REVISED

BUILDING DIGEST

134

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

PLASTICS AND THEIR APPLICATIONS IN BUILDINGS

Plastics are relatively new as building materials and their properties are very different from those of traditional ones such as concrete and metal. Out of several different types of plastics known today each plastics material has its own particular properties which make it suited to its own particular uses. Success in the use of plastics in building will depend on the correct choice of material and the care with which it is applied.

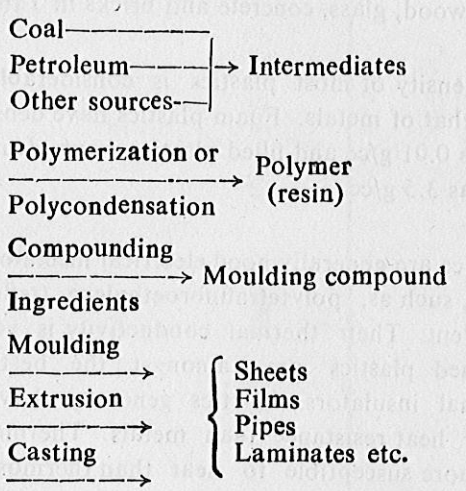
There is a general lack of awareness of the nature and characteristics of plastics and therefore the purpose of this Digest is to describe briefly the properties and applications of these materials in buildings.

In a general sense, the term plastic is applied to any material that can be deformed under stress without losing its cohesion and can retain the new form given to it. Many materials such as clay, mortar, concrete, some metals and glass are plastic under certain conditions but they are not included in the plastics family which consists of organic materials based mainly on carbon compounds. The term is used by the industry to designate materials which consist of organic materials based mainly on carbon compounds. In the engineering sense, a plastic is a mixture containing polymer and various ingredients such as plasticizer, stabilizer, antioxident, pigment, fillers etc. that are fabricated into a finished product.

Although many of the materials we encounter daily such as wood, paper, cotton, leather are polymers, almost all plastics are based on man made polymers. Polymers are large molecules which are manufactured from simple short molecules known as monomers. The monomer units are fitted together in the form of a long claim to produce a polymer molecule. The process by which polymers are produced is called polymerization. If only one kind of monomer is used the resulting polymer is called homopolymer, if two kinds are used, the product is a copolymer.

Depending upon the chemical nature of the monomer, the number of monomer units which go into building a polymer, types of ingredients mixed with the polymer, the arrangement of the atoms in the polymer molecule and the production method, a wide range of plastics with desired combinations of properties are obtained.

A schematic representation showing how plastics are manufactured is given below :



Types of Plastics

Polymer molecules may be linear and chain like, with or without branches or they may be tridimensional network structures resulting from permanent cross-links between the linear chains. Plastics may be broadly classified into two types – the thermoplastic and the thermosetting. Thermo plastics can be repeatedly softened by the application of heat and are usually soluble in specific solvents. Thermosetting plastics on the other hand are infusible and insoluble when finally cured.

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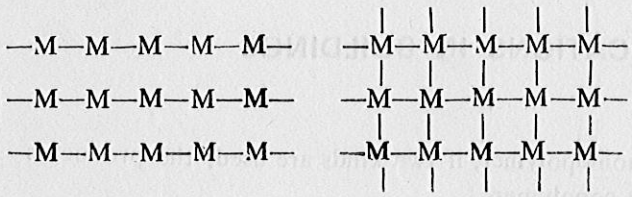
Molecular arrangement in the two types of plastics has been shown below, where M represents a molecule of monomer ;



Thermoplastic Thermosetting

The chains in thermoplastics are free to move apart and slide past one another under the action of heat and pressure whereas in thermosetting material the chains are rigidly held in place by the links between them.

Properties of Plastics

Some important characteristics of plastics have been compared with conventional materials such as steel, wood, glass, concrete and bricks in Table 1.

The density of most plastics is considerably lower than that of metals. Foam plastics have densities as low as 0.01 g/cc and filled plastics have densities as high as 3.5 g/cc.

Plastics are generally good electrical insulators, and some, such as, polytetrafluoroethylene (teflon), are excellent. Their thermal conductivity is very low. Foamed plastics are amongst the best known thermal insulators. Plastics generally have much lower heat resistance than metals. Thermoplastics are more susceptible to heat than thermosets. The maximum use temperature of most plastics is less than 100° C. This is, however, high enough for most building applications.

Plastics have coefficients of thermal expansion considerably higher than those of common metals. Their coefficient of thermal expansion is about ten times that of steel.

Mechanical Behaviour

In comparison with metals plastics have low moduli and high strength to weight ratio. The mechanical properties of polymeric materials are much more dependent on temperature and rate of applications of stress than are those of metals. Plastics are also subject to creep under sustained loads. Articles and structures made from plastics show a wide variation of impact strength, covering the whole range from very tough to very brittle. Reinforced plastics generally show very high strength and stability towards deformation.

Chemical Resistance

Most plastics may be used as corrosion resistant materials. However, care should be exercised in the selection of the best suitable plastic material in specific situations. In general, plastics are resistant to weak acids, weak alkalis, salt solutions and water. Strong oxidizing acids may attack plastics. Most polymers and plastics are affected by organic liquids e.g. fuels, oils and various organic solvents. Resistance to these agents depends on the temperature and the composition of the plastic. Only glass is superior to plastics in overall chemical resistance.

Fire Behaviour

All plastics are combustible but they vary considerably in their resistance to high temperature and fire. In general, thermoplastics are more susceptible to high temperature and fire. Some plastics are self extinguishing like polyvinyl chloride and phenol formaldehyde and others are slow to fast burning. Flamability depends on the polymer and other constituents such as fillers, reinforcements, plasticizers, fire retardent additives etc. The fire resistance properties of plastics can be improved by incorporating appropriate additives or using polymer with built-in fire resistance.

The combustion products of most plastics are similar to those of some natural products like wood, paper and fabrics because these are chemically similar products. For example, with sufficient air the main combustion products of most plastics, woods and fabrics are carbon dioxide and water which are harmless products, but if there is deficiency of oxygen due to poor ventilation large volumes of toxic carbon monoxide and smoke may be produced. If plastics contain combined chlorine, fluorine, nitrogen and sulphur, toxic gases like hydrogenchloride, hydrogencyanide, sulphur

Table 1

Plastics Vs Conventional Materials

Properties	Plastics	Steel	Wood	Glass	Concrete	Bricks
Unit weight g/cc	0.9 — 1.5	7.8	0.1 — 1.1	2.2	2.2	1.6 — 2.2
Tensile strength $kg/cm^2 \times 10^3$	.035— 4	3—24	0.18— 1.0	.071 — .71	.035	.016— .043
Thermal conductivity K Cal/mhr°C	0.1 — 0.3	70	0.1 — 0.3	0.6 — 0.7	1.3—1.6	0.3 — 0.8
Thermal coefficient of expansion of °C $\times 10^{-4}$	3 — 360	11—20	2.0	6 — 102	.015	.002
Average maximum use temperature °C	60 — 120	400—530	100 — 200	180 — 900	200	800

dioxide etc. may also be produced to an harmful level in a oxygen deficient area.

Weathering Behaviour

Plastics being organic in nature are susceptible to deterioration on weathering when used in the exposed situations. The most important elements of weather responsible for causing weathering deterioration of plastics are sunlight, heat and moisture. Other relatively less important factors are oxygen and various pollutants. Sunlight, particularly its ultraviolet component is the most significant factor in the breakdown and colour change of plastics. Indoor exposure offers partial protection but natural diffused light and artificial light, warmth and moisture may affect the material.

Plastics vary widely in their resistance to outdoor weathering. Some plastics have displayed good weather resistance e.g. polymethyl methacrylate, phenol formaldehyde, epoxy whereas some may show poor weather resistance e.g. unprotected polyethylene, polypropylene, polyvinyl chloride etc. Most commercial plastics, however, can now be formulated to have fairly good weathering resistance by incorporating into them ultraviolet absorbers, various pigments and fillers etc.

Appearance

Many polymers are inherently transparent, some are translucent, a few opaque. Polymers and plastics can be rendered translucent or opaque by incorporation of appropriate amounts of pigments or fillers.

A few important characteristics of individual plastics, both thermoplastics and thermosettings, have been listed in Table 2 and 3.

Applications of Plastics in Buildings

Out of about forty different groups of plastics known today, there are only a dozen of plastics which are of great importance to building industry. These have been listed in Table 4. Plastics are used in several applications in buildings such as decorative laminates for table tops; roof lighting and glazing sheets; bath tubs, terrace roofing and canopies; flooring and walling materials; hardware items; pipes and fittings, sanitary wares, thermal insulating materials; surface coatings and adhesives; moisture barrier films; electrical conduits, fitttngs and fixtures etc. Different building applications and the plastics most commonly used in these applications have been summarized in Table 5.

Use of plastics materials in a number of applications can replace conventional materials especially in such areas where scarce metals like copper, brass and even galvanized steel are used saving considerable amount of foreign exchange component involved. Frequent thefts of metallic parts is also a serious drawback.

Plastic pipes are considerably economical compared to conventional metal pipes. In addition they are lightweight, free from corrosion and incrustation and requiring easy installation and maintenance. Plastic piping systems have been used satisfactorily in a number of water supply schemes throughout the country. Termites and Rodents do not pose any serious threat to plastic pipes.

Hardware items like window stays and handles in polypropylene are commercially available and finding acceptance in the building industry. Flushing cisterns in high impact polystyrene and polypropylene, overhead water storage tanks in polyethylene and saw dust filled polyvinyl chloride door and window frames are further applications where plastics can economically replace metals with the added advantage of freedom from some of the inherent drawbacks of metals like corrosion, incrustation etc.

In certain other applications plastics could be used in buildings with some added advantage but on higher initial cost. For example, roof lighting and glazing sheets in glass fibre reinforced polyester will allow natural light to come in and thus causing saving in electricity. Their use in schools, hospitals and other public buildings could be justified on the basis of non-breaking character of these materials compared to glass which will shatter into pieces due to vandalism. Other examples are use of polyvinylchloride tiles and epoxy resins in industrial walling and flooring to provide very good chemical resistance which is not generally provided by conventional materials. Also their light weight may provide some saving in cost of foundation.

Table 2

Important Properties of Some Major Thermoplastics (Unfilled or Unreinforced)

Name of Thermoplastic	Tensile strength kg/cm²	Elongation per cent	Tensile modulus $\times 10^3$ kg/cm²	Deflection Temperature °C, at 18.5 kg/cm²	Water Absorption (in 24 hours per cent
Polyethylene					
(i) Low density	45—250	90—800	1—4	32—49	< 0.02
(ii) High density	220—400	20—1000	4—13	43—54	< 0.01
Polypropylene	300—400	200—700	11—16	51—60	< 0.01
Polyvinyl chloride					
(i) Rigid	360—640	2—40	25—43	54—80	0.07—0.40
(ii) Flexible	100—250	200—450	—	—	0.15—0.75
Polystyrene*	360—850	1—2.5	30—43	105	0.03—0.10
Polymethyl methacrylate	500—900	2—10	25—34	70—100	0.1 —0.4

*General Purpose

Table 3

Important Properties of Some Major Thermosetting Plastics (Filled or Reinforced)

Thermosetting material	Tensile strength kg/cm^2	Elongation per cent	Tensile modulus $\times 10^3$, kg/cm^2	Resistance to Heat (continuous) °C	Water Absorption (in 24 hrs) per cent
Epoxy* (Moulding compounds)	715—2145	4.0	217	150 — 250	0.05—0.20
Unsaturated Polyester	285—3570	0.5—5.0	57—320	150 — 175	0.01—1.00
Phenol formaldehyde (cast resin)	285—640	—	134	70 — 150	0.12—0.36
Urea formaldehyde (Moulding compounds)	400—930	0.5—1.0	70—100	75	0.40—0.80
Melamine Formaldehyde (Moulding Compounds)	357—930	0.3—0.9	80—170	100 — 200	0.08—0.80

*Glass Fibre filled

Table 4

Main Plastics for Usage in Buildings

Name of Plastics	Abbreviation
Polyethylene	PE
Polyvinyl chloride	PVC
Polystyrene	PS
Polypropylene	PP
Polymethyl methacrylete	PMMA
Polyvinyl acetate	PVA
Melamine formaldehyde	MF
Urea formaldelyde	UF
Phenol formaldehyde	PF
Polyester	PEs
Epoxy	EP
Polyurethene	PU
Acrylonitrile butadiene styrene	ABS
Glass fibre reinforced polyester	GRP

Indian Plastics Industry

Indian plastics industry made a modest start in 1926 with the manufacture of combs, soap boxes, ash trays and other domestic products from imported celluloid sheets and rods. It was only after the World War II that the Indian plastics industry began to make rapid progress. Phenolformaldehyde was produced in the country for the first time in 1946. Production of some high tonnage and bulk plastics like polystyrene and polyethylene started in the late fifties. In sixties, the developments were pretty fast and the manufacture of polyvinylchloride, urea formaldehyde, melamine formaldehyde and polyesters took place for the first time in the country. Today almost all the major plastics raw materials and a number of consumer products are produced in the country.

Table 5

Plastics Vs Building Application

Applications	Type of Plastics
Decorative Laminates	PF, UF, MF
Flooring Materials	PVC, PU, EP, PEs
Glazing and Roof Lighting	PMMA, GRP
Thermal Insulation	PU, PS
Lighting fixtures and fittings	PMMA, PVC, PS, PF
Panells, Siding and Wall covering	GRP, PVC, PMMA, PS
Electrical conduits	PVC, PE
Pipes and fittings	PVC, PE
Plumbing and Bath Fixtures	GRP, PMMA, PS, ABS
Resin Bonded Boards	PF, UF, MF
Water vapour Barrier films	PE, PVC
Building Hardwares	PP, ABS, UF, PF

Plastics for Rural Development

Plastics can be used in a number of applications for rural development in the fields of agriculture, canal lining, packaging, food grain storage and water management. Plastic piping systems are being used in a number of rural water supply schemes. Polyvinyl chloride CAPs have been used for food grain storage. Plastic films have been used in canal lining to check water seepage. Other important applications of plastics are use of plastic pipes for drip irrigation, polyethylene films for mulching and use of plastics in gobar gas plant. Plastics have also been used in low cost housing in some countries e.g. Jute/Polyester composites and roofing sheets from agricultural fibres and resins.

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need, this Institute is bringing out a series of Building Digests from time to time and the present one is the 134th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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