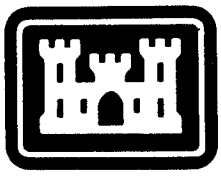
ENGINEER MANUAL

EM 1110-3-174
April 1984

ENGINEERING AND DESIGN

Sanitary and Industrial Wastewater Collection

Mobilization Construction



DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
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DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314

EM 1110-3-174

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Engineer Manual
No. 1110-3-174

9 April 1984

Engineering and Design
SANITARY AND INDUSTRIAL WASTEWATER COLLECTION
Mobilization Construction

1. Purpose. This manual provides guidance for the design of gravity systems for sanitary and industrial wastewater collection at U.S. Army mobilization facilities.

2. Applicability. This manual is applicable to all field operating activities having mobilization construction responsibilities.

3. Discussion. Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:

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Colonel, Corps of Engineers
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DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314

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CHAPTER 1

GENERAL

1-1. Purpose and scope. The manual provides information, instructions, procedures, and criteria for the design of gravity systems for sanitary and industrial wastewater collection at Army installations.

1-2. Design objectives and limitations. The design of a wastewater collection system must provide an engineered system of sewers, complete with all appurtenant facilities, sufficient in size, slope, and capacity to collect and convey the required wastewater flows to an acceptable point of discharge. Sewers and appurtenances must be structurally sound. Elimination of excessive infiltration and inflow is essential in avoiding increased costs of sewer maintenance, wastewater pumping and treatment. Contributing waste flows which are harmful to sewer pipe materials and appurtenant structures, or create fire and explosion hazards, are to be handled separately. Wastewaters from fuel loading and dispensing systems, grease and oil from vehicle wash racks, aircraft washing and garage or shop floor drains, must be directed through POL product separators to prevent such wastes from entering the sewers. Combined sewers will not be permitted.

1-3. Alternatives to gravity sewers.

a. Wastewater pumping. There may be areas in which the topography is not well suited for construction of a gravity sewer system. In such areas, the installation of a gravity system would require deep and expensive trench excavation, jacking, boring, tunneling, or construction of long sewer lines to avoid unfavorable terrain. In cases like these, the existing topography and subsurface conditions at the site will determine if a pump or ejector station would be more feasible. Generally, a gravity sewer system will be justified until its cost exceeds the cost of a pumped system by 10 percent.

b. Grinder pumps and vacuum systems. Some areas under consideration may be further limited by high ground water, unstable soil, shallow rock, or extremely adverse topography, and neither gravity sewers nor pump or ejector stations will be suitable. To overcome these difficulties, grinder pumps with small diameter (less than 4-inch) pressure sewers may be utilized. In a typical installation, wastewater from individual buildings will be discharged to a holding tank, and then periodically transferred by grinder pump through small diameter pipe, into either a central pressure main, conventional gravity sewer, pumping station, or wastewater treatment facility. Vacuum systems offer an alternative to pressure sewers and may be used under similar circumstances.

CHAPTER 2

PRELIMINARY DESIGN CONSIDERATIONS

2-1. Existing conditions. As an important initial step in the design process, existing maps, drawings, surveys, boring logs, and other data containing pertinent information on existing conditions in the area being sewered should be obtained. Possible sources of such information are an installation or facility engineer and the Army using service.

2-2. Field investigations. If maps are not available, or do not provide satisfactory information or sufficient detail of the site, field surveys must be performed. Depending on the magnitude and complexity of the project, subsurface exploration with soil borings may be required.

2-3. Guidelines for sewer system layout. The development of final sewer plans must await the final site plan, the completion of field surveys, and to some extent, the establishment of finished grades. However, the development of economical site plans often requires concurrent preliminary planning of the sewer system. The location of building and lateral sewers will depend not only upon topography, but also upon the type and layout of the buildings to be served. Main, trunk, and interceptor sewers will follow the most feasible route to the point of discharge. All sewers will be located outside of roadways as much as practicable, so that the number of roadway crossings will be reduced to a minimum. A sewer from one building will not be constructed under another building. The following general criteria will be used where possible to provide a layout which is practical, economical, and meets hydraulic requirements.

a. Follow slopes of natural topography for gravity sewers.

b. Check existing maps or field surveys along prospective sewer routes to assure that adequate slopes are available.

c. Avoid routing sewers through heavily wooded areas and areas which require extensive restoration after construction.

d. Check subsurface investigations for ground water levels and types of subsoil encountered. If possible, avoid areas of high ground water and the placement of sewers below the ground water table.

e. Locate manholes at changes in direction, size or slope of gravity sewers.

f. Sewer sections between manholes should be straight. The use of curved sewer alinement is not permitted.

g. Manholes should be located at intersections of streets when possible.

h. Avoid placing manholes where the tops will be submerged or subject to surface water inflow.

2-4. Protecton of water supplies. There must be no physical connection between a potable water line and the sewer system. Sewer design will meet the following criteria.

a. Sewers will be located no closer than 50 feet horizontally to water wells or earthen reservoirs to be used for potable water supply.

b. Sewers will be located no closer than 10 feet horizontally to potable water lines; where the bottom of the water pipe will be at least 12 inches above the top of the sewer, the horizontal spacing may be a minimum of 6 feet.

c. Sewers crossing above potable water lines must be constructed of acceptable pressure pipe or fully encased in concrete for a distance of 10 feet on each side of the crossing. The thickness of the concrete encasement will be a minimum of 4 inches at pipe joints.

CHAPTER 3

HYDRAULIC DESIGN OF SEWERS

3-1. Quantity of wastewater. For any segment of proposed sewer, the design wastewater flow must be determined. Sanitary or domestic wastes based on the population served by a given segment, extraneous infiltration/inflow, and contributing industrial flows must be added to produce the design flow. Where existing flow records or data showing required flow capacity are not available, the following criteria will be used to develop design flows.

a. Tributary area. This is the area contributing wastewater to a particular sewer segment. The quantity of wastewater which is collected by a particular segment is dependent upon the types of personnel and industrial activities which are regularly found in the area.

b. Sanitary or domestic wastes.

(1) Contributing population. Domestic wastewater quantities normally are to be computed on a contributing population basis, except as noted in paragraphs d. and e. which follow. The population to be used in design depends upon the type of area which the sewer serves. If the area is strictly residential, the design population is based on full occupancy of all housing and quarters served. If the area served is entirely industrial, the design population is the greatest number, employed in the area at any time, even though some of these persons may also be included in the design of sewers in the residential area. For sewers serving both residential and industrial areas, the design population includes residents and nonresidents, but no person should be counted more than once. For design purposes, one-third of the nonresident population will be added to the resident population.

(2) Average daily flow. The average daily flow will be computed by multiplying the resident and nonresident contributing populations by 100 gallons per capita per day plus admissible daily flows from commercial and industrial operations. The average daily flow will be used only for designing sewers to serve the entire installation, or large sections of the installation, and where a major portion of the wastewater is generated by residents over a 24-hour period.

(3) Average hourly flowrate. When designing sewers to serve small areas of the installation where several buildings or a group of buildings are under consideration, and where the majority of wastewater is generated by nonresidents or other short term occupants, the average hourly flowrate will be used. The average hourly flowrate will be computed based on the actual period of waste generation. For example, 1,000 nonresidents at 30 gallons per capita per day would generate 30,000 gallons in 8 hours for an average hourly flowrate of 3,750 gph

(90,000 gpd). Note that the average daily flow would still be 30,000 gpd, or 30,000 gallons in 24 hours, but the sewer must be designed hydraulically to carry the 30,000 gallons in 8 hours, not 24 hours.

(4) Extreme peak flowrate. Extreme peak rates of flow occur occasionally and must be considered. Sewers will be designed with adequate capacity to handle these extreme peak flowrates. Ratios of extreme peak flowrates at average flows will be calculated with the use of the following equation:

$$r = \frac{C}{Q^{0.167}}$$

where:

r = ratio of extreme peak flowrate to average flow
Q = average daily flow or average hourly flowrate in mgd, gpd, or gph
C = constant, 3.8 for mgd, 38.2 for gpd, or 22.5 for gph

When designing sewers to serve the entire installation, or large areas of the installation, and where a major portion of the wastewater is generated by residents over a 24-hour period, the average daily flow will be used in the formula, and the extreme peak flowrate will be computed by multiplying the average daily flow by the ratio r. However, for sewers serving small areas of the installation where several buildings or a group of buildings are being considered, and where the majority of wastewater is generated by nonresidents or other short term occupants, the average hourly flowrate will be used in the formula, and the extreme peak flowrate will be computed by multiplying the average hourly flowrate by the ratio r.

(5) Peak diurnal flowrate. The peak diurnal flowrate will be taken as one half of the extreme peak flowrate.

c. Infiltration. Extraneous flows from ground water infiltration will enter the sewer system and is to be accounted for by adding 500 to 1,000 gpd/per inch per mile of pipe, to the peak rate of flow. Tests required for newly constructed sewers normally limit leakage to 500 gpd/per inch per mile.

d. Industrial waste flows. Industrial waste quantities cannot be computed totally on a population or fixture unit basis. Industrial waste sewers and sanitary sewers will be designed for the peak industrial flow as determined for the particular industrial process or activity involved.

e. Fixture unit flow. The size of building connections, including those from theaters, cafeterias, clubs, quarters, and other such buildings, will in all cases be large enough to discharge the flow

computed on a fixture unit basis. This requirement applies to building connections only, and not to the lateral or other sewers to which they connect.

3-2. Gravity sewer design. Sewers will be designed to discharge the wastewater flows as required by paragraph 3-1. Generally, it is not desirable to design sewers for full flow, even at peak rates. Trunk and interceptor sewers will be designed to flow at depths not exceeding 90 percent of full depth; laterals and main sewers, 80 percent; and building connections, 70 percent. The minimum sizes to be used are 6-inch for building connections and 8-inch for all other sewers. The following formula, charts, procedures, and criteria will be used for design.

a. Design formula and charts. The Manning formula will be used for design of gravity flow sewers as follows:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where:

V = velocity in fps
n = coefficient of pipe roughness
R = hydraulic radius in feet, and
S = slope of energy grade line in feet per foot

(1) Roughness coefficient. The design of life for the mobilization program is 5 years, and the sewer pipe can be considered new or relatively new during the entire design life of the installation. The roughness coefficient (n) for new pipe for use in the Manning formula will be 0.013 for pipe sizes 12 inches and larger, and 0.014 for pipe sizes 10 inches and smaller. Variation of n with depth of flow has been shown experimentally, and may be considered in designing sewers to flow partially full. Solutions to the Manning formula for full pipe flow is shown in figure 3-1, which will be used in conjunction with figure 3-2 for sewers flowing partially full.

(2) Velocity. Sewers will be designed to provide a minimum velocity of 2.0 fps at the average daily flow, or average hourly flowrate, and a minimum velocity of 2.5 to 3.5 fps at the peak diurnal flowrate, as determined in paragraph 3-1. Maximum velocity is set at 10.0 fps in the event that grit becomes a problem.

(3) Slope. Assuming uniform flow, the value of S in the Manning formula is equivalent to the sewer invert slope. Pipe slopes must be sufficient to provide the required minimum velocities and depths of cover on the pipe.

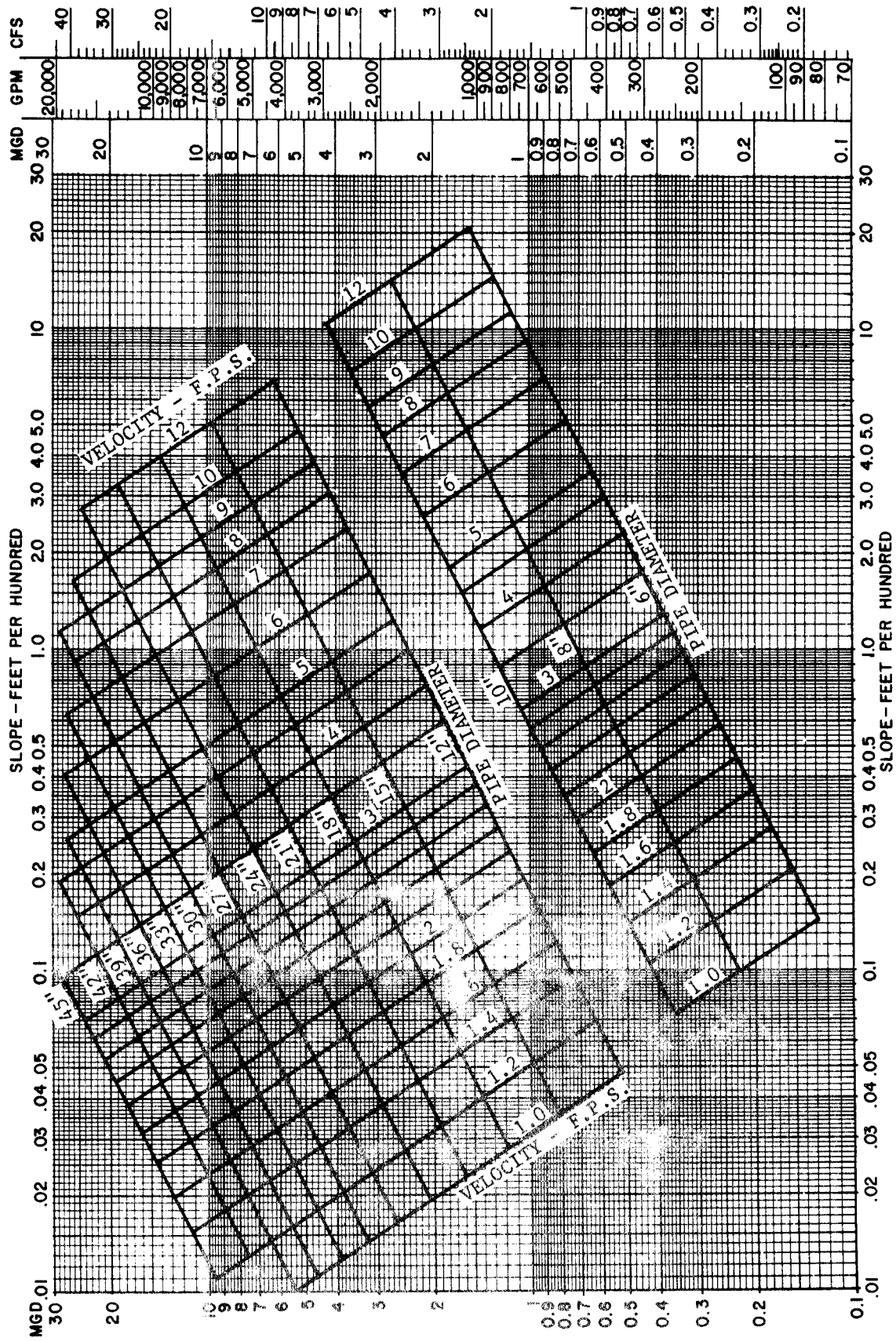

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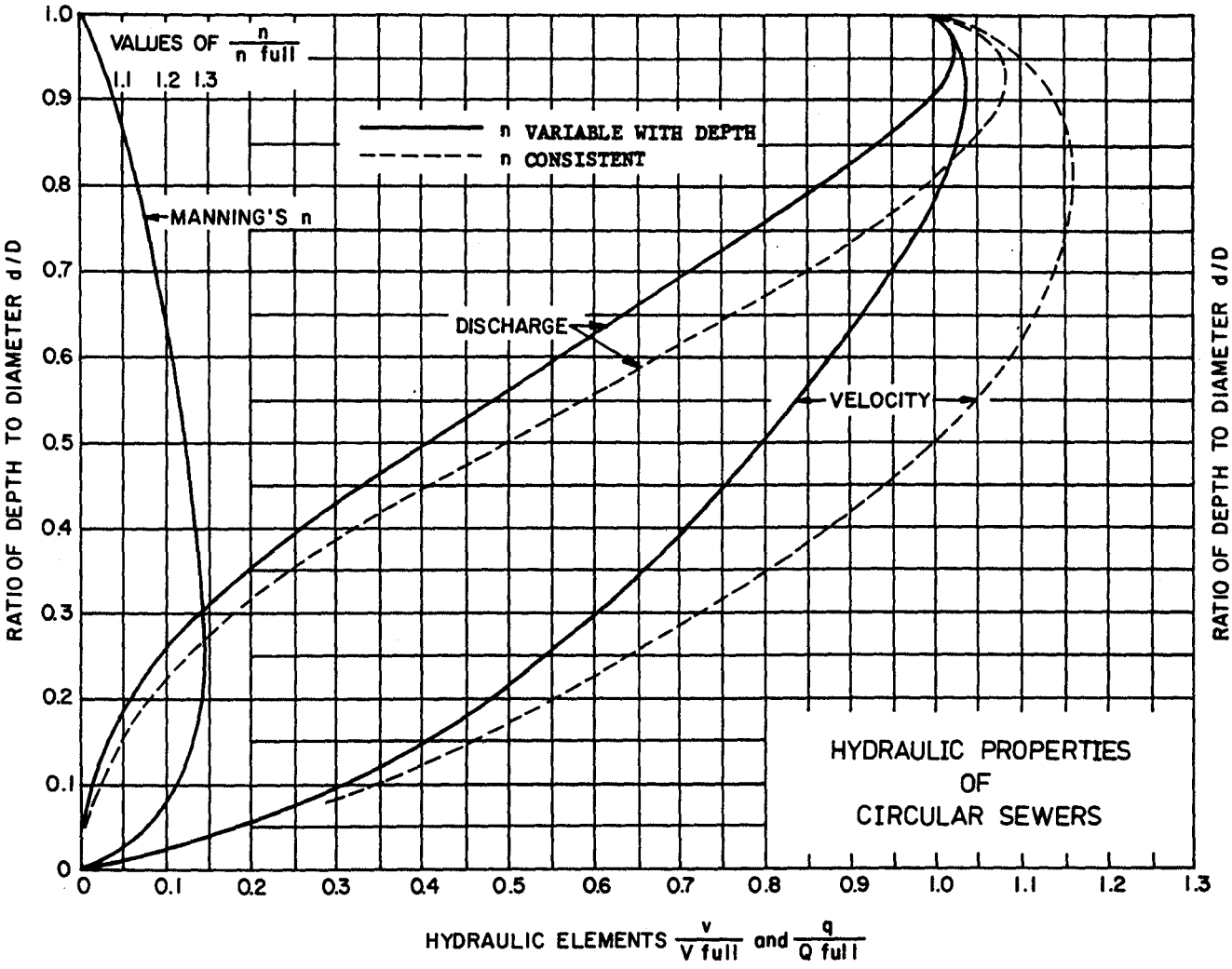
FIGURE 3-1. PIPE FLOW CHART



CLAY PIPE ENGINEERING MANUAL BY NATIONAL CLAY PIPE INSTITUTE, 1982, P. 25.

FIGURE 3-2. HYDRAULIC PROPERTIES OF CIRCULAR SEWERS

(a) Adequate cover must be provided for frost protection. Generally, a minimum 2 feet of earth will be required to protect the sewer against freezing. Where frost penetrates to a considerably greater depth or lasts for an appreciable length of time, greater cover will be required.

(b) Sufficient cover must also be provided to protect the pipe against structural damage due to superimposed surface loadings. Concentrated and uniformly distributed loads are discussed in chapter 5.

b. Design procedure. After a preliminary layout has been made, a tabulation will be prepared setting forth the following information for each sewer section:

(1) Designation of manholes by numerals or letters.

(2) Contributing populations - resident and nonresident.

(3) Design flows - average, daily peak and extreme peak.

(4) Length of sewer.

(5) Invert elevations.

(6) Invert slope or gradient.

(7) Pipe diameter and roughness coefficient.

(8) Flow depths at design flows.

(9) Velocities at design flows.

(10) Depths of cover on the pipe - maximum and minimum.

c. Hydraulic profile. In most situations where small to medium sized gravity sewers are installed in long runs, it will be safe to assume uniform flow throughout the entire length of conduit. However, in cases where larger sewers, 24-inch diameter and above, are constructed in runs of less than 100 feet, and with a number of control sections where nonuniform flow may occur, a plot of the hydraulic profile is recommended.

d. Critical flow. Gravity sewers will ordinarily be designed to maintain subcritical flow conditions in the pipe throughout the normal range of design flows. However, there are exceptions in which supercritical flow may be required, and will be justified. Where supercritical flow will occur, care must be taken in the design to insure that downstream pipe conditions do not induce a hydraulic jump or other flow disturbance. Depths of flow within 10 to 15 percent of

critical depth are likely to be unstable and will be avoided where pipes will flow from 50 to 90 percent full. Critical depths for various flows and pipe diameters can be obtained from standard hydraulics textbooks.

CHAPTER 4

SEWER SYSTEM APPURTENANCES

4-1. Manholes.

a. Requirement. Manholes are required at junctions of gravity sewers and at each change in pipe direction, size or slope, except as noted hereinafter for building connections.

b. Spacing. The distance between manholes must not exceed 400 feet in sewers of less than 18 inches in diameter. For sewers 18 inches in diameter and larger, and for outfalls from wastewater treatment facilities, a spacing of up to 600 feet is allowed provided the velocity is sufficient to prevent sedimentation of solids.

c. Pipe connections. The invert of the outlet pipe from a manhole will be on line with or below the invert of the inlet pipe. When the outlet pipe from a manhole is larger than the largest inlet pipe, the crown of the outlet pipe is to be no higher than the lowest inlet pipe crown. Where the invert of the inlet pipe would be more than 24 inches above the manhole floor, a drop connection will be provided. Typical manholes, dimensions, materials, and methods of construction are shown on Standard Mobilization Drawing No. XEC-001.

d. Frames and covers. Manhole top elevations will be set to avoid submergence of the cover by surface water runoff and ponding. Frames and covers must be sufficient to withstand impact from wheel loads where subject to vehicular traffic.

e. Design standards.

(1) Smooth flow channels will be formed in the manhole bottom. Laying half tile through the manhole, or full pipe with the top of the pipe being broken out later, are acceptable alternatives.

(2) In areas subject to high ground water tables, manholes will be constructed of materials resistant to ground water infiltration.

f. Materials of construction. The primary construction materials to be used for manhole structures are precast concrete sections, prefabricated fiberglass units, cast-in-place, reinforced or nonreinforced concrete and, if necessary, brick masonry. In the past, most manholes were built of brick masonry, and are now frequently the source of significant volumes of ground water infiltration. More recently in attempts to alleviate this problem, precast concrete and fiberglass manholes have been utilized. In certain situations precast units will not be suitable, and cast-in-place reinforced concrete will be required. Cast-in-place construction permits greater flexibility in

the configuration of elements, and by varying reinforcing the strength of similar sized structures can be adjusted to meet requirements.

4-2. Building connections. Building connections will be planned to eliminate as many bends as practical and provide convenience in rodding. Generally, connections to other sewers will be made directly to the pipe with standard fittings rather than through manholes. However, a manhole must be used if the connection is more than 100 feet from the building cleanout.

4-3. Cleanouts. Cleanouts must be installed on all sewer building connections to provide a means for inserting cleaning rods into the underground pipe. An acceptable cleanout will consist of an upturned pipe terminating at, or slightly above, final grade with a plug or cap. Preferably the cleanout pipe will be of the same diameter as the building sewer, and never smaller than 6 inches.

CHAPTER 5

STRUCTURAL DESIGN OF SEWERS

5-1. General. The structural design of a sewer requires that the supporting strength of the pipe as installed must equal or exceed the external loading multiplied by a factor of safety. The following criteria for structural design of sewers are based on the assumption that sewers will be laid in trenches entirely below the natural ground surface and backfilled with suitable materials, that the sides of the trench will be nearly vertical below the top of the pipe and will have slopes no flatter than one horizontal to two vertical above the pipe, and that the trench width at the top of the pipe will be relatively narrow. In general, the trench width will be limited to the maximum allowed or recommended by the pipe manufacturer.

5-2. Loads on sewers. There are three kinds of external loads to which a sewer laid in a trench may be subjected. They are (1) loads due to trench filling materials, (2) uniformly distributed surface loads, such as stockpiled materials or loose fill, and (3) concentrated surface loads, such as those from truck wheels.

a. Trench fill loads. The Marston formula will be used for calculating loads on rigid conduits as shown in the following equation:

$$W_t = C_t w B_t^2$$

where:

W_t = vertical load on conduit in pounds per lineal foot
C_t = trench load coefficient for buried conduits
w = unit weight of trench fill materials in pcf, and
B_t = horizontal width of trench at top of pipe in feet

For calculation of loads on flexible conduits the prism formula will be used as shown in the following equation:

$$W_t = H_w B_c$$

where:

H_w = height of fill from top of pipe to ground surface in feet
B_c = horizontal width or outside diameter of pipe in feet

In the absence of soil density measurements, the weight per cubic foot of various materials may be taken as 120 pounds. The load coefficient C_t is a function of the fill height H divided by the width of trench

B_t, and will be determined from figure 5-1. An examination of the Marston formula will show the importance of the trench being as narrow as practicable at and below the top of the pipe.

b. Uniformly distributed loads. Distributed loads on rigid and flexible conduits will be calculated by the following equation:

$$W_d = C_s p F B_c$$

where:

W_d = vertical load on the conduit in pounds per lineal foot
C_s = surface load coefficient for buried conduits
p = intensity of distributed load in psf
F = impact factor, and
B_c = horizontal width or outside diameter of pipe in feet

The load coefficient C_s is dependent upon the area over which the load p acts. It will be selected from table 5-1 as a function of the area width D and length M, each divided by twice the height of fill H. The impact factor F will be determined with the use of table 5-2.

Table 5-2. Impact Factor (F) vs. Height of Cover

Height of Cover, ft.	Installation Surface Condition			
	Highways	Railways	Runways	Taxiways, Aprons, Hardstands, Run-up Pads
0 to 1	1.50	1.75	1.00	1.50
1 to 2	1.35	*	1.00	**
2 to 3	1.15	*	1.00	**
Over 3'	1.00	*	1.00	**

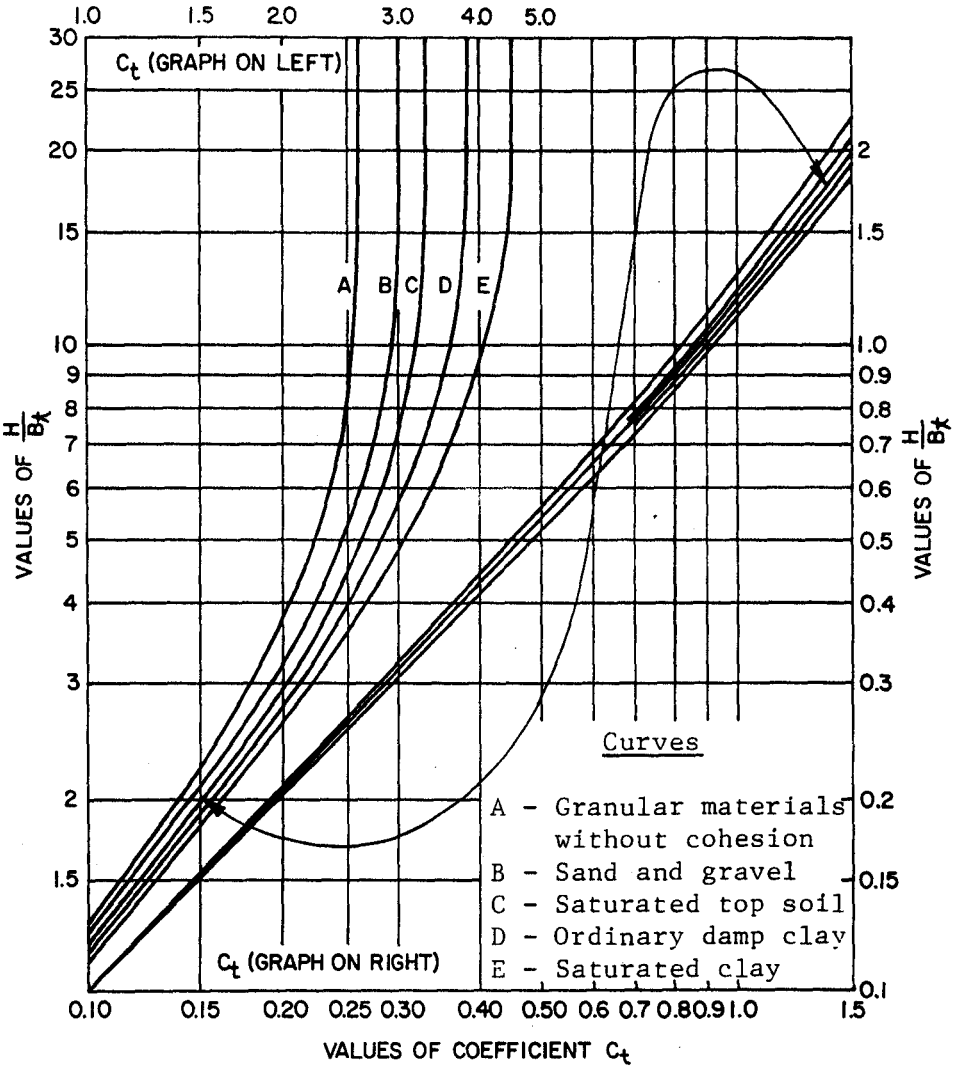
* Refer to data available from American Railway Engineering Association (AREA)
** Refer to data available from Federal Aviation Administration (FAA)

Note that for a static load, F = 1.0.

Source: Handbook of PVC Pipe - Design and Construction by Uni-Bell Plastic Pipe Association, Second edition, 1982, p. 151.

c. Concentrated loads. The formula to be used for calculating concentrated loads on rigid and flexible conduits is given by the following equation:

$$W_c = C_s P F / L$$



DESIGN AND CONSTRUCTION OF SANITARY AND STORM SEWERS - WPCF MANUAL OF PRACTICE NO. 9 BY WATER POLLUTION CONTROL FEDERATION, 1970, P. 189.

FIGURE 5-1. TRENCH LOAD COEFFICIENTS

Table 5-1. Surface Load Coefficient

Values of Load Coefficients, C_s, for Concentrated and Distributed Superimposed Loads Vertically Centered Over Conduit*

$\frac{D}{2H}$ or $\frac{B_c}{2H}$	$\frac{M}{2H}$ or $\frac{L}{2H}$ 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	5.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.128
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.345	0.355	0.360
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.440	0.454	0.460
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.548
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.624
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.584	0.597	0.628	0.650	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.742	0.766	0.784
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.774	0.800	0.816
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.820	0.849	0.868
1.5	0.121	0.238	0.345	0.440	0.525	0.596	0.650	0.703	0.742	0.774	0.820	0.861	0.894	0.916
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.894	0.930	0.956

*Influence coefficients for solution of Holl's and Newmark's integration of the Boussinesq equation for vertical stress.

Source: Design and Construction of Sanitary and Storm Sewers - WPCF Manual of Practice No. 9 by Water Pollution Control Federation, 1970, p. 206.

where:

W_C = vertical load on the conduit in pounds per lineal foot
C_S = surface load coefficient for buried conduits
P = concentrated load in pounds
F = impact factor, and
L = effective length of conduit in feet

An effective length of 3 feet will be used in all cases, except where pipe lengths are less than 3 feet, in which case the actual length of pipe will be used. The load coefficient C_S is a function of conduit width B_C and effective length L, each divided by twice the height of fill H. Determination of the load coefficient will be by the use of table 5-1, and impact factor F will be selected from table 5-2. It will be noted from table 5-2 that the effect of a concentrated or distributed load diminishes rapidly as the amount of cover over the sewer increases.

5-3. Supporting strength of sewers. A sewer's ability to resist external earth and superimposed loads depends not only on the pipe's inherent structural capability, but also on the method of installing the pipe in the trench, i.e., class of bedding, type of backfill materials, percentage of compaction, etc.

a. Rigid conduit. Pipe strength in general will be determined by the three-edge bearing test or TEBT (termed crushing strength in various pipe specifications) and is expressed in pounds per lineal foot. However, since this does not represent the actual field loading conditions, a relationship must be established between calculated load, laboratory test strength and field support strength. The following definitions and terminology will be used to develop field support strength.

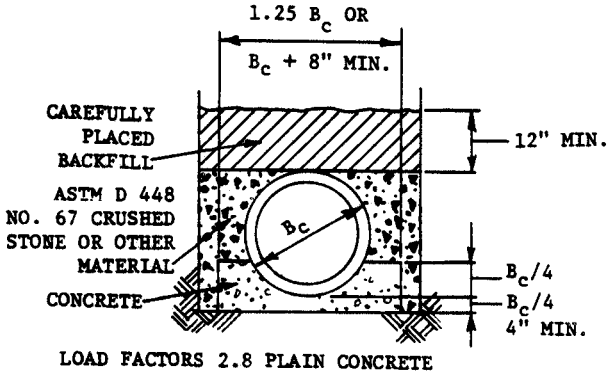
(1) Field support strength is the maximum load in pounds per lineal foot which the pipe will support when installed under specified trench bedding and backfill conditions.

(2) The load factor is the ratio of the field support strength to the three-edge bearing test and will be selected from figure 5-2 depending on the class of bedding used.

(3) Safe supporting strength is the field support strength divided by a factor of safety, equal to 1.5 for rigid conduits.

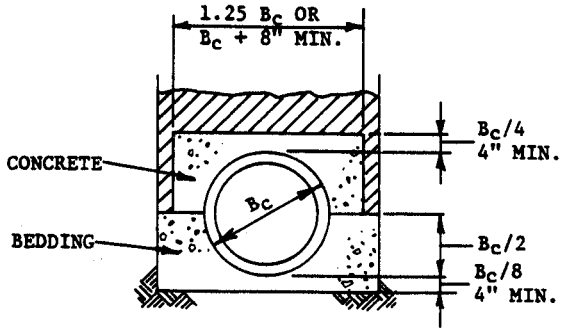
(4) The total load calculated in paragraph 5-2 must not exceed the safe supporting strength.

(5) An additional parameter is the working strength, which is the three-edge bearing strength divided by the factor of safety.



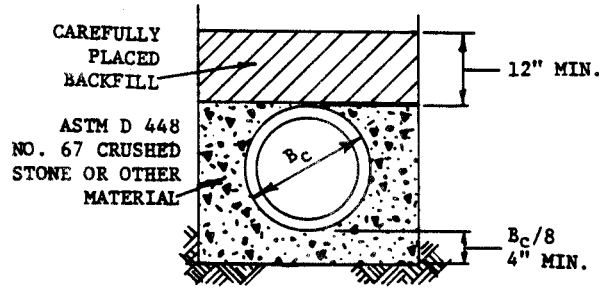
LOAD FACTORS 2.8 PLAIN CONCRETE
3.4 REINFORCED CONCRETE P=0.4% (TRANSVERSE STEEL)

CLASS A-I



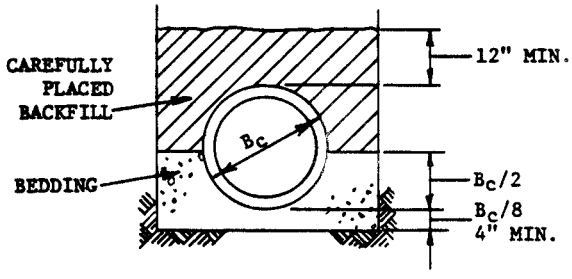
LOAD FACTORS 2.8 PLAIN CONCRETE
3.4 REINFORCED CONCRETE P=0.4% (TRANSVERSE STEEL)

CLASS A-II



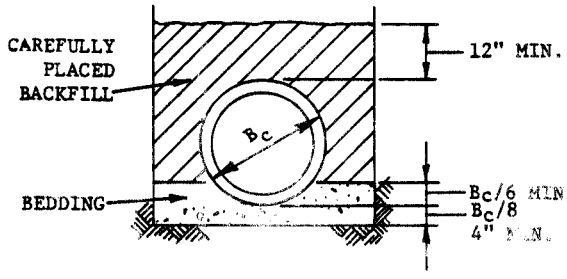
LOAD FACTOR 2.2

CRUSHED STONE ENCASEMENT



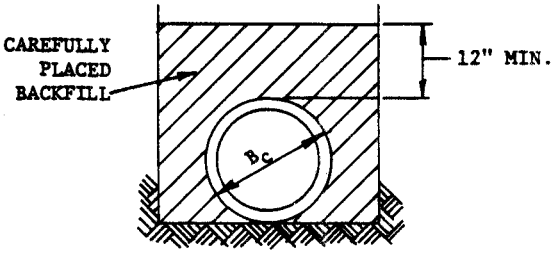
LOAD FACTOR 1.9

CLASS B



LOAD FACTOR 1.5

CLASS C



FLAT OR RESTORED TRENCH BOTTOM
LOAD FACTOR 1.1

CLASS D

LEGEND:
B_c = Outside diameter of pipe
H = Backfill cover above top of pipe
D = Inside diameter of pipe
d = Depth of bedding material below pipe
A = Area of transverse steel in the cradle of arch expressed as 3 percent of the area of concrete at the invert or crown

NOTE: For rock or other incompressible material, the trench should be overexcavated a minimum of 6 inches and refilled with granular material.

CLAY PIPE ENGINEERING MANUAL BY NATIONAL CLAY PIPE INSTITUTE, 1982, P. 52-53.

FIGURE 5-2. LOAD FACTORS AND CLASS OF BEDDING

b. Special rigid conduit testing. For piping not tested and rated by the TEBT method, other strength criteria will be applied as follows. Reinforced concrete pipe strength will be based on D-loads at the 0.01-inch crack load and/or ultimate load as described in the ACPA Concrete Pipe Handbook. For ductile iron pipe, ANSI A21.50 will be used to calculate the required pipe thickness classification in relation to field loadings. The strength of cast iron soil pipe, which normally will be used for building connections only, should be evaluated as outlined in the CISPI Cast Iron Soil Pipe and Fittings Handbook.

c. Flexible conduit. The capability to resist pipe deflection and buckling under loads is the primary criterion used in the structural design of flexible conduit. When loaded the pipe walls will deflect, thereby creating a passive soil support at the sides of the conduit. This pipe-soil system is essential in providing a high effective strength, often enabling it to out perform rigid pipe under identical loading and soil conditions. While the three-edge bearing strength is an appropriate measure of load carrying capacity for rigid conduits, it is not applicable for describing flexible pipe stiffness. Because a flexible conduit must successfully interact with the surrounding soil to support its load, the method of backfill placement, types of materials used, soil compaction, etc., are more critical than trench width or bedding. PVC will be designed as recommended by the manufacturer.

d. Pipe installation.

(1) Bedding. Figure 5-2 depicts various classes of bedding generally used when installing sewers.

(2) Backfill and compaction. Backfill materials and compaction requirements will be included in the specifications. The possible use of locally available materials for backfill will be investigated. Compaction requirements will be designated for the particular soil and moisture content at the site.

(3) Installation manuals. Installation manuals for the particular types of pipe to be specified will be reviewed to ascertain that bedding, backfill, and compaction are adequate for the existing subsurface conditions at the site.

5-4. Special designs. Sewers should be routed to avoid areas where soils investigations indicate poor soil conditions, rock, or rough terrain. In cases where these conditions cannot be avoided, the following special design approaches are to be considered.

a. Unsatisfactory soil conditions. In situations where unstable materials occur at shallow depths, it will generally be acceptable to

overexcavate native soil to just below the trench bottom and replace with a layer of crushed stone, gravel, or other coarse aggregate. Concrete or wooden cradles can be used in lieu of aggregates.

b. Installation in rock. Where sewers must be constructed in rocky terrain, trenches will be sufficiently wide to provide clearance between the sides and bottom of the pipe, and any rock in the trench. Pipe must be installed to avoid all contact with rock, or any other unyielding material in the trench. A granular type bedding or concrete cradle will normally be provided along the pipe bottom, and trenches will be backfilled with satisfactory materials.

c. Aboveground sewers. Sewers are normally laid underground, and at sufficient depths to be protected from impact and freezing. However, in cases where valleys, watercourses, structures, or other obstacles must be crossed, it is sometimes more advantageous to install sewers aboveground. Sewers supported from bridges, piers, suspension cables, or pipe beams, etc., will be designed with adequate structural capability. Protection against freezing and prevention of leakage are important design considerations. Expansion jointing may also be required.

d. Jacking, boring, and tunneling. In situations where sewers must be constructed more than 15 feet below ground surface, through embankments, under railroads, or where surface conditions make it difficult or impractical to excavate open trenches, it will be necessary to install the pipe by other methods. In these cases, pipe may be pushed, jacked, bored, or tunneled into place. A casing pipe will normally be required for sewers installed under railroads, primary access roads and airfield pavements. The void space between the sewer pipe and casing will be filled with special aggregates capable of being blown into place, or with commercially available polyethylene or other type spacers, saddles, and seals. Depending on soil resistance, rigid extra strength pipe can be forced underground by machine for distances of 50 to 150 feet.

CHAPTER 6

SEWER PIPE MATERIALS, FITTINGS, AND JOINTS

6-1. General. Factors which will be considered in the selection of sewer pipe materials and piping systems are:

- Availability of pipe in required sizes, strengths, etc.
- Availability of fittings, connections, and adapters.
- Ease of handling and installation.
- Physical strength.
- Flow characteristics or friction coefficient.
- Joint watertightness and ease of installation.
- Resistance to acids, alkalis, high temperature or corrosive wastes, and corrosive soils.

No pipe manufactured is suitable for all sewer installation requirements and conditions. The pipe materials covered in this chapter are the ones most often used for sanitary and industrial waste sewers. Each type of pipe will be evaluated to determine its suitability for the particular design. Where iron or concrete pipe are to be considered, special attention will be paid to subsurface and soil conditions. The characteristics of the soil in which a pipe is placed affect the rates of corrosion, with the most corrosive soils being those having poor aeration and high values of acidity, electrical conductivity, dissolved salts, and moisture content. The relative potential for corrosion may be estimated by evaluating the degree of corrosion of existing metallic or concrete pipelines previously buried in the soil. Facility engineer personnel will normally have knowledge of these matters. When this information is not available, or is nonconclusive, resistivity tests of the soil will be conducted and results evaluated as required. Pipe materials found inappropriate for use will be deleted from the project specifications.

6-2. Ductile iron.

a. Ductile iron (DI) pipe is utilized for sewers requiring a high resistance to external loading, a high degree of toughness and ductility. It is well suited for most sanitary sewers including river crossings, piping at wastewater treatment facilities, pipe located in unstable soils, highway and rail crossings, water line crossings, depressed sewers and piping aboveground. However, the use of DI pipe is limited somewhat by a susceptibility to corrosion from wastewaters containing acids, and from aggressive soils. DI pipe will normally be

cement lined and can be provided with a bituminous coating inside or a polyethylene lining. Exterior bituminous coatings are standard, and where soil is extremely corrosive, a polyethylene encasement may be required.

b. Pipe is available in diameters 3-inch through 54-inch, and in 18 or 20 foot laying lengths. Allowable trench and superimposed surface loads for DI pipe are computed and tabulated in ANSI A21.50. The ordinary range of loadings can be met without special bedding materials and procedures. The DIPRA Handbook of Ductile Iron Pipe Cast Iron Pipe will be referenced for guidance in designing and installing ductile iron pipe.

6-3. Cast iron soil.

a. Cast iron soil (CIS) pipe will normally be allowed only as an option for buiding connections. CIS pipe is used primarily for building interior drainage, waste and vent piping, as described in chapter 1 of the CISPI Cast Iron Soil Pipe & Fittings Handbook. CIS pipe is resistant to internal and external corrosion when provided with a bituminous coating and is not subject to abrasion from grit, sand, or gravel.

b. CIS pipe is available in 2-inch through 15-inch diameters, in 5 and 10 foot laying lengths, and is manufactured in service (SV) and extra heavy (XH) classifications. Pipe joints will be either compression type using rubber gaskets, or bell and spigot type calked with lead and oakum. Structural design of CIS pipe will be in accordance with the methods outlined in chapter 5 of the CISPI Cast Iron Soil Pipe & Fittings Handbook, with special emphasis given to external loadings and pipe strength.

6-4. Vitrified clay.

a. Vitrified clay (VC) pipe is manufactured from clay and shale products to form an ideal material for sewer use. VC pipe has a high resistance to corrosion from acids and alkalies and resists scouring and erosion well. This provides a distinct advantage in serving as industrial waste sewers, or sanitary sewers subject to hydrogen sulfide generation. It should be noted that availability of some sizes and strength classifications is limited in certain geographical areas. VC pipe is also known for brittleness.

b. VC pipe is available in nominal diameters 4-inch through 42-inch, and laying lengths of 1 to 10 feet. VC pipe is manufactured in standard and extra strength classifications. The NCPI Clay Pipe Engineering Manual provides engineering data to be used in designing clay pipe sewers.

6-5. Concrete.

a. Concrete sewer pipe is appropriate for applications requiring large diameter sizes or high strength characteristics. Care should be taken when specifying concrete pipe to assure that it is suitable for the environment in which it will be installed. Type II A cement, as specified in ASTM C 150, is sufficient for most installations. Type I may be used in certain situations where less than 0.1 percent soluble sulfates (SO_4) occur in the soil, or the wastewater contains less than 150 mg/l sulfates. If the soil contains more than 0.2 percent water soluble sulfates, or the wastewater sulfate concentration exceeds 100 mg/l, Type V cement will be required. Unlined concrete pipe is subject to scouring by wastewaters carrying grit and sand at high velocities.

b. Reinforced concrete (RC) pipe will be used where high external loadings are anticipated and large diameters or tight joints are required. The advantages of RC pipe include a wide range of diameters, 12-inch through 108-inch, and laying lengths, 4 feet to 24 feet, which are available. A disadvantage is the lack of corrosion resistance to acids, especially critical where hydrogen sulfide is generated in substantial quantities. However, special PVC or clay liner plates, coatings of coal-tar, coal-tar epoxy, vinyl, or epoxy mortar can be applied to the pipe for corrosion protection. Nonreinforced concrete sewer pipe is generally available in diameters 4-inch through 30-inch, and in minimum laying lengths of 3 feet. Concrete pipe joints are either bell and spigot type using O-ring gaskets, or tongue and groove type made with cement mortar or bituminous mastic. Design of concrete sewers will be in accordance with the ACPA Concrete Pipe Handbook.

6-6. Asbestos-cement.

a. Asbestos-cement (AC) pipe is made from a mixture of asbestos fibers and portland cement. AC pipe matches the durability of concrete pipe but weighs less and is manufactured in a wide variety of strength classifications and laying lengths. AC pipe will deteriorate in a corrosive environment of hydrogen sulfide, acid wastes or aggressive soils; however some degree of protection can be provided with plastic linings. AC pipe material allowed for sewers will be limited to Type II as recommended in ASTM C 500.

b. For gravity sewers 8-inch in diameter and above, AC pipe is manufactured in five strength classifications conforming to ASTM C 428, namely, Class 1500, 2400, 3300, 4000, and 5000. The class designation refers to the minimum three-edge bearing test strength in pounds per lineal foot of pipe. Classes 1500, 2400, and 3300 are generally available in diameters 8-inch through a maximum of 30-inch, and Classes 4000 and 5000 in diameters 10-inch through 42-inch. Laying lengths normally are 10 and 13 feet. Joints are made with couplings employing rubber ring gaskets.

6-7. Polyvinyl chloride plastic.

a. Polyvinyl chloride (PVC) pipe is chemically inert to most acidic and alkaline wastes, and is totally resistant to biological attack. Since it is a nonconductor, PVC pipe is immune to nearly all types of underground corrosion caused by galvanic or electrochemical reactions, in addition to aggressive soils. Durability, light weight, a high strength-to-weight ratio, long laying lengths, watertight joints and smooth interior surfaces are characteristics which make PVC pipe an attractive alternative for use in sewer systems. Disadvantages include possible chemical instability due to long-term exposure to sunlight, excessive pipe deflection under trench loadings when installed improperly or subjected to high temperature wastes, and brittleness when exposed to very cold temperatures.

b. PVC sewer pipe is available in diameters 4-inch through 24-inch, and in laying lengths of 10 to 20 feet. Pipe dimensions comply with the standard dimension ratio (SDR) system, which means that mechanical properties are constant without regard to pipe sizes. Joints are integral bell and spigot type, and utilize elastomeric gaskets.

c. PVC pipe must be installed to provide continuous passive lateral soil support along the conduit. Manufacturer's design manuals, in addition to the Unibell PPA Handbook of PVC Pipe, will be utilized in checking deflection, backfilling, and trench loads. Allowable pipe deflections will be indicated in the project specifications.

6-8. Acrylonitrile-butadiene-styrene plastic.

a. Acrylonitrile-butadiene-styrene (ABS) composite pipe consists of two concentric thermoplastic tubes integrally connected across the annulus by a truss-like bracing. The annular void space is filled with portland cement concrete, or other suitable material, to form a bond between the inner and outer tubes. ABS composite pipe is termed a "semi-rigid" pipe because it resists deflection better than most other plastics. The pipe is light in weight and resists attack by acids, alkalies, and biological growths. ABS composite pipe is available in diameters 8-inch to 15-inch, and in one laying length of 12.5 feet. ABS pipe is joined by either socket type molded fittings, which are solvent fused to the pipe, or by means of mechanical seal couplings utilizing O-ring gaskets. The solvent welded joints minimize the possibility of poor joint construction, and greatly reduce ground water infiltration. Manufacturer's design and installation manuals will be used for selecting pipe embedment, backfill and compaction requirements.

b. ABS solid wall plastic pipe is manufactured from the same compounds as composite pipe, however, the pipe wall is of one solid material. The pipe is available in diameters 3-inch through 12-inch

and has the same jointing as composite pipe. However, it does not match the stiffness of composite pipe.

6-9. Reinforced plastic mortar.

a. Reinforced plastic mortar pipe (RPMP) is composed of a siliceous sand aggregate reinforced with glass fibers, and embedded in a thermosetting polyester resin. RPMP is ideally suited for large diameter applications, and performs extremely well in resisting pipe wall deflection and internal/external corrosion. The unique fiberglass/resin construction provides optimum protection against attack from a wide range of chemically aggressive environments including hydrogen sulfide and other sewer gases, most natural soils, salt, and brackish water and galvanic or electrolytic reactions. No special coatings or cathodic protection are required. Even though RPMP is officially designated a flexible conduit, its structural integrity is such that for most installations, the trench preparation and backfill requirements are considerably less than with other flexible conduits, and even some rigid ones. Its other advantages include light weight and a smooth, glass-like interior surface.

b. RPMP is available in diameters 8-inch through 144-inch, and in laying lengths of 10, 20, and 40 feet. Joints are bell and spigot type utilizing O-ring gaskets. Manufacturer's design and installation manuals will be used for guidance in selecting appropriate trench and backfilling procedures.

APPENDIX A

REFERENCES

Nongovernment Publications.

American Concrete Pipe Association (ACPA),
8320 Old Courthouse Rd., Vienna, VA 22180

Concrete Pipe Handbook.

American National Standards Institute, Inc. (ANSI),
1430 Broadway, New York, NY 10018

A21.50-1976 Thickness Design of Ductile-Iron Pipe.

American Society for Testing and Materials (ASTM),
1916 Race Street., Philadelphia, PA 19103

C 150-81 Portland Cement.

C 428-81 Asbestos-Cement Nonpressure Sewer Pipe.

C 500-79a Standard Methods of Testing Asbestos-Cement Pipe.

D 448-80 Standard Sizes of Coarse Aggregate for Highway Construction

Cast Iron Soil Pipe Institute (CISPI),
1499 Chain Bridge Rd., Suite 203, McLean, VA 22101

Cast Iron Soil Pipe & Fittings Handbook.

Ductile Iron Pipe Research Association (DIPRA),
1301 West 22nd Street, Suite 509, Oak Brook, IL 60521

Handbook of Ductile Iron Pipe Cast Iron Pipe.

National Clay Pipe Institute (NCPI),
1015 15th Street, NW, Suite 804, Washington, D.C. 20005

Clay Pipe Engineering Manual.

Uni-bell Plastic Pipe Association (PPA)
2655 Villa Creek Drive, Suite 164, Dallas, TX 75234

Handbook of PVC Pipe.