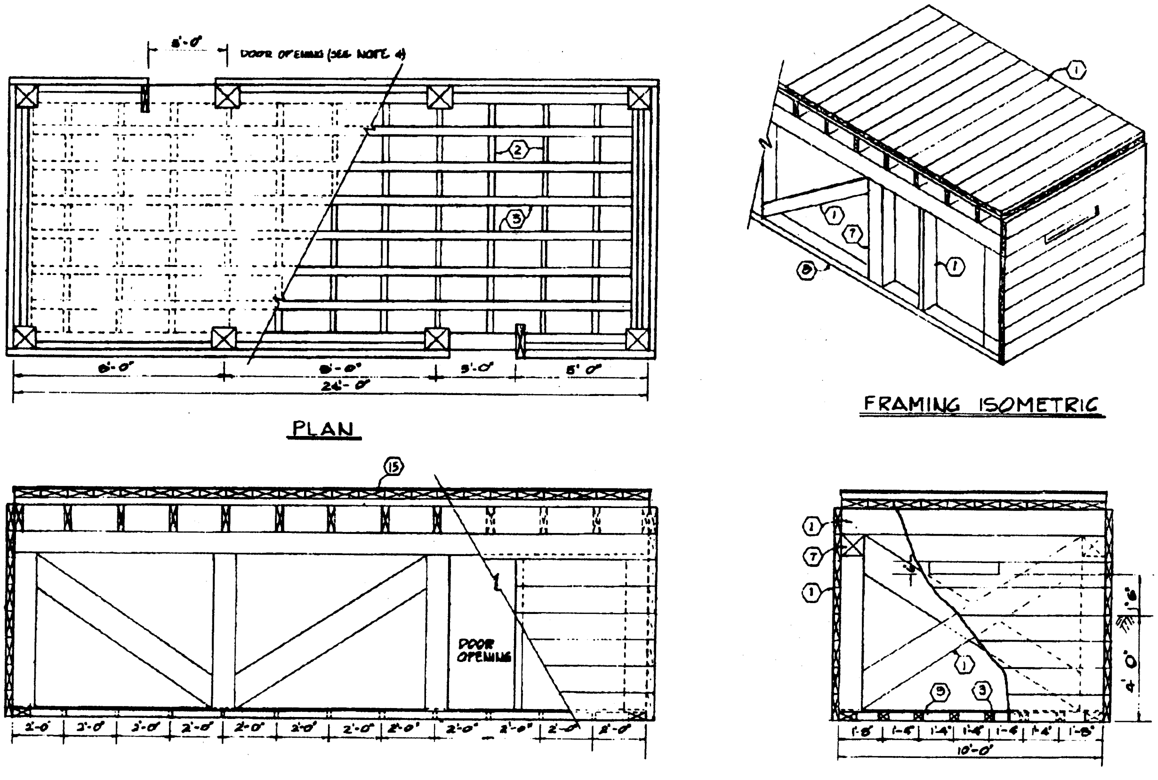
BILL OF MATERIAL

ITEM	DESCRIPTION	UNIT	QTY		
			13604	13605	13606
①	PILE, WOOD TRT 55	EA	5	–	–
	PILE, WOOD TRT 45	EA	–	5	–
	PILE, WOOD TRT 40	EA	–	–	5
②	LUMBER, 12 X 12 X 16 RGH	EA	2	2	2
③	LUMBER, 6 X 6 X 16 RGH	EA	2	2	2
④	LUMBER, 8 X 8 X 16 RGH	EA	2	2	2
⑤	LUMBER, 2 X 12 X 12 S4S	EA	31	31	31
⑥	LUMBER, 3 X 12 X 12 RGH	EA	6	6	6
⑦	LUMBER, 3 X 12 X 20 RGH	EA	20	20	16
⑧	LUMBER, 3 X 12 X 24 RGH	EA	16	8	8
⑨	LUMBER, 2 X 6 X 12 S4S	EA	10	10	10
⑩	LUMBER, 2 X 4 X 16 S4S	EA	15	13	12
⑪	PLYWOOD, EXT 3/4 X 48 X 96	SH	6	6	6
⑫	STL BAR HRL FLT 5 X 6	FT	20	20	20
⑬	BOLT, DRIFT STL 1 X 30	EA	12	12	12
⑭	BOLT, MACH 3/4 X 14 SQ HD	EA	16	16	16
⑮	BOLT, MACH 3/4 X 16 HEX HD	EA	96	48	48
⑯	BOLT, MACH 3/4 X 18 HEX HD	EA	32	48	32
⑰	BOLT, MACH 3/4 X 20 SQ HD	EA	16	16	16
⑱	BOLT, MACH 3/4 X 22 SQ HD	EA	8	–	–
⑲	BOLT, MACH 1/2 X 10 HEX HD	EA	16	16	12
⑳	BOLT, LAG GALV 3/8 X 3 HEX HD	BX	1	1	1
㉑	NUT, SQ 3/4N	PG	9	8	7
㉒	NUT, SQ 1/2N	PG	1	1	1
㉓	WASHER, FLAT SQ GALV 3/4N	EA	360	240	240
㉔	WASHER, FLAT SQ GALV 1/2N	PG	1	1	1
25	WASHER, FLAT SQ GALV 3/8N	EA	50	50	50
26	CEMENT 1-A EXPORT	BG	15	15	15
27	NAILS, COMMON BRITE 60D	BX	2	2	2
28	NAILS, COMMON BRITE 16D	PG	6	6	6
29	NAILS, COMMON BRITE 8D	PG	1	1	1
30	BOLT, EYE 3/4 - 10 X 16 UNC STEEL	EA	4	4	4
31	TURNBUCKLE, 24N	EA	2	2	2
32	CABLE CLAMP, 1/2N	EA	24	24	24
33	WIRE ROPE, 1/2N	RL	1	1	1
34	LUMBER, 4 X 12 X 20 RGH	EA	4	4	4
㉟	LUMBER 8 X 12 X 16 RGH	EA	2	2	2

Figure 9-26.—Tower.



8' x 12' x 8' BUNKER
ASSEMBLY 14001
SCALE: 3/8"=1'-0"



10' x 24' x 8' BUNKER
ASSEMBLY 14003
SCALE: 3/8"=1'-0"

BUNP0219

Figure 9-27.—Bunker.

BILL OF MATERIAL				
ITEM	DESCRIPTION	UNIT	ASSEMBLY QUANTITIES	
	BUNKER ASSEMBLY 8' X 12' X 8' BUNKER ASSEMBLY 10' X 24' X 8'		14001	14003
△B ⬡1	LUMBER 3" X 12" RGH TRT	BF	1744	2716
△B ⬡2	LUMBER 2" X 4" S4S	BF	38	74
⬡3	LUMBER 4" X 4" RGH TRT	BF	64	192
△B ⬡4	LUMBER 8" X 8" RGH	BF	384	
⬡5				
⬡6				
△B ⬡7	LUMBER 10" X 10" RGH	BF		800
△B ⬡8	LUMBER 4" X 8' RGH TRT	BF	107	182
⬡9	PLYWOOD EXT 3/4" X 48" X 96"	SH	3	8
10	NAIL COMMON BRITE 60D	BX	70	3
11	NAIL COMMON BRITE 16D	PG	4	7
12	NAIL COMMON BRITE 8D	LB	4	4
13	DRIFT PIN 1/2 X 16	EA	8	20
14	BAG SAND ACRYLIC 14" X 26"	HD	11	43
△B ⬡15	ROOFING FELT 30LB W/NAILS AND CEMENT	RL	1	3
16	CREOSOTE 5 GAL	CN	1	2
⬡17	FENCE CHAIN LINK 8' X 50'	RO	1	1
18	FENCE POST 2 3/8 DIA X 10F 8N	EA	5	5
19	BAR TENSION GALV 5/16 X 3/4	EA	2	2
20	BAND TENSION 2 3/8	EA	14	14
21	BOLT SQNK 5/16 X 1 1/4	EA	14	14
22	NUT .312-18 UNC #1 HD GALV	HD	1	1
23	WIRE TENSION NO 7.5 LB	CL	1	1
24	HOG RINGS GALV 9GA	PG	1	1
25	CEMENT 1-A EXPORT	BG	2	2
26	PLASTIC SHEET POLTHN .006 X 10 X 100	RO	1	1

△B

LUMBER CUT OFF LIST		
	ASSY NO'S	NO. OF PCS
LUMBER 3" X 12" X 12' - 0 RGH. TRT	14001	26
LUMBER 2" X 4" X 8' - 0 RGH. TRT	14001	7
LUMBER 4" X 4" X 12' - 0 RGH. TRT	14001	4
LUMBER 8" X 8" X 12' - 0 RGH.	14001	6
LUMBER 3" X 12" X 8' - 0 RGH. TRT.	14001	35
LUMBER 3" X 12" X 10' - 0 RGH. TRT.	14003	54
LUMBER 3" X 12" X 12' - 0 RGH. TRT.	14003	31
LUMBER 2" X 4" X 10' - 0 S4S	14003	11
LUMBER 10" X 10" X 12' - 0 RGH.	14003	8
LUMBER 4" X 8" X 10' - 0 RGH. TRT.	14003	7
LUMBER 4" X 4" X 12' - 0 RGH. TRT.	14003	12
LUMBER 4" X 8" X 8' - 0" RGH. TRT.	14001	2
LUMBER 4" X 8" X 12' - 0" RGH. TRT.	14001	2

BUNTU219

NOTES:

1. SANDBAGS WILL BE STACKED THREE WIDE ON ALL FOUR SIDES AND TOP.
2. EMPTY SANDBAGS WILL BE NAILED TO BUNKER WALL EVERY FIFTH LAYER TO PREVENT DISPLACEMENT (USED LIKE A BRICK TIE).
3. CUT 3' X 6" APERTURE ON ALL FOUR SIDES AS REQUIRED.
4. BRACING IS SIMILAR ON ALL FOUR SIDES.
5. DOOR OPENING LOCATION AND QUANTITY IS OPTIONAL.
6. △A INSTALL ELECTRICAL ITEMS TO SUIT FIELD REQUIREMENTS.
7. DESIGN INFORMATION TAKEN FROM 7TH ENGINEERING DRAWING #279.
8. HEX SYMBOL ON B/M DENOTES ITEM SHOWN ON DRAWING.
9. CHAIN-LINK FENCE 8' X 50', ITEM 17 TO 25 IS PROVIDED FOR ROCKET PROPELLED GRENADE (RPG) PROTECTION.
10. SANDBAGS WILL BE FILLED THREE-FOURTH FULL.
11. STABILIZE BAGS BY FILLING WITH 1 PART CEMENT TO 10 PARTS DRY EARTH. IN A SAND GRAVEL MIXTURE, INCREASE RATION TO 1 TO 6.
12. IF BUNKER REQUIRES CAMOUFLAGE USE NCFSU ASSY 02016 THRU 02020.
13. ITEM 26 IS PROVIDED FOR CANOPY OVER ENTRANCE FOR INCLEMENT WEATHER PROTECTION.

Figure 9-27.—Bunker—Continued.

- Earthquake
- Tornado
- Major fires (such as forest fires that imminently endanger populated areas)
- Other disasters which may be decreed as a national emergency by the President of the United States or other officials authorized to declare emergencies and activate a military response

All actions taken by the NCF in response to a natural disaster are dedicated to reduce, prevent, and repair damage. Certain measures that can be taken by the NCF in preparation for the types of potential disasters that may be indicative of a specific geographical area are as follows:

- Maintain emergency communication equipment in a state of readiness.
- Identify shelter areas designed to withstand specific types of disasters within those geographical areas that are prone to them.
- Advance stockpiling of critical materials, such as food, water, medicinal supplies, and basic creature comfort items (blankets, soap, emergency clothing, etc.).
- Maintain copies of the local Disaster Preparedness Plan within each department of a unit.
- Maintain an active disaster recovery organization and make sure each person is fully aware of what is expected of them. When assigned to recovery teams, ensure that training has been accomplished.
- Identify and maintain a listing of CESE and of operators required for each type of disaster response.

Each NCF unit is responsible for disaster control measures to protect its own personnel, equipment., campsites, and jobsites. The standard organization of an NCF unit makes it a highly effective disaster control and recovery unit. These units must be prepared to give direct assistance to any military installation or civilian community to assist in returning conditions to as near normal as possible after a natural disaster occurs.

WAR DAMAGE REPAIR

When naval facilities are damaged by military action, they must be repaired to operational use in the shortest time possible. The United States has a policy of maintaining a forward defense strategy which contributes significantly to allied solidarity. Advance basing is provided to support any deployed force. The NCF is tasked to establish and man the forward logistics support facilities to ensure sustainability of the operational forces according to the naval maritime strategy. This strategy identifies war damage repair as a critical NCF capability. The list of critical war damage repair capabilities shown below is not all-inclusive. It is only an example of some of the tasks that may be assigned to the NCF in the event of conflict or attack upon the facilities of the United States or its allies.

- Airfields and operational facilities
- POL pipelines
- Fuel storage areas
- Fleet hospital facilities
- Piers and wharf facilities
- Railroad facilities that support fleet operations
- Communication facilities

OPNAVINST 3501.115C is the required operational capabilities and the projected operational environment (ROC/POE) which describes the major identifiable tasks that the NCF is expected to accomplish. The above listing is only a few of the many items identified by the ROC and POE.

Materials, procedures, and techniques for rapid repair of bomb-damaged airfield runways and taxiways have been under development for several years. The need for such developments has grown because of the substantial increase in the diversity and lethality of both air-launched and surface-launched weapons, capable of inflicting damage on airfield runways and taxiways.

As part of the mobilization planning process of the Navy, the NCF has developed standard units of material, personnel, and equipment to perform specific combat-related functions at advanced naval bases. Advanced base functional component (ABFC) P-36 is the functional component for use in performing rapid runway repair tasks. The ABFC P-36 rapid runway repair component contains the material and equipment required for the repair of bomb craters using specified types of earthmoving and earthworking equipment for crater cleanout, backfilling, grading, and compaction. Traffic surface panels, emplaced over the repaired craters, are fabricated from the following:

- Prefabricated panels of AM-2 matting.
- On-site-assembled traffic surface panels prepared from prefabricated bolt-together panels.
- On-site preparation of fiber glass mats.

Typically, ABFC P-36 is provided to an advanced naval airbase located in friendly territory for rapid runway repair. ABFC P-36 is also included with the ABFCs to be deployed with the NCF participating in the seizure, construction, and occupation of an advanced naval airbase in enemy territory.

All U.S. military services have evaluated rapid runway repair extensively. Presently, the U.S. Navy incorporates the methods and standards set forth in U. S'. *Air Force Regulation* 93-12 (AFR-93-12), which furnishes detailed guidance for rapid runway repair. This regulation lists and defines the use of specific equipment, materials, and manpower requirements necessary to repair a war-damaged runway. Air Force regulations of this type are similar in format and purpose to a U.S. Navy Instruction.

Other than the ABFC Component P-36, other facilities within the ABFC system for rapid repair of airfield support are as follows:

- Facility 121 OOWD—War damage repair kit for aircraft fuel station
- Facility 124 OOWD—War damage repair kit for ready-fuel storage
- Facility 125 OOWD—War damage repair kit for POL pipeline
- Facility 136 OOWD—War damage repair kit for airfield

When the previous facilities are incorporated with the P-36 and P-25 components, it greatly enhances the capability of the NCF to respond to a hostile action scenario directed against the United States or allied air facilities.

APPENDIX I

MATH TABLES

Almost every job a Builder works on requires a working knowledge of mathematics. The tables/charts in this appendix should be a good tool for you to use when you need to make math conversions.

Table Appendix I-1 is a decimal equivalent chart that you can use to convert fractions to decimals or decimals to fractions. For example: 5/32 = 0.15625; 0.875 = 7/8; and 1/64 = 0.015625.

Table AI-1.—Decimal Equivalents

Fraction	16th	32nd	64th	Decimal	Fraction	16th	32nd	64th	Decimal
			1	.015625				33	.515625
		1	2	.03125			17	34	.53125
			3	.046875				35	.546875
	1	2	4	.0625		9	18	36	.5625
			5	.078125				37	.578125
		3	6	.09375			19	38	.59375
			7	.109375				39	.609375
1/8	2	4	8	.125	5/8	10	20	40	.625
			9	.140625				41	.640625
		5	10	.15625			21	42	.65625
			11	.171875				43	.671875
	3	6	12	.1875		11	22	44	.6875
			13	.203125				45	.703125
		7	14	.21875			23	46	.71875
			15	.234375				47	.734375
1/4	4	8	16	.250	3/4	12	24	48	.750
			17	.265625				49	.765625
		9	18	.28125			25	50	.78125
			19	.296875				51	.796875
	5	10	20	.3125		13	26	52	.8125
			21	.328125				53	.818225
		11	22	.34375			27	54	.84375
			23	.359375				55	.859375
3/8	6	12	24	.375	7/8	14	28	56	.875
			25	.390623				57	.890625
		13	26	.40625			29	58	.90625
			27	.421875				59	.921875
	7	14	28	.4375		15	30	60	.9375
			29	.453125				61	.953125
		15	30	.46875			31	62	.96875
			31	.484375				63	.984375
1/2	8	16	32	.500	1	16	32	64	1.000

Metric Conversions

In metric conversion, the unit you most often use is the meter. Terms in the metric system are all in units of 10. Multiples of these are obtained by prefixing the Greek words: deca(10), hecto(100), and kilo(1,000). Divisions are made by prefixing the Latin words: deci(l/10), centi(l/100), and mili(l/1,000).

Metric measures of length

10 millimeters	=	1 centimeter (cm)
10 centimeters	=	1 decimeter (dm)
10 decimeters	=	1 meter (m)
10 meters	=	1 decameter (dkm)
10 decameters	=	1 hectometer (hm)
10 hectometers	=	1 kilometer

Inches to Millimeters

Table Appendix I-2 provides you a quick reference table to convert inches to millimeters.

Table AI-2.—Conversion of Inches to Millimeters

INCHES	MILLI-METERS	INCHES	MILLI-METERS	INCHES	MILLI-METERS	INCHES	MILLI-METERS
1	25.4	26	660.4	51	1295.4	76	1930.4
2	50.8	27	685.8	52	1320.8	77	1955.8
3	76.2	28	711.2	53	1346.2	78	1981.2
4	101.6	29	736.6	54	1371.6	79	2006.6
5	127.0	30	762.0	55	1397.0	80	2032.0
6	152.4	31	787.4	56	1422.4	81	2057.4
7	177.8	32	812.8	57	1447/8	82	2082.8
8	203.2	33	838.2	58	1473.2	83	2108.2
9	228.6	34	863.6	59	1498.6	84	2133.6
10	254.0	35	889.0	60	1524.0	85	2159.0
11	279.4	36	914.4	61	1549.4	86	2184.4
12	304.8	37	939.8	62	1574.8	87	2209.8
13	330.2	38	965.2	63	1600.2	88	2235.2
14	355.6	39	990.6	64	1625.6	89	2260.6
15	381.0	40	1016.0	65	1651.0	90	2286.0
16	406.4	41	1041.4	66	1676.4	91	2311.4
17	431.8	42	1066.8	67	1701.8	92	2336.8
18	457.2	43	1092.2	68	1727.2	93	2362.2
19	482.6	44	1117.6	69	1752.6	94	2387.6
20	508.0	45	1143.0	70	1778.0	95	2413.0
21	533.4	46	1168.4	71	1803.4	96	2438.4
22	558.8	47	1193.8	72	1828.8	97	2463.8
23	584.2	48	1219.2	73	1854.2	98	2489.2
24	609.6	49	1244.6	74	1879.6	99	2514.6
25	635.0	50	1270.0	75	1905.0	100	2540.0

Table AI-3.—Conversion of Fractions and Decimals to Millimeters

FRACTION OF AN INCH (IN 64THS)	Decimal OF INCH	MILLIMETERS	FRACTION OF INCH (IN 64THS)	Decimal	MILLIMETERS
1	.015625	0.3968	33	.515625	13.0966
2	.03125	0.7937	34	.53125	13.4934
3	.046875	1.1906	35	.546875	13.8903
4 (1/16")	.0625	1.5875	36	.5625	14.2872
5	.078125	1.9843	37	.578125	14.6841
6	.09375	2.3812	38	59375	15.0809
7	.109375	2.7780	39	.609375	15.4778
8 (1/8")	.125	3.1749	40 (5/8")	.625	15.8747
9	.140625	3.5817	41	.640625	16.2715
10	.15625	3.9686	42	.65625	16.6684
11	.171875	4.3655	43	.671875	17.0653
12	.1875	4.7624	44	.6875	17.4621
13	.203125	5.1592	45	.703125	17.8590
14	.21875	5.5561	46	.71875	18.2559
15	.234375	5.9530	47	.734375	18.6527
16 (1/4")	.250	6.3498	48 (3/4")	.750	19.0496
17	.265625	6.7467	49	.765625	19.4465
18	.28125	7.1436	50	.78125	19.8433
19	.296875	7.5404	51	.796875	20.2402
20	.3125	7.9373	52	.8125	20.6371
21	.328125	8.3342	53	.818225	21.0339
22	.34375	8.7310	54	.84375	21.4308
23	.359375	9.1279	55	.859375	21.8277
24 (3/8")	.375	9.5248	56 (7/8")	.875	22.2245
25	.390623	9.9216	57	.890625	22.6214
26	.40625	10.3185	58	.90625	23.0183
27	.421875	10.7154	59	.921875	23.4151
28	.4375	11.1122	60	.9375	23.8120
29	.453125	11.5091	61	.953125	24.2089
30	.46875	11.9060	62	.96875	24.6057
31	.484375	12.3029	63	.984375	25.0026
32 (1/2")	.500	12.6997	64 (1 INCH)	1.000	25.3995

CONVERSION OF FRACTIONS AND DECIMALS TO MILLIMETERS

Table Appendix I-3 provides a convenient chart for converting fractions of an inch and decimals of an inch to millimeters. For example: 1/64 of an inch = 0.3968 millimeters.

CONVERSION OF MEASUREMENTS

Table Appendix I-4 provides you a convenient conversion chart for converting measurements. For example: 50 meters = 54.68 yards; 64 meters = 65.62 + 4.37 = 69.99 yards.

NOTE: 1 nautical mile = 1.852 kilometers

Table AI-4.—Conversion Chart for Measurements

Conversion Chart for Measurement								
inches								**centi-meters**
cm							**inches**	
feet						**meters**		
meters					**feet**			
yards				**meters**				
meters			**yards**					
miles		**kilo-meters**						
km	**miles**							
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.21	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.81	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.70
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.40	22.97	2.13	2.76	17.78
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
12	7.46	19.31	13.12	10.97	39.37	3.66	4.72	30.48
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
24	14.91	38.62	26.25	21.95	78.74	7.32	9.45	60.96
30	18.64	48.28	32.81	27.43	98.42	9.14	11.81	76.20
36	22.37	57.94	39.37	32.92	118.11	10.97	14.17	91.44
40	24.37	64.37	43.74	36.58	131.23	12.19	15.75	101.60
48	29.83	77.25	52.49	43.89	157.48	14.63	18.90	121.92
50	31.07	80.47	54.68	45.72	164.04	15.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64.00	229.66	21.34	27.56	177.80
72	44.74	115.87	78.74	65.84	236.22	21.95	28.35	182.88

CUBIC CONVERSION CHART

There will be times when you have to work with dry volume. For example, a job that requires the placing of concrete. If your forms are 16' by 7' by 6" (which equals 56 cubic feet), how many cubic meters of concrete is required? By using the cubic conversion chart (Table Appendix I-5) you find that 50 cubic feet equals 1.416 meters, and 6 cubic feet equals 0.170 cubic meters. You add the two together and find that you need 1.586 cubic meters of concrete.

Table AI-5.—Cubic Conversion Chart

Cubic Conversion Chart					
Cubic Meters				**Cubic Feet**	**Cubic Yard**
Cubic Yard			**Cubic Meters**		
Cubic Feet		**Cubic Meters**			
Cubic Inches	**Cubic Centimeters**				
1	16.39	0.028	0.76	35.3	1.31
2	32.77	0.057	1.53	70.6	2.62
3	49.16	0.085	2.29	105.9	3.92
4	65.55	0.113	3.06	141.3	5.23
5	81.94	0.142	3.82	176.6	6.54
6	98.32	0.170	4.59	211.9	7.85
7	114.71	0.198	5.35	247.2	9.16
8	131.10	0.227	6.12	282.5	10.46
9	147.48	0.255	6.88	317.8	11.77
10	163.87	0.283	7.65	353.1	13.07
20	327.74	0.566	15.29	706.3	26.16
30	491.61	0.850	29.94	1059.4	39.24
40	655.48	1.133	30.58	1412.6	52.32
50	819.35	1.416	38.23	1765.7	65.40
60	983.22	1.700	45.87	2118.9	78.48
70	1174.09	1.982	53.52	2472.0	91.56
80	1310.96	2.265	61.16	2825.2	104.63
90	1474.84	2.548	68.81	3178.3	117.71
100	1638.71	2.832	76.46	3531.4	130.79

Example: 3 cu. yd = 2.29 cu. m

Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.

CONVERSION OF LIQUID MEASUREMENTS

When you have a problem concerning liquid volume in metrics, remember that the liter is the foundation for liquid measure in the metric system. By referring to Table Appendix I-6, and the back of a circumference ruler, you should be able to accurately solve any problem you may encounter.

Table AI-6.—Gallon and Liter Conversion Chart

GALLON	LITER	GALLON	LITER	GALLON	LITTER
.1	.38	1	**3.79***	10	37.85
.2	.76	2	7.57	20	57.71
.3	1.14	3	11.36	30	113.56
.4	1.51	4	15.14	40	151.42
.5	1.89	5	18.93	50	189.27
.6	2.27	6	22.71	60	227.12
.7	2.65	7	26.50	70	264.98
.8	3.03	8	30.28	80	302.83
.9	3.41	9	34.07	90	340.69

NOTE: 1 US GALLON = 3.785412 LITERS
100 US GALLONS = 378.5412 LITERS

CONVERSION OF WEIGHTS

When you are working with units of weight in the metric system, the kilogram (kg) is the foundation of measure. Table Appendix I-7 provides a conversion of U.S. weights and metric weights. Be familiar with this chart so when you work with blueprints (especially overseas) made under the metric system, you will not make costly mistakes.

Example: Convert 28 pounds (lb) to kilograms (kg).

28 pounds = 20 lb + 8 lb

From the chart: 20 lb = 9.07 kg and 8 lb = 3.63 kg

Therefore: 28 lb = 9.07 kg + 3.63 kg = 12.70 kg

NOTE: 1 POUND = 0.4535924 KG; 1 U.S. SHORT TON = 2,000 POUNDS; AND 1 METRIC TON = 1,000 KG

Table AI-7.—Weight Conversion Chart

Weight Conversion Chart						
Ounces						**Grams**
Grams					**Ounces**	
Pounds				**Kilograms**		
Kilograms			**Pounds**			
Short Ton		**Metric Ton**				
Metric Ton	**Short Ton**					
1	1.10	0.91	2.20	0.45	0.04	28.1
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.81	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.17	1981.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Table Appendix I-8 is taken from the Steelworker, Volume 1 TRAMAN, NAVEDTRA 12529. It has been added to provide you with another tool when you are faced with the need to make mathematics conversions.

Table AI-8.—English and Metric System Units of Measurement

COMMON EQUIVALENTS AND CONVERSIONS

METRIC CONVERSION TABLES

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number × Factor	
1 inch	= 25 millimeters	in × 25.4*	= mm
1 foot	= 0.3 meter	ft × 0.3048*	= m
1 yard	= 0.9 meter	yd × 0.9144*	= m
1 mile†	= 1.6 kilometers	mi × 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 × 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 × 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 × 0.836127	= m^2
1 acre	= 0.4 hectare	acres × 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 × 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 × 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 × 0.764555	= m^3
1 quart (1q.)	= 1 liter	qt (1q.) × 0.946353	= *l*
1 gallon	= 0.004 cubic meter	gal × 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) × 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) × 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp × 0.745700	= kW
1 pound per square inch	= 0.97 kilogram per square centimeter	psi × 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm × 0.0393701	= in
1 meter	= 3.3 feet	m × 3.28084	= ft
1 meter	= 1.1 yards	m × 1.09361	= yd
1 kilometer	= 0.6 mile	km × 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 × 0.155000	= in^2
1 square meter	= 11 square feet	m^2 × 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 × 1.19599	= yd^2
1 hectare	= 2.5 acres	ha × 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 × 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 × 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 × 1.30795	= yd^3
1 liter	= 1 quart (1q.)	*l* × 1.05669	= qt (1q.)
1 cubic meter	= 250 gallons	m^3 × 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g × 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg × 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW × 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 × 14.223226	= psi

MATHEMATICS— We have added the following section to supplement the tables/charts in this appendix. It also provides a refresher for the worker who has encountered a time lapse between his or her schooling in mathematics and the use of this subject in the field.

COMMON CONVERSIONS

1. To convert square inches to square feet, divide square inches by 144.
2. To convert square feet to square inches, multiply by 144.
3. To convert square feet to square yards, divide by 9.
4. To convert square yards to square feet, multiply by 9.
5. To convert square feet to squares, divide by 100.

Examples:

Convert 1,550 square inches into square feet.

$$\begin{array}{rl} & \mathbf{10.76}\ \mathit{sq\ ft} \\ \mathbf{144}\ \mathit{sq\ in.} & \overline{\big)\mathbf{1550}\ \mathit{sq\ in.}} \end{array}$$

Convert 15 square feet to square inches.

15 sq ft x 144 sq in. = 2160 sq in.

Convert 100 square feet to square yards.

$$\begin{array}{rl} & \mathbf{11.11}\ \mathit{sq\ yd} \\ \mathbf{9}\ \mathit{sq\ ft} & \overline{\big)\ \mathbf{100}\ \mathit{sq\ ft}} \end{array}$$

Convert 10.3 square yards to square feet.

10.3 square yards x 9 square feet = 92.7 square feet

The mathematics problems described in this section are examples only and are not converted into the metric system. However, if you so desire, you can convert all of the problems by using the metric conversion tables in appendix I-8 of this manual. If you need more information on metrics, order *The Metric System,* NAVEDTRA 475-01-00-79, through your Educational Services Officer (ESO).

LINEAR MEASUREMENT

Measurements are most often made in feet (ft) and inches (in.); therefore, it is necessary that a sheet metalworker know how to make computations involving feet and inches. In addition, you become familiar with the symbols and abbreviations used to designate feet and inches, such as the following:

12 inches = 1 foot; 12in. = 1 ft; 12" = 1'

CHANGING INCHES TO FEET AND INCHES

To change inches to feet and inches, divide inches by 12. The quotient will be the number of feet, and the remainder will be inches.

Example:

Change 30 1/2 inches to feet and inches.

$$\begin{array}{rll}
 & \underline{2 \qquad \textit{ft}} & (\textit{quotient}) \\
12 & \overline{)\,30\ 1/2} & \\
 & \underline{24} & \\
 & 6\ 1/2\ \textit{in.} & (\textit{remainder})
\end{array}$$

CHANGING FEET AND INCHES TO INCHES

To change feet and inches to inches, multiply the number of feet by 12 and add the number of inches. The result will be inches.

Example:

Change 3 feet 6 inches to inches.

3 ft x 12 = 36 inches + 6 inches = 42 inches

CHANGING INCHES TO FEET IN DECIMAL FORM

To change inches to feet in decimal form, divide the number of inches by 12 and carry the result to the required number of places.

Example:

Express 116 inches as feet to 2 places.

$$\begin{array}{r}
9.666 \\
12\,\overline{)116.000} \\
\underline{108} \\
80 \\
\underline{72} \\
80 \\
\underline{72}
\end{array}$$

Answer: 9.67

CHANGING FEET TO INCHES IN DECIMAL FORM

To change feet in decimal form to inches, multiply the number of feet in decimal form by 12.

Change 26.5 feet to inches.

$$\begin{array}{r}
26.5 \\
\underline{12} \\
530 \\
\underline{265} \\
318.0\ \textit{inches}
\end{array}$$

ENGINEER’s MEASURE TO CARPENTER’s MEASURE

Some construction drawings have dimensions in engineer’s measurements instead of carpenter’s measurements. Engineer’s measurements are based on feet and decimal parts of a foot, where as Carpenter’s measure is based on feet, inches, and fractions of an inch. You must know how to convert an engineer’s measure to a carpenter’s measure. For example, using the carpenter’s rule (3-4-5) many times your calculation will be in engineer’s measure such as the diagonal of a right triangle being 12.65', and you can not find 12.65' on your tape measure, so you must convert this to inches and fractions of an inch (1/32, 1/16, 1/8, 1/4). As Builder’s we try and convert all dimensions to the nearest sixteenth of an inch.

Convert 12.65' to feet, inches, and sixteenths of an inch.

You already know that feet a is given (12') now, you need to convert the decimal part of a foot (.65') into inches and sixteenths of an inch by multiplying .65' by 12".

$$\begin{array}{r} .65' \\ \times 12'' \\ \hline 7.80.'' \end{array}$$

Now, you have converted the .65' to inches which is (7") with a remainder of .80". Next, convert .80" to sixteenths of an inch by multiplying .80 x 16.

$$\begin{array}{rl} .80'' & \\ 16 & \\ \cline{1-1} 12.80 & /\text{sixteenths of an inch} \end{array}$$

Now that you have converted .80" to sixteenths of an inch which is (12.80/16), you can not leave this equation like it is without rounding off. In this example you must round up to (13). So the answer to this calculation is:

Answer: 12'7 13/16"

ANGLES

Angles are of four types:

1. Right angle—a 90° angle.
2. Acute angle—an angle less than 90°.
3. Obtuse angle—an angle greater than 90°, but less than 180°.
4. Reflex angle—an angle greater than 180°.

AREAS

All areas are measured in squares.

The area of a square is the product of two of its sides and since both sides are equal, it may be said to be the square of its side.

NOTE: The area of any plane surface is the measure of the number of squares contained in the object. The unit of measurement is the square of the unit which measures the sides of the square.

AREA OF A RECTANGLE

A = L x W

where

A = area of a rectangle

L = length of a rectangle

W = width of a rectangle

AREA OF A CROSS SECTION

The cross section of an object is a plane figure established by a plane cutting the object at right angles to its axis. The area of this cross section will be the area of the plane figure produced by this cut.

The area of the cross section is L ö W.

The most common units are square inches, square feet, square yards and in roofing, “squares.”

1 square foot = 144 square inches

1 square yard = 9 square feet

1 square of roofing = 100 square feet

Convert 17,250 square foot to squares of roofing.

$$\begin{array}{r} \mathbf{172.5}\ \mathit{squares} \\ \mathbf{100}\ \mathit{sq\ ft}\ \overline{)\,\mathbf{17250}\ \mathit{sq\ ft}} \end{array}$$

CONVERSION OF UNITS OF CUBIC MEASURE

It is often necessary to convert from one cubic measure to another. The conversion factors used are as follows:

1 cubic foot = 1,728 cubic inches

1 cubic yard= 27 cubic feet

1 cubic foot = 7.48 U.S. gallons (liquid measure)

1 U.S. gallon (liquid measure) = 231 cubic inches

1 bushel (dry measure)= 2,150.42 cubic inches

Example:

1. How many cubic feet are therein 4,320 cubic inches?

$$\begin{array}{rr} & 2.5\ \textit{cubic feet} \\ 1728 \,\big) & \overline{4320} \\ & \underline{3456} \\ & 8640 \\ & \underline{8640} \end{array}$$

To convert cubic inches to cubic feet, divide by 1,728.

2. How many cubic inches are therein 3.5 cubic feet?

$$\begin{array}{r} 1728 \\ \underline{3.5} \\ 8640 \\ \underline{5184} \\ 6048.0\ \textit{cubic inches} \end{array}$$

To convert cubic feet to cubic inches, multiply by 1,728.

3. How many cubic yards are therein 35 cubic feet?

$$\begin{array}{rr} & 1.29 \\ 27 \,\big) & \overline{35.00} \\ & \underline{27} \\ & 80 \\ & \underline{54} \\ & 260 \\ & \underline{243} \\ & 17 \end{array}$$

To convert cubic feet to cubic yards, divide by 27.

To convert cubic yards to cubic feet, multiply by 27.

4. How many gallons are contained in a tank having a volume of 25 cubic feet?

$$\begin{array}{r} 7.48 \\ \underline{25} \\ 3740 \\ \underline{1496} \\ 187.00\ \textit{gallons} \end{array}$$

To change cubic feet to gallons, multiply by 7.48.

To change gallons to cubic feet, divide by 7.48.

CIRCUMFERENCE OF A CIRCLE

Definition of Pi: Mathematicians have established that the relationship of the circumference to the diameter of a circle is a constant called Pi and written p. The numerical value of this constant is approximately 3.141592653. For our purpose 3.1416 or simply 3.14 will suffice.

The formula for the circumference of a circle is $C = \pi D$ where C is the circumference and D is the diameter. Since $D = 2R$ where R is the radius, the formula may be written $C = 2\pi R$.

Area of a Circle

The formula for the area of a circle is:

$$A = \pi r^2$$

where

A = area of circle

r = radius of circle

$\pi = 3.1416$

Since r = d/2 where d is the diameter of a circle, the formula for the area of a circle in terms of its diameter is:

$$A = \pi\left(\frac{d^2}{2}\right) = \frac{\pi d^2}{4}$$

GEOMETRIC SOLIDS

In describing plane shapes, you use only two dimensions: width and length; there is no thickness. By adding the third dimension (thickness), you describe a solid object.

Consider the solids described below.

1. A **PRISM** is a figure whose two bases are polygons, alike in size and shape, lying in parallel planes and whose lateral edges connect corresponding vertices and are parallel and equal in length. A prism is a right prism if the lateral edge is perpendicular to the base. The altitude of a prism is the perpendicular distance between the bases.

2. A **CONE** is a figure generated by a line moving in such a manner that one end stays fixed at a point called the “vertex.” The line constantly touches a plane curve which is the base of the cone. A cone is a circular cone if its base is a circle. A circular cone is a right circular cone if the line generating it is constant in length. The altitude of a cone is the length of a perpendicular to the plane of the base drawn from the vertex.

3. A **PYRAMID** is a figure whose base is a plane shape bounded by straight lines and whose sides are triangular plane shapes connecting the vertex and a line of the base. A regular pyramid is one whose base is a regular polygon and whose vertex lies on a perpendicular to the base at its center. The altitude of a pyramid is the length of a perpendicular to the plane of the base drawn from the vertex.

4. A **CIRCULAR CYLINDER** is a figure whose bases are circles lying in parallel planes connected by a curved lateral surface. A right circular cylinder is one whose lateral surface is perpendicular to the base. (Note: Any reference in this text to a cylinder will mean a circular cylinder.) The altitude of a circular cylinder is the perpendicular distance between the planes of the two bases.

COMMON VOLUME FORMULAS

All factors in the formulas must be in the same linear units. As an example one term could not be expressed in feet while other terms are in inches.

Volume of a Rectangular Prism

V=l x w x h

where

V = Volume in cubic inches

w = width of the base in linear units

l = length of base in linear units

h = altitude of the prism in linear units

Example:

Find the number of cubic inches of water which can be contained by a rectangular can 5" x 6" x 10" high.

V=l x w x h

V = 5" x 6" x 10" = 300 cubic inches

Volume of a Cone

$$V=\frac{A\times h}{3}$$

$$\text{or } V=\frac{\pi r^2 h}{3}$$

$$\text{or } V=\frac{\pi d^2 h}{12}$$

where

V = Volume of a cone in cubic units

A = Area of the base in square units

h = Altitude of a cone in linear units

r = Radius of the base

d = Diameter of the base

Example:

Find the volume of a cone whose altitude is 2’6“ and whose base has a radius of 10".

$$V=\frac{\pi r^2 h}{3}=\frac{\pi\,(10)^2\,(30)}{3}=\pi\,(1000)$$

= 3141.6 cubic inches

Volume of a Pyramid

$$V=\frac{Ah}{3}$$

where

V = Volume in cubic units

A = Area of a base in square units

h = Altitude in linear units

Example:

Find the volume of a rectangular pyramid whose base is 3" x 4" and whose altitude is 6".

Area of the base = 3 x 4 = 12 square inches

$$V=\frac{12\times 6}{3}=24 \textit{ cubic inches}$$

Volume of a Cylinder

$V = Ah$

or $V = \pi r^2h$

$$or\ V=\frac{\pi d^2h}{4}$$

where

V = Volume in cubic units

A = Area of the base in square units

h = Altitude in linear units

r = Radius of the base

d = Diameter of the base

Example:

Find the volume of a cylindrical tank whose diameter is 9'6" and whose height is 11'6".

$$V=\frac{3.14\ (9.5)^2\times 11.5}{4}=814.73 \textit{ cubic feet}$$

PERCENTAGE

Percentage (%) is a way of expressing the relationship of one number to another. In reality, percentage is a ratio expressed as a fraction in which the denominator is always one hundred.

Example:

The ratio of 6 to 12, expressed as %:

$$\begin{array}{r} .5 \\ 12\overline{)6.0} \end{array}$$

The ratio of 6 to 12 may be expressed as .5 or 1. To change to %, move the decimal two places to the right.

$$\frac{.5}{1}=\frac{50}{100}=50\%$$

This means there are 50 parts to 100.

From a galvanized iron sheet weighing 46 1/4 pounds, an "ell" and one section of pipe were produced which weighed 30 pounds. Find the percentage of the scrap.

$$\begin{array}{rl} 46\ 1/4 & \textit{total weight} \\ -30 & \textit{amount used} \\ \hline 16\ 1/4 & \textit{weight of scrap} \end{array}$$

$$\frac{16\ 1/4}{46\ 1/4}=.351=35.1\%$$

PROPORTION

Proportion is a statement of two ratios which are equal.

Example

= 5/15 or 1:3 = 5:15

$$\frac{r}{3}=\frac{3r}{9}=r:3:=:3r:9$$

SOLVING PROPORTIONS

Given the proportion:

$$\frac{a}{b}=\frac{c}{d}$$

by cross multiplying: a x d = b x c

Example:

If 50 sheets of galvanized iron weigh 2,313 pounds, how much will 39 sheets weigh?

Let W = weight of 39 sheets

$$\frac{39}{50}=\frac{W}{2313}$$

CROSS MULTIPLY

50 x W = 39 x 2313

$$W = \frac{39 \times 2313}{50} = 1804.14$$

THE LAW OF PYTHAGORAS

The Law of Pythagoras is the square of the hypotenuse of a right triangle equals the sum of the squares of the two legs. It is expressed by the formula $a^2 + b^2 = c^2$.

1. **RIGHT TRIANGLE—** a triangle having one right angle.

2. **HYPOTENUSE—** The hypotenuse of a right triangle is the side opposite the right angle.

3. **LEG—** The leg of a right triangle is a side opposite an acute angle of a right triangle.

Δ ABC is a right triangle.

APPENDIX II

REFERENCES USED TO DEVELOP THE TRAMAN

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INDEX

Assignment Questions

Information: The text pages that you are to study are provided at the beginning of the assignment questions.

ASSIGNMENT 1

Tectbook Assignment: “Technical Administration,” chapter 1, pages 1-1 through 1-28.

1-1. The Personnel Readiness Capability Program is designed to provide accurate, up-to-date personnel information for all levels of management within the Naval Construction Force (NCF).

1. True
2. False

1-2. What instruction identifies and defines the skills required for peacetime and contingency operations within the NCF?

1. COMSECOND/ COMTHIRDNCBINST 5200.2
2. COMSECOND/ COMTHIRDNCBINST 5100.23
3. COMSECOND/ COMTHIRDNCBINST 1616.10
4. COMSECOND/ COMTHIRDNCBINST 1500.1

CATEGORIES OF SKILLS

A. Individual general
B. Individual rating
C. Military
D. Crew experience

Figure 1-A

IN ANSWERING QUESTIONS 1-3 THROUGH 1-6, REFER TO FIGURE 1-A.

1-3. What category of skills is primarily manipulative?

1. A
2. B
3. C
4. D

1-4. What skills can you acquire as a result of training for combat?

1. A
2. B
3. C
4. D

1-5. What category of skill is specifically related to knowledge?

1. A
2. B
3. C
4. D

1-6. By working on the construction of forms with other personnel, you acquire skills in what category?

1. A
2. B
3. C
4. D

1-7. Newly reporting personnel require a PRCP interview within how many days after reporting onboard an NCF unit?

1. 15
2. 30
3. 45
4. 60

1-8. When classifying crew members to a predetermined skill level,you should use what management tool?

1. Volume 1, PRCP Skill Definitions
2. NAVFAC P-458, PRCP Standards and Guides
3. Matrix Numbers 1 and 2
4. Section II, Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards

1-9. A PRCP interviewer conducts what two types of interviews?

1. Standard and specific
2. Individual rating and skill
3. Other and individual rating
4. Specific and other

1-10. The Standards and Guides for the Builder rating is contained in what volume of the NAVFAC P-458?

1. 1
2. 2
3. 3
4. 4

1-11. Before conducting an individual rating skill interview, you should

1. review the appropriate section of the Occupational Standards Manual
2. learn as much as you can about the skill and the tasks explained in the interviewing guides
3. prepare the interviewee’s service record
4. prepare the interviewee’s check off sheet

1-12. Skill levels can be assigned to individuals on the basis of their service or training record.

1. True
2. False

1-13. What is the NAVFAC number assigned to the Naval Construction Force (NCF) Manual?

1. NAVFAC P-315
2. NAVFAC P-318
3. NAVFAC P-405
4. NAVFAC P-458

1-14. The priorities, patterns, and tempo of a battalion training program are usually established by what authority?

1. The Chief of Naval Operations
2. The executive officer
3. The commanding officer
4. The operations officer

1-15. What officer coordinates the training and education of the personnel assigned to an NMCB?

1. The company commander
2. The operations officer
3. The training officer
4. The executive officer

1-16. What officer is in charge of the S-7 department?

1. Plans/training officer
2. Executive officer
3. Operations officer
4. Education officer

1-17. To meet training requirements, Public Works and associated non-NCF units must rely heavily on on-the-job-training and general military training.

1. True
2. False

1-18. In a Seabee organization, what is the primary purpose of on-the-job training?

1. To indoctrinate new personnel
2. To assist supervisors in developing management skills
3. To help individuals acquire the necessary knowledge, skills, and habits to do a specific job
4. Muster and make it

1-19. When used properly, what training method is most effective for providing on-the-job training?

1. Coach-pupil
2. Academic
3. Self-study
4. Group

1-20. In on-the-job training, the term “group instruction” relates to what other type of instruction?

1. Classroom
2. Self-study
3. Piecemeal
4. Case study

1-21. Piecemeal instruction includes letting others know what, when, where, how and why; explaining regulations, procedures, and orders; and holding special meetings.

1. True
2. False

1-22. Interviews between the trainee and the trainer in a developmental on-the-job training program do NOT accomplish which of the following objectives?

1. Establishing specific training requirements
2. Formulating overall training objectives
3. Assessing progress of the trainee
4. Resolving trainee questions

1-23. The most valuable end product of a peacetime military operation is a well-trained person.

1. True
2. False

1-24. Which, if any, of the following methods would be effective in evaluating the success of a training program?

1. Testing the trainee
2. Spot checking work performance
3. Checking the work schedule backlog
4. None of the above

1-25. Your supervisor expects you to meet production requirements and conduct training and to learn the process of paperwork.

1. True
2. False

1-26. What is the first step you should take when assigned a project?

1. Make sure you have enough crew members for the job
2. Determine the cost of the job
3. Make sure you understand the assignment clearly
4. Determine the priority

1-27. When planning a project, you must consider the capabilities of your crew.

1. True
2. False

1-28. As the crew leader, you are responsible for the time management for each crew member. When is the best time to confirm plans for the next workday?

1. At the beginning of each day
2. At the beginning of each week
3. At the close of each day
4. At the close of each week

1-29. For you to plan a project properly, you must be able to ORGANIZE. What is the first step in organizing a project?

1. Plan the job sequences
2. Plan for the equipment
3. Schedule the material
4. Schedule the tools

1-30. One of the most important attributes a good supervisor has is the ability to maintain firm control and to delegate authority as little as possible.

1. True
2. False

1-31. To get maximum production with minimum effort and confusion, you must

1. gain firm control
2. schedule daily staff meetings
3. plan, organize, and coordinate
4. make the resolution of complaints from your subordinates a top priority

1-32. Of the following mistakes, which one is the most common mistake made by a new supervisor?

1. Failure to coordinate
2. Failure to organize properly
3. Failure to delegate authority
4. Failure to produce

1-33. By delegating authority, you are relieved of the responsibility for a project.

1. True
2. False

1-34. When filling out a time card, you annotate what labor code for labor that does not produce an end product itself?

1. Direct
2. Indirect
3. Overhead
4. Training

1-35 What report provides the information needed by the operations office to analyze the labor distribution of total manpower resources for each day?

1. Direct Labor Report
2. Ops Report
3. SITREP
4. MANREP

1-36. What instruction provides the overall guidance for the Navy’s safety program?

1. OPNAVINST 5100.1
2. SECNAVINST 5100.2
3. OPNAVINST 5100.23
4. SECNAVINST 5200.23

1-37. The goal of any safety program is to prevent mishaps.

1. True
2. False

1-38. What serious hazard category constitutes a severe personnel injury?

1. I
2. II
3. III
4. IV

1-39. When a mishap occurs in your shop, you must submit an accident/mishap report to what person?

1. The operations officer
2. The NAVOSH manager
3. The project manager
4. The safety officer

1-40. The Navy’s permissible exposure limit (NEPL) for occupational noise is set at what number of decibels?

1. 75
2. 84
3. 96
4. 99

1-41. Eyesight is the most valuable tool a Builder will ever possess.

1. True
2. False

1-42. Navy and NCF personnel have the least control over which of the following potential pollution sources?

1. Military construction
2. Waste disposal
3. Commercial manufacturing
4. Facilities maintenance

1-43. Of the following methods for disposal of construction project waste, which one is NOT considered viable in the NCF?

1. Shredding
2. Source separations
3. Recycling
4. Site burial

1-44. Which of the following solid waste materials can be processed for recycling?

1. Metal
2. Glass
3. Lubricating oil
4. Each of the above

1-45. An oil slick on a water surface blocks the flow of what element from the atmosphere into the water?

1. Hydrogen
2. Carbon dioxide
3. Oxygen
4. Ozone

1-46. Petroleum-based fuels should not be used for burning of brush, scrub, and stumps for which of the following reasons?

1. They do not burn completely and may seep into the underground water table
2. They are too expensive to waste on scrub burning
3. They become carcinogenic when mixed with water
4. They coagulate and become solids, creating an impermeable soil strata

1-47. When unburned hydrocarbons and various other fuel components combine chemically, which of the following by-products is normally formed?

1. Lead sulfate
2. Carbon monoxide
3. Carbon dioxide
4. Sulfur dioxide

1-48. The EPA classifies material that is highly reactive or corrosive as hazardous waste.

1. True
2. False

1-49 A liquid that corrodes steel at a rate greater than 6.35 mm per year at 130°F test temperature presents what type of hazard?

1. Corrosive
2. Ignitable
3. Reactive
4. Toxic

1-50. A material that normally is unstable and can readily undergo violent change without detonating presents what type of hazard?

1. Corrosive
2. Ignitability
3. Reactivity
4. Toxic

1-51. A material that can degrade into components that are poisonous, even in low doses, to the environment or to the public health presents what type of hazard?

1. Corrosive
2. Ignitability
3. Reactivity
4. Toxic

IN ANSWERING QUESTIONS 1-52 THROUGH 1-54, REFER TO FIGURE 1-8 IN THE TEXTBOOK.

1-52. According to the example shown, what is the flash point of this material?

1. Above 200°F
2. 200°F and below
3. Below 100°F
4. Below 73°F

1-53. According to the example shown, what is the reactivity hazard of this material?

1. Oxidizes rapidly
2. Shock or heat may detonate
3. Violent chemical
4. Unstable if chilled

1-54. According to the example shown, what is the health hazard of this material?

1. Deadly
2. Extreme danger
3. Hazardous
4. Slightly hazardous

1-55. Project storage areas for combustible materials should be separated from other sources of ignition by what minimum distance?

1. 10 feet
2. 20 feet
3. 50 feet
4. 60 feet

1-56. What type of highly combustible drying oil is made from the flaxseed plant?

1. Tung oil
2. Form oil
3. Linseed oil
4. Canola oil

1-57. Methyl ethyl ketone is one of the chemicals used to produce which of the following products?

1. Roofing cement
2. Form oil
3. Canola oil
4. Contact cement

1-58. Oil-based paints are made from drying oils and unsoluble solids.

1. True
2. False

1-59. The size of asbestos particles detected in the air is reported in terms of what measurements?

1. Centimeter, millimeter, micron
2. Millimeter, micron, angstrom
3. Centimeter, micron, nanometer
4. Micron, nanometer, angstrom

1-60. A High Efficient Particulate Air (HEPA) filtered vacuum is used to scrub asbestos particles from contaminated air.

1. True
2. False

1-61. A Material Safety Data Sheet (MSDS) is required for each hazardous item you procure.

1. True
2. False

ASSIGNMENT 2

Textbook Assignment: "Planning, Estimating, and Scheduling," chapter 2, pages 2-1 through 2-55.

2-1. To plan a project, you must be familiar with which of the following documents?

1. Master plan and presentation drawing
2. Working and detail drawings
3. Construction drawings and specifications
4. Final and as-built drawings

2-2. What is the official contract drawing that you will mark on during construction to show the actual as-built conditions?

1. Final
2. Project
3. As-built
4. Red-lined

2-3. When a construction project is completed, what type of drawing must be submitted to ROICC?

1. As-built
2. Final
3. Red-lined
4. Working

2-4. In the preparation of construction drawings, most engineers use symbols adopted by what authority?

1. National Association of Home Builders
2. American Engineering Society
3. National Institute of Construction Engineers
4. American National Standards Institute

2-5. What type of plan shows the spot where a building is to be placed on a piece of land?

1. Site
2. Floor
3. Engineering
4. Structural

2-6. In what main division of a set of project drawings for a new building should you look to find the types and sizes of the windows?

1. Civil
2. Architectural
3. Structural
4. Mechanical

2-7. To find the size and placement of reinforcing steel in the grade beam for a building, you should look in what main division of the drawings?

1. Civil
2. Architectural
3. Structural
4. Mechanical

2-8. Which of the following divisions should contain the environmental pollution controls?

1. Architectural
2. Structural
3. Mechanical
4. Civil

2-9. How many types of NAVFAC specifications govern work performed by Seabees?

1. One
2. Two
3. Three
4. Four

2-10. Specifications from which of the following sources, combined with drawings, define the project in detail and show exactly how it is to be constructed?

1. The American Society for Testing and Materials
2. The American National Standards Institute
3. Manufacturers specifications
4. Project specifications

2-11. Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

1. True
2. False

2-12. The Construction Standards Institute (CSI) has organized the format of specifications into 16 construction divisions. NAVFAC has added a 17th division, what division is this?

1. ABFC
2. Expeditionary structures
3. Technology
4. PEB

2-13. CPA, CPM, and PERT are techniques used in the analysis of a flow of events and activities of a construction project. What is the generic title covering this construction management techniques?

1. Planning and estimating
2. Flow charting
3. Network analysis
4. Project analysis

2-14. In most NCF projects, construction activities should NOT be less than six days in duration.

1. True
2. False

2-15. What section of the project package contains the two week schedule?

1. One
2. Two
3. Three
4. Four

2-16. What section of the project package contains the Bill of Materials?

1. Six
2. Five
3. Three
4. Four

2-17. Scheduling is the process of determining the amount and type of work to be performed to complete a given task.

1. True
2. False

2-18. The work schedule of a battalion for one person per week is based on an average of how many hours?

1. 40
2. 48
3. 50
4. 55

2-19. In an NMCB, what is the normal duration of a workday to and from the jobsite?

1. 8 hours
2. 9 hours
3. 10 hours
4. 12 hours

2-20. NAVFAC P-405, Seabee Planner's and Estimatorrs Handbook, defines a man-day as how many hours per day?

1. 6
2. 8
3. 10
4. 12

2-21. What type of estimates are the basis for purchasing materials, determining equipment, and determining manpower requirements?

1. Activity estimates
2. Material estimates
3. Quality estimates
4. Quantity estimates

2-22. Master activities are usually assigned to the projects by what authority?

1. NMCBs
2. NCBs
3. NCRs
4. CBUs

2-23. Which of the following activities is NOT an activity that would be listed on a Master Activities List for a typical building project?

1. Moisture protection
2. Specialties
3. Furnishings
4. Paint

2-24. To install 20,000 square feet of 1/2-inch drywall over wall studs takes a total of how many man-days?

1. 80
2. 83
3. 88
4. 90

2-25. What NAVFAC publication lists the number of man-hours to accomplish one unit of work?

1. P-315
2. P-417
3. P-405
4. P-415

2-26. The man-day capability equation is used to calculate the duration of a construction activity.

1. True
2. False

2-27. For planning purposes, what authority assigns an availability factor to an NMCB?

1. Naval Construction Regiment
2. Naval Mobile Construction Battalion
3. Naval Construction Brigade
4. On-site commander

2-28. Which of the following information is NOT documented on Construction Activity Summary Sheets?

1. Notes
2. Man-day calculations
3. Tool requirements
4. PRCP skills

2-29. Material estimates are NOT used to determine which of the following elements for a project?

1. What construction material must be procured
2. If sufficient material is available
3. The labor involved to install the material
4. The amount of administrative support needed

2-30. During the construction phase of a project, what person should have control of the estimating work sheets?

1. The activity commander
2. The field supervisor
3. The project engineer
4. A crew chief

2-31. The estimating work sheet shows the various individual activities for a project with a listing of the required material.

1. True
2. False

2-32. A bill of material sheet is used to check the status of supplies, the location of material, and to prepare purchase documents.

1. True
2. False

2-33. To determine the construction equipment requirements for a deployment, you use equipment estimates with what type of schedules?

1. Production
2. Material
3. Equipment
4. Project

2-34. Which of the following items is NOT a long-lead item?

1. Pre-engineered buildings
2. Treated wood products
3. Lumber (small purchase)
4. Cabinets

2-35. To estimate the number of days equipment will be used on a project, you divide the quantity of work by the production rate per day.

1. True
2. False

2-36. What NAVFAC publication is an excellent source for preliminary labor estimates?

1. P-315
2. P-405
3. P-415
4. P-437

2-37. NAVFAC P-437 provides labor estimates that are based what number of hours per workday?

1. 12
2. 10
3. 8
4. 6

2-38. You use the production efficiency graph to determine what factor?

1. Production
2. Availability
3. Delay
4. Labor

2-39. What is the average production rate for a Seabee?

1. 85%
2. 75%
3. 67%
4. 62%

2-40. The Production Efficiency Guide Chart is a tool used to assist in weighing factors that contribute to the successful completion of a project.

1. True
2. False

2-41. Which of the following schedules is NOT a basic type of schedule used on a project?

1. Progress
2. Working
3. Equipment
4. Material

2-42. What method is the basis of the concept used to develop precedence diagrams?

1. Network path
2. Dependencies
3. Critical path
4. Activity path

2-43. You must use an activity block to show work sequence. What does the left side of the activity block represent?

1. Start
2. Completion
3. Man-day
4. Man-hour

2-44. Activities are divided into what total number of groups?

1. Five
2. Two
3. Three
4. Four

2-45. Two slash marks drawn through an activity connector on a precedence diagram identifies what type of activity?

1. Working
2. Equipment
3. Heavy construction
4. Critical

2-46. What concept do the boxes on a precedence diagram provide?

1. Timed events
2. Task functions
3. The logical sequence of events
4. Priority of events

2-47. What rule governs the drawing of a network?

1. All working activities do not contain float
2. Critical nodes must have two slash marks
3. Simultaneous activities are always linked
4. The start of an activity is linked to the end of all completed activities

2-48. What connector is used most often in a precedence diagram?

1. Finish to finish
2. Start to finish
3. Start to start
4. Finish to start

2-49. What connector on a precedence diagram represents parallel activities?

1. Finish to start
2. Start to finish
3. Start to start
4. Critical to finish

2-50. What symbol is used on a precedence diagram to identify a delay?

1. L
2. d
3. d@L
4. DEL

2-51. What type of schedule is used to coordinate the planning effort between companies to ensure that no particular company or rating is over tasked?

1. Level I Roughs
2. Level II Roughs
3. Level III Roughs
4. Level IV Roughs

2-52. The logic network, also referred to as precedence diagramming, is the basic management tool for controlling all resources that are directly related to what factor?

1. Material
2. supply
3. Logistics
4. Time

2-53. When computing a forward pass, you start with the very first activity and plug in what numerical value?

1. 1
2. 2
3. 3
4. Zero

2-54. The equation Early Start minus Lagtime minus Early Finish is used to calculate what time factor?

1. Free float
2. Duration
3. Leadtime
4. Forward pass

2-55. What equation is used to calculate total float?

1. Late Start minus Lagtime
2. Late Start minus Early Start
3. Early Start minus Duration
4. Duration minus Lag time

2-56. A histogram shows how many people in each rating are required on a daily basis to complete the tasks scheduled.

1. True
2. False

2-57. The primary task in resource leveling is to schedule the critical work as you have people available to do the work.

1. True
2. False

2-58. Engineered Performance Standards (EPS) are designed for

1. facilities maintenance type work
2. estimating job costs
3. the drafting section in an Engineering Department
4. establishing the work to be assigned to an NMCB

2-59. What person in the PWD organization is responsible for developing a manpower availability summary and a work plan summary on a monthly basis?

1. Shop foreman
2. Shop scheduler
3. Maintenance manager
4. Job order programmer

2-60. The scheduling system used for shop scheduling is composed of what total number of stages?

1. One
2. Two
3. Three
4. Four

2-61. The Public Works management plan for using shop force and specific job orders for a given month is known as the

1. Shop Load Plan (SLP)
2. Shop Leader's Schedule (SLS)
3. Shop Force Plan (SFP)
4. Master Job Plan (MJP)

ASSIGNMENT 3

Textbook Assignment: “Concrete Construction,” chapter 3, pages 3-1 through 3-43.

3-1. Before placing concrete, you should inspect all supporting members because wet concrete will always exert what type of pressure on them?

1. Pneumatic
2. Hydraulic
3. Hydrostatic
4. Kinetic

3-2. Nailing requirements must comply with what directive(s)?

1. Manufacturer’s recommendations only
2. NAVFAC instructions and blueprints
3. Plans and specifications
4. Crew Chief’s Handbook and local regulations

3-3. Supervisors should inspect all forms before and after each pour.

1. True
2. False

3-4. When working with concrete, personnel should wear gloves and protective goggles and have their shirt sleeves rolled down to prevent what hazardous result?

1. Aggregate poisoning
2. Concrete rash
3. Cement poisoning (lime)
4. Asphyxiation

3-5. When working with concrete, personnel should stand with their backs to the wind to prevent cement and sand from being blown into their eyes.

1. True
2. False

3-6. A temporary structure that can support its own weight and that of freshly placed concrete as well as the weight of materials, workmen, and equipment imposed upon it is known as

1. superstructure
2. formwork
3. subfoundation
4. scaffolding

3-7. As a supervisor of a form building crew, you should consider what factors as your principal objectives?

1. Time lines and crew training
2. Load size and job site location
3. Economy, quality, and safety
4. Local laws, cost of lumber, and blueprints

3-8. Formwork may represent as much as what percentage of the cost of a concrete structure?

1. 33%
2. 40%
3. 45%
4. 50%

3-9. Concerning formwork, in what area(s) will good judgement and ingenuity on the part of the supervisor help reduce costs?

1. Selection of materials and equipment
2. Planning fabrication and erection procedures
3. Scheduling reuse of forms
4. All of the above

3-10. Forms must be designed to meet what weight factor?

1. The weight of crew members they must support
2. The weight of the concrete they must support
3. The weight of the equipment they must support
4. The total weight to which they may be subjected

3-11. Earth, metal, lumber, plywood, and fiber are the most commonly used types of form material.

1. True
2. False

3-12. The majority of all formwork involves concrete. Concrete weighs a total of how many pounds per cubic foot?

1. 100
2. 125
3. 150
4. 175

3-13. For each inch of slab thickness, concrete slabs place a total load of how many pounds per cubic foot on the formwork?

1. 12.5 pounds per square foot
2. 14.5 pounds per square yard
3. 15 pounds per cubic inch
4. 40 pounds per cubic yard

3-14. In pounds per square foot of horizontal projection, what is the minimum recommended construction live load provision for the weight of crew members and equipment?

1. 10
2. 20
3. 50
4. 75

3-15. When powered concrete buggies are used in concrete operations, what is the minimum construction live load recommended for use?

1. 65 psf
2. 75 psf
3. 85 psf
4. 95 psf

3-16. What bracing technique is most often used to brace forms against lateral pressure?

1. Attaching vertical plates behind the wales
2. Attaching horizontal plywood sheets
3. Nailing a diagonal member and a horizontal member to a stud or wale (the diagonal member should be at a 45-degree angle to the horizontal member)
4. Nailing plywood sheets and studs to the wales

3-17. Which of the following factors does NOT have an effect on lateral pressure?

1. The consistency of the concrete
2. The amount and location of reinforcement
3. Vibration
4. The sulfate content

3-18. You have been given the assignment of determining the maximum concrete pressure for a form. The rate of placement is 5 feet per hour and the temperature is 70 degrees. What is the maximum concrete pressure for the form?

1. 600 psf
2. 700 psf
3. 800 psf
4. 900 psf

3-19. To determine the uniform load on a stud (ULS), you multiply the maximum concrete pressure by the maximum stud spacing. Then, by dividing the result by 12, you convert the answer into what unit of measurement?

1. Pounds per linear foot
2. Pounds per cubic foot
3. Pounds per square inch
4. Pounds per square foot

3-20. To determine the time required to place concrete, you divide the height of the form by the rate of placement.

1. True
2. False

3-21. Braces are used against wall forms to protect from mishaps due to external forces. The value of the external force is estimated to be how many times the wall height, in feet?

1. 10.5
2. 11.5
3. 12.5
4. 13.5

3-22. Designing wall forms and the bracing for them should be the responsibility of what person?

1. The crew chief
2. The on-site supervisor
3. The “forms manager”
4. The project engineer

3-23. What is the first step in designing wooden forms for a concrete column?

1. Determine the height of the column
2. Determine the largest cross-sectional column
3. Determine the materials available for sheathing, yokes, and battens
4. Determine the yoke spacing

3-24. In which of the following forms may reinforcing steel be used?

1. Bars or rods
2. Sheets or rolls
3. Squares or triangles
4. Rectangles or hexagons

3-25. To calculate manpower estimates, you must estimate what factor first?

1. Square footage of contact surface (SFCS)
2. Square footage of building surface (SFBS)
3. Square yards of rebar lay
4. Square yards of concrete

3-26. Reinforced concrete refers to concrete containing steel to reinforce and absorb what type of stresses?

1. Heat and gravitational
2. Hydraulic and static
3. Tensile and shearing
4. Geologic and kinetic

3-27. Reinforcing bars are hot rolled from steel recovered from which of the following sources?

1. Steel billets, railroad car axles, and railroad rails
2. Pile drivers and bikes
3. Ships and aircraft
4. Steel doors and hatches

3-28. When mixed properly, a good uniform batch of concrete should possess maximum values in durability, economy, and

1. ductility
2. appearance
3. strength
4. tension

3-29. What type of mix is considered the simplest form of concrete batching?

1. The 1:2:4 standard
2. The 1:2:4 builder’s
3. The 1:2:4 carpenter’s
4. The 1:2:4 mason’s

3-30. When a very rich mix is needed because great strength is required, you should use what mix design?

1. The 1:1:2 mix
2. The 1:2:5 mix
3. The 1:3:5 mix
4. The 1:4:8 mix

3-31. When a mix is required for large foundations or as a backing for masonry, you should use what mix design?

1. 1:1:2
2. 1:3:5
3. 1:4:8
4. 1:5:8

3-32. When large slabs and walls are to be poured, you should use what mix design?

1. 1:1:2
2. 1:2:5
3. 1:3:5
4. 1:4:8

3-33. You can use one of which of the following methods to achieve more control over the proportional quani- tities of the cement, water, and aggregate for a concrete mix?

1. Scratch batch or carpenter’s batch
2. Mason’s batch or aggregate plus
3. Luke’s or Builder’s batch
4. Book, trial batch, or absolute volume

3-34. Construction crews in the field must convert the designed trial mix proportions into field mix proportions by adjusting the mix for moisture and

1. aggregates
2. lime
3. entrained air
4. concrete

3-35. Admixtures are added to concrete, mortar, or grout immediately after mixing.

1. True
2. False

3-36. What is the most commonly used admixture used in concrete mixtures?

1. An air-entrained agent
2. A chlorine bleach agent
3. A dehumidifier agent
4. An alkaline agent

3-37. The primary reason for using an air-entraining agent in a concrete mix is to improve what property of the concrete?

1. Hardness
2. Tensile strength
3. Resistance to freezing and thawing exposure
4. Color

3-38. When sampling for a strength test, you should get a sample of not less than how many cubic feet?

1. 1
2. 2
3. 3
4. 4

3-39. Samples taken from revolving drum truck mixers must be taken at a minimum of how many intervals?

1. 1
2. 2
3. 3
4. 4

3-40. In obtaining a sample of concrete from a paving mixer, it should be collected from at least how many portions of the pile?

1. One
2. Two
3. Three
4. Five

3-41. You must take a sample to another location to conduct a compressive strength test. The time lapse between taking and molding the sample cannot exceed how many minutes?

1. 15
2. 30
3. 35
4. 45

3-42. How many times should you rod each layer of concrete placed in the compressive strength test mold?

1. 10 strokes
2. 15 strokes
3. 20 strokes
4. 25 strokes

3-43. The “flexural strength” of concrete is its ability to resist

1. rust
2. heat
3. humidity
4. a breaking force

3-44. You have a concrete pad that has a length of 60 feet, a width of 15 feet, and a thickness of 6 inches. What would be the volume of the concrete pad?

1. 350 cubic feet
2. 450 cubic feet
3. 500 cubic feet
4. 900 cubic feet

3-45. Test cylinders are cast in either metal or wooden molds.

1. True
2. False

3-46. A total of how many layers of concrete should be placed in the mold when a compressive strength test specimen is prepared?

1. One
2. Two
3. Three
4. Four

3-47. To calculate the number of cubic yards required for a pad, divide the cubic feet of the pad by what number?

1. 27
2. 28
3. 30
4. 40

3-48. Concrete specifications most often require that batching be performed by volume.

1. True
2. False

3-49. How many rotations of the drum on a transit mixer at “mixing speed” are required to produce concrete of the specified uniformity?

1. 10 to 30
2. 30 to 50
3. 70 to 100
4. 90 to 120

3-50. Which of the following structures is NOT an example of a precast concrete structure?

1. An electric pole
2. A “cast-in-place” concrete wall
3. A highway girder
4. A building member

3-51. You should not continue to operate a mobile concrete mixer plant if the hydraulic oil temperature exceeds what temperature?

1. 190°
2. 200°
3. 210°
4. 220°

3-52. What type of panels consist of two thin, dense, reinforced concrete-faced slabs separated by a core of insulating material?

1. Gate
2. Sandwich
3. Girder
4. Bellow

3-53. Post-tensioning is used if a unit weighs over 7 tons or is over how many feet long?

1. 10
2. 25
3. 30
4. 45

3-54. Conventional concrete weighs approximately how many pounds per cubic foot?

1. 100
2. 130
3. 150
4. 170

3-55. Depending on its intended use, the weight of lightweight concrete falls within what range, in pounds per cubic foot?

1. 10 to 15
2. 20 to 28
3. 30 to 75
4. 90 to 120

3-56. Heavyweight concrete has a density of up to how many pounds per cubic foot?

1. 400
2. 425
3. 450
4. 475

3-57. What type construction is a special form of precast concrete building?

1. K-span
2. Tilt-up concrete
3. S-80
4. Butler

3-58. When building casting surfaces for precast concrete panels, you should use 3,000 psi or higher reinforced concrete and ensure the slabs are at least how thick, in inches?

1. 5
2. 2
3. 6
4. 4

3-59. What material is most often used for edge forms?

1. 1-inch concrete slabs
2. 2-inch steel sheets
3. 2 by lumber
4. 4-inch aluminum rods

3-60. Bond-breaking agents are classified into what two types?

1. Paraffin and wax
2. Acidic and alkaline
3. Liquid and solid material
4. Sheet materials and liquids

3-61. A good bond-breaking agent can be made by mixing 5 pounds of paraffin with how many gallons of kerosene?

1. 5
2. 2 1/2
3. 3
4. 1 1/2

3-62. When welded wire fabric (WWF) is used, dowels or bars are NOT needed between the columns and panels.

1. True
2. False

3-63. To achieve proper strength, cast panels must be cured just like any other concrete.

1. True
2. False

3-64. At the jobsite, what type of lifting attachments can be made from rebar?

1. Hooks
2. Inserts
3. Hairpins
4. Spreaders

ASSIGNMENT 4

Textbook Assignment: “Masonry Construction” and “Shop Organization and Millworking,” chapters 4 and 5; pages 4-1 through 5-20.

4-1. Masonry is a construction method made up of prefabricated masonry units laid together in various ways and joined together by what type of mix?

1. 2:4:2 concrete
2. Mortar
3. Clay and straw
4. Epoxy

4-2. What type of planning ensures concrete masonry walls are laid out so maximum use is made of full-length and half-length masonry units?

1. Modular
2. Masonry
3. Standard
4. Developmental

4-3. In most construction accomplished by Seabees, what size concrete masonry units (CMUs) are used?

1. 8" x 3" x 12"
2. 8" x 4" x 12"
3. 8" x 8" x 16"
4. 8" x 4" x 16"

4-4. Which one of the two methods used by Builders to estimate CMUs is the quickest, but NOT the most accurate?

1. Solving for CMUs
2. Chasing the Bond
3. Square foot method
4. Metric inch method

4-5. Building specifications call for a 1:2 mortar mix. Using rule 38, how many sacks of cement are required to make up a 2-cubic yard mix?

1. 10
2. 13
3. 20
4. 26

4-6. It takes one person (skilled labor) a total of how many man-hours to lay 1,000 square feet of 8" x 8" x 16" concrete block?

1. 167
2. 160
3. 146
4. 118

IN ANSWERING QUESTION 4-7, REFER TO TABLE 4-4 ON PAGE 4-5 IN THE TEXTBOOK.

4-7. What total number of man-hours are required to construct 1,500 square feet of wall area using 8-inch by 8-inch by 16-inch CMU?

1. 200
2. 220
3. 240
4. 260

4-8. Brick masonry is masonry construction in which units of baked clay or shale of uniform size, small enough to be placed with one hand, are laid in courses to form walls.

1. True
2. False

4-9. A rowlock brick laid with its bed parallel to the face of the wall is what type of masonry unit?

1. Wythe
2. Stretcher (Bull)
3. Soldier
4. Header

4-10. A continuous vertical section of a wall that is one unit thick is what type of masonry unit?

1. Wythe
2. Soldier
3. Bull header
4. Stretcher

4-11. A unit laid flat on its bed across the width of a wall with its face perpendicular to the face of the wall is what type of masonry unit?

1. Wythe
2. Soldier
3. Header
4. Stretcher

4-12. A rowlock brick laid with its bed perpendicular to the face of the wall is what type of masonry unit?

1. Wythe
2. Stretcher
3. Soldier
4. Header

4-13. What type of masonry unit is used to bond two wythes?

1. A wythe
2. A stretcher
3. A soldier
4. A header

4-14. Standard U.S. brick are what nominal size?

1. 1/4 by 3 3/4 by 8 inches
2. 1/4 by 3 5/8 by 7 5/8 inches
3. 3 by 4 by 9 inches
4. 2 3/4 by 4 by 12 inches

4-15. Brick classified as being of high quality is known by what term?

1. Backup brick
2. Common brick
3. Face brick
4. Superior brick

4-16. What type of brick is designed to withstand exposure to below-freezing temperatures in a moist climate?

1. SW
2. NW
3. MW
4. LW

4-17. What type of brick is most often used for the backing courses in either solid or cavity brick walls?

1. Cored
2. Clinker
3. Glazed
4. Building

4-18. When cleanliness and ease of cleaning are necessary, you should use what type of brick?

1. Face
2. Cored
3. Glazed
4. Sand-lime

4-19. What type of brick is used extensively in Germany?

1. Clinker
2. Glazed
3. Cored
4. Sand-lime

4-20. Some well-burned brick may have a ultimate compressive strength that equals what maximum psi?

1. 15,000
2. 16,000
3. 17,000
4. 18,000

4-21. The compressive working strength of a brick wall or column laid with plain lime mortar normally falls within what range?

1. 200 psi to 250 psi
2. 300 psi to 350 psi
3. 350 psi to 450 psi
4. 500 psi to 600 psi

4-22. Bricks should always be stacked on

1. soft ground
2. planks
3. scaffolds
4. sand

4-23. When stacking brick, you should start tapering back when the pile reaches what minimum height?

1. 7 feet
2. 6 feet
3. 5 feet
4. 4 feet

4-24. The way the individual masonry units interlock or tie together into a single structural unit is known as what type of bonding?

1. Structural
2. Pattern
3. Common
4. American

4-25. The pattern formed by the masonry units and mortar joints on the face of a wall is called what type of bond?

1. Stack
2. Pattern
3. English
4. Running

4-26. Which of the following bonds is a variation of the running bond in which a header course appears at the fifth, sixth, or seventh course?

1. Running
2. Flemish
3. Common or American bond
4. Dutch bond

4-27. You must place a three-quarter brick at the corner of each header course in which of the following pattern bonds?

1. Common
2. English
3. Block
4. Stacked

4-28. A wall having an English bond pattern has alternating courses of

1. three-quarter and blind headers
2. stretchers and bull headers
3. headers and rigid-steel ties
4. headers and stretchers

4-29. To tie brick on the outside face of a wall to the backing course when no header courses are to be installed, what units should you use?

1. Copings
2. Metal ties
3. Flashing
4. Pieces of rebar

4-30. Moisture is prevented from seeping under a horizontal masonry surface by the installation of what units?

1. Sills
2. Copings
3. Parapets
4. Flashing

4-31. Water that accumulates on a flashing should be allowed to drain to the outside by the installation of what units?

1. Parapets at intervals of 6 to 12 inches
2. Concealed flashing
3. Weep holes at intervals of 18 to 24 inches
4. Sills at 12-inch intervals

4-32. To ensure a good bond between mortar and brick, you should NOT use which of the following joints?

1. Bed
2. Slushed
3. Cross
4. Header

4-33. The stronges mortar joints are how thick?

1. 1/4 inch
2. 1/2 inch
3. 3/4 inch
4. 7/8 inch

4-34. For which of the following reasons should you form a shallow furrow in the mortar of a bed joint?

1. To maintain the required width of brick spacing
2. To conserve mortar
3. To keep a gap from forming and allowing water to enter the wall
4. To allow the mortar to dry slightly before placing the brick

4-35. To cut a brick to an exact line with a brick chisel or brick set, you should follow which of the following procedures?

1. Break the brick with one blow of the hammer
2. Let the straight side of the cutting edge face you
3. Let the straight side of the cutting edge face the part of the brick that is to be saved
4. All of the above

4-36. You should spread bed joint mortar what maximum number of bricks ahead?

1. Five
2. Seven
3. Eight
4. Nine

4-37. For weathertightness, what is the best type of joint finish?

1. Flush
2. Bead
3. Concave
4. Weather

4-38. Which of the following joint finishes is NOT considered one of the three best?

1. Concave
2. Flush
3. Raked
4. Weather

4-39. The two common arch shapes are eliptical and circular.

1. True
2. False

4-40. The temporary wooden supports used to support arches during their construction are known by what term?

1. Shapers
2. Templates
3. Arch supports
4. Wedges

4-41. The solid sides of a building brick are known by what term?

1. The rakes
2. The cell
3. The slides
4. The fins

4-42. Tile masonry has a compressive strength of how many pounds per square inch?

1. 100
2. 200
3. 300
4. 400

4-43. Partition walls of clay tile 6 inches thick can resist for 1 hour a fire that produces heat that does not exceed what temperature, in degrees Fahrenheit?

1. 1100
2. 1200
3. 1700
4. 1900

4-44. The use of structural load-bearing tiles is restricted by building codes.

1. True
2. False

4-45. Stone masonry units are classified into what two types?

1. Coursed and rectangle
2. Random and regular
3. Ashlar and rubble
4. Squared and cubic

4-46. What type of stonework is the crudest of all types?

1. Standard rubble
2. Unsquared rubble
3. Random rubble
4. Coursed rubble

4-47. What type of rubble consists of roughly squared stones assembled in such a manner as to produce approximately horizontal bed joints?

1. Rough
2. Random
3. Modified
4. Coursed

4-48. The mortar used in stone masonry should be composed of what ratio of cement to sand?

1. 1 to 3
2. 2 to 3
3. 3 to 4
4. 4 to 5

4-49. When taking over an established shop, you should NOT make a survey of shop equipment.

1. True
2. False

4-50. The function of a shop will have an important bearing on the space and equipment needed.

1. True
2. False

4-51. You should refer to the Occupational Safety and Health Standards for the Construction Industry, Code of Federal Regulations, (29 CFR Part 1910) for what type of information?

1. Storage of fuels
2. Shop setup
3. Shop floor plans
4. Storage of tools, material, and equipment

4-52. You should ensure that your storage facilities are arranged to provide as much working space as possible.

1. True
2. False

4-53. What type of flooring material is unfortunately used most often by industrial shops?

1. Wood
2. Ceramic
3. Concrete
4. Tile

4-54. What type of floor material is preferred for shops?

1. Tile
2. Ceramic
3. Concrete
4. Wood

4-55. As a general rule, windows should be installed at what minimum height above the floor?

1. 48 inches
2. 50 inches
3. 54 inches
4. 60 inches

4-56. What number of feet above the floor is considered the minimum height for the ceiling of a Shop?

1. 10 feet
2. 11 feet
3. 12 feet
4. 13 feet

4-57. Shaped items of wood that are usually made from well seasoned kiln-dried lumber (4 to 9 percent moisture content) are known by what term?

1. Millwork
2. Kilnwork
3. Dry formwork
4. Framework

4-58. Which of the following units is NOT a form of setup millwork?

1. Prehung doors
2. Molding
3. Doorframes
4. Cabinets

4-59. Which of the following units is NOT a form of knocked-down millwork?

1. Stairs
2. Window frames
3. Doorframes
4. Cabinets

4-60. The Architectural Graphics Standard provides complete information on drawings.

1. True
2. False

4-61. When developing working drawings, you do NOT have to follow drafting standards closely.

1. True
2. False

4-62. Which of the following units is NOT an example of casework construction?

1. Desks
2. Chests
3. Bookcases
4. Window frames

4-63. Which of the following techniques is most often used to strengthen a shelf?

1. Installation of strongbacks
2. Adding additional nails
3. Adding thick wood blocks
4. Installation of additional face frames

4-64. The toeboard is usually set back from the face of a case by what distance?

1. 1 1/2 to 2 inches
2. 2 1/2 to 3 inches
3. 3 1/2 to 4 inches
4. 4 1/2 to 5 inches

4-65. What are the dimensions of a standard kitchen counter top, in height, depth, and thickness?

1. 36 by 25 by 1 1/2 inches
2. 40 by 26 by 1 1/2 inches
3. 42 by 24 by 2 1/2 inches
4. 44 by 36 by 2 1/2 inches

4-66. Which of the following joints should NOT be used to fasten together the stiles and rails in a cabinet?

1. Dado
2. Rabbet
3. Spline miter
4. Glue

4-67. After marking the location of a stud in a wall unit, you measure what distance in both directions to locate the next studs?

1. 12 inches
2. 14 inches
3. 16 inches
4. 18 inches

4-68. In addition to the lock-shouldered and the square-shouldered method used for building drawers, you can also use what other method?

1. Clamping
2. Multiple dovetail
3. Multiple miter
4. Singular dovetail

4-69. Drawer dimensions are usually given as width, height, and depth, in that order.

1. True
2. False

4-70. What type of cabinet door is the most difficult to construct?

1. Overlay
2. Flush
3. Lipped
4. Sliding

4-71. If a cabinet door is 36 inches in length, you should attach a total of how many 2-inch hinges?

1. Five
2. Two
3. Three
4. Four

4-72. Cabinet counter tops are usually covered with a layer of high-pressure plastic laminate that is what fraction of an inch thick?

1. 1/2
2. 1/4
3. 1/8
4. 1/6

4-73. Formica, Micarta, Texolite, Wilson Art, and Melamite are trade names what type of material?

1. Laminates
2. Glues
3. Bricks
4. Tiles

4-74. Polyvinyl resin (white glue), is stronger than aliphatic resin (yellow glue).

1. True
2. False

ASSIGNMENT 5

Textbook Assignment: "Quality Control" and "Maintenance Inspections," chapters 6 and 7, pages 6-1 through 7-46.

5-1. NAVFAC has developed three quality management programs to ensure quality workmanship. Which of the following programs is NOT one of these NAVFAC programs?

1. Construction Contract Quality Management
2. Facilities Support Contract Quality Management
3. Construction Quality Control
4. Total Quality Management

5-2. What Quality Management Program provides guidance to naval shore activities on how to obtain quality public works support services through quality assurance?

1. Construction Contract Quality Management, P-445
2. Facilities Support Contract Quality Management, MO-327
3. Construction Quality Control, MO-435
4. Total Quality Management, P-415

5-3. The Navy recognizes quality as individual contribution and team effort in an organization working together to improve the process/system or product.

1. True
2. False

5-4. Quality control checks should be conducted at what time intervals?

1. Monthly
2. Weekly
3. Daily
4. Hourly

5-5. Quality control is a management system established to ensure a construction project is completed with a specified minimum quality.

1. True
2. False

5-6. Quality Control measures are to be listed in "plain language" on what sheet?

1. QC
2. CAS
3. QM
4. TQL

5-7. The first step in ensuring quality is to establish a means for measuring QC progress.

1. True
2. False

5-8. The Daily QC Inspector's Report is used to document the completion of required checks, tests, and inspections.

1. True
2. False

5-9. What office can approve any battalion recommended field adjustment requests (FARs) or customer requested changes?

1. CESO
2. S-7
3. ROICC
4. QC

5-10. Any changes to a project that require 50 or more man-days of additional direct labor or cause an increase in the cost of the project by $500 or more must be approved by

1. the battalion commander
2. the operations officer
3. the QC officer
4. COMSECONDNCB or COMTHIRDNCB

5-11. What staff provides direct liaison between the batallion and the ROICC?

1. The COMSECOND
2. The operations
3. The QC
4. The executive

5-12. What agency publishes the Construction Inspector’s Guide, EP 415-1-261?

1. COMTHIRDNCB
2. COMSECONDNCB
3. BUPERS
4. U.S. Army Corps of Engineers

5-13. The primary function of an inspector is to make certain that the work is performed in every aspect with the

1. drawings and specifications
2. NAVFAC P-409
3. local regulations
4. QC guidelines

5-14. Concrete construction must meet the requirements set by

1. the battalion
2. local regulations
3. NAVFAC
4. the American National Standards Institute

5-15. What type of concrete foundation is used when the subsoil is not considered good enough for spread footings?

1. Mat (raft or floating)
2. Triangle
3. Pillar
4. Concentric

5-16. What is the lowest foundation of a concrete structure?

1. The bottom footing
2. The substructure footing
3. The spread footing
4. The leveling footing

5-17. What type of bolts are usually set to a template?

1. Check
2. Floor
3. Anchor
4. L-bend

5-18. CMUs are usually made with nominal widths of what size?

1. 3, 4, 5, or 6 inches
2. 6, 8, 10, or 12 inches
3. 3, 4, 6, 8, 10, or 12 inches
4. 1, 2, 3, 4, or 12 inches

5-19. What type of construction is used for shop buildings requiring relatively long-span construction?

1. Concrete
2. Steel
3. Wood
4. Special

5-20. For information on headers for light-frame construction, you should refer to what publication?

1. The Frame Graphics Guide
2. The Woodworkers Guide
3. The Architectural Graphics Standard (AGS)
4. The Header and Footer Standards Manual

5-21. For roofs, oriented stranded board (OSB) is widely used in residential construction.

1. True
2. False

5-22. What material is most often used for steel-floor framing?

1. Bessemer steel
2. Bingham steel
3. Light-gauge galvanized steel
4. Heavy gauge steel

5-23. If you use wood framing for walls instead of metal framing, the cost

1. is the same
2. is doubled
3. is tripled
4. is a little less

5-24. Membrane waterproofing is achieved by the placement of a moisture-impervious membrane. Which of the following materials can be used as membrane waterproofing material?

1. Polytetraflouro-tylene and cotton
2. Resin and polyurethane
3. Polyvinyl chloride, glycongen, and vinyl compounds
4. Polyethylene, bituminous membrane, and sheet rubber

5-25. Which of the following material is NOT an example of insulating material?

1. Foamed glass
2. Foamed plastics
3. Glass fibers
4. Bitumen

5-26. Floor finish is any material used as the final surface of a floor. Which of the following materials are used as floor finish?

1. Stucco and tile
2. Fiber glass and plaster
3. Sheet vinyl, wood, and slat block
4. Vermiculite and perlite

5-27. Stucco is composed of what ingredients?

1. Clay, sand, and water
2. Bitumen, felt, sand, and oil
3. Portland cement, hydrated lime, sand, and water
4. Lime, sand, and water

5-28. Stucco can be applied to masonry, concrete or

1. wood-frame walls
2. steel-frame walls
3. aluminum-frame walls
4. iron-frame walls

5-29. Built-up roofing is a membrane built up on the job from alternate layers of what materials?

1. Felt and oil
2. Fiber glass and resin
3. Bitumen-saturated felt and bitumen
4. Oil-saturated fibers and asbestors

5-30. When inspecting built-up roofing, you should verify the particular combination of plies, felt, binder, and cover indicated in the project specifications.

1. True
2. False

5-31. Of the three types of trim, which is the most often used by the NCF?

1. Metal
2. Wood
3. Plastic
4. Steel

5-32. Exterior doors are NOT often made of which of the following materials?

1. Solid wood
2. Steel
3. Sheet metal
4. Aluminum

5-33. Interior doors are NOT often made of which of the following materials?

1. Hard wood
2. Soft Wood
3. Sheet metal
4. Aluminum

5-34. Skylights may be constructed from Monel Metal, aluminum, copper, and galvanized iron.

1. True
2. False

5-35. You should not paint if the temperature is below what degrees, in Fahrenheit?

1. 10
2. 20
3. 30
4. 40

5-36. What type of paint is used for interior walls?

1. Oil-based wall
2. Lead-based wall
3. Flat wall
4. Carbon-based wall

5-37. During pile-driving operations, the inspector must be present and during the driving of every pile and a digging permit must maintained at the site.

1. True
2. False

5-38. During pile-driving operations, what condition is indicated by the bending or staggering of the hammer?

1. A broken hammer
2. Shearing of the pile
3. A boulder has been hit
4. Overdriving

5-39. During timber construction operations, the inspector must ensure the timber is stored with the high end of the stack cantilevered forward at the top to provide an cave effect.

1. True
2. False

5-40. During timber operations, the inspector must reject and require replacement of any timber damaged during erection.

1. True
2. False

5-41. What NAVFAC publication contains detailed information applicable to the maintenance of structures?

1. P-315
2. P-349
3. P-410
4. P-450

5-42. Foundations should be inspected at what time intervals?

1. Monthly
2. Quarterly
3. Every 4 months
4. Yearly

5-43. What structures are used under foundations to spread loads over enough soil area to bring unit pressure to allowable limits?

1. Footings
2. Separators
3. Substructures
4. Levels

5-44. Which of the following conditions does NOT indicate localized displacement of a foundation has occurred?

1. Cracked walls
2. Sloping floors
3. Stable fill
4. Sticking doors

5-45. Unventilated crawl spaces do NOT provide a natural habitat for fungus and termites.

1. True
2. False

5-46. Pentachlrophenol is a wood preservative that is used to prevent infestation of what pest?

1. Termites
2. Wasps
3. Rodents
4. Birds

5-47. The basic supporting members of wood frame structures are divided into three groups for inspection purposes. The first group is sills and beams, the second group is posts and columns, and the third group is

1. stairways and steps
2. girders and joists
3. roofs and chimneys
4. doors and floors

5-48. Asphalt, vinyl tile, and linoleum are the most often used types of floor covering?

1. True
2. False

5-49. Wood floors should be inspected at least once each

1. month
2. quarter
3. year
4. decade

5-50. Concrete floors should be painted at least every 2 years.

1. True
2. False

5-51. What is the primary factor that makes tile flooring easier to replace than linoleum?

1. Tile is larger
2. Tile has a felt lining
3. Tile has an adhesive backing
4. Tile is smaller

5-52. Stairways and doors should be inspected each

1. week
2. month
3. quarter
4. year

5-53. Which of the following categories is NOT a category of exterior wall?

1. Load-bearing walls
2. Nonbearing walls
3. Curtain walls
4. Nonreinforced walls

5-54. Which of the following types of cracks is NOT a category of wall cracks?

1. Horizontal movement cracks
2. Shrinkage cracks
3. Racked-down corners
4. Stretcher cracks

5-55. Efflorescence may indicate the penetration of moisture into a wall to an extent that could cause deterioration of interior wall coverings.

1. True
2. False

5-56. What material is most often used to make interior walls?

1. Glass
2. Fiberboard
3. Drywall
4. Tile

5-57. When conducting the required quarterly inspection of windows, you can expect weathering to be the most common cause of window failures.

1. True
2. False

5-58. The recommended remedy for splitting and checking of dry timber is to install what type of bolts?

1. Roofing
2. Form
3. Stitch
4. Anchor

5-59. Asphalt and coal-tar pitch are NOT compatible and contact between the two should be avoided.

1. True
2. False

5-60. Of all types of metal roofing, what type has the lowest cost?

1. Aluminum
2. Corrugated, galvanized steel
3. Noncorrugated, galvanized steel
4. Monel

5-61. One of the most frequent causes of failure of galvanized roofs is the lack of maintenance painting.

1. True
2. False

5-62. Many roof failures are the result of inadequately maintained drainage systems.

1. True
2. False

5-63. Inspection of painted surfaces that are in exterior environments should be conducted at what time intervals?

1. Monthly
2. Quarterly
3. Semiannually
4. Anually

5-64. When repairing concrete structures, you should cover the reinforcing steel with a minimum of how many inches of concrete?

1. 1
2. 2
3. 3
4. 4

5-65. Deck slabs that have been damaged by heaving movements should must be replaced.

1. True
2. False

5-66. What problem can result when expansion bolts on a deck are inadequate in number or are not functioning properly?

1. Accelerated rusting
2. Heaving of the deck
3. Spalling of columns
4. Racked-down corners

5-67. Main members of steel structures are removed when the section becomes seriously deformed or when corrosion has caused the removal of what percentage of the section?

1. 10
2. 20
3. 30
4. 40

5-68. What types of timber have proven to be best suited for waterfront structures?

1. Spruce and tamarack
2. Hemlock and larch
3. Knotted pine and cedar
4. Southern yellow pine, Douglas fir, and oak

5-69. The use of cresote-treated lumber for wood decking is NOT recommended.

1. True
2. False

5-70. To permit drainage and ventilation, decking should be laid with what size spaces between each plank?

1. Between 1 1/2 to 2 inches
2. Between 3/8 inch to 1/2 inch
3. 3/6 inch
4. 1/8 inch

5-71. Piles that have been weakened by marine borers can be strengthened and protected by encasing them in

1. leather jackets
2. aluminum jackets
3. steel jackets
4. concrete jackets

5-72. Structures made of cut stone and cast concrete and laid up with mortar or similar materials are considered masonry structures.

1. True
2. False

5-73. The use of earth for waterfront structures is confined largely to dikes and levees.

1. True
2. False

5-74. Vegetative covering is usually grown on the sides and top of earth structures to prevent erosion.

1. True
2. False

ASSIGNMENT 6

Textbook Assignment: “Heavy Construction” and “Advanced Base Planning and Field Structures,” chapters 8 and 9, pages 8-1 through 9-33.

6-1. The lower part of a bridge is known by what term?

1. Superstructure
2. Substructure
3. Trough
4. Foundation unit

6-2. What part of a building is located below the surface of the ground?

1. The superstructure
2. The substructure
3. The foundation
4. The deadman

6-3. What part of a building rises from the foundation to a location above the ground?

1. The footing
2. The pile bent
3. The grade beam
4. The foundation wall

6-4. What type of foundation is most often used for small buildings?

1. Continuous
2. Grade beam
3. Spread
4. Mat

6-5. What type of foundation is located at grade level around the entire perimeter of a building?

1. Grade beam
2. Foundation Wall
3. Continuous
4. Spread

6-6. What type of foundation is located under isolated columns or at intervals along a wall?

1. Mat
2. Continuous
3. Grade beam
4. Spread

6-7. What total number of rows of posts or piles does a pier contain?

1. One
2. Two
3. Three
4. Four

6-8. What total number of rows of posts or piles does a bent contain?

1. One
2. Two
3. Three
4. Four

6-9. A timber pile bent can support a span of how many feet?

1. 25
2. 50
3. 75
4. 90

6-10. A trestle bent can support a combined span length of what maximum length, in feet?

1. 30
2. 40
3. 50
4. 60

6-11. The pile bent pier is composed of what minimum number of pile bents?

1. One
2. Two
3. Three
4. Four

6-12. A trestle bent pier is specifically designed to carry what type of loads?

1. Horizontal
2. Vertical
3. Longitudinal
4. Transverse

6-13. What type of bracing provides stability at right angles to the center line of the superstructure of a bridge?

1. Longitudinal
2. Transverse
3. Diaphragm
4. Bent

6-14. Which of the following structures is NOT a part of the superstructure of a bridge?

1. Stringers
2. Flooring
3. Trestle bent
4. Handrails

6-15. What members of the superstructure of a bridge are the main load-carrying members?

1. The treads
2. The bents
3. The stringers
4. The diaphragms

6-16. What part of the flooring system protects the deck?

1. The tread
2. The bent
3. The stringer
4. The diaphragm

6-17. For excavations in average soil, OSHA recommends a slope of what angle?

1. 15 degrees
2. 20 degrees
3. 30 degrees
4. 45 degrees

6-18. Before beginning an excavation, you must have a digging permit.

1. True
2. False

6-19. Which of the following situations does NOT require shoring?

1. When using clay, silt, loam, or non-homogeneous types of soil
2. When there is insufficient room for sloped banks
3. In industrial or commercial areas where new construction is next to buildings
4. When sloping is considered adequate

6-20. What two methods are most often used to shore high vertical excavation banks?

1. Needling and sheet piles
2. Saddling and underpinning
3. Interlocking sheetpiling and soldier piles
4. Sloping and footing

6-21. What type of piles are H-shaped and are driven into the ground with a pile driver?

1. Code H
2. Interlocking sheet
3. Soldier
4. Bearing

6-22. What type of piles are watertight?

1. Code W
2. Interlocking sheet
3. Soldier
4. Bearing

6-23. What type of piles are usually straight tree trunks with the limbs and bark removed?

1. Code T
2. Interlocking sheet
3. Soldier
4. Timber bearing

6-24. What types of piles are usually H-pile?

1. Timber bearing
2. Steel bearing
3. Concrete
4. Shell

6-25. What type of piles can be either precast or cast in place?

1. Timber bearing
2. Steel bearing
3. Concrete
4. Drop

6-26. There are three main types of pile-driving hammers. Which of the following is NOT a pile-driving hammer?

1. Drop
2. Pneumatic
3. Diesel
4. Hydraulic

6-27. For driving heavy piles into hard or dense soil, what pile-driving hammer provides the best results?

1. Drop
2. Pneumatic single action
3. Diesel
4. Steel double action

6-28. What type of pile-driving hammer is most often used?

1. Drop
2. Pneumatic
3. Diesel
4. Hydraulic

6-29. What part of a pile-driving hammer protects it from damage by receiving and transmitting the blow of the hammer or ram?

1. Lead
2. Catwalk
3. Cap
4. Hammer guide grove

6-30. Statistics on accidents show that a free moving power crane is one of the most dangerous machines used in the Navy.

1. True
2. False

6-31. The pile-driving crew is usually made up of people manning which of the following positions?

1. Rig operator and signalman
2. Safety supervisor and rigger
3. Safety advisor and signal maker
4. Driver and loftman

6-32. During a pile-driving operation, what individual is the boss and normally the only person giving signals to the operator?

1. Hoisting engineer
2. Signalman
3. Loftman
4. Hook-on person

6-33. A pile supported by skin friction alone is referred to as what type of pile?

1. Friction
2. End-bearing
3. Combination pile
4. Sliding

6-34. A pile supported by bedrock or an extra dense layer of soil at the tip is known as what type of pile?

1. Friction
2. End-bearing
3. Combination
4. Substratum-friction

6-35. What type of piling is most often used in military construction?

1. "Z" pile
2. Steel sheet pile
3. Timber pile
4. Precast concrete

6-36. When a pile changes direction or becomes easier to drive, you should take what corrective action?

1. Drive faster
2. Drive a supporting pile next to it
3. Pull the pile
4. Drive slower

6-37. Which of the following conditions does NOT cause bouncing?

1. A crooked pile
2. A hammer that is too light
3. A crushed pile butt
4. An obstruction is met

6-38. A pile supported partly by skin friction and partly by a substratum of extra dense soil at the tip is known as what type of pile?

1. Friction
2. End-bearing
3. Combination
4. Substratum-friction

6-39. Which of the following actions is NOT a necessary step for constructing a bent?

1. Aligning
2. Cutting
3. Capping
4. Hammering

6-40. When selecting a timber pile to build a bent around, the timber pile should be long enough to leave what minimum amount of space?

1. 1 foot
2. 2-3 feet
3. 5 feet
4. 6-7 feet

6-41 Jetting equipment does NOT include

1. a water pump
2. a length of flexible hose
3. a metal jet pipe
4. a hydraulic pump

6-42. In the direct lift methos, a crane is used to pull the pile.

1. True
2. False

6-43. The tidal lift method is used to pull piles driven in tidewater.

1. True
2. False

6-44. A typical crew for bearing piles will NOT include

1. a crew leader
2. a crane operator
3. 5 or 6 crew members
4. an hoisting engineer

6-45. The time in man-days required to drive a pile depends on what two factors?

1. Length and circumference of the pile
2. Length and weight of the pile
3. Weight and circumference of the pile
4. Type and length of the pile

6-46. Waterfront structures are divided into what total number of categories?

1. One
2. Two
3. Three
4. Four

6-47. A mole is run out from the shoreline to check the along shore wave action or deflect it away from the shore.

1. True
2. False

6-48. A breakwater that is paved on the top for the use as a wharfage structure is known by what term?

1. Level top
2. Groin
3. Mole
4. Jetty

6-49. Bulkheads are NOT constructed to fall into which of the following classifications?

1. Pile and sheathing
2. Wood sheet pile
3. Steel sheet pile
4. Groin

6-50. Which of the following types of construction is NOT a type of steel construction used today?

1. Wall-bearing
2. Tilt-up
3. Long-span
4. Skeleton

6-51. What publication contains drawings for advanced-base piers?

1. NAVFAC P-72
2. NAVFAC P-405
3. NAVFAC P-437, Vol. 1
4. NAVFAC P-437, Vol. 2

6-52. What part of a pier is located between pile bents?

1. The fender
2. The dolphin
3. The wharf
4. The bay

6-53. Which of the following attachments prevent timbers from moving laterally?

1. Driftpins
2. Anchor bolts
3. Split rings
4. Scabs

6-54. An ABFC system does NOT include which of the following groups?

1. Component
2. Facility
3. Assembly
4. supply

6-55. Component Site Plans are contained in what publication?

1. NAVFAC P-437, Vol. 1, Part 1
2. NAVFAC P-438, Vol. 1, Part 3
3. NAVFAC P-439, Vol. 1
4. NAVFAC P-440, Vol. 2

6-56. You have the NSN for an assembly that you want to design and you need the line-item requirements. In this situation, you should refer to what publication?

1. NAVFAC P-440, Vol. 1
2. NAVFAC P-439, Vol. 1
3. NAVFAC P-438, Vol. 2, Part 2
4. NAVFAC P-437, Vol. 2, Part 3

6-57. In NAVFAC P-72, what is the category code for Hospital and Medical?

1. 100
2. 300
3. 500
4. 700

6-58. An ABFC building can be tailored to meet your specific needs.

1. True
2. False

6-59. ABFC assemblies required only in the North Temperate Zone are coded with what letter?

1. A
2. C
3. N
4. T

6-60. A K-Span building are NOT designed for use as

1. office spaces
2. a hangar
3. a supply building
4. a sports arena

6-61. What nomenclature is used to identify the two types of K-Span building machines?

1. MIC 120 and MIC 240
2. MIC 250 and MIC 260
3. MIC 360 and MIC 380
4. MIC 400 and MIC 410

6-62. The P-240 panel forming machine produces what type of units for a K-span building?

1. L spans
2. Straight panels
3. I spans
4. Doorframes

6-63. The design of the foundation for a K-Span building does NOT depend on

1. the size of the building
2. the existing soil conditions
3. the wind load
4. local construction rules

6-64. Towers are designed to provide horizontal support.

1. True
2. False

6-65. Seabees are tasked to help in humanitarian operations, providing disaster control and recovery measures in the event of natural disasters such as

1. hurricanes, floods, and earthquakes
2. flood, tornadoes, and fires
3. earthquakes, typhoons, and monsoons
4. plaques and volcanic eruptions

6-66. What publication describes the major identifiable tasks that the NCF is expected to accomplish?

1. NAVFAC P-72
2. NAVFAC P-437
3. OPNAVINST 3501.115
4. OPNAVINST 3501.118

6-67. Traffic surface panels are fabricated from which of the following?

1. Prefabricated panels of AM-2 matting
2. On-site assembled traffic panels
3. On-site preparation of fiber glass mats
4. Each of the above

6-68. The U.S. Navy incorporates the methods and standards contained The U.S. Air Force Regulation 93-12 (AFR 93-12) for detailed guidance for what type of operations?

1. Rapid runway repair
2. Bunker installation
3. K-span buildings
4. Evacuations