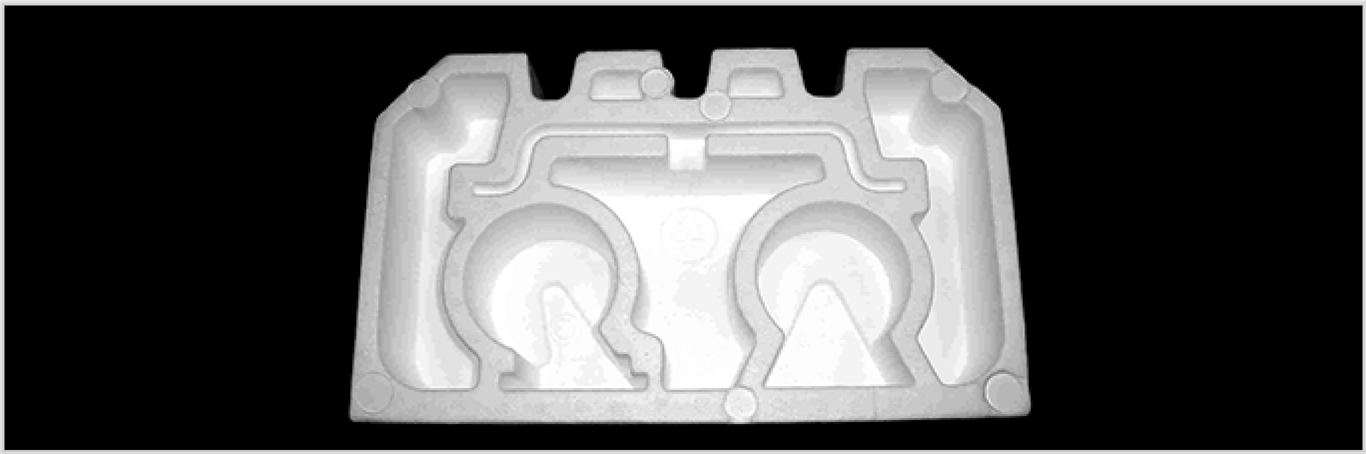
Rigid Polymer Foam (HD)

Description

Image



Caption

Rigid polystyrene foam is used for packaging, thermal insulation and sound absorption. © Granta Design

The material

Polymer foams are made by the controlled expansion and solidification of a liquid or melt through a blowing agent; physical, chemical or mechanical blowing agents are possible. The resulting cellular material has a lower density, stiffness and strength than the parent material, by an amount that depends on its relative density - the volume-fraction of solid in the foam. Rigid foams are made from polystyrene, phenolic, polyethylene, polypropylene or derivatives of polymethylmethacrylate. They are light and stiff, and have mechanical properties the make them attractive for energy management and packaging, and for lightweight structural use. Open-cell foams can be used as filters, closed cell foams as flotation. Self-skinning foams, called 'structural' or 'syntactic', have a dense surface skin made by foaming in a cold mold. Rigid polymer foams are widely used as cores of sandwich panels.

Composition (summary)

Hydrocarbon

General properties

Density		10.6	-	29.3	lb/ft^3
Price	*	6.95	-	7.65	USD/lb
Date first used		1931			

Mechanical properties

Young's modulus	0.029	-	0.0696	10^6 psi
Shear modulus	0.00798	-	0.0283	10^6 psi
Bulk modulus	0.029	-	0.0696	10^6 psi
Poisson's ratio	0.27	-	0.33	
Yield strength (elastic limit)	0.116	-	1.74	ksi
Tensile strength	0.174	-	1.8	ksi
Compressive strength	0.406	-	1.74	ksi
Elongation	2	-	10	% strain

Hardness - Vickers		0.28	-	1.2	HV
Fatigue strength at 10^7 cycles	*	0.122	-	1.39	ksi
Fracture toughness		0.0215	-	0.0824	ksi.in^0.5
Mechanical loss coefficient (tan delta)	*	0.005	-	0.15	

Thermal properties

Glass temperature		152	-	340	°F
Maximum service temperature		152	-	332	°F
Minimum service temperature		-172	-	-99.7	°F
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.0196	-	0.0364	BTU.ft/h.ft^2.F
Specific heat capacity		0.239	-	0.456	BTU/lb.°F
Thermal expansion coefficient		12.2	-	38.9	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e16	-	1e20	µohm.cm
Dielectric constant (relative permittivity)	1.21	-	1.45	
Dissipation factor (dielectric loss tangent)	8e-4	-	0.008	
Dielectric strength (dielectric breakdown)	153	-	279	V/mil

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Castability	1	-	3
Moldability	3	-	4
Machinability	3	-	4
Weldability	1	-	2

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent

Acetic acid (glacial)	Limited use
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Limited use
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Acceptable
Nitric acid (70%)	Limited use
Phosphoric acid (85%)	Acceptable
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Unacceptable
Benzene	Unacceptable
Carbon tetrachloride	Excellent
Chloroform	Unacceptable
Crude oil	Limited use
Diesel oil	Limited use
Lubricating oil	Limited use
Paraffin oil (kerosene)	Acceptable
Petrol (gasoline)	Acceptable
Silicone fluids	Excellent
Toluene	Unacceptable
Turpentine	Unacceptable
Vegetable oils (general)	Limited use
White spirit	Limited use

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Unacceptable
Acetone	Unacceptable
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Limited use
Glycerol	Excellent
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

Chlorine gas (dry)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Acceptable
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Self-extinguishing

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Acceptable
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	1.05e4	-	1.16e4	kcal/lb
CO2 footprint, primary production	*	3.68	-	4.07	lb/lb
Water usage	*	52.2	-	57.8	gal(US)/lb
Eco-indicator 95		420			millipoints/kg
Eco-indicator 99		368			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	814	-	897	kcal/lb
Polymer molding energy	*	2.09e3	-	2.31e3	kcal/lb
Coarse machining energy (per unit wt removed)	*	75.3	-	83.3	kcal/lb
Fine machining energy (per unit wt removed)	*	290	-	321	kcal/lb
Grinding energy (per unit wt removed)	*	529	-	585	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.601	-	0.662	lb/lb
Polymer molding CO2	*	1.55	-	1.71	lb/lb
Coarse machining CO2 (per unit wt removed)	*	0.0522	-	0.0576	lb/lb
Fine machining CO2 (per unit wt removed)	*	0.201	-	0.222	lb/lb
Grinding CO2 (per unit wt removed)					

	* 0.366	-	0.405	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✖			
Recycle fraction in current supply	0.1			%
Downcycle	✔			
Combust for energy recovery	✔			
Heat of combustion (net)	* 1.89e3	-	1.99e3	kcal/lb
Combustion CO2	* 1.37	-	1.44	lb/lb
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

Foaming of insulation with CFCs has a damaging effect on the ozone layer - it is now abandoned. Monomers and foaming agents pose hazards; good practice overcomes these.

Supporting information

Design guidelines

Energy management and packaging requires the ability to absorb energy at a constant, controlled crushing stress; here polyurethane, polypropylene and polystyrene foams are used. Acoustic control requires the ability to absorb sound and damp vibration; polyurethane, polystyrene and polyethylene foams are all used. Thermal insulation requires long life; polyurethane foams were common but are now replaced by phenolics and polystyrenes. When fire-protection is needed phenolic foams are used. Foams are usually shaped by injecting or pouring a mix of polymer and foaming agent into a mold where the agent evolves gas, expanding the foam. The mix can be palletized, and the mold part-filled with solid pellets before foaming (see "Expanded foam molding" in this database). Expanding in a cold mold gives a solid surface skin, creating a sandwich-like structure with attractive mechanical properties

Technical notes

The properties of foams depend, most directly, on the material of which they are made and on the relative density (the fraction of the foam that is solid). Most commercial foams have a relative density between 1% and 30%. To a lesser extent, the properties depend on the size and the shape of the cells. Low density, closed cell, foams have exceptional low thermal conductivity. Skinned rigid foams have good bending stiffness and strength of low weight.

Typical uses

Thermal insulation, Cores for sandwich structures, Panels, Partitions, Refrigeration, Energy Absorption, Packaging, Buoyancy, Floatation.

Links

Reference
ProcessUniverse
Producers