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Prospects of Expanded Polystyrene Sheet as Green Building Material

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Abstract

As urbanization is rapidly growing the construction of residential area is perpetrating intensely and at the same time the world is also facing the energy resource shortage. Hence there is a need to modify the housing design and construction technologies which are used in the country to reduce the cost, CO_2 emission, and to provide more indoor comfort with least energy needs. There is a need to focus on such materials which along with traditional construction materials that are concrete and steel will satisfy the properties like thermal conductivity, embodied energy, durability, sound insulation, earthquake resistance & strength. The use of expanded polystyrene sheet (EPS) which are made from small beads of polystyrene mixed with pentane as the blowing agent are best suitable for our purpose. In this paper an attempt has been made to review the various aspects of EPS imbedded in the reinforced concrete and its prospective design & implementation in the building to make it energy efficient. EPS having a thermal conductivity in the range of 0.032 - 0.038W/(m·K) as compared to concrete that falls in the range of 0.4-0.7 W/(m·K) which is much lower helping to reduce the energy consumption. The unit weight of EPS embedded structure is upto 35% less than the conventional concrete structure and the pre-assembled units reduces the overall cost of structure significantly. Hence, EPS embedded structure results in a sustainable and economical structure.

Keywords: construction methodology, Expanded polystyrene sheet (EPS), CFC reduction, sustainable material.

1. Introduction

The requirement of advancement in the construction methodology resulted in the reduced energy consumption for their heating, ventilation and air-conditioning. As we know the most significant portion of energy provided to a building is utilized in heating and cooling of the building, many attempt has been made to insulate the building thermally. In 1839 Eduard Simon he created a new product made of large number of styrene and linked together through polymerization which we call as the expanded polystyrene sheet (EPS) today. The main advantage of which is that during the production process it does not include any halogens and hence causes no harm to the Ozone layer. Expanded polystyrene (EPS) have been used for decades, but the consumption in construction industry has increased by 50% within the past 5 years **[1]**. It is generally placed in the cavity of wall to reduce heat loss and from earlier research it is found that the reduction in heat loss is in the range of 60 to 80%.

2. Objective

The objective of this paper is to prove the suitability of expanded polystyrene embedded in reinforced concrete on the basis of cost reduction, CFC Emission, more indoor comfort, least energy needs, thermal conductivity, Embodied energy, durability, sound insulation and earthquake resistance and to provide a prospective design methodology best suited as per Indian environment.

3. Advantages

Using pre reinforced Expanded polystyrene sheets will reduce the overall construction cost as it reduces the duration of construction drastically hence the labour cost is reduced consequently. It also can be assembled where the bearing capacity of soil is low as the dead weight of the superstructure is very less compared to that of conventional reinforced concrete structure hence it needs less strength for the foundation reducing the material cost. The walls with EPS embedded in concrete and steel reinforcement (EPSCSR) prove to be very comfortable for the inhabitant in terms of heating and cooling as well as sound insulation for peaceful indoor environment. Since EPS has a very low thermal conductivity value, in the range of 0.032-0.035 W/(m·K), in summer it keeps the interior cooler and in winter in keeps the building warmer by preventing the external effect of environment. It thus, minimizes the energy required for heating or cooling up to 60-80% depending upon the thickness as well as density of EPS used and also the thickness of concrete applied on both sides of which can also vary from 2-4 cm depending on the strength required. While in conventional structures we use brick, in case of EPSCSR we provide external concrete layer which prevents the attack of termites, insects and rodents and provides moisture barrier to the wall. The mesh of EPSCSR is made from galvanized steel, so the system has no impact on the wood products. As the EPSCSR sheets are impermeable it requires minimal long-term maintenance, especially in areas prone to extreme weather and temperature conditions summer heat, winter snow, heavy rains and high wind. It is found earlier that buildings made with EPSCSR can withstand wind velocities of more than 300 Km/ hr and endure earthquakes of 0.4 g Ground Acceleration or more than 7.5 on the Richter scale [2].

4. Behavior of Composite, Non-Composite and Partial Composite EPSCSR under Load

4.1 Fully Composite Panel Behavior

The flexural design of composite panels is similar to that of solid panels that have the same cross-sectional thickness. Sandwich panels whose wythes (layers of concrete) are connected in such a way that both the wythes resist applied flexural loads as if they were an integral section are said to be fully composite panels. In this case the connectors must transfer the required longitudinal shear so that the bending stress distribution on the cross section of the panel is as shown in the figure 1. It is found that composite EPSCSR takes more loads in comparison to other. This theory is same as that applied for regular reinforced concrete beams **[3**].

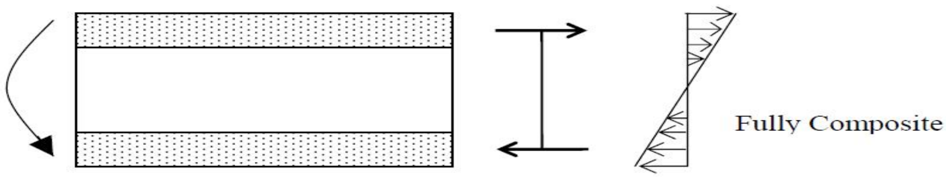

Figure 1: Behavior of Fully Composite Panel.

4.2 Non Composite Panel Behavior

Sandwich panels in which the two concrete layers (Wythes) are connected with connectors that have no capacity for longitudinal shear transfer are said to be non composite panels. The flexural design of non-composite sandwich panels is identical to that of solid panels that have the same sectional properties as the structural wythes (or layer of concrete) of the non composite panels. One additional consideration is the distribution of loads between the wythes for a panel that has two "structural" wythes. The distribution of loads is based on the relative flexural stiffness of each wythe. Once this distribution is made each wythe is then individually designed as a solid panel. In the case of EPSCSR the two layers of concrete have the same flexural stiffness. If the two concrete wythes are of equal stiffness and reinforcement, each wythe resists equal load and the bending stress distribution is as shown in the figure 2.

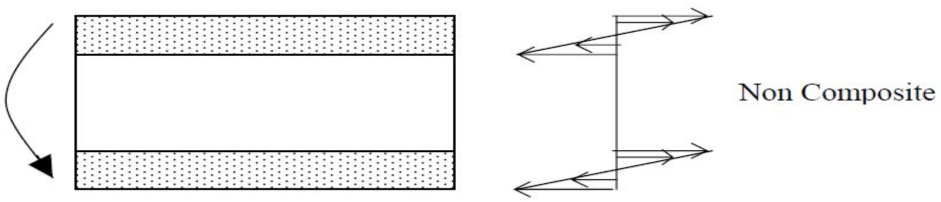

Figure 2: Behavior of non-Composite Panel.

4.3 Partially Composite or Semi-Composite Panel Behavior

Sandwich panels in which the connectors can transfer between zero and 100 percent of the longitudinal shear required for a fully composite panel is said to be semi-composite panels. The bending stress distribution in this type of panel is shown in the figure 3.

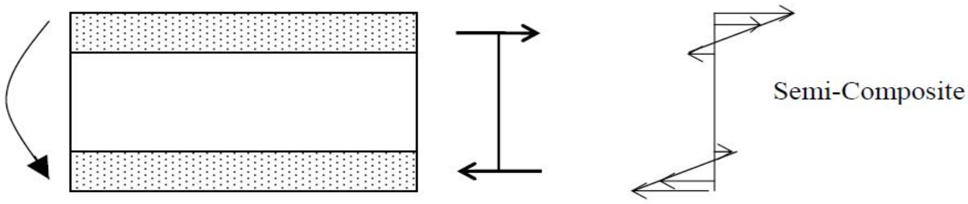

Figure 3: Behavior of semi or partially Composite Panel.

It is found that ESPCSR panel with dimension 600 mm × 2400 mm × 150 mm ,(i.e. span to depth ratio 16) having self weight avg. 2.10 KN will resist peak applied load 20 KN (avg.). Ultimate moment, flooring load and service load carrying capacity of above specimens are 6.08 KNm, 0.72 KN, and 7.5 KN respectively (a test report). [3]

5. Construction Methology

5.1 Fabrication & Casing of EPS sheets

As we know that the effect of forces are primarily on the surfaces of the beam or column and is very less near its inner core. This concept is utilized while forming EPSCSR.

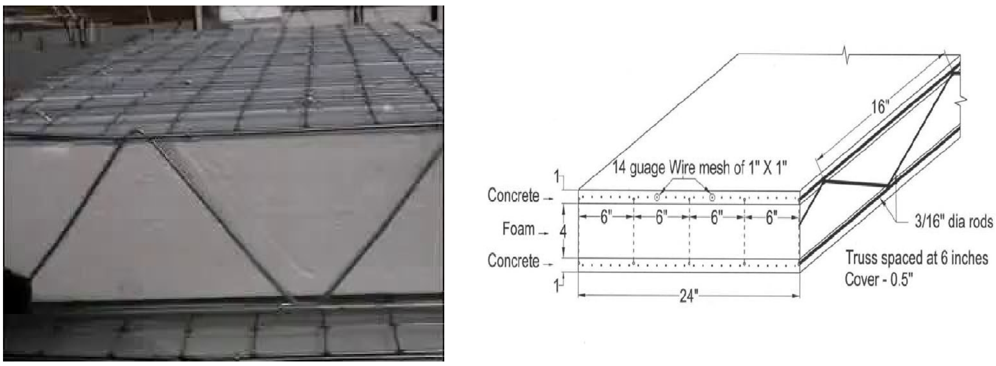

Figure 4: Cross-section of EPSCSR before concreting [3]

It consists of EPS inserted in galvanized steel wire mesh provided on both sides and trussed in transverse direction with suitable spacing to provide support and strength to the entire panel as shown in the figure 4.

4.2 Assembling of EPSCSR

After the fabrication and casing of EPS sheets these are assembled as per Patent number US 8,122,662 B2 Dated: 28th Feb 2012 . After construction of conventional foundation (as per the dead load) these cased EPS sheets are assembles directly according to the plan of the building and panels are joined together by twisted wires. The roofs are also constructed accordingly and the whole building is assembled as shown in figure 5.

Depending on the height of structure we decide the thickness of concrete layer provided on both side of cased EPS panel as well as the thickness of galvanized steel bars used for casing the EPS sheet. The concreting is usually done either by manually applying the concrete using toweling on the cased EPS panel or by Shortcreting method, guniting method and using modern air-placed concreting method.

The concrete on each side of the panel can be in the range of 20 – 30 mm and should be reinforced with 14 gauge wire mesh of 25 x 25 mm, placed in core of the wall, with 10 - 15 mm concrete cover. The steel trusses can be of 5 mm diameter wire spaced at 150 mm center to center longitudinally. The top and bottom chords of the steel trusses should be rooted for about 13 mm into the concrete thickness. Steel truss wire used in the panels was tested in tension [4].

Figure 5: Figure showing the assembling of roof and concreting

6. Present Indian Scenario

In India presently we use expanded polystyrene sheet on the outer face of the wall to provide insulation [6]. No doubt this somehow fulfills our purpose to reduce the energy needs but this system does not reduce the cost of construction. Even our Indian standard system does not have any relevant code related to the construction methodology involving EPSCSR. We know the most of south eastern cost are storm prone and some of the fields in northern India are affected by flood water for 3 to 4 months a year. Government has to shift them to some remote area by expending a huge sum of money. In this context if we use EPSCSR system to build the shelters for them, it will not only reduce the burden on government but also provide efficiency in disaster management. While conventional concreting and other similar kind of available materials like woods can be used in place of EPS panel but they are not as durable as the EPS panels. The wood may be affected by moisture; insects and termite, at the same time trees are of much more importance hence is not suitable for this purpose. Cement is the backbone for global infrastructure development whose every tones production emits 0.87 tonnes of CO_2 approx 7% of world's CO_2 emission. In India the sources of lime are limited and production of 45.33 million tones (MT)/ annum and with an annual growth rate of 9.7 % is expected to reach 407 MT by 2020 which will affect the cement industry badly in future hence we need to economize its use [7]. At the same time the construction industry uses 20 Crore truck load of sand per year which is obtained by dredging of river bed which also causes serious impact on environment and ecology [8]. The use of EPSCSR can be used to minimize the production of cement and to benefit the environment.

7. Conclusion

Rapid development of new technologies makes for new possibilities, and the material options are essentially boundless. Thus, this review cannot touch on every available option. Instead, it includes the most common and readily available material options currently used in the EPSCSR industry and highlights the material options focused upon in this research.

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