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A Study on use of Reinforced Thermocol Panels as an Alternate Building Material

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Abstract-Thermocol or polystyrene has already found extensive use as filler material in structural members. Various studies have also shown that thermocol panels offer high bending stiffness at low densities due to minimal compressive and flexural strength. It is because of their ability to withstand external forces, that construction materials are considered in the design of a structural framework. There have been cases where similar ideas have been tried, one such case being "Thermo 'Cool' Houses" a German technology brought to coastal parts of Surathkal by Captain Karl Neugebauer, the engineer and promoter of Eco-thermo Constructions. The houses are built using thermocol moulds and the strength is obtained by filling the block with concrete. These houses are aimed to be very energy efficient. An investigation was focused on the strength capability of lightweight web sandwich panel (LWSP). This study dealt with the LWS's strength under flexural loading (one point load & three point load) by treating these LWSPs as a floor and also, studying LWSP strength under axial load by treating these LWSPs as a wall. It was found that the material cost for building using the Reinforced Thermocol technology was lesser than the quarried stones for building a wall. Although due to the labour intensive process that masonry work requires, the conventional method was more expensive on labour than the Reinforced Thermocol technology. Hence the technology offers a way of meeting the housing demand at a total lower cost. Thus we aim to prove that by using Reinforced Thermocol as an alternate building material we can achieve an easy, fast and cheap method of construction.

Index Terms-Thermocol; panels; EPS; LWSP; Compressive Strength; Flexural Strength.

1. INTRODUCTION

In 1976, the International Labour Organization's World Employment Conference introduced the "basic needs" approach as one that attempts to define the absolute minimum resources necessary for long-term physical well-being of a human being. The list of immediate "basic needs" is food, water, clothing and shelter.Today, the demand for home ownership has risen due to steady population growth and the consequent rural to urban migration. With the increasing demand for housing there is a rise in demand for the conventional building material. This has resulted in depletion and overexploitation of our resources.

In engineering, the best way to solve the rising housing deficit in the countryisbyconsidering cheaperandbetterwaysofbuilding that will reduce 65 and 30 per cent of overall costs brought about by building materials and labour respectively. Materials represent a major expense in the overall cost of a construction project. Minimizing procurement costs presents important prospects for reducing costs. A 5% rise in labour costs could increase the cost of construction project by 1.5%.Construction using prefabricated materials to get buildings up fast is a relatively new method in India. Parts of the building are pre-made in the factories in order to cut down on construction time, labour, and lower the overall cost of a project.Majority of buildings were and still are built using the borrowed traditional masonry method i.e. borrowed from the European culture of stone and mortar or brick and mortar method of construction. Most are familiar with this method of construction and, along with a number of advantages, there is a deep psychological attachment to masonry construction that has contributed to its continuation as the main building method.

1.1. *Expanded Polystyrene (EPS) Technology*

EPS is used in the building and construction industry and huge quantities are utilized to make insulation foam for walls, roofs and floor insulation. EPS has also found uses in road construction, bridges, swimming pools, retaining walls, basements and construction of soundproof rooms. Here, panels are first prefabricated in the factory. The raw materials are imported and used to manufacture the expanded polystyrene beads which are then moulded into EPS blocks.Different panels are then cut from the blocks and galvanised steel mesh attached to both sides. These panels once ready, are taken onsite to be assembled, and shotcrete or concrete, depending on the panel used, is then used to sandwich and cover the panels, forming a monolithic structure.

2. LITERATURE REVIEW

Jalal A. Saeed et al., [1997] have experimentally studied the behaviour and flexural strength of Ferro cement one way slabs with square openings under two point loads taking into consideration number of wire mesh layers and size of the openings as variables.Salihuddin Radin Sumadi et al., [2008] have developed two mathematical models to predict compressive strength of high workability slag-cement based mortars and the ultimate load of Ferro cement encased aerated concrete sandwich wall elements. The values predicted from the mathematical models were 95%-100% accurate to the experimental results.Ade S. Wahyuni et al., [2012] had carried out an investigation of new lightweight sandwich reinforced concrete (LSRC) section using prefabricated autoclaved aerated concrete (AAC) blocks as infill in the section where concrete is considered ineffective under bending.T. Chandra Sekhar Rao et al., [2012] carried out an experimental study on the strength and behavioural aspects of cored Ferro cement box-beams for precast purposes. Have proposed an empirical formula based on the layers of wire mesh for the ultimate moment capacity of box-beam.Nahro Radi Husein, V. C. Agarwal, Anupam Rawat, [2013] concluded that LWSP showed significant resistance proportional to its weight under flexural load. The reduction percentage of weight between these LWSPs with aerated concrete core with normal concrete is about 20% in weight. Changing the web panel to thermocol reduced the weight of the sandwich panel about 30%.The high stiffness of LWSP with thermocol the strength between first crack load and ultimate load is about (34-38) % under flexural load with one point and three point loading. The LWSP specimen's resistance to axial load were significantly high so it's suitable to use it as a wall especially with aerated concrete core. They also concluded that the role of wire mesh was in a strength capacity and in failure mode which prevents the sudden and brittle failure of these panels and increase in ductility of the panels.

3. MATERIALS AND MANUFACTURING

3.1. *Raw material*

Reinforced Thermocol is made from styrene, a by-product of crude oil extraction. It is also found in the natural starch contained in many fruit such as strawberries and food products such as wine coffee beans and cinnamon.
Reinforced Thermocol is a derivative of ethylene and benzene and is made using a polymerization process which produces translucent spherical beads of polystyrene with sizes ranging from 0.5 to 1.3mm in diameter. During this process a low boiling point hydrocarbon usually pentane gas, is impregnated to the material.
Pentane has a Global Warming Potential (GWP) of zero. The European Union does not register pentane as substance hazardous to human health or the environment.

3.2. *Manufacturing process*

Manufacturing process of expanded polystyrene is carried out in three stages:

3.2.1. *1st Stage – PRE-EXPANSION*

The raw material (beads) are heated in special machines called pre-expanders with steam introduced to the vessel at temperatures of approximately 100^{o}C. The steam causes the pentane to be released from the beads. During the process of pre-expansion the beads swell up to almost 50 times their original size. Once the desired volume has been reached, the expanded beads are released into a bed dryer and all condensed steam moisture is dried from the surface. This process takes approximately 3 min to finish.

3.2.2. *2nd Stage – INTERMEDIATE MATURING*

Once the expanded beads have been dried, they are blown into large open silos or mesh bags for the aging process. This is because on cooling, the expanded beads form a vacuum in their interior which must be equalized to atmospheric pressure to prevent collapse or implosion of the beads. Hence this process allows the beads to fill back up with air. This process can take from 12 hours to 48 hours in order to achieve a greater mechanical elasticity and improve expansion capacity of the beads and also depends on the desired expanded density required of the beads.

3.2.3. *3rd Stage – FINAL MOULDING*

In this stage, the pre-expanded beads are transported to moulds where they are further subjected to steam so that as the beads are compressed, they bind together to form a block "block moulding" – that are later cut into panels and shaped – or products are moulded in their final finished shape "shape moulding".

3.3. *Material Specification*

3.3.1. *Roof slab panel*

Fig.1. Roof slab panel

Table 1. Roof slab panel specifications

Sl. No.	Sample Designation	Dimensions (mm) (B x L x t)	Effective Span (mm)
1.	RF-001	1220 x 1055 x 85	1020
2.	RF-002	1230 x 1050 x 130	850
3.	RF-003	1230 x 1460 x 170	1260
4.	RF-004	1240 x 1460 x 160	1260

3.3.2. *Wall panel*

Fig.2. Wall panel

Table 2. Wall panel specifications

Sl. No.	Designation	Dimension (mm) (L x T x H)
1.	WL001A	1230 x 100 x 1530
2.	WL001B	1230 x 150 x 1530
3.	WL002	720 x 110 x 1250
4.	WL003	690 x 110 x 625
5.	WL004	530 x 115 x 731
6.	WL005	1043 x 100 x 1248
7.	WL006	1066 x 140 x 1250

4. TESTING

4.1. *Material Type*

The following types of the materials of EPS were tested:
i. EPS 70 – density of 15 Kg/m3
ii. EPS 100 – density of 20 Kg/m3
ii. EPS 150 – density of 25 Kg/m3
iv. EPS 200 – density of 30 Kg/m3
v. EPS 250 – density of 35 Kg/m3
Additional types are also available for specific applications; for example, types with compressive-stress values, at 10%, of 0.4 and 0.5 N/mm2.

4.2. *Tests*

4.2.1. *Compressive strength*

The most important property of a structural material which will be covered with concrete is the compressive strength which is determined by loading as dictated by the standards.

4.2.2. *Flexural strength*

Tensile strength is commonly defined in one of the three ways: direct tensile strength, tensile splitting strength or flexural strength. The flexural strength is about 1.5 times the tensile stress determined by splitting test

Flexural strength may be determined by using the two methods:-

Test method 1 – A loading system utilizing centre loading on a simply supported beam, supported at both ends.

Test method 2 – A loading system utilizing two symmetric load points equallyspaced from their adjacent support joints at each end with a distance between load points.

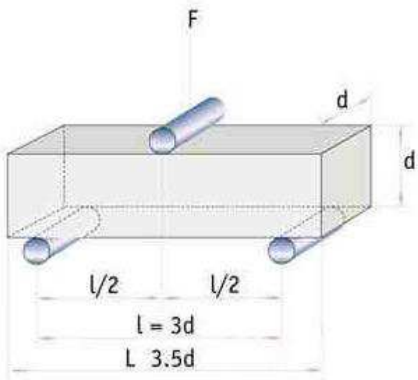

Fig. 3. Test Method 1

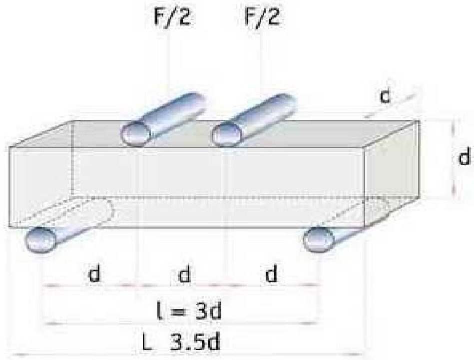

Fig. 4. Test Method 2

Four Point Loading - A loading system utilizing centre loading on a simply supported beam, supported at both ends.

5. RESULTS

Table 3. Strength of different types of eps materials

Panel Density	15 Kg/m^3	20 Kg/m^3	25 Kg/m^3	30 Kg/m^3	35 Kg/m^3
Compressive Strength (N/mm^2)	0.07	0.1	0.15	0.2	0.25
Bending Strength (N/mm^2)	0.115	0.15	0.2	0.25	0.35

Table 4. Roof slab panel test results

Sl.No.	Sample Designation	Ultimate LoadkN/m^2	Remarks
1.	RF-001	15.8	Used for sunshade, Non load bearing roof like sloping roofs
2.	RF-002	10.5	Used for sunshade, Non load bearing roof like sloping roofs
3.	RF-003	18.4	Used for roof for spans within 6ft
4.	RF-004	38.4	Used as load bearing, flat roof for span within 13ft

Table 5.Wall panel test results

Sl.No.	Sample Designation	Ultimate Load kN/m	Remarks
1.	WL001A	76.94	Vertical faces Unconfined
2.	WL001B	85.93	Vertical faces Unconfined
3.	WL002	125.5	Vertical faces Confined
4.	WL003	264.7	Vertical faces Confined
5.	WL004	186.32	Vertical faces Confined
6.	WL005	352.7	Vertical faces Confined
7.	WL006	447.33	Vertical faces Confined

Table6. Cost comparison

Sl. No.	Item	Cost of Blocks (Rs.)	Cost of Plastering on Both Sides (Rs.)	Cost of Other Works (Rs.)	Total Cost (Rs.)
1.	Brick work	690	660	322	1672
2.	Cement Block	546	660	430	1636
3.	LWSP	1170	80	131	1381

Cost analysis - Savings on using LWSP with respect to:

(i). Brick work : 17.4%

(ii). Cement block: 15.6%

6. CONCLUSION

- ➢ The first task of the field study was to determine the suitability of using Reinforced Thermocol technology in construction.
- ➢ The second task of the field study involved evaluating the cost of using Reinforced Thermocol as a construction material.

Based on the present work, the following conclusions were made:

- The tests for the compressive and flexural strength, as well as use of Reinforced Thermocol as a filler material proved that that technology can be used for structural purposes.
- A comparison was made between the prices of using Reinforced Thermocol technology and using the conventional stone and mortar method.
- The evaluation mainly concentrated on the material cost as well as labour cost as aspects that greatly influence the total cost of construction.
- The cost of materials while using the Reinforced Thermocol technology proved to be more expensive than using the conventional stone and mortar for wall construction.
- But since the conventional method of construction is more labour intensive, labour proved to be more costly than using Reinforced Thermocol technology.
- Reinforced Thermocol thus proved to be a cheaper method of construction.

The hypothesis has thus been proven showing that Reinforced Thermocol technology can provide a low cost solution to the national housing deficit in the country.

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