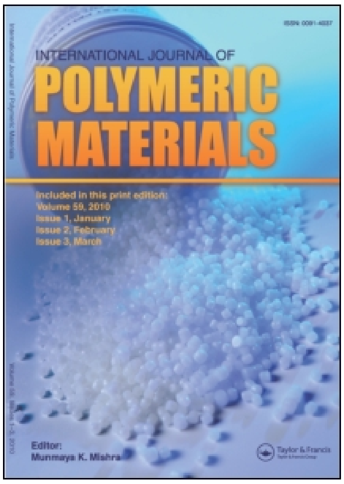

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Plastics in Building

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Although the portion of the total volume represented by plastics in building is small compared to the giants such as concrete, steel, and timber, the rate of increase in the use of plastics in building over the past 20 years exceeds the rate for any other material, and it is probable that the total number of different uses of plastics in building is as large as, if not larger than, that of any other material. The picture is complicated by the fact that plastics are often and increasingly being employed in combination with other materials rather than as pure plastics.

TYPES OF USES

There are many ways of characterizing the uses of plastics in building, but one convenient classification is into:

A) Non-structural

B) Structural and semi-structural

C) Auxiliary to other materials.

NON-STRUCTURAL

The non-structural uses of plastics, that is uses in which they are not subjected to significant or primary load-bearing applications, are by far the largest in volume and the most diverse in the number of different applications. Advantage is taken of the formability and moldability of plastics, the range of colors and textures possible, toughness, lightness, wear resistance, and other attributes as these appear advantageous in a particular application in competition with other materials. It is manifestly impossible to cover the entire range of non-structural applications, but a few of the most important will serve to illustrate.

Floor covering

Floor coverings, based mainly on polyvinyl chloride, coumarene-indene resins and similar polymeric materials, constitute a large and growing application for plastics materials in building. Compounded with fibrous materials such as asbestos, a variety of fillers such as silica and plasticizers as necessary, these materials are calendered or otherwise formed into sheet stock which is applied either in the form of rolls and sheets or cut into smaller squares or rectangles to be applied in the form of tile. The wide variety of colors and textures including imitations of other materials such as brick and terrazzo provide a large number of figures and finishes. The materials have good wear resistance and moderately good indentation resistance if not used at too high temperatures. They can be applied over substrates such as concrete, wood, metal and composition board with a variety of adhesives compounded for the particular application. The flexible flooring market has been largely taken over by these materials (Figure 1).

Wall covering

Interior wall covering is divided principally into two categories: flexible sheet materials and rigid boards. Flexible sheet materials are mainly composed of the flexible forms of polyvinyl chloride with or without supporting

FIGURE 1 Polyvinyl chloride flooring in terrazzo texture. (Armstrong)

backing such as fabric, paper, and felt. As is true of flooring, a wide variety of colors, textures and figures can be imparted to the material during the manufacturing process, and the materials can be applied with suitable adhesives to a variety of substrates such as composition board, gypsum board, plaster, and others. The rigid boards, principally the high-pressure decorative laminates, consist of decorative sheet materials such as printed paper impregnated and overlaid with a layer of transparent melamine formaldehyde and backed with layers of phenolic-impregnated kraft paper, all pressed and fused together at high temperatures and pressures. Similar boards consist of lignocellulose hardboard faced with a melamine-formaldehyde decorative overlay.

Polyvinyl chloride and the acrylics are among the most commonly employed materials for exterior wall covering. Extruded PVC lap siding has become quite familiar and is widely advertised. Other forms in which plastics are employed include flat and contoured sheets or wall panels, thermo-formed sheets, and thin films laminated to a variety of substrates. Evidently, resistance to weathering is of utmost importance. Furthermore, because of their large coefficients of thermal expansion, care must be taken in design to allow for dimension changes (Figure 2).

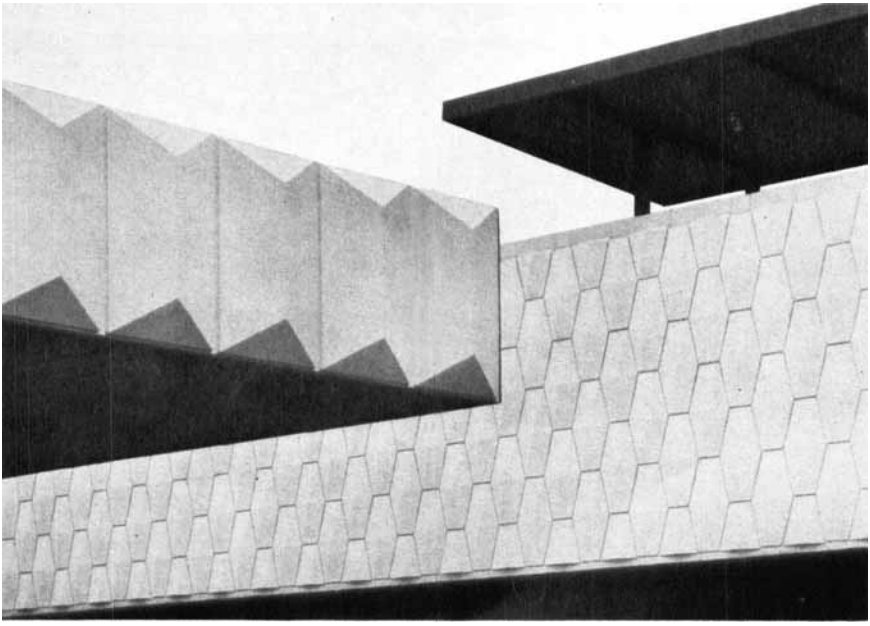

FIGURE 2 Thermo-formed panels for exterior wall covering. (Organa–Bautenschutz)

Roofing

Plastics materials are entering the roofing field mainly in the form of rubbery compounds which can be sprayed or otherwise applied to surfaces such as concrete, metal, and wood, where they polymerize into rubbery adherent membranes. Elastomeric materials entering this field are mainly neoprene, hypalon, and polyurethane compounded with a variety of fillers and stabilizers.

Piping

After a considerable period of experimentation and trial, polyvinyl chloride and ABS are finding increasing acceptance for plumbing lines, particularly drain, vent, and waste, but also for water supply. The principal problem here has been and continues to be the question of whether these materials can withstand the high temperatures and continuous pressures involved in hot water supply lines (Figure 3).

Illumination

The transparent plastics, particularly acrylics and polycarbonate, are widely used for both natural and artificial lighting as well as for illuminated signs. The high degree of light transmission as well as the colorability of these

FIGURE 3 Lightweight plastics water pipe.

plastics with either pigments or dyes recommends them for these applications. Their impact resistance and resistance to breakage is an important factor; for example, for equal thicknesses such as double-strength glass, the acrylics have approximately 20 times the impact resistance of double-strength glass. They can also be fairly readily cast or thermo-formed into curves and shapes such as are used for dome-shaped top lighting in buildings. Finally, they are considerably lighter than glass for equal thickness. On the other hand, they are considerably less scratch and abrasion resistant than glass; their coefficients of thermal expansion are considerably higher and, consequently, must be taken into account to a greater extent than is true of glass; if not properly formulated they may tend to turn yellow with age; and they may tend to craze if not properly fabricated (Figure 4).

Insulation

Many plastics can be foamed readily and some, particularly polystyrene, polyurethane, and, to some extent, polyvinyl chloride, are commonly employed

FIGURE 4 Luminous ceiling of lightweight panels. Counterfront and wall surfacing of high pressure decorative laminates. (Parkwood)

as foams for thermal insulation of buildings. In the approximate range of one to two pounds per cubic foot, they are among the most efficient insulators for buildings. They may be prefoamed in the factory and fabricated into slabs or other shapes; they may consist of expandable beads, as in the case of polystyrene, which can be placed and heated so that they will expand and fill the space to be insulated or, as in the case of polyurethane, they may be mixed liquid and poured into the space to be filled in which they rise to form a foam and harden in place. Foaming in place is particularly advantageous for irregular spaces which are hard to fill otherwise (Figure 5).

FIGURE 5 Foamed polystyrene slabs for insulation and plaster base. (Dow)

Vapor barriers

When concrete slabs are cast directly on the ground, it is frequently necessary to interpose a barrier between the concrete and the soil to prevent water from working through the concrete, which is always somewhat porous, into the space above. Similarly, in insulated spaces it is frequently necessary to prevent vapor from moving into the insulation where it may be chilled and condense if the dew point is reached. Plastic films, particularly polyethylene, are frequently employed as vapor barriers under concrete slabs and, to a lesser extent, in connection with insulation in walls and roofs. Evidently, the degrees of vapor diffusion through the film must be low enough to prevent sufficient passage of vapor to cause condensation (Figure 6).

FIGURE 6 Polyethylene vapor barrier under concrete slab. (Union Carbide)

Hardware

Thermo-setting plastics such as phenolics and ureaformaldehyde, and thermo-plastics such as nylon are fairly extensively employed for a large variety of small hardware parts such as knobs, cams, sliders, gears and rollers. Their ready formability into intricate parts, and the resistance to wear and abrasion of such materials as nylon, combined with colorability and other attributes recommend plastics for these purposes.

Window parts

Plastics alone, or combined with other materials such as steel and wood are being employed in increasing quantities for window frames and window sash. Polyvinyl chloride, for example, may be used alone or formed over a wood or metal core so as to utilize the strength and stiffness of the wood or metal and combine it with the formability, integral color, low thermal coefficient of heat transfer, and resistance to corrosion or decay of the plastic to provide a composite which attempts to take advantage of the best attributes of both materials. A problem that must be kept in mind in designing and fabricating such parts is that the thermal coefficient of expansion of plastics is considerably higher than that of either metal or wood, and with changes in temperature, therefore, the design must be such as to overcome any tendency to crack, buckle or deform otherwise.

Counters, tabletops, and furniture

The high-pressure decorative laminates have become standard materials for these applications in building as well as for other finished items such as the surfaces of flush doors and similar applications (Figure 4).

STRUCTURAL AND SEMI-STRUCTURAL

The moderate strength and generally low stiffness or low modulus of elasticity of most unmodified plastics limits their usefulness in structural and semi-structural applications. For such uses plastics are usually best combined with other materials into composites whose combined properties and behavior frequently transcend the capabilities of the individual constituents acting alone. There are various ways of classifying plastics-based composites, but one convenient classification is into:

A) Fibrous
B) Particulate
C) Laminar.

Additional classifications sometimes include skeletal and flake.

Fibrous composites

Many materials, when drawn into fine fibers, experience a considerable rise in strength as compared with their massive forms. This phenomenon is well known among polymeric materials used for textile fibers, but, perhaps, the outstanding example is glass. In massive form, glass may have a bending strength or modulus of rupture in the vicinity of 5,000 to 6,000 psi, largely controlled by its tensile strength. When drawn into fine fibers, glass may develop strengths in excess of 1,000,000 psi under laboratory conditions. Commercial glass commonly ranges between 400,000 and 700,000 psi. Modulus of elasticity, on the other hand, is not particularly affected by the process of drawing into fibers and remains about the same whether in fibrous or massive form.

For building purposes, the most common fibrous reinforcing material for plastics-based composites is glass. This may be employed in the form of continuous filaments, or the fibers may be chopped into shorter lengths in the form of staple. Continuous filaments, in turn, are frequently gathered into bundles, called rovings, or into finer yarns to be employed for woven fabrics. Staple can also be twisted into yarn. Chopped fiber is most commonly employed in building in the form of a random mat combined with enough binder to hold it together until it can, in turn, be fabricated into a finished part.

By far, the most commonly employed resins for fiber-reinforced plastics are the unsaturated polyesters, although other resins such as the epoxies, polyurethane, and phenolics are employed to a limited extent. Two principal procedures are employed. In the first, layers of mat, or fabric, or both are layed up on a mold and saturated by brushing or spraying or otherwise applying the liquid resin. This may be a simple hand layup on a single male or female mold, it may employ vacuum pressure by means of a flexible bag or membrane surrounding the part to be molded, or it may employ two-part molds in a more or less standard compression molding machine. Which method is employed depends largely on the size of the part and the number of pieces to be fabricated. The second most commonly employed method is the spray-up procedure, in which rovings are fed through a chopper and blown simultaneously with a spray of the resin onto the surface of the mold. Again, the final molding may be on a simple one-part mold, vacuum bag, or in matched molds. Molds may or may not be heated, depending on the speed of production desired and the number of parts to be produced.

Two examples of building components utilizing fiber-reinforced plastics are shown in Figures 7 and 8.

Particulate composites

As the name suggests, particulate composites consist of particles of some kind embedded in a continuous matrix of a plastic material. The most commonly-employed resins are the unsaturated polyesters. For building purposes, perhaps the outstanding example of particulate composites consists of a mixture of mineral aggregate and polyester, the difference between this and portland cement concrete being that the polyester forms the binder rather than portland cement. Since this material is seldom used in large, massive form, but usually in relatively thin plates or molded shells, the aggregate is generally relatively small in diameter, in the nature of a coarse sand. The fabrication process is, in principle, simple. Aggregate and liquid matrix are mixed and poured into a mold or form or, in the case of flat plate, merely cast onto a horizontal table the surface of which has the texture, design or configuration wanted in the surface of the plate. Exposed and colored aggregates may be

FIGURE 7 Market building roof of glass fiber reinforced polyester curved conoids, Argenteuil, France. (Stephane du Chateau)

employed, colors can be incorporated into the matrix, and a variety of configurations, designs, and so forth can be achieved. Once the casting has been made, it is set aside to harden, usually overnight. The following day the part is ready to be fabricated into final form and to be used—unlike portland cement concrete, which normally takes 21 to 28 days for a complete cure to be effected.

Details of this type have been used for facing panels for building, for molded components, and as parts of sandwiches, such as are described below.

Figure 9 illustrates building panels in which the facings are polyester concrete surrounding a core of polyurethane foam.

Laminar composites

In laminar composites, sheets of materials are combined and frequently impregnated with a plastic matrix. For building purposes, the most common examples are the decorative high-pressure laminates. These begin with an overlay sheet, usually a printed paper, but wood veneers, fabrics, and other materials in sheet form may also be employed. The overlay sheet is impregnated with a melamine formaldehyde resin, overlaid with the same material,

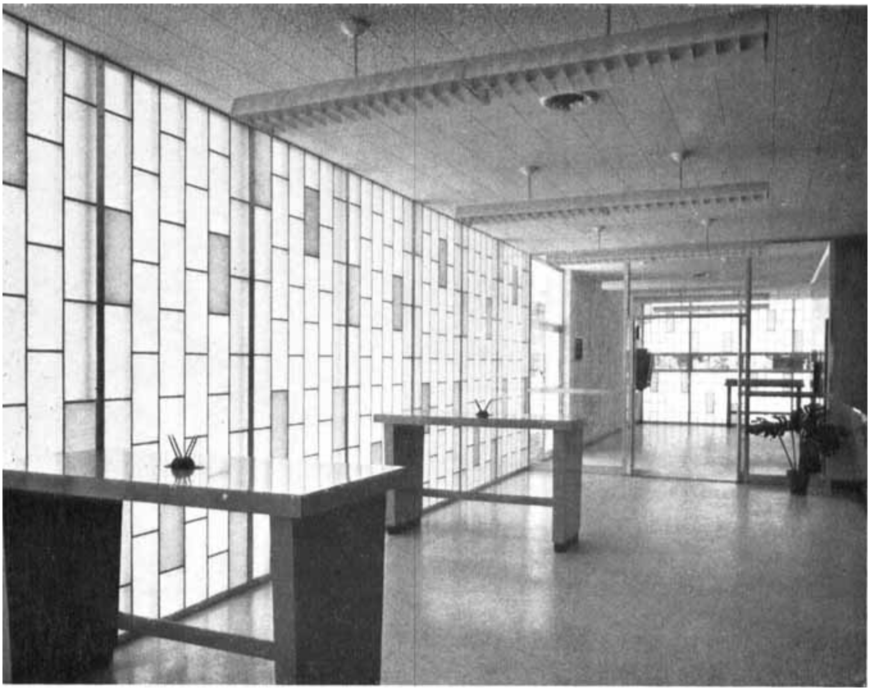

FIGURE 8 Translucent sandwich wall panels with glass fiber reinforced polyester facings on aluminium grid core. (Kalwall)

and backed with several layers of phenolic resin impregnated kraft paper. The assemblage is placed in a hot-plate press and cured at 1,000 to 2,000 psi and temperatures in the vicinity of 300 to 350 F. The final sheet has a decorative surface protected by transparent melamine formaldehyde, and a backup of phenolic kraft paper of sufficient thickness to give it the necessary body. This sheet, in turn, is frequently bonded by means of a suitable adhesive to a substrate such as plywood for use as counter and tabletops and furniture parts. The decorative high-pressure laminates are also employed as surfaces of flush doors, wall covering, and for many other similar purposes.

Mechanical grades of high-pressure laminates, including paper based and fabric based are utilized to some extent for electrical parts, but the principal use of the high-pressure laminates is in the decorative form.

A particularly important special case of laminar composites is represented by structural sandwiches. For building purposes, these customarily consist of two relatively thin, high-strength, high-stiffness facings, combined with a relatively thick low-density, lower strength and low-stiffness core. The combination is light in weight, but the geometry of the sandwich with the

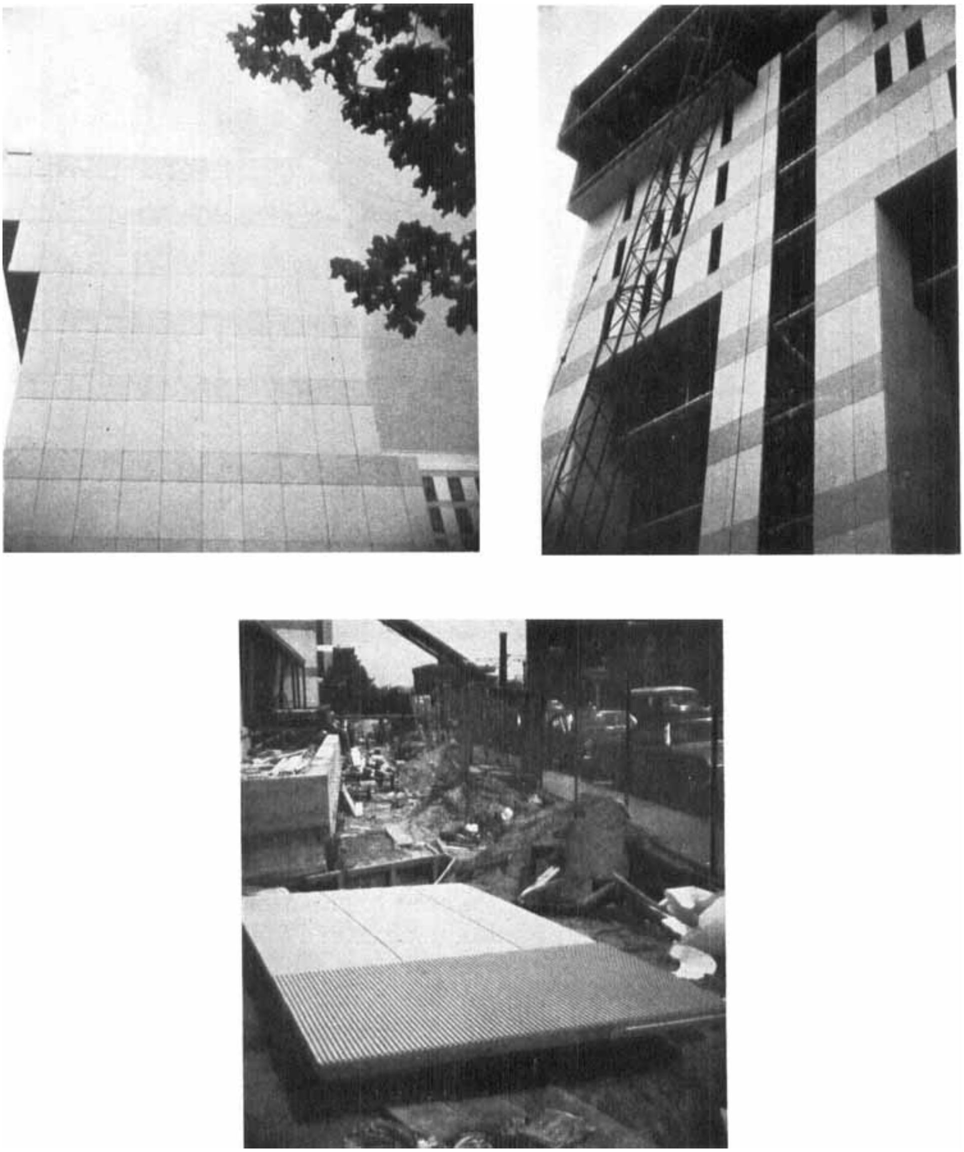

FIGURE 9 Sandwich wall panels with glass fabric reinforced polyester concrete facings and foamed polyurethane core. (top pictures) panels in place (bottom picture) single three-inch thick panel.

high-strength, high-stiffness facings at maximum distance from the neutral axis provides a composite that has high strength and high stiffness with relatively low weight. For building purposes, the facings have the additional functions of resisting weather, resisting internal wear and tear, and providing surface textures and colors. The cores have the additional functions of providing thermal insulation, and the combination of facings and core must provide the necessary acoustical isolation.

Facings of structural sandwich construction include, in addition to such plastics-based materials as high-pressure laminates and reinforced plastics, other materials including plywood, lignocellulose hardboard, steel, aluminum, cement-asbestos board, wood particle board, and other similar materials. The cores based on plastics materials include a variety of foams, particularly polystyrene and polyurethane, a honeycomb configuration of phenolic resin impregnated kraft paper, a variety of reinforced plastics configurations molded for the particular purpose; and, in addition, other materials such as fiberboard, plywood, particle board, mineral wool, glass wool, foamed glass, foamed concrete, and others.

Figures 8 and 10 illustrate applications of different kinds of structural sandwiches in buildings.

AUXILIARIES

Among the principal uses of plastic as auxiliaries to other materials are protective and decorative coatings, adhesives, sealants, high-strength mortars and similar materials, and binders for particle boards.

Coatings

The advent of polymeric materials into the coatings field is causing a considerable revolution. The traditional classifications of paint, varnish, lacquer, and enamel are breaking down and essentially new forms and combinations are appearing. Polymeric vehicles and film formers with increased life plus faster drying and better hardening combined with superior resistance to wear and abrasion are invading the traditional oil-based paints to provide fast-hardening films. Coatings may be applied as liquids or they may be laminated to substrates in the form of films and sheets.

Adhesives

The synthetic resin adhesives have created a revolution in woodworking, particularly as they have made possible completely waterproof and high-strength joints for plywood, laminated structural timbers, and for furniture

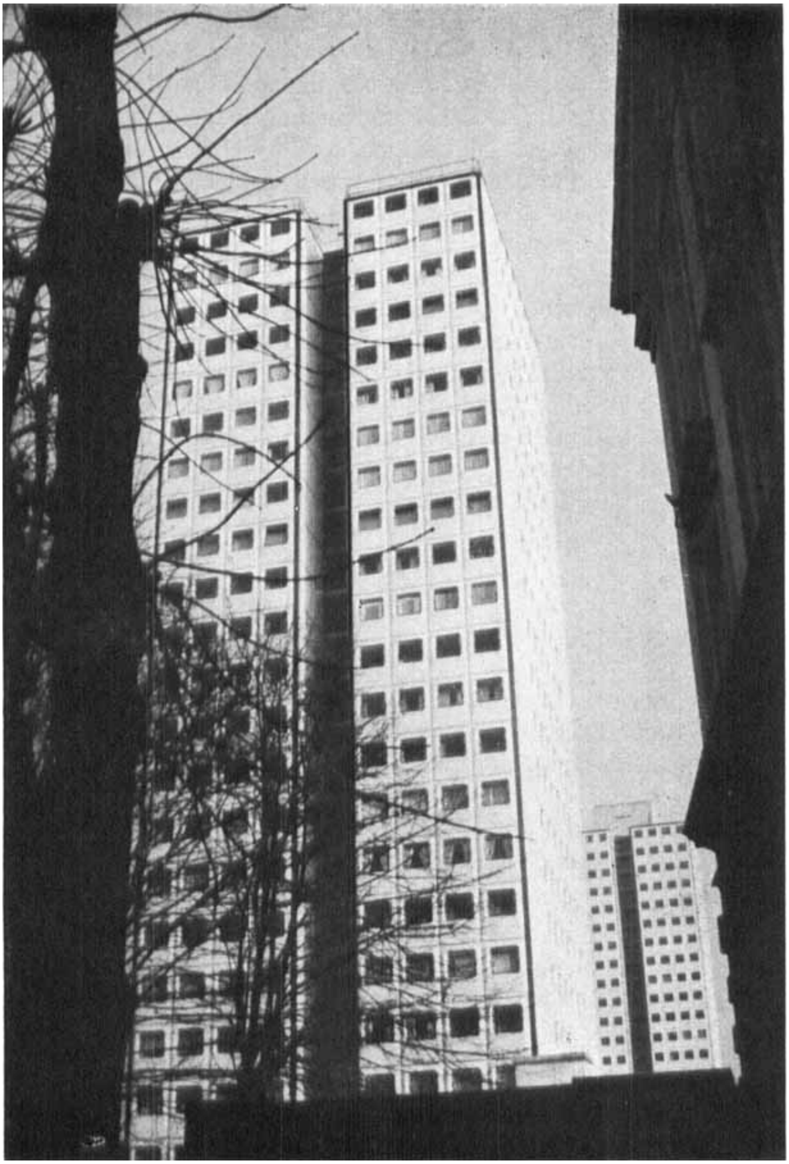

FIGURE 10 Wall panels, apartment building sandwich panels have molded glass fiber reinforced polyester outer facings with baked urethane coating. Core is foamed concrete, and inner facing is reinforced gypsum. (Greater London Council)

and cabinet work generally. Materials other than wood are bonded with high-strength engineering adhesives. Their importance in sandwich construction has already been noted. They are important in the bonding of building components in the shop.

Adhesives for field assembly have so far made little headway. Field conditions are much less suited to the use of adhesives because of temperature fluctuations, extremes of moisture, problematical cleanliness, and the difficulty of obtaining close tolerances in the field. However, the potentialities for the field use of adhesives are large, and they can be expected to expand in the future. Already, big-box components for buildings are being bonded together with adhesives in the field.

The ideal adhesive for use in the field is one which can readily be applied at any temperature, permits the components to be fitted into final position with all necessary adjustments, and can then be made to harden almost instantaneously so as to avoid the necessity of clamps or other holding means for long periods of time.

Sealants

With the marked trend toward industrialization of building components, that is, the production of building components in the shop for assembly at the site, has come the need for reliable means of sealing the joints between such components. The elastomeric polymers have moved into this area as many of the traditional sealing materials have proven inadequate. The requirements are severe. The sealants must provide a weather-tight joint, and must take severe tension, compression, and shear strains as the adjacent components move because of changes in temperature, moisture, and other stresses in the building. They must retain a tenacious bond to the adjacent materials and they must do this under extremes of temperature, moisture, and atmospheric pollution. Among the most commonly employed elastomers for this purpose are the polysulfides, silicones, polyurethanes, and various synthetic rubbers. Many of these are two-component compositions which must be mixed and utilized within a limited time; others are one-component compositions which harden upon exposure to atmospheric constituents such as atmospheric moisture.

Mortar additives

By adding plastics latices to standard mortars, the tensile strength of the mortar and the strength of the bond between mortar and masonry unit such as brick or concrete block can be considerably increased. As a consequence, at least moderate tensile stresses can be applied across such mortar joints, in contrast with conventional mortars, and, as a further consequence, brick walls can be considerably thinner than is ordinarily necessary. Furthermore, such wall panels can be prelaid on the ground or other convenient spot and then hoisted into place, thus minimizing the dependence upon weather and reducing the amount of scaffolding and hoisting equipment necessary with conventional brick laying (Figure 11).

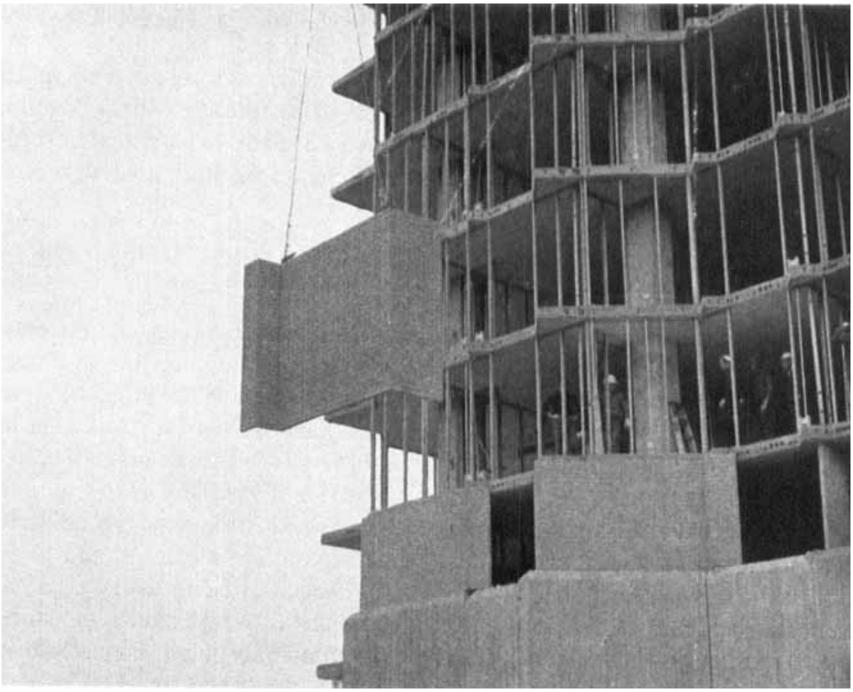

FIGURE 11 Prelaid brick wall panels employing latex-modified high-strength mortar. (Dow)

Similar additives in plaster permit stronger, more tenaciously adhering and thinner applications than are possible with standard materials, at the same time that they accelerate the hardening of the plaster or stucco.

The epoxies have been found useful for the repair of cracks in concrete which otherwise might lead to deterioration, leakage, or both. Such cracks, when properly repaired, have been found to be stronger than the surrounding materials.

Particle boards

Boards made of particles such as wood chips are finding widespread use in building, furniture, and cabinet making. The binders in such boards are customarily ureaformaldehyde if the boards are to be used in protected locations or phenolformaldehyde if they are expected to be exposed to the weather or other more severe conditions.

BUILDING TRENDS

Several trends occurring in building may have a marked influence on the uses of plastics. Among these are large enclosures, air-supported buildings, and the trend toward industrialization.

Large enclosures

These structures are used to enclose large spaces which can provide controlled environments in which subsidiary structures, considerably simpler than those required to withstand outdoor conditions or the extremes of weather, can be built of simpler materials with a considerable degree of freedom. Such large enclosures are exemplified by space frames, shells, and air-supported structures.

An example of a large space-framed shell is the spherical dome erected for the Montreal Fair in 1967 and retained afterwards as a large aviary. It consists of a framework of triangular-pentagonal-hexagonal arrangements of small metal bars to the outer surface of which are attached thermo-formed bubble-shaped acrylic units, gray at the top and changing to clear at the bottom to control solar insolation. The acrylic units withstand the wind loads and transfer them to the space frame. The units are snapped to the frame and sealed with synthetic rubber gaskets (Figure 12).

Such large space frames are becoming more and more common as large enclosures are needed to house activities requiring ample space. Plastics are likely to find extensive use in the skins and in the interior space dividers.

Air-supported structures

Throughout the world there has been a trend toward the use of air-supported structures to enclose large spaces. The membranes employed are either clear plastics or are fabrics such as glass or nylon coated with one of the plastic materials such as polyvinyl chloride. The minimum of material is required, and the pressures needed to hold up membranes against even moderately heavy winds are relatively low. Consequently, large, clear unobstructed spaces can be achieved. The simplest type of air-supported structure is a

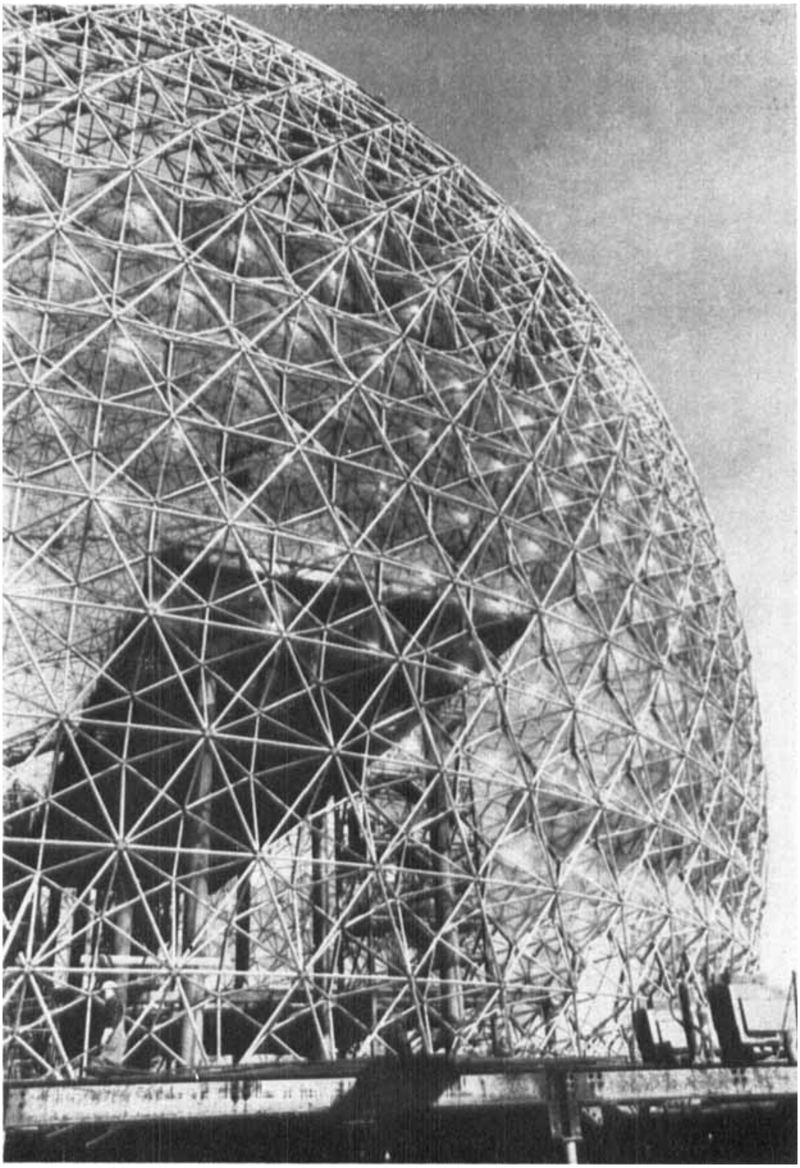

FIGURE 12 Spherical space-framed dome with thermo-formed acrylic facing bubbles, Expo '67, Montreal. (Rohm and Haas)

single membrane held down along its edges to a foundation sufficiently heavy to resist the uplift forces. For very large spans it is frequently necessary to reinforce the membranes with cables (Figure 13).

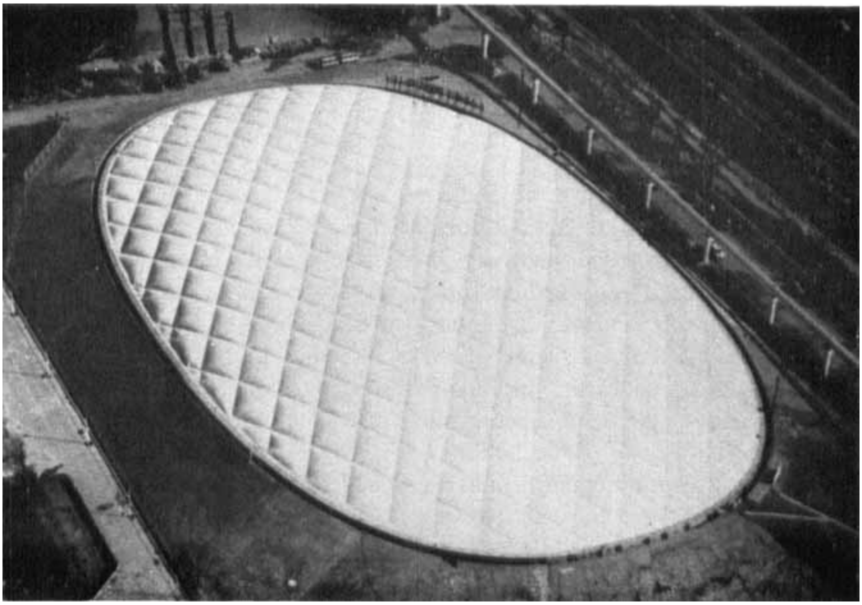

FIGURE 13 Air-supported roof, 250 ft. by 470 ft., of United States Building, Expo '70, Osaka. Roof is coated fabric, held by steel cables to peripheral ring. (David Geiger)

In a second type of structure, a double envelope is used such as an arched circular tube which spans the space involved and is inflated with enough pressure to hold its shape. There is, therefore, no overpressure in the space that is enclosed and it need not be sealed. Other configurations such as quilted membranes and pillows are possible (Figure 14).

Still a third method involves a repeating system of strips of membrane held by small cables which, in turn, are attached to a second set of cables anchored to the ground. By repeating this arrangement, a structure can be extended indefinitely without building up high peripheral uplift stresses (Figure 15).

Industrialization

A major trend in building involves the production of building components in the shop for rapid assembly in the field. Because plastics are pre-eminently materials that lend themselves best to shop production, they should fit in well with this trend. Industrialization, therefore, can be a stimulus to the greater use of plastics in building. Examples of such uses include the prefabricated structural sandwich panels, prefabricated cabinet work, and the trend toward molded bathroom components, in which plastics have made rapid strides (Figure 16).

CONSTRAINTS AND PROBLEMS

Fire

There can be little question that the most serious constraint on the uses of plastics in building is their susceptibility to fire. They are organic materials and, therefore, can be destroyed by hot enough fires. Some do not ignite, some are self-extinguishing and others are slow to fast burning. Fire is, therefore, a limitation and must be kept in mind just as it must be with other combustible building materials. However, the building fraternity feels that the burning characteristics of most traditional materials are well known, whereas there is a great deal of confusion surrounding the behavior of plastics. This may well lead to over-reaction. Obviously, plastics should not be used if their fire susceptibility constitutes a real hazard; but neither should they be

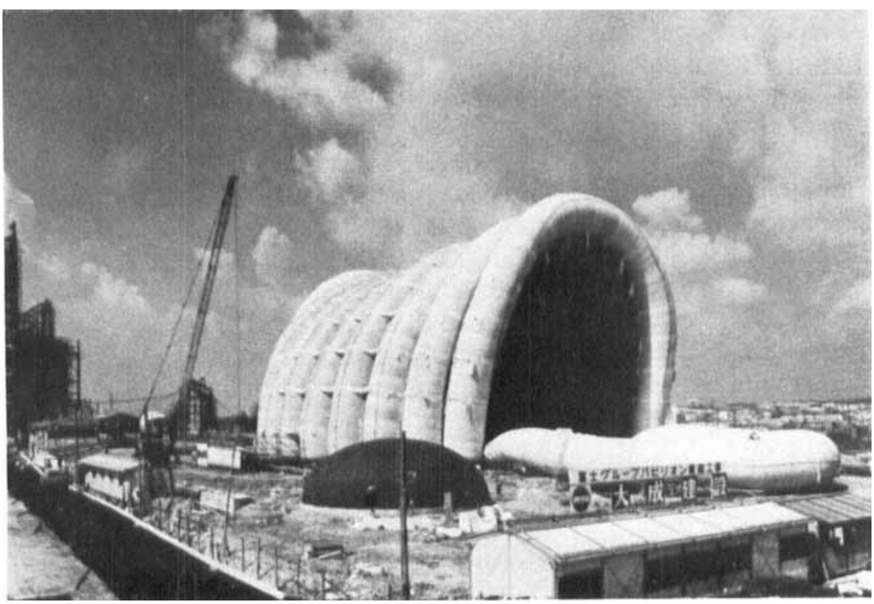

FIGURE 14 Fuji Building, Expo '70, Osaka. Inflated arched tubes form structure. (Taisei)

FIGURE 15 Air-supported structure of transparent plastic strips fastened to primary cables attached to secondary cables anchored to ground. (Goodyear)

excluded if they can be employed as safely as accepted materials. They should, of course, conform to the same safety regulations as are applied to materials generally.

There is considerable confusion and uncertainty respecting fire tests, their adequacy, and how they should be improved. Several types of tests of fire resistance are employed and most of these, quite properly, are used for all materials. The same requirements are equally applicable to all. The one test directly designed for plastics is a flammability test in which a small horizontal bar is exposed to the flame of a Bunsen burner for a specified period of time. From this test, plastics are rated as non-flammable, self-extinguishing, and slow to fast burning.

In the fire endurance test, a specimen of large area is used as a partition in a room-sized furnace. A gas fire of controlled and increasing intensity is applied, and the time required for penetration by fire and smoke is noted, or the rate at which the temperature on the other side of the specimen rises. The time for failure is noted in minutes and hours.

The most widely-used test is the flame-spread test in which the material comprises the roof of a fire brick tunnel, and a gas flame is ignited at one end in contact with the end of the specimen. The rate at which the specimen burns along the length of the chamber is noted and compared with that of

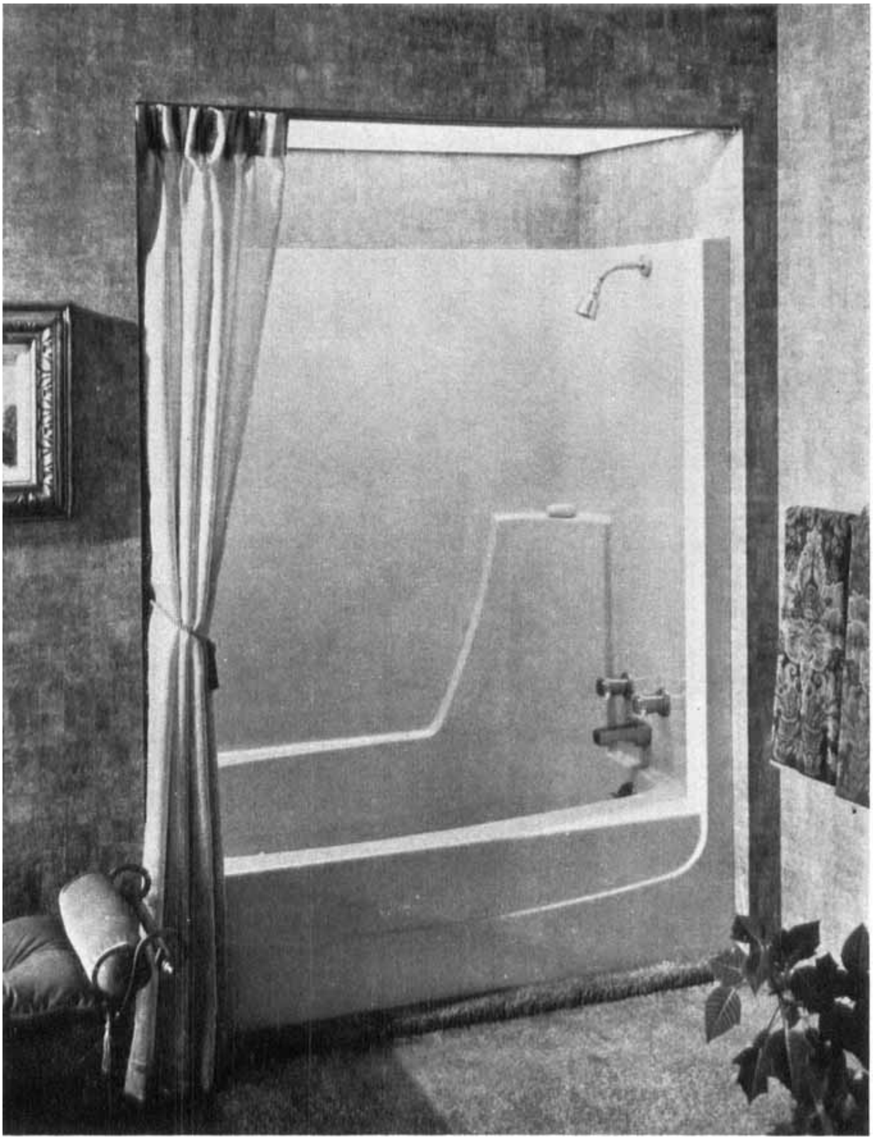

FIGURE 16 Prefabricated combination tub and surrounds of gel-coated glass fiber reinforced polyester. (Owens-Corning)

red oak as a standard. The rate at which smoke is evolved is measured by photo-electric cell and also compared with that of red oak. Using red oak as 100, materials that burn faster or give off more smoke have numbers higher than 100 whereas others are lower. Cement-asbestos board, for example, which does not burn at all, is rated at zero.

Table I gives results of flamespread tests on a selected number of plastics materials. It will be seen that some rate higher than red oak in one or both respects and others rate lower.

Many building codes have restrictions on the uses of materials depending on the flamespread rate, but serious gaps in regulations exist with respect to smoke; and many fire officials feel that smoke is frequently more of a danger than flame. It is because of smoke evolution and uncertainty reflecting quantities of noxious or toxic gases given off by plastics that many fire officials are becoming extremely cautious with respect to plastics and their uses in buildings.

Durability

A major constraint holding back the wider use of plastics in building is uncertainty respecting their durability over the time spans involved in the useful life of buildings. There are still many incompletely answered questions respecting durability. Some plastics have been in use in buildings or similar structures for moderately long periods. Acrylic lighting, for example, has been in use for 25 years or more; and there are instances of polyvinyl chloride exteriors surfaces that are 15 or more years old. Vinyl fluoride film has shown excellent durability under exposure in southern latitudes for 15 or more years. Some glass fiber reinforced plastic building panels are 12 to 15 years old and boats are older than that. On the other hand, there are many examples where plastics have deteriorated badly in a year or two when the wrong material was used in the wrong place.

For interior uses, practically all plastics are durable under normal indoor conditions. There are exceptions such as segregation and cracking of improperly-plasticized upholstery material and wall covering, and the yellowing of unstablized transparent plastics.

Exterior exposure is much more severe than interior, and here plastics must be employed with great caution. Deterioration may or may not be serious depending upon the application. Fading, for example, may or may not be objectionable depending upon whether it is uniform or not. Loss of gloss may or may not be objectionable. Loss of gloss or transparency, or color changes accompanied by crazing, fogging, or bloom may be serious. Actual cracking and disintegration of the material is, of course, serious; it may or may not be catastrophic.

TABLE I

Flamespread tests (ASTM E84)

Underwriters' Laboratories, Building Materials, List, Jan. 1971.

Glass fiber reinforced plastics		Flamespread	Fuel	Smoke Evolution
	1	65	10	over 500
	2	50	—	500
	3	25	—	250
	4	25	—	over 500
	5	30	—	200
	6	55–70	10–15	over 500
	7	30	—	200
	8	20	—	300
	9	35	—	450
	10	65	10	over 500
	11	80	—	300–500
	12	75	15	over 500
	Manufacturers' Data			
A.	1	20	—	860
	2	45	20	170
	3	17	—	760
	4	20	—	635
	5	17	—	920
B.	1	200	64	123
	2	30–75	5–15	200 plus
	3	25	0	over 500
Polyester Concrete				
	(Manufacturer's Data)	3	0	55
High Pressure Laminates				
	Underwriters' Laboratories			
1	Unbonded	20	0	5
2	,,	55–70	5	95–130
3	Bonded to Cement—Asbestos Board	25	0	30
4	,, ,,	75–85	20	20
5	Bonded to Cement—Asbestos Board	15	0	15
5a	Unbonded	30	0	30
6	,,	75	10	95
7	,,	320–350	40–120	200–250
Foam				
	Underwriters' Laboratories			
1	Boards, blocks	10	0	135
2	,, ,,	5	0	50–85
3	,, ,,	25	0	125–165
4	,, ,,	25	0–20	over 500
5	,, ,,	10–25	0	150–450
6	Sprayed on Cement—Asbestos	25	0	150–190
7	,, ,, ,,	30	5	175–200
8	,, ,, ,,	25	0	over 500

Deterioration may be combatted by an understanding of climatic conditions and the selection of the materials suitable for the application. Design should take into account the properties of the materials. For example, the high coefficients of thermal expansion of many plastics materials must be allowed for. Finally, as is true of any material, it is wise to design new and unexplored applications in such a way that they can be easily removed and replaced if necessary without disrupting the rest of the building.

CONCLUSION

It should be evident that there are many uses of plastics in building and that they are growing. It should also be evident that there is a great deal of research and development necessary; first of all, to determine what the properties of plastics should be to meet the requirements of buildings and, secondly, how the plastics should be designed and tailored to meet those requirements. Beginning with the fundamentals of molecular structure, there is a tremendous range of problems calling for solution and requiring the services of theoreticians, resin chemists, engineers, designers, builders, and maintenance crews to utilize plastics in their best and most efficient ways. Intelligently employed, they can take their proper place with older, more traditional materials of construction in the design and production of buildings for the future.