Rigid thermoplastic foams

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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000693
Canadian Building Digest, 1974

Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 167

Rigid Thermoplastic Foams

Originally published 1974

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Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

Thermoplastic foams are based on linear or slightly branched (non-cross-linked) polymers and thus have properties normally associated with thermoplastics (**CBD 158**). They exhibit a definite melting range and are generally susceptible to attack by organic solvents. With thermoplastic foam systems the polymerization of the base resin is generally completed first, and the polymer then compounded, melted and foamed. This Digest will describe thermoplastic foams, with particular emphasis on polystyrene foam, the major commercial product and oldest of this class of materials.

Owing to the nature of the techniques employed in their production, thermoplastic foams are not adaptable to batch mixing operations nor to on-site (in situ) placement. Those that will be discussed are polystyrene, poly(vinyl chloride) and cellulose acetate. Other well-known commercial thermoplastic foams are based on polyethylene, polypropylene and ABS. Table 1 and Table 2 summarize typical properties and main applications of selected rigid thermoplastic foams used in construction and related fields.

Table I. Typical Properties of Rigid Thermoplastic Foams (1)*

Plastic Foam	Density lb/ft³	Thermal Resistance of 1-in. Specimens,** °F/Btu/hr ft² (ASTM D-2326)	Coeff Thermal Exp, 10^{-5}/°F (ASTM D-696)	Water Vapour Transmission, perm-in. (ASTM C-355)	Water Absorption (short term), % by vol (ASTM D-2127)	Compressive Strength at 10% Deflection, psi (ASTM D-1621)	Max Continuous Service Temp. °F
Polystyrene							
Extruded Type	1.5-5.0	4.0-6.0	3.0-4.0	0.3-1.5	<0.5	25-140 at 5% deflection	165-175
Moulded Bead Type	1.0-5.0	4.3-3.7	3.0-4.0	0.4-2.2	<3.0	13-115	167-185

Poly (vinyl chloride) (PVC)	2.0-6.0	4.0-6.0	4.0-6.0	<0.15	Nil	45-250	200
Cellulose Acetate	6.0-8.0	3.0-3.3	2.5	-	1.9-2.5 at 50% RH	125	350

* Some of the data given have been obtained by testing commercial products at DRB/NRC.
** Thermal resistance given at 70°F mean temperature.

Table II. Characteristics and Applications of Rigid Thermoplastic Foams

Plastic Foam	General Characteristics	Applications*
Polystyrene (extruded and moulded bead)	Relatively good thermal insulation efficiency. Readily attacked by some organic solvents (e.g., in adhesives, paints and some fuels). Forms available: slabs, sheets and boards.	Thermal insulation for walls, roofs, ceilings and perimeter. Low temperature insulation.
PVC	Good thermal insulation; very low water vapour permeability and water absorption. High strength and rigidity. Available as boards and blocks with a wide range of densities.	Low temperature insulation (cold storage). Core material in sandwich panels.
Cellulose Acetate	Desirable properties include good strength, solvent resistance, resistance to high temperature. Slow burning. Available as boards and rods.	Structural framing, ribs, panels. high cost limits its use in the construction field to areas requiring high strength.

* Although some thermoplastic foams have very low water vapour permeability, they should always be used in conjuction with a vapour barrier.

Polystyrene Foams

Cellular plastics based on polystyrene resin are generally closed-cell, rigid foams that can be manufactured in densities from 1 to 30 lb/ft^3; most are in the 1 to 5 lb/ft^3 density range. Currently, there are two main types of polystyrene foam; extruded foam and moulded bead foam. Although there are applications in which either type may be employed, the two materials should not be considered readily interchangeable.

Extruded Foam

To produce this type of foam a molten polystyrene-based plastic compound containing a blowing agent is extruded at elevated temperature and under pressure through a slit orifice to the atmosphere; at this point the mass expands to about 40 times its pre-extrusion volume. It is extruded in board form with continuous surface skin or in large billets that can be cut into standard board or fabricated into other desired shapes. Woodworking tools (hand-operated or power-driven) are commonly used to convert foams into useful shapes, although wire cutting provides a smoother surface. Extruded foam has a simpler, more regular structure (Figure 1) than moulded bead foam (Figure 2); and also has better strength properties and higher water resistance.

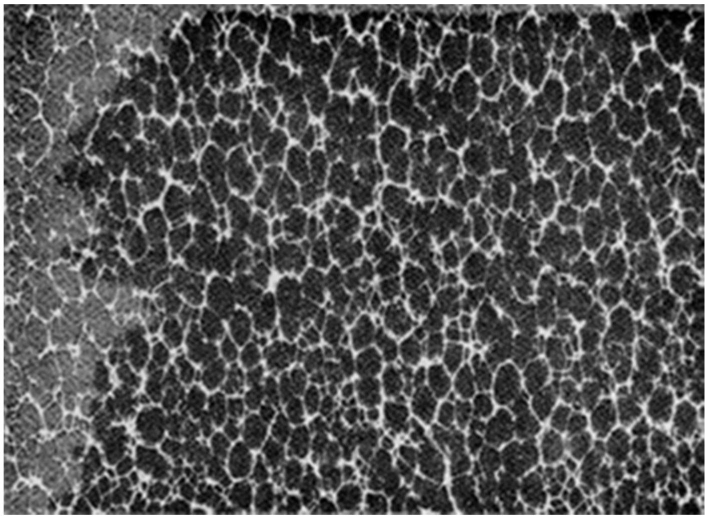

Figure 1. Photomicrograph [*] *of cross-section of extruded polystyrene foam, 10X.*

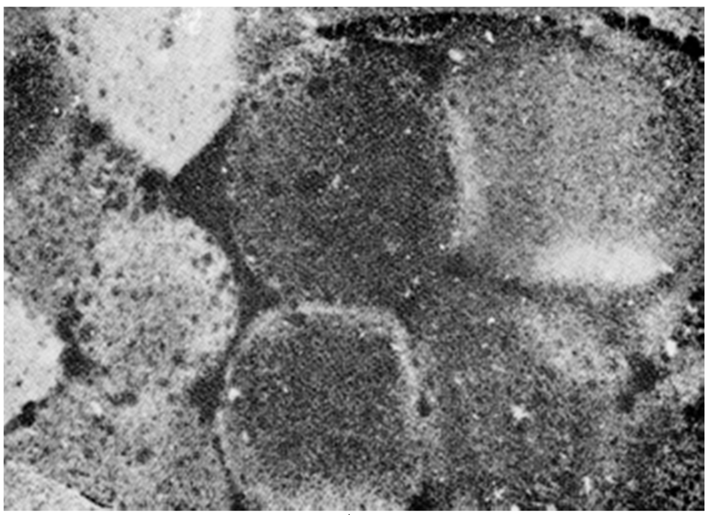

Figure 2. Photomicrograph [*] *of cross-section of moulded bead polystyrene foam, 10X.*

Bead Foam

This material is produced from expandable polystyrene beads (granules) ranging in size from 0.2 to 3.0 mm (0.008 to 0.118 in.) and in shape from round particles to ground chunks. There are two methods used in the preparation of the beads. In one, polymer granules are heated with a blowing agent (usually a hydrocarbon) that penetrates them. In the second method styrene monomer is polymerized in the presence of a blowing agent so that the blowing agent becomes entrapped in the plastic beads. Typical blowing agents are hydrocarbons (e.g. isomeric pentanes and hexanes), halocarbons and mixtures of both.

The expandable beads are converted to foam as follows. They are subjected to heating by steam, hot water or hot air to give pre-expanded beads; aged (or conditioned) for a period of time; the pre-expanded beads again heated (in a mould) so that they undergo additional expansion, flow to fill the interstices (spaces between particles) and fuse. This results in an integral moulded piece.

Properties and Durability

As with most foamed plastics, the properties of polystyrene foams are a function of the plastic used in the matrix, density, type and size of cell, and the techniques of production. Unlike the thermoset foamed urethanes, thermoplastic polystyrene foams are quite deformable, resilient at low densities, and non-abrasive. As polystyrene polymer has no nutritive value, the derived foam will not support fungus or bacterial growth and has no effect on plant or animal life. It is not a barrier to rodents, ants and termites, however. It is known that they will chew through foamed polystyrene to reach food; that birds will peck at it and use it for lining their nests.

Polystyrene foams generally have poor outdoor weathering resistance. The plastic matrix deteriorates when exposed to direct sunlight for extended periods, as evidenced by a characteristic yellowing. To protect polystyrene foam against the effect of outdoor weathering and physical damage adequate coating should be applied on the surface. Multiple coats of water-dispersed exterior paints will provide protection against deterioration by outdoor weathering; and portland cement plaster, latex-modified plasters and asphalt emulsions are often used to provide protection against physical damage. Thick epoxy or polyurethane coatings also give good protection from physical damage, but they are expensive. Coatings containing aromatic or chlorinated hydrocarbons, ketones and esters dissolve polystyrene foam and should be avoided. Special grades of styrene-acrylonitrile copolymer foams are solvent resistant.

As with other thermoplastic foams, polystyrene foams undergo slight deterioration in their mechanical properties (e.g., reduction in strength) when the temperature is raised to the heat distortion point (160 to 170°F; 71 to 77deg;C). General purpose polystyrene foams are flammable and may produce dense smoke under fire conditions.

Under small thermal and moisture gradients, polystyrene foams absorb relatively low amounts of water. Experimental evidence shows, however, that under larger fluctuating temperature and moisture gradients some polystyrene foams can absorb high proportions of water. Even under conditions where the water vapour transmission of some polystyrene foam is very low, it may be questionable as an adequate vapour barrier. It cannot be expected to act as a continuous vapour barter or as an air barrier.

The adhesives used to bond polystyrene foam to itself or to other materials should not contain solvents that dissolve it. A poly(vinyl acetate) based adhesive is satisfactory for foams that will not be immersed in water. Asphalt adhesives (as hot melt or emulsion) or hydraulic cement are satisfactory for construction purposes. When optimum resistance to moisture or heat is required, a setting type of adhesive (e.g., epoxy) is recommended. Portland cement is an ideal adhesive for bonding polystyrene foam to masonry, which has a rough surface.

Applications

Polystyrene foams (either extruded or moulded bead board) are used in buildings primarily as thermal insulation. Three specific areas of application are masonry wall insulation, perimeter insulation, and roof insulation.

Masonry buildings can readily be insulated by placing foam board between exterior and interior walls or by bonding (adhering) the foam directly to the wall (e.g. with portland cement mortar) and plastering directly over it. The cut surface cells of the foam are a good base for all types of plaster.

Perimeter insulation is applied below ground level along the edges of a concrete foundation and is used in both residential and industrial slab-type foundations. The property requirements of foam used for such installations are relatively high thermal resistance for a given thickness, good moisture resistance and adequate compressive strength.

Roofs may be insulated with either integral skin extruded board or cut foam board (extruded or higher density moulded bead foam). As polystyrene foam is a thermoplastic, the material should be protected or special care taken to protect it front overheating and melting when hot asphalt or coal tar pitch is used to adhere it to the deck. Polystyrene foams used in roof insulation should have good dimensional stability and high flexural and compressive strength, and should preferably be fire-retardant grade.

Low-temperature insulation is another application for which a large quantity of plastic foam is used. Dimensional stability, high thermal resistance for a given thickness, and low water vapour permeability to prevent accumulation of condensed water and ice are important requirements. The foams used may be either extruded or moulded bead boards. Common applications include low temperature storage facilities in the fresh produce, dairy and meat industries; refrigerated pipes, refrigeration equipment, insulated truck bodies, railroad cars and ships.

Polystyrene foam is also used widely as core material in exterior sandwich panels because of its high thermal resistance, resistance to water and water vapour, ease of fabrication and ease of bonding to various facings (metal, wood, concrete or plaster). The primary disadvantage (in this application) is that it undergoes distortion by heat.

Low cost and good buoyancy characteristics make polystyrene foam suitable for flotation applications as buoyant support for floating structures such as floating docks, marinas, fishing floats, life rafts, life belts and jackets, and navigation buoys. A disadvantage of conventional polystyrene foam is its poor resistance to oil and gasoline (spills), but improved foams resistant to these materials are commercially available.

Following construction, the packaging field is the major outlet for foamed polystyrene. Many consumer industrial and military packaging problems have been successfully solved with impact-absorbing, low density and low cost, expanded polystyrene foams. It is so versatile in this field that it is impossible to enumerate its present and potential uses completely, but some of the most common include protective packaging of delicate instrument kits and electronic components, food produce trays and egg crates. Its ability to provide a high thermal resistance in a small space is an advantage in the packaging of temperature-sensitive items for shipping or storage.

Attractive appearance and ease of workability also make polystyrene foam an interesting material as an art medium or handicraft material and in the fabrication of consumer items such as chairs, tables, lamp bases.

Poly(vinyl chloride) Foams

Poly(vinyl chloride) foam (PVC), also referred to as vinyl foam, is available in a variety of types and combinations of properties, depending on the compounding ingredients (e.g., use of plasticizers and copolymers) and the production process. Available types include flexible, open-cell and partly open-cell, semi-rigid, and rigid closed-cell foams.

Rigid closed-cell vinyl foams provide good thermal insulation but have not been used extensively on this continent because of high cost and processing difficulties. They have very low moisture absorption and water vapour permeability, good solvent resistance and inherent self-extinguishing or flame-retardant properties. Under fire conditions, however, PVC foams decompose to produce dense smoke that is both irritating and corrosive.

The greatest interest in rigid PVC foam is in applications where low flammability requirements prevail. Applications of rigid PVC include use as thermal insulation, core material in structural panels, and marine applications.

A new type of PVC-based material, the recently developed cross-linked rigid vinyl foam, has (in addition to the properties inherent in conventional PVC foam) considerably higher strength-to-weight ratio, higher rigidity, and better dimensional and thermal stability. It is essentially a closed-cell foam. One type of such foam is produced from a combination of PVC homopolymer (predominant ingredient), vinyl monomer, maleic anhydride and isocyanate, using chemically released CO_6 for foaming. The exceptional lightweight strength and rigidity of the cross-linked foam makes it specially suited for use as a sandwich core between metal or reinforced plastic sheets; these are used in the fabrication of boat hulls and structural parts for aircraft.

Cellulose Acetate

These foams have very good strength, solvent resistance, and high thermal stability; and have a wide service-temperature range (-70 to +350°F; -57 to +177°C). They are available at higher densities (6 to 8 lb/ft^3), which makes them more expensive, so that their use is limited to applications where high strength is required: for core material in sandwich panels (where they are bonded to metal, wood or glass); rib structure in the fabrication of lightweight, reinforced plastic parts; radome housings; ribs, posts, panels, and framing in shelters. Because they are buoyant, they are also used in flotation applications: in lifeboats, buoys and other flotation devices.

Reference

1. Guide to Plastics, by the Editors of Modern Plastics Encyclopedia, McGraw Hill, Inc., New York, 1970.