Experimental analysis on Expanded Polystyrene Shortcreting panel

Giridharan A.
giridharan407@gmail.com

New Prince Shri Bhavani College of Engineering and Technology, Chennai, Tamil Nadu

ABSTRACT

Affordable quality housing is vital in developing countries to meet their growing population. Development of a new cost-effective system is crucial to fulfilling these demands. In view of this, a study is carried out to develop Expanded Polystyrene (EPS), as a new affordable building system. Experimental investigation and finite element analysis to study the structural behavior of the EPS panel under axial load are undertaken. The panel consists of lightweight Structural panel consisting of an insulated polystyrene core sandwiched between two engineered layers of Galvanized Steel welded wire fabric mesh. To complete the panel form process a Galvanized steel wire truss is pierced completely through the polystyrene core and welded to each of the outer layer sheets of Galvanized steel welded wire fabric mesh. The panels are loaded with axial load until failure. The ultimate load carrying capacity, load-lateral deflection profile, strain distributions, and the failure mode are recorded. Partial composite behaviors are observed in all specimens when the cracking load is achieved. Finite element analysis is also carried out to study the effect of slenderness ratio and shear connectors affect the strength and behavior of the panels. An empirical equation to predict the maximum load which is the major parameters that carrying capacity of the panels is proposed. The EPS panel system proposed in this research is able to achieve the intended strength for use in low rise building. The panel building system has tremendous flexibility—it can be used in place of wood or metal-framed walls, masonry block walls or precast panels. It is an excellent structural system that can be used in floors, ceilings, and roofs. The panel building system saves construction time while providing greater structural integrity. As an eco-friendly alternative building system, panel components are manufactured with all recycled plastics and steel – no forest products are used. The panel building system is safe and friendly to humans and wildlife. Also by the use of expanded polystyrene, we can standardize the climatic conditions inside the building. The cost of the construction is also reducing by the usage of expanded polystyrene wall panels in the construction of the building.

Keywords — EPS Panel, Project

1. INTRODUCTION

1.1 General

An innovative modular house system design utilizing an alternative concrete residential building system called EPS panels. The conventional country bricks have certain disadvantages like more porous and highly previous. The use of wire cut bricks for such in filled works prove to be uneconomical. The panel is a prefabricated Three Dimensional Lightweight Structural panel consisting of a super-insulated polystyrene core sandwich between two engineered layers of Galvanized Steel welded wire fabric mesh. To complete the panel form process a Galvanized Steel wire truss is pierced completely through the polystyrene core and welded to each of the outer layer sheets of Galvanized Steel welded wire fabric mesh. Panels with wire mesh that becomes a structural wall when concrete, gunite, cement, plaster or stucco are shotcrete into place. Unlike other building systems, Panel is an environmentally friendly – recycled green product. The panel building system has tremendous flexibility - it can be used in place of wood or metal-framed walls, masonry block walls or pre-cast panels. It is an excellent structural system that can be used in floors, ceilings, and roofs. The Panel building system saves construction time while providing greater structural integrity. As an eco-friendly alternative building system, Panel components are manufactured with all recycled plastics and steel - no forest products are used. The Panel building system is safe and friendly to humans and wildlife.

1.2 Precast building system

The precast building system is a system where parts, members and elements of structures are produced either on-site or at the factory, and transported to the site of construction. Using concrete material, the precast component may be cast in formwork in a position other than the actual one. After the concrete has matured, the forms are removed and the component is installed and fixed in the actual position. The benefits of precast concrete as compared to the conventional system include its better quality control and, fast delivery and installation. In most cases, precast panels are cast with high-quality concrete and therefore results in smooth surface appearance.

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The structural elements of load-bearing wall structure systems consist of load-bearing walls and floors while the structural elements of the frame and skeletal structure systems consist of columns, beams and floors. The frame and skeletal structure systems are utilized mainly for industrial buildings, shopping malls, car parks, sporting facilities and office buildings, whereas the load-bearing wall structures are suitable for apartment buildings, nursing homes, dormitories, and hotels (Bohdan, 1966).

Fig. 1: Precast structure systems

Wall element of a building can be constructed using the precast system. A precast wall system can be comprised of flat or curved panels (solid, hollow-core, or insulated), window or mullion panels, ribbed panels. These precast elements are normally used as cladding material which non-load is bearing (Freeman, 1999). This is due to their structural capability as load bearing elements are often overlooked. For instance, in the case of low or medium rise buildings, the number of reinforcements required in handling and erecting cladding panels such as wall and window panels are often more than necessary for carrying imposed loads. Thus, with relatively few modifications, these panels can function as a load bearing members especially in the low to medium rise buildings.

1.3 Precast panel
A precast sandwich panel is a layered structural system composed of low-density core material which acts integrally with the high strength facing material. Structures made of precast sandwich panels can be remarkably strong and lighter in weight. The trend for “stronger-lighter” product is becoming increasingly important in the construction industry.

Various forms of sandwich construction may be obtained by combining different leaves and core materials. The leaves may be constructed out of varieties of materials such as concrete, steel, Aluminium, or carbon fiber material. The core layers are often composed of lightweight concrete, fiber reinforced composite, balsa wood, foam, polymer foam and structural honeycomb material such as aluminium honeycomb concrete. These materials can be combined to form composite panels which enable the optimum design to be produced for particular applications.

A typical concrete sandwich panel consists of an insulation layer which is enclosed by inner and outer concrete leaves. The concrete leaves may be of a standard shape, such as a flat slab, hollow-core section or double tee. The leaves can be connected together using a shear connector.

Structural sandwich panels provide the dual functions of transferring load and insulating the structure. They may be used solely for cladding, or they may act as beams, bearing walls, or shear walls. Interest in sandwich panels as load-bearing wall panels has been growing over the past few years because manufacturers are looking for more viable products and are pleased with their structural efficiency, insulation property, light weight and aesthetics values. Sandwich panels are similar to other precast concrete members with regard to design, detailing, manufacturing, handling, shipping and erection; however, because of the presence of insulation layer, they do exhibit some unique characteristics and behavior.

Fig. 2: Typical precast concrete panel with its components
2. METHODOLOGY

2.1 General
The construction of the EPS wall panel is done by the following method. The methodology worked out to achieve the above-mentioned objectives is followed as shown in the flow chart below:

![Flowchart showing methodology](image)

2.2 Material testing
To investigate the properties of the materials such as cement and fine aggregate used for casting the specimens. Various laboratory tests were performed and the test results obtained were compared with the Indian Standard values. The test results are tabulated below.

2.3 Tests for cement
The following experiments were conducted to find the properties of cement as per IS-4031
(a) Standard Consistency Test
(b) Initial Setting and Final Setting Time Test
(c) Specific Gravity Test

2.3.1 Standard consistency test: Take 400 gms of cement was weighed accurately and it was put in a clean tray. To start with about 25% by weight of cement water was taken and mixed carefully by spatula. The paste was prepared in a standard manner and filled into the Vicat mould within 3-5 minutes. The surface of the cement paste was levelled on top of the mould with a trowel.

<table>
<thead>
<tr>
<th>Weight of cement (gm)</th>
<th>Percentage of water added (in terms of weight of cement)</th>
<th>Volume of water added (ml)</th>
<th>Penetration from bottom (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>28</td>
<td>112</td>
<td>37</td>
</tr>
<tr>
<td>400</td>
<td>30</td>
<td>120</td>
<td>36</td>
</tr>
<tr>
<td>400</td>
<td>32</td>
<td>128</td>
<td>31</td>
</tr>
<tr>
<td>400</td>
<td>34</td>
<td>136</td>
<td>25</td>
</tr>
<tr>
<td>400</td>
<td>36</td>
<td>144</td>
<td>16</td>
</tr>
</tbody>
</table>

The plunger is attached in moving the rod and brought down to touch the surface of the paste and quickly released it allowing to sink into the paste by its own weight. The reading was taken by noting the depth of penetration of the plunger. Other trial paste was prepared with an increasing percentage of water and test was repeated until the needle penetration was about 5 mm to 7 mm above the bottom of the mould.

2.3.2 Initial setting time of cement: The time interval for which cement products remains in the plastic condition is known as initial setting time. Normally this test must be carried within 30 minutes. Take 400 gms of cement sample was taken and it was mixed with 0.85 times the water required to produce a cement paste with standard normal consistency. The Vicat mould was placed on the non-porous plate and was filled with the prepared cement paste within 5 minutes. The surface of the paste was made smooth in level with the mould by using a trowel. By shaking the mould slightly, air if any, expelled from the sample. The needle was gently lowered to touch the surface of the plate and then the indicator was adjusted to show zero reading. The needle penetrated into the paste comes to rest; the reading on the index of the scale was noted. The moving rod was raised and the procedure of releasing the needle was repeated at every 30 seconds until the reading of the index scale shows 5 ± 5 mm from the bottom of the mould.
2.3.3 Final setting time of cement: The needle used in this test was replaced by the annular attachment. The needle was released quickly allowing it to penetrate into the paste. When the needle comes to rest; the reading on the index scale was noted. The procedure of releasing the needle was repeated every 30 seconds until the reading on the index scale shows 5 ± 5 mm from the bottom of the mould. Releasing the needle was continued at every 2 min. till the needle makes an impression on the test block. Then the time is noted down. The time that elapsed between the moment when water is first added to the cement and the moment at which the needle makes only an impression on the test block. The procedure is repeated by taking different proportions of cement and ash.

<table>
<thead>
<tr>
<th>Time at which water is added to cement(min)</th>
<th>Time at which the needle fails to pierce the test block by 5.0±0.5mm(min)</th>
<th>Initial setting time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>45</td>
<td>45</td>
</tr>
</tbody>
</table>

2.3.4 Compressive strength of mortar cube

Table 4: Compressive strength of mortar cube

<table>
<thead>
<tr>
<th>S no.</th>
<th>Period of curing (days)</th>
<th>Compressive strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>34 N/mm²</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>44 N/mm²</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>54 N/mm²</td>
</tr>
</tbody>
</table>

2.3.5 Specific gravity of cement: Specific gravity is normally used in mixture proportioning calculations. The specific gravity of Portland cement is generally around 3.15 while the specific gravity of Portland-blast-furnace-slag and Portland- Pozzolana cement may have specific gravities near 2.90. Specific gravity can be defined as the density of any substance to the density of other reference substance at a specified temperature. The specific gravity bottle was weighed in a dry state. The bottle was filled with distilled water and weighed (\(w_1\)). The specific gravity bottle was dried and filled with kerosene and again weighed (\(w_4\)). Weigh the sample of cement and add this cement to the specific gravity bottle and weighed again. Then the bottle was rolled gently in the inclined position until no further air bubbles rise to the surface. Then the bottle was filled with kerosene at the top and weighed (\(w_3\)). Weight of bottle and cement (\(W_2\)). Weight of cement is noted.

\[
\text{Specific gravity of cement} = \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)} = \frac{1.303 - 0.675}{(1.303 - 0.675) - (1.772 - 1.401)} = 3.14
\]

Table 5: Specific gravity of cement

<table>
<thead>
<tr>
<th>S no.</th>
<th>Description (gm)</th>
<th>Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of empty bottle ((w_1))</td>
<td>0.675</td>
</tr>
<tr>
<td>2</td>
<td>Weight of bottle + Cement ((w_2))</td>
<td>1.303</td>
</tr>
<tr>
<td>3</td>
<td>Weight of bottle + Cement + Kerosene ((w_3))</td>
<td>1.772</td>
</tr>
<tr>
<td>4</td>
<td>Weight of bottle + Kerosene ((w_4))</td>
<td>1.401</td>
</tr>
<tr>
<td>5</td>
<td>Specific gravity of cement</td>
<td>3.145</td>
</tr>
</tbody>
</table>

Calculation:

Specific gravity of cement

\[
= \frac{w_2 - w_1}{(w_2 - w_1) - (w_3 - w_4)}
= \frac{1.303 - 0.675}{(1.303 - 0.675) - (1.772 - 1.401)}
= 3.14
\]

2.3.6 Specific gravity test for fine aggregate

The specific gravity bottle was weighed in the dry state noted as \(w_1\). The weight of the bottle partially filled with aggregate \(w_2\). The weight of the bottle partially filled with aggregate and water \(w_3\). Weights of bottle fully filled with water \(w_4\) are noted.

Calculation:

\[
\text{The specific gravity of fine aggregate} = \frac{w_2 - w_4}{[w_4 - w_1] - [w_3 - w_2]}
= \frac{1385 - 681}{(1534 - 681) - (1961 - 1385)}
= 2.56
\]
Table 6: Specific gravity of fine aggregate

<table>
<thead>
<tr>
<th>S no.</th>
<th>Description (gm)</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of empty pycnometer ($w_1$)</td>
<td>681</td>
<td>681</td>
<td>681</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Weight of pycnometer + Fine Aggregate ($w_2$)</td>
<td>1385</td>
<td>1395</td>
<td>1393</td>
<td>1392</td>
</tr>
<tr>
<td>4</td>
<td>Weight of pycnometer + water ($w_4$)</td>
<td>1534</td>
<td>1534</td>
<td>1534</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>The specific gravity of FA</td>
<td>2.56</td>
<td>2.59</td>
<td>2.56</td>
<td>2.59</td>
</tr>
</tbody>
</table>

2.4 Tensile test on G.I steel
The tensile test is carried out using a tensile testing machine for galvanized steel is given in table 7: Tensile test on G.I steel.

Table 7: Tensile test on G.I. steel

<table>
<thead>
<tr>
<th>S no.</th>
<th>The diameter of steel wire</th>
<th>Finding (N/mm2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.0 mm</td>
<td>825.68</td>
</tr>
<tr>
<td>2</td>
<td>2.5 mm</td>
<td>911.42</td>
</tr>
</tbody>
</table>

Fig. 4: Tensile test 2 mm
Fig. 5: Tensile test 2.5 mm

2.5 Expanded polystyrene
EPS is composed of individual cells of low-density polystyrene. EPS is extraordinarily light and can support many times its own weight in water. Because its cells are not interconnected, heat cannot travel through EPF easily, so it is a great insulator. They are also used for non-weight-bearing architectural structures. Expanded Polystyrene insulation is a lightweight, rigid, closed cell insulation. EPS is available in several compressive strengths to withstand load and back-fill forces. This closed-cell structure provides minimal water absorption and low vapor permanence.

2.6 Mix ratio
2.6.1 Mortar mix design: The mix design of mortar is based on the concept of filling the voids between the solid particulate aggregate with a binder, a similar concept to that obtaining in many building materials as e.g. concrete, coated stone, etc. In the case of mortar, the mortar, the volume proportion of binder required to achieve this is such that mixes of between about 1:21/2 and 1:31/2 by volume of binder to aggregate were used historically.

Table 8: Compressive strength of mortar cube

<table>
<thead>
<tr>
<th>S no.</th>
<th>Grade</th>
<th>Mortar ratio</th>
<th>IS 2250-1981 compressive strength (N/mm²)</th>
<th>Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MM 7.5</td>
<td>1:4</td>
<td>7.5 and above</td>
<td>10.4</td>
</tr>
<tr>
<td>2</td>
<td>MM 5</td>
<td>1:5</td>
<td>5 to 7.5</td>
<td>5.9</td>
</tr>
<tr>
<td>3</td>
<td>MM 3</td>
<td>1:6</td>
<td>3 to 5</td>
<td>3.5</td>
</tr>
</tbody>
</table>

The requirement of filling the voids in the sand which are about 25 and 40 per cent by volume. Typically, a binder to the sand ratio 1:3 produces a broadly acceptable mix in terms of the working or plastic properties. As the voids are filled, the mix should be relatively acceptable to the operative and not prone to excessive bleeding or segregation, so long as the sand grading is acceptable.

2.6.2 Design for 1:4 panel
Step 1:
Calculate the dry volume of materials required for 1m³ cement mortar. Considering voids in sands, we assume that material consists of 60% voids. That is, for 1m³ of wet cement mortar, 1.6m³ of materials are required.

\[
(1.6 \times X) / (1 + X)
\]

X is a proportion of sand

\[
Dry\ volume \ = \ (1.6 \times 4) / (1 + 4) \ = \ 1.28\ m³
\]

\[
Total\ dry\ volume \ of\ sand \ = \ dry\ volume \times\ bulk\ density
\]

\[
\ = \ 1.28 \times 760
\]

\[
\ = \ 972.8\ Kg
\]

\[
Total\ volume \ = \ volume \times 972.8
\]
\[ = 0.01585 \times 972.8 \]
\[ = 15.418 \text{ Kg} \]

Step 2:
\[ \text{Cement} = \frac{15.418}{4} = 3.85 \text{ kg} \]
10% adding in cement = 4.235 kg

Step 3:
50% adding in sand = 15.418 \times 1.5
\[ = 23.127 \text{ kg} \]

Step 4:
\[ \text{Water /cement} = 0.5 = 0.5 \times 4.235 \]
\[ = 2.1175 \text{ kg} \]

2.6.3 Design for 1:5 panel

Step 1:
Calculate the dry volume of materials required for 1m³ cement mortar. Considering voids in sands, we assume that material consists of 60% voids. That is, for 1m³ of wet cement mortar, 1.6m³ of materials are required.
\[
\frac{1.6 \times X}{1 + X} = \text{Dry volume} \]

\[ X \text{ is a proportion of sand} \]

\[ \text{Dry volume} = \frac{1.6 \times 5}{1 + 5} = 1.3 \text{m}^3 \]

\[ \text{Total dry volume of sand} = \text{dry volume} \times \text{bulk density} \]
\[ = 1.3 \times 760 = 988 \text{ Kg} \]

\[ \text{Total volume} = \text{volume} \times 988 \]
\[ = 0.01585 \times 988 = 15.6598 \text{ Kg} \]

Step 2:
\[ \text{Cement} = \frac{15.659}{5} = 3.13 \text{ kg} \]
10% adding in cement = 3.443 kg

Step 3:
50% adding in sand = 15.659 \times 1.5 = 23.4885 kg

Step 4:
\[ \text{Water /cement} = 0.5 = 0.5 \times 3.44 \]
\[ = 1.72 \text{ kg} \]

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>W/C Ratio</th>
<th>Cement (Kg)</th>
<th>Fine Aggregate (Kg)</th>
<th>Water (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:4</td>
<td>.5</td>
<td>4.235</td>
<td>23.127</td>
<td>2.1175</td>
</tr>
<tr>
<td>2</td>
<td>1:5</td>
<td>.5</td>
<td>3.443</td>
<td>23.48</td>
<td>1.72</td>
</tr>
</tbody>
</table>

2.7 Design load for panel

2.7.1 Design load for panel 1:4

One leaf thickness = 25 mm, Height of the wall = 650 mm,

Width of the wall = 410 mm, Mortar = 1:4, fck = 10.4 N/mm²,

\[ \text{Gross area of wall} = 410 \times 50 = 20500 \text{mm}^2 \]

\[ \text{Area of the steel} = (\pi \times 2.5 \times 2.5 \times 42) / 4 = 206 \text{mm}^2 , \]

\[ \text{Area of mortar} = 20500 - 206 = 20294 \text{mm}^2 , \]

\[ \text{fck} = 10.4 \text{N/mm}^2, \text{fy} = 911.4 \text{N/mm}^2 \]

\[ P_u = 0.4 \times Fck \times Ac + 0.67 \times Fy \times Asc \]
\[ = (0.4 \times 10.4 \times 20294) + (0.67 \times 911.4 \times 206) \]
\[ = 197072.08 \text{ = 197 KN} \]
\[ = 19.7 \text{Ton}. \]
2.7.2 Design load for panel 1:

One leaf thickness = 25 mm, Height of the wall = 650 mm,

\[ \text{Width Of The Wall} = 410 \text{ mm}, \text{ Mortar} = 1:5, \text{ Fck} = 5.9 \text{ N/Mm}^2, \]

\[ \text{Gross Area Of Wall} = 410 \times 50 = 20500 \text{ mm}^2 \]

\[ \text{Area of the steel} = (\pi \times 2.5 \times 2.5 \times 42)/4 = 206 \text{ mm}^2, \]

\[ \text{Area of mortar} = 20500-206 = 20294 \text{ mm}^2, \]

\[ \text{fck} = 5.9 \text{ N/mm}^2, \text{ fy} = 911.4 \text{N/mm}^2 \]

\[ P_u = 0.4 \times Fck \times Ac + 0.67 \times Fy \times Asc \]

\[ = (0.4 \times 5.9 \times 20294 ) + (0.67 \times 911.4 \times 206) \]

\[ = 173685.268 N = 173 KN \]

\[ = 17.3 \text{ Ton.} \]

2.8 Testing of EPS panel under axial loading

2.8.1 Experimental programme

A 50 mm square reinforcing mesh composed by galvanized steel bars with 25 mm of diameter was placed with a cover of 25 mm measured from the inner side of the mortar layer. Steel connectors with the same material and 25 mm of diameter were placed between the reinforcing meshes. The main properties for the EPS and the reinforcing steel used in the experimental program are presented in table 10.

The panels were cast in wooden moulds with the mortar layer parallel to the ground. Initially, the mortar of the layer closest to the ground was poured into the moulds. Then, the steel mesh, the connectors and the EPS were placed (see figure 6). Finally, the last mortar layer is cast and finished.

Table 10: Number of specimens

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>Panel size(mm)</th>
<th>Number of specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:4</td>
<td>650X410X100</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1:5</td>
<td>650X410X100</td>
<td>2</td>
</tr>
</tbody>
</table>

2.8.2 Test setup

Also, the displacement of each specimen was measured using the linear variable differential transformer (LVDT is an acronym for Linear Variable Differential Transformer. It is a common type of electromechanical transducer that can convert the rectilinear motion of an object to which it is coupled mechanically into a corresponding electrical signal) are shown in figure 7. A load cell with 50T capacity was mounted on the plate fixed at the centre portion. The load-deflection behaviour was obtained automatically from the system attached.

During the test, a crack was generally observed parallel the lateral surface of the panel. The crack opening increased as the compressive load was applied, leading to the failure of the panel. It was observed that the height of the panels may affect considerably the results obtained. In general, the increase in this dimension produces a considerable reduction in the maximum load.
3. RESULT AND DISCUSSION

3.1 General
In this chapter, the experimental results of all the panel are being compared with theoretical results. Their behavior throughout the test is described using mechanically obtained data on deflection behavior and the load carrying capacity. All the panels are tested for their ultimate strengths.

3.2 Material test results

Table 11: Comparisons of material testing results

<table>
<thead>
<tr>
<th>S no.</th>
<th>Name of the test</th>
<th>Experimental value</th>
<th>As per codal value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Specific gravity of cement</td>
<td>3.14</td>
<td>IS:4031(Part-3)1988 Range-3.15</td>
</tr>
<tr>
<td>2</td>
<td>Standard consistency of cement</td>
<td>32%</td>
<td>IS:4031(Part-4)-1988 Penetration 5-7mm</td>
</tr>
<tr>
<td>3</td>
<td>Initial setting time of cement</td>
<td>45 min</td>
<td>IS 12269-1987 Not &lt; than 30 mins clause 5.3</td>
</tr>
<tr>
<td>4</td>
<td>Final setting time of cement</td>
<td>445 min</td>
<td>IS 12269-1987 Not &gt; than 600mins clause 5.3</td>
</tr>
<tr>
<td>5</td>
<td>Average Compressive strength test of cement mortar cube 28days</td>
<td>54 N/mm²</td>
<td>Not &lt; 53 N/mm² as per IS 12269 – 1987</td>
</tr>
<tr>
<td>6</td>
<td>Specific gravity of F.A</td>
<td>2.56</td>
<td>IS 2386(Part-3)1963. Range(2.6-2.7)</td>
</tr>
<tr>
<td>7</td>
<td>Sieve analysis of F.A</td>
<td>FM=2.78</td>
<td>IS 2386(Part-1)1963 Medium sand 2.6-2.9</td>
</tr>
<tr>
<td>8</td>
<td>Tensile strength for steel</td>
<td>911.42N/mm²</td>
<td>IS:1605-2005</td>
</tr>
</tbody>
</table>

3.3 Deflection results
During the test, a crack was generally observed parallel the lateral surface of the panel. The crack opening increased as the compressive load was applied, leading to the failure of the panel. It is important to remark that such observations must be considered taking into account some of the panels available with each configuration.

Table 12: Load-deflections observation

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Ref.</th>
<th>Load P&lt;sub&gt;max&lt;/sub&gt;(KN)</th>
<th>Deflection(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spec.1</td>
<td>Spec.2</td>
<td>Avg.</td>
</tr>
<tr>
<td>1:5</td>
<td>S1,S4</td>
<td>108</td>
<td>110</td>
</tr>
<tr>
<td>1:4</td>
<td>S2,S3</td>
<td>152</td>
<td>148</td>
</tr>
</tbody>
</table>

3.4 Ultimate and failure load behaviour
Vertical Faces of the test Specimen are confined, which showed improved load carrying capacity and better stiffness and less cracking.

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Table 14: Ultimate and failure load behavior

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ref.</th>
<th>Panel size (mm)</th>
<th>Ratio</th>
<th>Ultimate load (KN)</th>
<th>Failure load (KN/M)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>650X410X100</td>
<td>1:5</td>
<td>108</td>
<td>203.7</td>
<td>Vertical face unconfined</td>
</tr>
<tr>
<td>2</td>
<td>S2</td>
<td>650X410X100</td>
<td>1:4</td>
<td>152</td>
<td>286.79</td>
<td>Vertical face confined</td>
</tr>
<tr>
<td>3</td>
<td>S3</td>
<td>650X410X100</td>
<td>1:4</td>
<td>148</td>
<td>279.2</td>
<td>Vertical face confined</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>650X410X100</td>
<td>1:5</td>
<td>110</td>
<td>207.5</td>
<td>Vertical face unconfined</td>
</tr>
</tbody>
</table>

3.4.1 Experimental and theoretical results panel S1: The panel S1 were being tested under the loading frame under axial loading. The type of failure observed is a buckling failure. The ultimate load carrying capacity and deflection observed are 152 kN and 2.9 mm. The ABAQUS analysis results are similar to experimental results.

Table 15: Load and deflection panel S1

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>Specimen size (mm)</th>
<th>Deflection (mm)</th>
<th>Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:5</td>
<td>650X410X100</td>
<td>0</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Fig. 10: Load vs. deflection graph of panel S1

![Load vs. deflection graph of panel S1](image)

Fig. 11: Analysis using ABAQUS of S1

3.4.2 Experimental and theoretical results for panel S2: The panel S2 were being tested under the loading frame under axial loading. The type of failure observed is a buckling failure. The ultimate load carrying capacity and deflection observed are 152 kN and 2.9 mm. The ABAQUS analysis results are similar to experimental results.

Table 16: Load and deflection panel S2

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>Specimen size (mm)</th>
<th>Deflection (mm)</th>
<th>Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:5</td>
<td>650X410X100</td>
<td>0</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.9</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Fig. 12: Load vs. deflection graph of Panel S2

![Load vs. deflection graph of Panel S2](image)
3.4.3 Experimental and theoretical results for PANEL S3: The panels S3 were being tested under the loading frame under axial loading. The load, as well as deflections, are noted. The type of failure observed is a buckling failure. The ultimate load carrying capacity and deflection observed are 148 kN and 2.6mm. The ABAQUS analysis results are similar to experimental results.

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>Specimen size(mm)</th>
<th>Deflection (mm)</th>
<th>Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:4</td>
<td>650X410X100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>148</td>
<td>2.6</td>
</tr>
</tbody>
</table>

![Graph showing Load vs deflection](image1)

**Fig. 14:** Load vs deflection graph of panel S3

![Graph showing Analysis using ABAQUS](image2)

**Fig. 15:** Analysis using ABAQUS of S3

3.4.4 Experimental and theoretical results for panel S4: The panel S4 were being tested under the loading frame under axial loading. The load, as well as deflections, are noted. The type of failure observed is a buckling failure. The ultimate load carrying capacity and deflection observed are 148 kN and 2.6mm. The ABAQUS analysis results are similar to experimental results.

<table>
<thead>
<tr>
<th>S no.</th>
<th>Ratio</th>
<th>Specimen size(mm)</th>
<th>Deflection (mm)</th>
<th>Load (KN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:4</td>
<td>650X410X100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>148</td>
<td>2.6</td>
</tr>
</tbody>
</table>

![Graph showing Load vs deflection](image3)
5. CONCLUSION
The structural behavior of the EPS panels expected in practice is investigated experimentally. Despite the limited number of tests, the results indicate that the compressive strength of the mortar and the thickness of the panels are the main aspects that affect the maximum load resisted by the panels. Such load increases with the increase of the compressive strength and decreases with the reduction of the panel thickness. All these observations are in good agreement with the results estimated with the analytical formulation proposed.

Possible failure mechanisms are due to the lateral instability or buckling of the individual leaf of the panel. For panels with small height, thin EPS (short steel connectors) or less resistant mortar the first failure mechanism predominates. The parametric study performed with the new formulation proposed shows that the increase of the number or of the diameter of the steel connectors increases the maximum load due to the lateral instability. On the other hand, the increase of the thickness of the mortar layer produces a consequent increase in the maximum load estimated for both failure mechanisms. It was found that the resistance of the panels is maximized if the reinforcing mesh is centered at the mortar layer. Any other position dislocates the gravity centerline of the mortar layer thus generating an eccentricity that reduces the global normal load resisted.

If the position of the reinforcing mesh is not centered in the mortar layer, special care should be taken to select the diameter of the bars used. In this case, the use of meshes with thicker bars may have an adverse effect, producing the reduction of the maximum load resisted by the panel.

6. REFERENCES