

THE POSSIBILITIES OF POLYSTYRENE WASTE RECYCLING

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ABSTRACT

The aim of this paper is to introduce the main possibilities of polystyrenes recycling, to describe not only its characteristics but its usage mainly in the construction industry as well. Furthermore, the paper gives the literature knowledge of the produced foamed polystyrene waste recycling in different fields.

INTRODUCTION

Polystyrene is one of the long-known synthetic resins, which is produced during the polymerization of styrene, and which already happens even at rest. Polymerization is speeded up by heating, by strong light, and by certain catalyses. Polymerization happens in the form of radical substitution in the presence of a peroxide catalyst. The final product is a chain-like macro molecule. It is an achromatic (clear), hyaline (glassy), transparent, brittle material, a very good electric insulator. According to its use it is a widely used material. Nowadays its production in foamed forms such as a heat insulating material in construction and also as a packaging material is becoming more and more significant [1]. The consequence of producing PS in an increasing quantity is more polystyrene waste. In connection with this, within this article we intend to introduce the perspectives and possibilities of recycling waste. Based on the above the objective of this paper is to introduce the perspectives and possibilities of polystyrene waste recycling.

THE POLYSTYRENE

Polystyrene (PS) is one of the most widely used plastics. It is an aromatic vinyl polymer, its monomer is styrene (vinyl benzene). It is thermoplastic, and as a result of this it can be easily manufactured and cast into molds. It is flammable, irritating and poisonous gases are generating while burning. Being dangerous and having a strong contaminating effect on nature, its use is being tried to be confined and substituted by other materials. EPS was discovered by an apothecary, namely Eduard Simon from Berlin, in 1839. As for its physical properties, polystyrene is a hard and clear plastic. Its melting point is 240 °C, but becomes soft at lower temperature (95 °C). Its average density is 1040 - 1130 kg/m³. It dissolves well in organic solvents. As for its production: several forms can be gained through extrusion, injection-molding and vacuum forming. These forms can be CD cases, housings of smoke detectors, license plate frames, laboratory Petri dishes, and different packaging materials for household appliances. In its high impact polystyrene form (HIPS) it can be used as coatings, vehicle units, plastic model

assembly kits, and toys [1, 2]. The foamed form of polystyrene is one of the plastic products used for the longest time used plastic in construction industry. According to its manufacturing processes polystyrene can be divided into two groups: traditional expanded polystyrene foams (EPS) and extruded polystyrene foams produced with a lately developed technology (XPS).

Table 1
Main physical properties of EPS and XPS [3]

Physical properties		Material	
		Extruded polystyrene (XPS)	Expanded polystyrene (EPS)
Density (kg/m ³)	minimum	20	18
	maximum	80	50
Thermal conductivity, λ (W/mK)	minimum	0.025	0.029
	maximum	0.035	0.041
Thermal range (°C)	minimum	-60	-80
	maximum	75	80
Moisture absorption (at relative moisture of 23°C/80%, Wt. - %)	minimum	< 1 ¹	5 ¹
	maximum		
Incombustibility class	minimum	B1	B1
	maximum	B2	B2
Tensile strength (N/mm ²)	minimum	0.3	0.15
	maximum	0.35	0.52

¹ average value

Expanded polystyrene (EPS)

Expanded polystyrene (abbreviated as EPS) is a thermoplastic, closed-cell structured polymer, which is made of mineral oil (petroleum) and natural gas with the help of complex processes. Its base material is polymerized styrene, which contains foaming and flame retarding agent(s). Foamed polystyrene contains 1.5-2 % polymerized polystyrene and 98 - 98.5 % air. During foaming, pentane is used as a power-gas, to increase flame resistance to maximum 5-7 % hexane-bromine-cyclododecane can be applied (all given in volume-percentage). It is biologically inactive, not a toxic material. Among its most important properties we can mention that EPS has a low density (30 kg/m³), heat insulating ability, hydrophobicity, as well chemical resistance to acids and alkalines [4, 5].

EPS is one of the cheapest facade insulating materials. The typical thermal conductivity value of expanded polystyrene is between 0.03 – 0.04 W/mK. Its thermal conductivity ability depends on the temperature, vapor content and mass

density [7].

Properties of the heat insulating panels made from expanded polystyrene foam do not change with time. The foam neither decays, nor rots. Constant UV rays (ie. sunshine) cause the surface of the material turn yellow, become rigid and brittle. The surface of materials rightly built in is always covered, thus its protection must be kept in mind only in case of long-term storing. Expanded polystyrene (EPS) panels must be protected against the harmful effects of humidity in all cases as the moisture content highly influences thermal conductivity.

Form-foamed expanded polystyrene (FPS)

The base material contains pentane power-gas and other aggregates influencing the properties (ie. hydration, flammability) of the finished foam. During production, 110-120 °C steam is used to blow the beads, no other material is added. The steps of production are similar to those of EPS: pre-expanding, conditioning, form foaming, conditioning of the finished product, and in the case of FPS there is no dimensioning [6].

Graphite facade heat insulation

In the construction industry graphite polystyrene foam panels are successfully used, which differs from traditional white EPS panels as they are enriched with graphite aggregate, thus its heat insulating ability with the same thickness shows a 22.5 % better data ($\lambda = 0,032$ W/mK) than the white heat insulating panel ($\lambda = 0.04$ W/mK). It is excellent to insulate passive houses.

Extruded polystyrene (XPS)

The base material of pressed polystyrene is also polymerized polystyrene, using 3-7 % carbon-dioxide to foam, then 1-6 % fire-resistant material, colouring and talc powder may complete the mixture. Hard, closed-cell structured polystyrene foam produced with extruding and blowing processes. It can act as the ideal base material of manufacturing outdoor signs, decorative rods.

It must be protected against high temperature (above 60-70 °C) and UV radiation. Their density is 25-35 kg/m³, their thermal conductivity rate is between 0.029 and 0.035 W/mK. The most significant property of extruded foams thanks to their closed-cell structure is the really low, almost negligible hydration (0.2 – 1.0 V %). As a result of this they are mainly used in areas subjected to water such as footings, reverse layer order flat roofs, green roofs, cellar walls etc. As extruded polystyrene foams have significant technical properties like hydration, tensile strength, thermal conductivity factor therefore these are much better than those of expanded polystyrene foams [1, 2, 6].

UTILIZING POLYSTYRENE WASTE

Polymer materials are unique products which have different durability depending on the chains they are built of. Today, as they are produced in more and

more quantity, resulting a higher amount of plastic getting into the waste, which means increased costs of waste disposal [8]. This is the reason why it is important to optimize the practical approaches of recycling waste such as prevention, minimizing, or reusing [9].

Only a small number of companies recycle polymer materials for the sake of manufacturing new EPS products. Basically there are two types of binding material: thermoplastic and thermosetting. Polystyrene belongs to the type of thermoplastic thus it is a very good material for recycling [10]. Thermosetting types are not suitable for re-fusion, but those thermoplastic ones can be recycled, in this way and different types of recycled polystyrene can be formed from them, with varied properties [11].

More factors must be taken into consideration such as the availability and quantity of the resulting waste. The range of recycling must imply environmental efficiency, social responsibility and tracking of the product [12].

Previous researches have proved that EPS products improve heat retaining thanks to their low density and low thermal conductivity [13] which can be ascribed to their cavernous cell structure.

The great majority of expanded polystyrene ends up as communal waste which contaminates our environment in the long run, and causes high costs for its manufacturer in the short run. More possibilities are available for its utilizing (Figure 1).

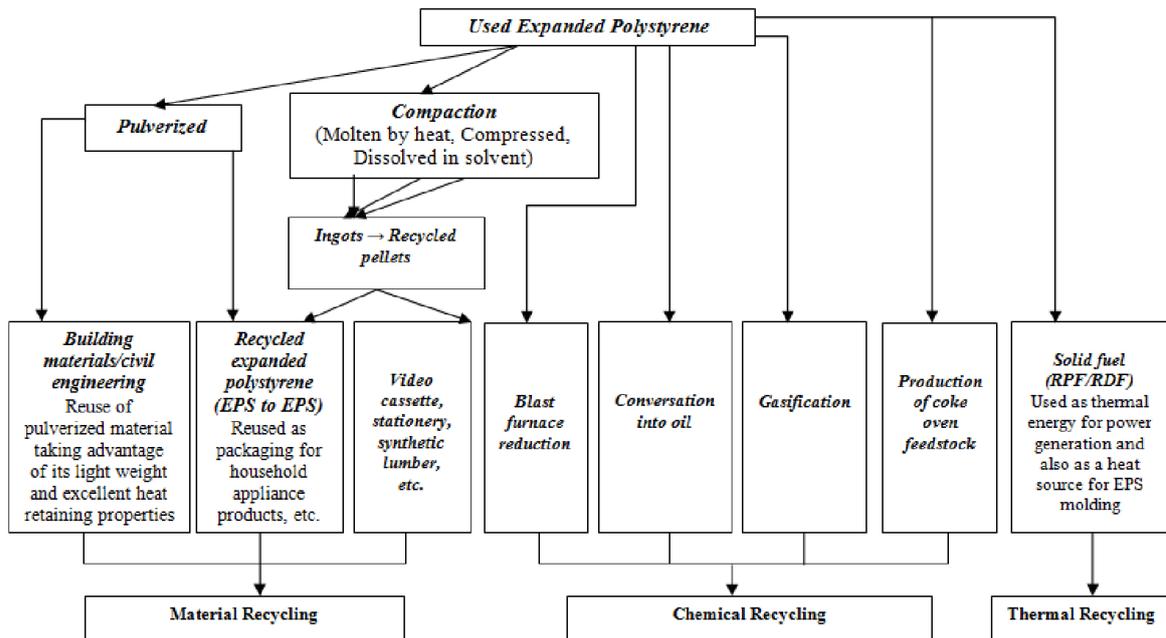


Fig. 1

Possibilities of recycling PS [as shown on <http://www.eps-recycling.net/wp-content/uploads/2010/11/three-recycling-processes.jpg>]

After grinding it can be used in building materials to improve their heat insulating properties, or to produce new PS products. Reducing the volume of EPS by smelting, pressing or solution, it can be transformed into recycled pellets from

which recycled expanded polystyrene can be produced but it is also suitable for manufacturing stationeries, video cassettes, or other plastic products. With the help of thermo processes, oil, gas and charcoal can be made from it, during the process of steel production it can substitute charcoal, or if burnt its useable heat can produce hot water and electricity [14].

PS can be disposed at most junkyards in Hungary, and a great number of plastic processing firms receive and recycle this material which does not contaminate the environment even at the end of its life-cycle. The simplest and long-time used process in our country is that the residual and severed “hungarocell” is ground, and mixed with cement paste to reuse it as a light-weight building material [6].



Fig. 2
PS light-weight concrete [<http://www.e3-lifestyle.com>]

Brick-making factories can use the fine powder produced during grinding as a pore-forming aggregate or plaster-making firms mix it to heat insulating plasters [9]. If no considerable amount of grit is attached to the grit, it means that the recycled material can be used for agricultural purposes as well. Adding it to hard clay-bearing ground, it breaks that ground, promotes the working of drainage, allocates the roots to air thus speeds up the plants growing [14].

Sandwich-boards, plastic plant-pots and other products can also be made from the material thus another life-cycle can be started. It is not a coincidence that according to the Environmental Construction Organization (ECO) headquartered in Bonn, polystyrene has proved to be highly environment-friendly in the field of heating materials [6].

One of the best-known Hungarian examples of using polystyrene in the construction industry is the industrial mortar invented by Antal, István [15], which mortar contains expanded polystyrene and cement. The mortar contains the expanded polystyrene and a part of the cement in the form of granules deriving from the shredding of pressed and conditioned foam concrete containing polystyrene foam. Within this shred the granules have the particle size range of 0.5-10 mm. In addition, 1 m³ of shred in an unpaired, almost anhydrous state contains 50-200 kg cement. To produce the mortar, conditioned foam concrete containing extruded polystyrene foam is ground to a granule size of maximum 10 mm, and then cement, later – during outwork – water is added. With this type of mortar

different building structures can be created.

Exceeding the above mentioned, the novelty of a recently started research is that beyond the traditional building industrial applications (ie. aggregate in making light-weight concrete), the binder of the construction industrial product itself would also be inert industrial waste. Setting into that, a precious, lightweight, fire-resistant facade insulating material with good heat insulating abilities, good mechanical rigidity, or even other load-bearing product can be created, at minimal costs.



Fig. 3
Geo-polymer-polystyrene composite [16]

One setting method can be to mix into the mixture of furnace fly-ash and $\text{Ca}(\text{OH})_2$ which can result in a similar building material, but its bonding mechanism is closer to that of concrete as it is a hydraulic binder. An other setting possibility is to mix it into fly-ash based geo-polymer which material has good heat insulating properties on its own, settles quickly at room temperature (it can reach 70 % of its final mechanical strength in 24 hours), its production cost is relatively low, furthermore we could achieve the recycling of materials that have become waste [16]. Further advantage of geo-polymer is that it can be created from any material containing amorphous silicate-or aluminosilicate-phase, thus can be created from industrial waste therefore further alloying of beneficial properties can also be solved easily.

SUMMARY

As for utilizing polystyrenes deriving from primary and secondary sources, we can draw the following conclusions:

- By extrusion, injection-molding and vacuum-forming different containers can be produced from it, such as license plate frames, laboratory Petri dishes, or household utensils can also be produced such as packing materials, vehicle parts, and toys.
- Expanded polystyrene (EPS) can be utilized in the construction industry, mainly as an insulating material, taking advantages of its most significant properties: low density, heat insulating ability, hydrophobicity and its

chemical resistance to acids and bases. It is the most widely used among facade heat insulators.

- The great majority of expanded polystyrene ends up as communal waste which contaminates our environment, and causes high costs for its manufacturer. After grinding it can be used in construction materials to improve their heat insulating properties, or to produce new PS products. After smelting, recycled expanded polystyrene can be made from it.
- During chemical recycling, the goal is to regain styrene monomer in order to utilize it as a base material. Using thermo processes is an efficient way to handle contaminated EPS waste which means that burning EPS can be used for energy production.
- A future application of PS waste might be its encapsulation in geopolymer which improves its inflammability property facilitating the utilization.

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