Evaluating Properties of Lightweight Sandwich Wall Panels

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Abstract— There is a huge growing requirement of building materials in India due to the existing housing shortage of 46.3 million units, mainly for the low income groups in urban India. Estimated urban housing shortage in 2015 was 56.43 million, while the housing shortage of rural India in 2015 was 62 million units. Thus total estimated housing shortage for Urban & rural India in 2015 was 128.43 million units. To fulfill this basic need of urban habitat; India requires innovative, energy efficient building materials for strong and durable housing in fast track method of construction at affordable cost. All these concerns have lead to develop an energy efficient and economical material. Lightweight pre-fabricated Sandwich wall Panel which provides rapid or faster construction and contributes to environmental protection, can provide a solution to many of the above issues and concerns. The paper describes the overview of sandwich wall panel, method of construction and its properties. Additionally, this sandwich construction deals with the problem of delimitation of face sheets leading to their premature failure. This can be avoided by providing binding cover over the core. The study conducted involved the development of high performance cement based mortar mix to cast Ferrocement cover. The results revealed the potential application of Ferrocement cover over lightweight insulation core to produce lightweight structural elements which leads towards the industrialization of building system.

Key words: Sandwich wall, Ferrocement, flexural strength, compressive strength, polystyrene

I. INTRODUCTION

Lightweight pre-fabricated sandwich structural element in building construction is a growing trend in construction industry. Sandwich construction element consists of cover of high performance material and a thick lightweight and low strength material as core. Ferrocement is regarded as highly versatile thin material possessing superior properties, thus suits its role as insulating and strength bearing cover. Thermocol (polystyrene) panel is a lightweight material which exhibits relatively higher insulation properties than the conventional core materials. It can be used as a potential material for core in sandwich composite because combine lightweight sandwich panel has more compressive strength compared to the traditional concrete wall panels.

In concrete construction, self-weight of structure itself represents a very large proportion of the total load on the structures thus, reduction in the self-weight of the structures by adopting an appropriate approach results in the reduction of element cross-section, size of foundation and supporting elements there by reduced overall cost of the project. Sandwich panel is a three-layer element comprising of two thin, flat facing plates of relatively higher strength material and between which a thick core of relatively lower strength and density is encased or it could consists of thin skin box of relatively higher strength material in-filled with relatively weaker and lower density material known as core. Thus using as effective structural form in the building and construction industries.

II. LITERATURE REVIEW

Nahro Radi Husein et al., [2013] investigated the strength capability of lightweight web sandwich panel (LWSP) in terms of first crack load, load-deflection curve for flexural load with (one point loading and third point loading), modules of rupture, ultimate flexural load, axial load-deformation curve and the failure mode. The unit weight of the LWSP's which have aerated concrete as a core is (1850-1950) Kg/m^3 and the unit weight of the LWSP's which have thermocol as a core (1250-1300) Kg/m^3. Pradeep A. S., [2016] studied that Reinforced thermocol panel offers high bending stiffness at low densities due to minimal compressive and flexural strength. Also the material cost for building using the Reinforced Thermocol technology is lesser than the quarried stones for building a wall. Thus this technology offers a way of meeting the housing demand at a total lower cost.

P. Poluraju., [2014] made a Comprehensive review of state of art on the performance of 3D panels for structural applications under general loading. It showed that 3D panels are effective in load carrying capacity, shear capacity and flexural capacity. The axial compressive strength of wall panels, shear strength of wall panels in case of lateral loading application and flexural strength of slab panels are suitable for economical, safety and eco-friendly building construction. I. Ahmad, N. [2008], presents overview of structural behavior of precast lightweight concrete sandwich panel. Precast lightweight concrete sandwich panel offers a lighter system which is critical for the construction industry. It provides a quick and efficient construction system when construction costs are critical or the job site is subjected to harsh construction environments. These panels provide structural and thermal benefits and also provide architectural benefits. Abhijit Mandlik [2013], performed experimental investigation of engineering properties such as compressive strength, modulus of elasticity, drying shrinkage and creep, of expanded polystyrene (EPS) aggregate concrete varying in density. Cost of EPS is less compared to that of normal concrete. Increase in the EPS beads content in concrete mixes reduces the compressive and tensile strength of concrete. All the EPS concrete without any special bonding agent show good workability and could easily be compacted and finished.

III. MATERIALS

A. Cement:

Ordinary Portland Cement (OPC) of 'ULTRATECH CEMENT' brand was used during the study. The OPC used of grade 53 complied with the Type I Portland cement as in IS: 1489 Part (I):1991.

B. Sand:

Locally available river sand passing through 4.75 mm sieve was used as fine aggregate in mortar for encasement. Initially the sand was dried in an oven at the temperature of 105 ^{0}C ± 5 ^{0}C. After that it was sieved accordingly. The sand used was as per the specifications of IS 1542(1992). The fineness Modulus was found to be 2.36.

C. Water:

Water is one of the most important constituents without which mortar cannot be produced. It should not contain any substance, which can be harmful to the hydration process of cement and durability of mortar. In general, water, which is acceptable for drinking, is also suitable for the concrete mixing. In this study tap water was used for the preparation of the mortar.

D. Thermocol:

Polystyrene sheets having width 20mm were used as central core.

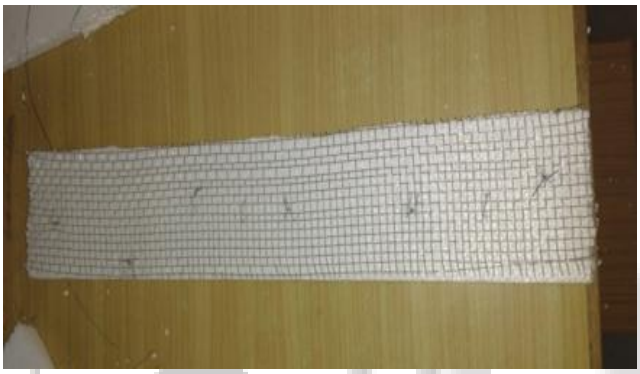

Fig.1: Thermocol with Wire Mesh

E. Wire Mesh:

Square welded wire mesh locally available in the market were used as the reinforcement in Sandwich panel. The wire mesh has average diameter 0.45 mm. Square wire mesh is having opening 0.5mm ×0.5mm.

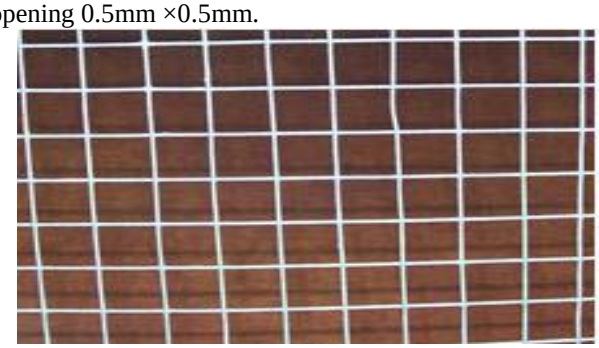

Fig. 2: Wire mesh

Mix Proportion for Mortar
Cement to sand ratio 1:2
Water cement ratio 0.4

IV. PRELIMINARY TESTS

Different tests were performed on sandwich panels. Panels were prepared in Cube and beam mould. Panels size were 15×15×7 cm and beam size were 10×30×7cm. Two types of mesh configuration were used. First consisted of single mesh layer on each size of Thermocol core and second consisted of double layer of mesh on both sides of Thermocol core. This inner core was sandwiched between Ferrocement mortar of 1: 2 ratio. Physical and mechanical properties of Panels were determined and discussed to determine it use and adaptability.

A. Tests Done On Sandwich Panel:

- Water Content Test
- Density Test
- Water Absorption Test
- Flexural Strength Test
- Vertical Load Carrying Capacity Test
- Compressive Strength Test
- Thermal conductivity Test
- Panel Impact Resistance Test
- Acid Resistance Test
- Ultrasonic Pulse Velocity Test
- Rebound Hammer Test

V. RESULTS AND DISCUSSION

Various tests were conducted on the sandwich panels to determine its properties.

Water Content Test: The average water content of sandwich panel is 1.15% to 1.7% which is less than 2% hence it is normal. At time of oven drying at temperature 105± 5 degree centigrade to panel, some thermocol get burn due to high temperature hence care must be taken while performing test so that temperature should be carefully maintained.

Density Test: The average density of panel was 1570 kg/m^3 which are comparatively less than concrete and brick.
Water Absorption test: The average water absorption value is 4.76% which is less than 5% hence it is normal.

Flexural strength test: Table 1. shows that flexural strength varies between 11.96 N/mm^2 to 14.96 N/mm^2 which is absolutely better. This flexural strength is better in double layer mesh than single layer mesh. The problem of separation of mortar and thermocol with mesh has taken place during testing of flexural strength.

Sr. No.	Layer Of Mesh Used	Maximum Load (KN)	Deflection (Mm)	Flexural Strength (N/Mm$^{2)}$
1	Single	21.15	3.70	13.22
2	Single	20.85	3.50	13.03
3	Single	18.65	5.20	12.16
4	Single	19.15	6.20	11.96
5	Double	21.90	3.80	13.69
6	Double	23.90	5.50	14.94
7	Double	20.60	6.00	12.87
8	Double	21.65	4.00	13.44

Table 1: Flexural Strength Test

Vertical load carrying test: Vertical load carrying capacity of panel ranges from 186.5 KN/m to 239.0 KN /m.

Compressive Strength Test: Table 2. Shows that Compressive strength value of panels which ranges from 12.90 to 14.96 N/mm^2.

Sr. No	Layer of Mesh	Failure Load (KN)	Compressive Strength(N/mm^2)
1.	Single Layer	145.23	12.90
2.	Single Layer	150.55	13.38
3.	Single Layer	142.62	12.68

4.	Single Layer	148.65	13.21
5.	Double Layer	162.21	14.42
6.	Double Layer	165.35	14.70
7.	Double Layer	168.28	14.96
8.	Double Layer	164.50	14.62

Table 2: Compressive Strength Test

Thermal Conductivity test: It gives very good resistance to flame penetration as it transfer less temperature from one end to another end. But thermocol was burnt out during the test.

Sr. No.	Time (In Hours)	Temperature (flame side)	Temperature (opposite side)	% heat transfer/ conductivity
1	00	36	36	0
2	0.5	70	52	25.71
3	1.0	97	59	39.17
4	1.5	128	65	49.22
5	2.0	180	70	61.11
6	2.5	227	75	66.96
7	3.0	245	80	67.35

Table 3: Thermal Conductivity Test

Panel impact resistance test: In impact test it can with stand upto height 1.5 meter drop of 5Kg weight. Table 4 shows the value of height of drop.

Sr. No.	Height of Drop of weight (5 kg)	Remark
1	1	No breakage
2	1+0.5 = 1.5	Panel breaks

Table 4: Panel Impact Resistance Test

– Acid Resistance Test

Initial weight 2795 grams
After one day it is 2772 grams
After two days it is 2761 grams
% loss in weight = 0.82%

Compressive strength after this test give result 7.11 N/mm^2. It is affected by acid attack. The weight of panel got reduce and due to acid, cement on surface of panel got washed out in some quantity. Also thermocol is affected by it.

NDT test: In order to determine its strength and grading USPV and rebound hammer test are performed and results are shown in table 5 & 6. It gives fair results regarding mortar quality grading in ultrasonic pulse velocity test.

Sr. No.	Layer of mesh	Pulse Velocity (Km/sec)	Concrete grading
1.	Single	3.13	Fair
2.	Single	3.26	Fair
3.	Single	3.4	Fair
4.	Single	3.13	Fair
4.	Double	3.75	Good
5.	Double	3.57	Good
6.	Double	3.4	Fair
7.	Double	3.95	Good

Table 5: Ultrasonic Pulse Velocity Test

Sr. No.	Layer of mesh	Compressive Strength (N/mm^2)
1.	Sample 1 (single layer)	8.5
2.	Sample 2 (single layer)	13
3.	Sample 3 (single layer)	14
4.	Sample 4 (single layer)	13.5
4.	Sample 5 (double layer)	18
5.	Sample 6 (double layer)	15
6.	Sample 7 (double layer)	16
7.	Sample 8 (double layer)	18.5

Table 6: Rebound Hammer Test

VI. Conclusion

The paper mainly examines the properties of sandwich panels. The use of Thermocol core along with wire mesh layers have helped to enhance property of precast wall panels. Based upon the experimental results following conclusions can be drawn:

The panels, which are extremely strong yet lightweight, compared to other building methods, are ideal for a wide range of building applications.

This reduces cost and significantly cuts down building time. In the development of new low energy, low cost, environmentally and ecologically sound housing solutions for the 21st century, Sandwich wall panel is the ideal product for re-housing and for new housing or industrial construction.

As compared to conventional building method it is less time consuming & also cost effective. Also it saves major building materials. It is very useful where the other building materials are not easily available. It is environment friendly. Sandwich wall panels are useful where there is need of quickly rehabilitation.

It has less water absorption than conventional brick masonry. It also has less density than conventional methods. So it is more advantageous and light in weight.

The conventional method of construction using brick or stone masonry is more labour intensive, labour proved to be more costly than using Sandwich wall technology. Sandwich Thermocol panels thus proved to be a cheaper method of construction.

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