.Polystyrene The **Wonder Material**

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on Tuesday 5th December 2000

History Polystyrene (crystal) was first commercialised by Dow Chemical in the U.S.A. in 1937. Expandable Polystyrene bead was introduced in Europe by Badische Anilinen und Soda Fabriken (BASF) in 1952.

Chemistry

Polystyrene is a linear polymer formed from the radical polymerisation of Styrene monomer (a strong smelling, colourless, aromatic liquid boiling at approx. 150 degrees Celsius) which is manufactured from products arising from the distillation of crude oil.

When an initiating compound (such as Benzoyl peroxide) is added to Styrene monomer and heat is applied the monomer units combine together to form an ever-lengthening chain until all the Styrene monomer is used up.

Manufacture

On an industrial scale Expandable Polystyrene is made by a continuous batch process. Styrene monomer is mixed with an equal portion of water and heated in a stirred vessel together with additives used to initiate the reaction and to stabilise the liquid mixture. It is at this stage that any fire retardant compounds are added to ensure thorough dispersion of the additive. Somewhat before the polymerisation is complete the reaction vessel is closed and a quantity of liquid Pentane is added under pressure. The temperature of the mix is increased and the reaction taken to completion (less than 0.1% Styrene monomer residue in the polymer).

The mix is cooled down and passes through several processes to remove water, dry the polymer and grade it into several sizes before treating it with powdery coatings designed to facilitate the conversion of the polymer into its final usable form at the converter/customer.

The physical form of the polymer at the end is an opaque bead of about 1mm in diameter similar in appearance to a ball bearing. It has the look and feel of granulated sugar and is often referred to as "sugar". The different grade sizes are used for different applications of the final product. In general smaller sizes are used for packaging applications and large sizes for insulation.

Conversion

The conversion of the ExpandABLE to the ExpandED bead takes places in 3 main steps, viz. preexpansion, maturing and moulding.

Preexpansion takes place in a stirred vessel into which steam is introduced either at atmospheric pressure (continuous expansion) or at elevated pressure of about 0.5-1.0 bar (batch preexpansion). During this process the steam softens the polymer structure and at the same time begins to boil off the pentane dissolved in the bead thus causing the bead to expand in size and at the same time reduce in density. For packaging application the density is controlled to approx 15-25 kg/m3 while for insulation applications the range is normally 10-20kg/m3.

Maturing is the process by which the bead rests before moulding in order to stabilise its internal pressure. During the prexpansion the bead has grown an internal cell structure like the centre of a Malteser but has not had time to absorb air into the cells to equalise internal and external pressure. If the beads were attempted to be moulded at this stage severe collapse of the beads would occur rendering the mouldings shrunken and distorted. Thus the beads have to be rested in large porous sacks for periods from 2-48 hours dependent on bead size and density. The smaller the bead size and lower the density the less time is needed for the maturing process. Once maturing is completed the beads are ready to be moulded.

Moulding takes place by injecting beads into the cavity of an aluminium mould. In the case of packaging applications the moulds are attached to automatic contour moulding machines capable of cycling in 40-60 sec. Large machines can have moulds with multiple cavities thus capable of producing many mouldings per cycle. Handling of these mouldings can become a problem if too many are produced too quickly. In the case of moulding for insulation it is normal for EPS to be moulded in the form of a large oblong block up to 8m long and with cross section of 1x1m with cycle times of between 2 and 10 minutes depending on density. From these blocks the insulation boards can be cut to the thickness (e.g. 50-100mm) as required for the particular insulation application using hot wire cutting machines. It is not uncommon nowadays to see insulation products moulded on contour machines particularly where complex shapes are required. This eliminates the need for time-consuming and expensive post-moulding cutting and gluing processes.

Properties

It is the properties of a material that determine its ultimate application. The advantageous properties of Expanded Polystyrene (EPS) are as follows:

- Good strength to weight ratio
- Excellent thermal insulation
- Low water permeability
- Low water absorption
- Good shock absorption

Good impact sound insulation
Resistant to bacterial growth
Non-corrosive
Non-toxic
Flexible in design
High production rates possible
Smooth surface and clean appearance
Printable

Applications
Expanded Polystyrene is a product for all seasons as can be seen from the table below:

Season	Property	Application
Spring	Protection/Decoration	Fish/produce boxes
		Bedding trays/cups
		Clay heave
		DIY
Summer	Boyancy	Marinas/Surfboards
Autumn	Support Structures	Water purification
		Lost foam
		Bean bags
Winter	Insulation	Buildings/caravans
		Ground
		Sound

Selected applications
Boxes: The light weight, good insulation and smooth non-toxic surface aiding hygiene and printability make EPS an ideal solution for packing edible produce such as fish fruit and vegetables. In the case of fish almost all fresh fish in Europe is delivered to market in EPS boxes. A challenge for the future is to find a reuse for these boxes, as currently they survive only one trip. Methods have been developed to render the boxes back to solid polystyrene which can then reenter the crystal (non-expandable) polystyrene chain.

Bedding trays: The rigidity of trays and the insulation afforded to roots of the growing seedlings make EPS an obvious choice. Trays for already potted plants is a big but low margin operation where densities as low as 14-15 kg/m3 are common to maintain the economics.

Cups for both hot and cold drinks are ideal in EPS where very fine bead can be used in specially constructed moulding machines with cycles of 4-5 sec. Superbly smooth surfaces on the cups are produced by highly polished aluminium or stainless steel moulds. Wall thicknesses down to below 1mm are possible at bead densities of 40-100 kg/m3.

DIY products include ceiling tiles, coving, ceiling roses and veneer etc for home decoration. Success here is due to the low weight/low cost and pattern mouldability properties of EPS. Insulation is an added bonus but at the small thicknesses used this is more in the perception than the reality. However as a lining paper to prevent condensation on the inner surface of outside walls the insulation factor is critical.

Lost foam mouldings made with faultlessly smooth surfaces and complicated designs allow the casting of metal parts (e.g. for car and engineering industries) as EPS is easily burned away during the metal pouring operation. Special grades with low carbon residues are needed for critical stainless steel castings.

Bean bags are both fun and therapeutic as they will mould to the human (and animal) shape readily aiding comfort and support for certain medical conditions. Low weight, rigidity and flowability are the prime factors.

EPS beads are also being used in a revolutionary *water purification* process in sewage treatment works. Beds of bead several feet thick are used to support a bacterial culture through which sewage filtrate is passed. The bacteria consume the last remains of nitrogenous impurities allowing safe discharge of the treated sewage into the national river system.
A related application using EPS beads to filter out silt from floodwater has potential for a cheap lightweight water purification plant useful to third world countries where environmental disasters have caused the contamination of drinking water supplies.

The use of EPS in the construction of floating walkways, jetties and pontoons for *marinas* is well developed making use of the properties of lightweight (bouyancy), minimal water absorption and high rigidity. Protection of EPS using a concrete shell allows use to be extended to where substantial contact with diesel oil is likely.

Insulation of walls, roofs and floors of domestic and commercial buildings represents a very large market for the use of EPS. In the UK, cavity walls are still very popular and sheets of EPS attached to the inner leaf of the outside wall but not quite bridging the cavity provides substantial heat retention without compromising protection from water penetration. Used as an insulant on the outside of the external wall EPS provides an even better heat retention capacity. In this case the whole of the wall is in the warm

Zone and can act as a heat sink/radiator as the heating system comes on or goes off allowing a smoothing out of temperature fluctuations within the room.
Cut to falls EPS is the ideal solution for flat roof insulation. Similarly, cutting EPS to the shape to fit under corrugated roof systems is perfectly straightforward with the new generation of profile hot wire cutters. In floors, EPS, even at light economic densities, can support normal domestic traffic. Also when applied as a floating floor on top of concrete, EPS can substantially reduce the amount of noise transmitted by foot traffic. This proves vey useful in blocks of flats.

As a lightweight fill material EPS has been extensively used as a *void former* in the construction of bridges and elevated motorways. It is also increasingly used as a *fill material* in soft soil conditions under road surfaces. Settlement of new embankments can be alleviated and large rotational forces on bridge abutment walls and foundations can be reduced by the use of layers of EPS block to absorb the stresses. This leads to earlier completion dates and simpler and cheaper bridge designs.

A further application for EPS underground uses its innate compressibility at low density to absorb the pressures caused by the movement of clay soils when expanding in wet conditions around the foundations of buildings using piled ground beams. (*Clay Heave*)

Future

There is no doubt that despite the already extensive use of EPS in many applications and industries further developments of products particularly in the area of improved thermal performance will lead to the identification of new and perhaps unexpected applications.