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Plastics in Glazing and Lighting Applications

Please note

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Certain plastics are attractive materials for use in glazing and lighting applications because of their light weight, ease of handling and installation, high light transmission and better shatter resistance than glass. Greater freedom of design is another advantage that plastic has over glass: it frees the designer from the restriction of flat window surfaces and permits curved or formed windows. Although plastic glazing is usually more costly initially than glass, repeated replacement of glass with break-resistant plastic glazing makes it more economical and safer.

General Properties

Some of the general properties that make plastics unique as glazing materials are:

Optical properties. -- Both thermoplastics and thermosetting plastics may be highly transparent, opaque, or have any degree of clarity and light transmission in between. The total solar energy transmission may run as high as 90% with 92-93 in the visible region (400 to 750 nm).

Transmission in the visible, ultraviolet (UV) and infrared (IR) is a variable (depending on the wavelength) and can be controlled to a large extent by composition. Thus the UV transmission can be made high to achieve beneficial effects such as killing germs, or it may be cut off entirely by using UV absorbing additives to reduce deterioration of the plastic. Similarly a substantial portion of the heat-inducing In light can be either transmitted or absorbed, depending on the composition. Like glass, most clear plastics used as glazing provide a 'greenhouse effect' because the solar radiation that is converted to heat in an enclosure is not transmitted back to the exterior. Soils, plants and frames inside the greenhouse absorb this radiation during the day, and reradiate it as heat energy at night. The enclosure (glass or plastic) blocks the passage of the IR radiation to the outside air, thus providing a small but significant source of heat and reducing the cost of the operation. Since clear plastics transmit approximately as much solar radiation as glass and also retain heat, their use as green- house enclosure material is widespread.

Formability. -- Plastics offer great possibilities for design. They are easily and economically formed in two and three dimensions to almost any desired shape for complete integration with the building design.

Impact Resistance. -- As plastics have an impact resistance greater than glass, they are recommended for applications where resistance to shattering or vibration is required. Although some plastics have good impact resistance (Table 1), they are not unbreakable. A hard blow, e.g., a thrown brick, can cause breakage but plastic glazing breaks into large, dull-edged pieces rather than the sharp fragments that may fly from a smashed glass window. Moreover, the light weight of the plastic imparts little momentum to the broken pieces so the injury hazard is greatly reduced. The USA standard on safety glazing materials[1] the use of plastics in applications previously reserved for tempered glass, wire-reinforced glass, or laminated safety glass, e.g., in hazardous locations in new residential, commercial and public buildings. The latest Canadian national standard for safety plastic glazing is CAN 2-12.12-M79.[2]

Table 1. Typical properties* of plastic glazing materials compared with glass.

Glazing Material	Specific Gravity (ASTM D792)	Coeffient of Thermal Expansion (ASTM D696) 10^{-5}/°C	Visible Light Transmission	Tensile Strength (ASTM D638), MPa	Impact Strength (notched specimen), J/M (ASTM D256, Izod test)	Flexural Modulus (ASTM D790), GPa
PMMA (acrylic)	1.19	3.1	91-93	72	21-27	2.4-3.4
Polycarbonate	3.8	3.8	82-89	62-72	640-860	2.2-2.6
GRP**	1.40-1.60	3.4-4.4	76-85	76-117	430-1070	50-100
PVC**	1.30-1.40	5.0-10	76-89	38-62	13-64	2.60-3.7
Sheet glass (Soda-lime glass)	2.46-2.49	0.85	88-90	--	brittle	--

* As the materials produced by various manufacturers differ, these data should be regarded as guides only.
** Transparent and translucent glazing sheet containing 25-35 weight per cent of glass reinforcement in the form of chopped strand mat.

Common Plastic Glazing Materials

The most common plastics used in light transmitting applications are acrylics, polycarbonate (PC), poly(vinyl chloride) (PVC) and glass fibre reinforced polyester (GRP). Typical properties of the major glazing materials are given in Table 1.

Acrylics. -- This term refers to a family of plastics (**CBD 158**), the most important and widely used being poly(methyl methacrylate) (PMMA). PMMA sheet, one of the most weather-resistant plastics,[3] produced worldwide under several proprietary names, e.g. Lucite, Plexiglas, Perspex, and Oroglas. Acrylic plastics used for light transmission applications are made by the cell casting process. In this method, catalyzed methyl methacrylate monomer syrup is cast between plate glass cells and cured by heating up to 120øC (248°F). Cell cast sheet is considered to provide the best over-all properties of all the forms of acrylic sheet, especially optical clarity.

PMMA and other acrylics have good resistance to many chemicals, including salt spray or corrosive atmospheres but are attacked by aromatic and chlorinated hydrocarbons, esters, ketones and ethers. PMMA is used for glazing in industrial plants, schools and other institutional buildings where high breakage rate (usually caused by vandalism) makes use of glass costly. Hazardous locations are glazed with PMMA sheet to meet the requirements of safety glazing legislation. PMMA glazing has long been used in military and commercial aircraft. Tinted acrylic sheet can be used to reduce solar heat gain through windows.

Acrylic is being used increasingly in buildings for skylights, large area enclosures for shopping centres, restaurants and swimming pools.

Polycarbonate (PC). -- The standard grades of PC have relatively high modulus of elasticity, dimensional stability, strain resistance, low water absorption and high impact resistance (Table 1). Its relatively high light transmission (82 to 89 %) and high impact resistance make PC suitable for difficult applications, including security glazing, light transmitting doors, partitions and skylights, windows in schools, hospitals, industrial plants, decorative store fronts and in buildings having a high rate of breakage, light transmitting shields for equipment, and in youth camp buildings. Because of its resistance to heat, relatively good weathering and transparency, PC is being used more and more in commercial and residential lighting applications. Examples of such uses include street light globes, airport lighting, highway diffusers, home light fixtures and patio lights.

Polycarbonate sheet used for outdoor applications is stabilized against the effects of sunlight. Prolonged exposure to the outdoor environment, however, causes yellowing of the sheet and formation of surface microcracks on the front side. This results in considerable reduction in impact strength.

Glass Fibre Reinforced Polyester (GRP). -- GRP consists of thermosetting polyester resin (**CBD 159**, **CBD 205**) reinforced usually with 25 to 35 weight per cent glass fibres. The glass fibre reinforcement in the general purpose material used for light transmission applications is usually in the form of chopped strand mat. Low cost and useful properties, including light weight, high light transmission (up to 85%), toughness and good impact over a wide range of temperature, make GRP sheeting a popular material for glazing and lighting applications.

Transparent and translucent GRP panels (usually corrugated) are used in many light transmission applications, including glazing for skylights, luminous ceiling or roofing, inner partitions, railway stations, sport arenas, swimming pools and agricultural buildings. A special grade of GRP sheeting has been developed for use as glazing in flat-plate solar collectors.[3] Although the GRP material for outdoor service is stabilized against the harmful effects of the ultraviolet (UV) portion of solar radiation, current commercial products still deteriorate under the influence of the weather. The deterioration results in discoloration, fibre pop out, surface microcracking, reduced light transmission, and increased brittleness. The length of satisfactory performance depends on the formulation, degree of stabilization, methods of manufacture and nature of surface finish.

Poly(vinyl chloride) (PVC). -- PVC is the most economical of plastics. Rigid PVC is available as extruded flat and corrugated sheets in transparent and translucent grades. Clear PVC is less weather resistant than polycarbonate and considerably less weather resistant than acrylics. An array of colours adds to its versatility from a decorative point of view and also as a control of daylight utilization. Glazing and lighting applications include skylights and roofing, closed-in tennis courts and swimming pools, beach houses, and awnings. Vacuum forming of vinyl sheeting adds to the variety of applications, e.g., industrial glazing and textured light diffusers.

Durability

The optical properties of plastics deteriorate through loss of surface quality, discoloration of the resin, or change of colour of added pigments or dyes. Loss of surface quality can be caused by scratching during service or by several types of surface deterioration caused by exposure to the environment. Scratching is the predominant surface damage of plastic sheets not subjected to outdoor weathering. Scratches are caused by airborne particles whose hardness is greater than the plastics used in glazing or lighting applications. During cleaning operations hard particles may also cause scratches.

Many attempts have been made to harden the surface of plastics. They usually involve the application of a thin layer of a hard, transparent material, e.g., silica or quartz, or a film or coating of silicone or melamine polymer. The use of such coatings or films is limited by the methods of application and the incompatibility of their properties of stiffness, brittleness and thermal coefficients of expansion with those of the plastic substrate.

Natural weathering often causes deterioration of optical properties through discoloration, pitting, crazing or microcracking, surface erosion, exudation or leaching of ingredients, fibre pop out (in GRP) and chemical and/or photochemical degradation. Figure 1 illustrates the effect of outdoor weathering on the light transmittance of the three most common plastics used in glazing and lighting applications. Weathering has little effect on the visible light transmission of PMMA as shown by the 11-1/2-year old glazing in the outer pane of an exterior window. Commercial polycarbonate glazing under similar conditions and for the same duration had a moderate reduction in visible light transmission. The light transmission of a translucent GRP sheet exposed outdoors (45°, facing south) was considerably reduced. Mechanical properties, e.g. tensile strength and impact resistance, of many plastics deteriorate when subjected to prolonged outdoor exposure.

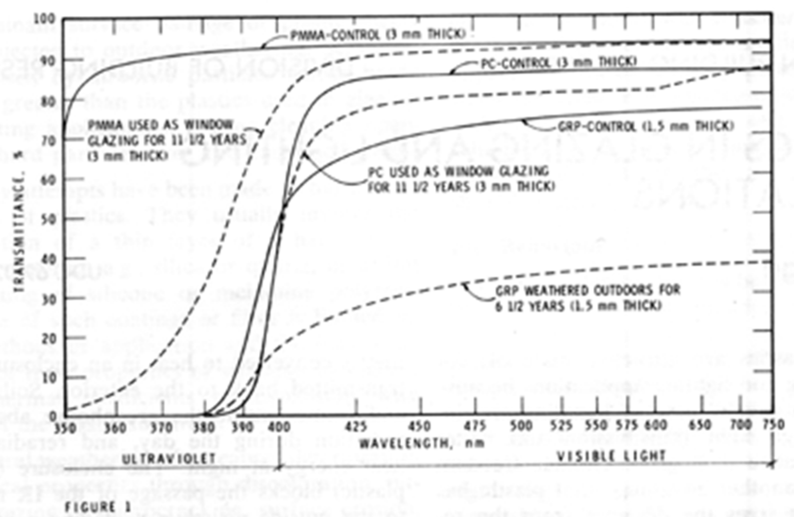

Figure 1. Effect of weathering on the light transmission of glazing plastics.

As plastics are relatively soft and generally soluble in some organic liquids, the cleaning recommendations of the material suppliers should be strictly followed.

Fire Behaviour

Plastic materials are combustible or softened by heat and are not intended for use where wire glass is required as a fire stop. Recommended practices must be observed for safe design when these materials are used in glazing and lighting applications. When tested by ASTM method D635, PMMA has a burning rate (mm/min.) of 25-33, GRP, 18-51, and PC and rigid (unplasticized) PVC are rated as self-extinguishing. Rigid PVC is considered to be one of the most fire-resistant plastics. In a big fire, however, PVC decomposes and produces toxic and irritating gases (mainly HCl and CO).

References

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