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APPLICATION OF FOAMED POLYSTYRENE AS A SURROGATE BUILDING MATERIAL IN MODERN BUILDING CONSTRUCTION

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Abstract

Installing foamed polystyrene as a thermal insulation on building is to provide comfort, to protect man from too much or too less heat, to provide saving of heating energy, and to protect building from damage due to insufficient or incorrectly installed insulation that causes thermal flow and water vapor condensation. In order to consider insulation materials for the construction of buildings, materials should satisfy a number of precisely defined requirement such as: low volume mass, frost resistance, good mechanical properties, good conductivity of stream and gases, low water absorption, resistance to the effect of fire, good thermal insulation properties, low-price and ability of recycling. The paper discussed the application of foamed polystyrene as a surrogate building material in modern building construction. Serious problems such as: moisture, rotting of materials, mildew, blooming, flaking and frosting damaged occur with most familiar building materials. The following properties of foam polystyrene were focused on: mechanical, chemical, biological and its thermal insulation materials used in building constructions. The advantages of foamed polystyrene stretched beyond common building materials with less disadvantages. Hence, the optimization of foamed polystyrene as man-made material for building construction should be focused and improved on its future uses among others building materials.

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INTRODUCTION

A successfully designed building that functions properly in all respects is composed of building systems, materials and technologies that are selected and integrated to be mutually supportive as a cohesive "whole" system. Building materials are used in the building and construction industry to create building structures. Many naturally-occurring substances such as rocks, sand, wood, clay, twigs and leaves have been used to construct buildings. Apart from naturally occurring materials, materials like ceramics, papers and membranes, plastics, metal, gypcrete, glass, fabric, concrete composites and synthetic are being used as man-made products to support, use and make building materials in a modular fashion.

Man-made products are referred to as ready-made materials made from various materials that are fitted as major or part of the building. There are trends in building materials from being natural to becoming more man -made and composite; biodegradable to imperishable; local to being transported globally; repairable to disposable; chosen for increased levels of fire safety, improved seismic resistance and excellent thermal insulation (Chemical Engineering News, CEN, 2008). This trend amplifies the application of polystyrene as a major building material.

Polystyrene (PS) is a "polymer of styrene". Polymer are large molecules consisting of adjoined identical molecules, and styrene is a colorless, oily liquid. In chemical terms, polystyrene is a long chain hydrocarbon wherein alternating carbon centers are attached to phenyl group (Mark, 2009). Polystyrene's chemical formula is $(C_8H_8)_n$: it contains the chemical elements of carbon and hydrogen. The general polystyrene is an amorphous resin which is clear, possesses electrical properties and a good stiffness. Varying levels of polybutadiene are combines with the polystyrene to create high impact polystyrene to improve the impact resistance and toughness.

Polystyrene is produced without the use of any chlorofluorocarbons (CFC), making none present in final product. When Polystyrene is made, it structure is that of a rigid transparent thermoplastic, resembling stiff white foam. As a thermoplastic polymer, polystyrene is solid or glassy at normal temperature but flows when heated above 100^{0}C and becomes rigid again when cooled*(Mihai, Huneault and Favis (2007)*. This temperature behavior is exploited for extrusion (Styrofoam).

Polystyrene is also known as Styrofoam. Styrofoam is made from a material called polystyrene, a very lightweight and durable product that lends itself to many useful purposes. Although, Styrofoam is a petroleum-based material made from harmful chemicals such as styrene and benzene, it is still commonly used in making auto parts, boats, containers, building materials among other (Dow Chemical, 2012). Recently, synthetic polystyrene foam has been used in construction with structural materials, such as concrete, reinforcement bar. It is lightweight, easily shaped, and an excellent insulator. Foamed polystyrene is usually used as part of structural insulated panel. it is used to sandwiched between wood and cement or insulating concrete foams. Polystyrene foams are good thermal insulators and therefore often used as building insulation materials, such as insulating concrete foam and structural insulated panel building systems (Taylor, Manbeck, Janowiak and Hiltunum, 1997).

Material Characteristics

Polystyrene is in a solid or glassy state at room temperature. It is actually transparent plastic that is rigid. It streams when heated and can be used for extrusion and moulding, and when cools off it becomes solid again. Polystyrene is a colorless and oily liquid and has limited flexibility. It can also be transparent or made in different colors. It is one of the most common types of plastic, and it can be found in the home, in the office, at industrial sites, and just about any

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other place you would find plastics(Alhmed and Salih, (2016). Polystyrene is also made into a foam material called expanded polystyrene (EPS) and extruded polystyrene (XPS). They are made of same plastic, but the manufacturing processes differ. Foamed polystyrene can be more than 95 percent air and is widely used to make home and appliance insulation, surfboards, food service, packing and more.

Thermal Characteristics

Expanded polystyrene as a product of polystyrene has air in its cellular structure and that is the reason why polymer has low thermal conductivity. Due to the system of closed cells, polystyrene does not have capillary absorption of water. Expanded polystyrene is a weak thermal conductor, and its thermal conductivity depends on volume mass. Also, thermal conductivity depends on percentage of wetness. When it comes to thermal diffusivity, polystyrene has a very small thermal diffusivity that represents longer transfers of heat through polystyrene. Likewise, when temperature changes, there is a tendency for material to response to new environment by changing its volume. When thermal expansion of polystyrene compared with other materials, volume of polystyrene expand more than other materials such as ceramic and glass(CEN, 2008). With prevention of expanding or contracting, thermal stress occurs when material is cooled or heated. Thus, polystyrene has more thermal coefficient of expansion and more value of modulus in comparison with ceramics and metals.

Mechanical, Biological and Chemical Characteristics

Expanding polystyrene has very low volume mass, rigid and tough, brittle but can be hardened when other materials are added to give a great insulation characteristics and very low absorption of water. Polystyrene is a hard material but brittle with a density of 1.050 g/cm3. Polystyrene is resistant to all construction adhesives unlike plasters, mortars, renders with or without the water dispersion of polymer which is called acrylic (*Wunsch, 2000)*. The effect of temperature on polystyrene practically has no lower limit to its application- insulation. When the upper limit is about 85°C, it can handle a current temperature over100°C. Softening and sintering occurred as a result of longer exposure to high temperatures, so it is resistant to bitumen products to 80°C and cold bituminous products free of organic solvents such as benzene, acetone, etc. It has no resistant to direct impact as hot bitumen and adhesives containing organic solvents such as glue for rubber and plastics (Yang, Tang, Wu, Zhao, Song, Gao, Yang & Jiang, 2015). The natural characteristics of polystyrene are also a matter of interest. Pentane (gas) that is used during polystyrene production has no effect on the degradation of the ozone layer in the stratosphere. Although, pentane is also destroyed by microorganism and photo gradation on 2-3km from earth by sun radiation and in contact with soil. Hence, it does not contain neither develop greenhouse gasses. Polystyrene has resistance to fungi and bacterial, resistance to rotting, does not attract termites, ants, and rodents and non-reactive to food items. Very small amount of styrene can leach out of polystyrene products and into food under high heat. Thus, avoid the use of foamed polystyrene containers for heating food chiefly high in vitamin A, which can add to the leaching effect and cause potential health risks.

To improve properties of polystyrene (copolymers), other polymers with desired properties like polybutadiene rubber are added during the process of polymerization. Some example of copolymers include high impact polystyrene and acrylonitrile butadiene styrene(Maul, Frushour, Kontoff, Eichenauer, Ott, & Schade, 2007). The chemical stability of polystyrene is provided by transformation of carbon-carbon double bonds into less reactive single bonds. Polystyrene is water resistant and has resistance to diluted acids and bases, to aliphatic alcohols, to glycols and

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polyglycols. In terms of flammability, like most organic materials, polystyrene is also flammable. In its combustion, the products released out the followings: carbon monoxide, carbon dioxide, water and soot. Low mass per unit volume are released during burning a minimal amount of heat, which creates a small fire load.

Polystyrene in Building Construction

The flow of polystyrene in building business and modern building construction is significant. Polystyrene is made into foam material called Styrofoam but technically called foamed polystyrene among other products which is valued for its insulating and cushioning properties. Thermal insulation materials should satisfy a number of strictly defined requirement such as low volume mass, good mechanical properties, low water absorption, good thermal insulation properties, good conductivity of steam and gasses, recyclability, frost resistance, resistance to the effects of fire (Ahemed & Salih, 2016). The use of polystyrene products on a building structure is a personal choice.

Polystyrene is one of the materials that is currently in use due to their applications in building business. It is used in many components as a part or whole of construction. It is used as insulation directly or with a combination of other building materials to construct super structure and substructure components including internal and external building element/components such as floor, roof, wall, and for heating systems among others. Polystyrene that is used for wall insulation is a product that must be more than 15kg/m3 in weight (70KPa). Polystyrene used on outer walls are not harmful for humans and can be used in every climate condition with less than 2% water absorption (Owens Corning Formula, OCF, 2011). Also, some additive are used to improve insulation properties, such as granite to suit the client desire.

Thermal conductivity of this type of expanded polystyrene plate is 0.037W/MK. This special production of expanded polystyrene for socle is also used for balcony and terrace. Standard produced polystyrene cannot be installed in floor construction because of the acoustic conductivity. So, the new program of EPS is invented with small rigidity valued (10-20MN/M3) to suit floor construction(Dow Chemical, 2012). With this type of EPS, the acoustic impart is reduced. It does not have harmful on human health and its sound conductivity decreases till LW=34 dB.

Special type of polystyrene is produced for roof construction. This product for roof construction is very easy to install because the material is light with a very good thermal insulation property. Panels of expanded polystyrene with plug for pipe laying are used for under floor heating and the upper side is vacuum coated with polystyrene film. The two types of panel of expanded polystyrene are called ordinary and hard load panel. They are generally used in building construction industry as insulated concrete forms for playground flooring, external door insulation, ceiling tiles, boiler jackets insulation, floatation–pontoons, mariners buoys, cavity wall insulation, road construction, building facades, landscaping, load bearing applications, under-floor heating tiles, acoustic tiles, sound deadening among others.

Advantages of Foamed Polystyrene

There is no perfect material so ever. Every material has its good and bad sides. The followings are the observed advantages of polystyrene:

- Polystyrene foams are good thermal insulators and are therefore often used as building insulation materials such as insulating concrete forms and structural insulated panel building systems
- More thermal coefficient of expansion and more value of modulus in comparison with ceramics and metals
- Use for non-weight bearing architectural structure (such as

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ornamental pillars)

- Exhibits good damping properties before it is used widely for external and internal building wall
- Used for packaging consumer's product.
- Used for producing smoke detector housing, disposal plastic cutlery and dinnerware among others.
- Has low density, chemical stability, consumption resistance and low factor of friction
- Widely used for modelling and essentially for aesthetics function of the structure
- Volumes of polystyrene expand more than other materials such as ceramic and glass
- Used for lightweight protective packaging, surfboard, roadway and road bank stabilization system
- No development of greenhouse gasses
- Resistance to all construction adhesives, plastics, mortals, renders, with or without the water dispersion of polymer
- No effect on the degradation of the ozonelayer in the stratosphere
- Has ability for vibration control and good electrical insulation properties
- Good process ability and good deformation processing
- Temperature effects on polystyrene practically have no lower limit to it application installation
- Non-toxicity and does not have harmful on human health
- Low cost of purchase and very important for energy savings
- Used for modern landfills
- Manufacturing process not necessarily more harmful than the process of paper
- Addition of more resources make recycling of polystyrene possible
- Reconstituted foam or chip-foam mainly used in the upholstery trade,

Disadvantages of Foamed Polystyrene

The disadvantages of using polystyrene are dependence of the properties of the various influence such as:

- High thermal tensile
- Low modulus of elasticity
- Low surface hardness
- Susceptibility of aging, creeping and relaxation
- Low thermal conductivity
- Poor stability at elevated temperatures
- Cause leaching effect on hot food, liquid (tea) and fruits that are that are high in vitamin A
- Made from non-renewable petroleum products and flammable like most organic materials
- Chronic, low-level exposure risks undetermined
- Non-biodegradable in the environment
- Release carbon monoxide among others substances, in its construction

Conclusion

Foamed polystyrene which is technically known as styrofoam is made into foam material called expanded polystyrene (EPS) or extruded polystyrene (XPS) which is valued for its insulating and cushioning properties. Foamed polystyrene can be more than 95 percent air and is widely used in automobile, appliances, electronics, and food services, medical packaging and construction (insulation) among others. Investment in thermal protection are economically justified because of the energy saving for heating. Polystyrene is used for building construction because of it great thermal insulation properties; it is unique material among all thermal material like ceramics, glass, metals etc.

Building business has a lot of different thermal insulation materials and the effect of their use primarily depend on: selection of appropriate thermal insulation, material, thickness of layer of insulating material selected and proper installation of

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that timber element (pitched and flat roofs, external and partition walls, floors, etc.). Making decision on which material to use as thermal insulation, properties of thermal insulation material must be analyzed among properties of other materials used to construct the specific elements of the structure. In the comparison with other thermal insulation materials that are usually used in building construction, polymers are highly ranked among thermal materials with mineral origin (rock and glass wool) or organic origin (cane and wood fibers). Other thermal insulations have good fire resistance and good connections with mortars during application, but they absorb water, have no moisture and frost resistance damaged by fire or rodents, and rotting also occurs.

The following factors must be considered on the choice of thermal insulation material: coefficient of thermal conductivity, specific heat, factor of resistance to water vapor diffusion, coefficient of thermal elongation, and density of materials. What is more needed is to analyze the position of the structural element in relation to the environment and analyze thermo-hydrometric condition of environment.

Foamed polystyrene is mostly used in term of thermal insulation function. It is observed that polystyrene has the smallest value of volume mass or density, excluding its mechanical properties; it is easy to transport, install and apply as well. The properties of foamed polystyrene as man-made products for new building construction have stirred the building industries as materials are: lightweight and portable, easily recyclable, easily laminated with epoxy resin, high thermal insulation, ideal for outdoor/indoor works, resistant to moisture, extremely durable, compression resistant, branded by printing or adhesive labelling, easily recyclable, versatile in strength, low-price, manufactured into different shapes, sizes and compression materials, high shock absorbency characteristics, different coating with other building materials among others. Therefore, foamed polystyrene products have a new chain in building construction and its modular fashion should be focused on so as to improve its future uses.

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