Nonlinear Finite Element Analysis, Testing and Evaluation of Infilled Wall Panel

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Abstract: **- Masonry blocks are widely used in structures for load bearing or non load bearing system. The masonry structures are normally unreinforced and in the recent earthquakes showed its weakness against the lateral loading and its dead weight and the brittle characteristics caused loss to the lives and properties. The light weight sandwich wall panels can be the elucidation for the damages. The light weight wall panels are more advantageous ductile characteristics due to the reinforcement. The factory made EPS panels (Expanded Polystyrene with welded wire mesh on both sides) are used for the development of light weight sandwich concrete wall panels which become the key factor for its increased cost. The present investigation proposed to develop the simple and reliable technologies for the development of light weight inner core material for the light weight wall panel.The inner core concrete material is developed by mixing the higher percentage of polystyrene beads by volume with normal concrete and the normal concrete is used for the outer skin portions. 3mm and 5mm sizes of spherical beads with different volume percentage are investigated. The cubes were casted, cured, weighed and tested under compression for its 7th and 28th day strength. The result indicates that the proposed material is appropriate for the inner core light weight concrete. The study showed that the light weight concrete with 3mm size polystyrene beats with 75 volume percentage is seems to optimal for light weight concrete with higher compressive strength. The sandwich wall panel is analytically examined using the test results of light weight concrete inner core. Both material and geometrical nonlinearities were considered in the finite element analysis. The results are found to be comparable for the sandwich panel with EPS infill as well as with the proposed light weight concrete infill.**

Keywords: Light weight concrete, EPS Bead Concrete, Wall panel, Finite Element Analysis, Nonlinear Analysis

INTRODUCTION:

Stonework is most commonly used in structures for structural (load bearing) and non-structural members. Though these type of structures are good in compression, but weak under lateral loads. Furthermore, due to heavy dead weight and inefficient these are not used liberally. The progressin light weight sandwich wall panels has led to more usage when related with stonework. Since the Sandwich panels are commonly made with EPS core, owing to cost, it is improvident. More over light weight concrete can be used as infills in the sandwich wall panels. Light weight concrete can be produced by replacing the normal aggregate in concrete by light weight aggregate or any other lighter materials either partially or fully depending upon the prerequisite of density and strength. Also demand for light weight structures like
Infilled wall panels due to its low weight which further reduces the dead weight of the structure.

Light weight concrete is used for both structural and non-structural applications. As a structuralmaterial it should have specific characteristics to meet thestrength and performance requirements for the application.Thus, naturally, before indorsing any material for aspecific application (whether structural or non-structural) there is a need to study the mechanical characteristics toestablish its suitability. In the case of lightweight aggregateconcrete it was recommended that the compressive strength should be above 17 MPa for it to be useful as a structuralconcrete. Also, if the concrete is required for insulationpurposes, the density of the concrete should be 800 kg/m^{3}orlower.
Expanded polystyrene is a stable low density foam ofnon-absorbent, hydrophobic, closed cell nature. It wasreported that this can be used as ultra-lightweight aggregate suitable for developing concretes for both structural and Non-structural applications by varying its volume percentage in mortar or concrete. These beads can be used in concrete for make it light and might be used as core material for the wall panels

Need for Study:

By replacing the concrete mix or mortar with EPS beads by volume percentage will reduce the overall weight of concrete. Thus light weight concrete can be used as filler material in the infilled wall panels. As the EPS beads are light in weight, non-absorbent, fire resistant and also has thermal properties it can be widely used in concrete mortar in use of filler material.

The development of computer and the computer software, made simpler to predict the behaviour of the structures. The selection of a mathematical model for simulation is a very important step in any analysis. The FEM involves dividing a structure into a discrete number of elements from which the approximate numerical solution is obtained. The accuracy of the results depends on the selection of the suitable elements with the appropriate material characteristic modelling.

Objective:

The main objective of this paper involves,

a. To produce light weight concrete by replacing mix with EPS beads.
b. Analysing wall panel model with the experiment data.

Literature Review

Stonework has been used from past several decades as structural load bearing members and for also non loading members. Due to the increase in dead weight, uneconomic, etc. The stonework is gradually reduced. Increase in technology and encroachment in civil engineering has led to develop a new light weight material for structural members. The use of EPS boards in the precast wall panels has be developed. Benayoune et al has developed a sandwich panel by placing wire mesh in outer layers and a truss connector connecting both the meshes. Based on experimental results it was concluded that the precast sandwich panels can be used for housing. Furthermore Thomas and Stine had tested the sandwich panel with EPS core with truss connectors can be used for construction. Due to the cost effective of the factory made EPS panels were uneconomical to common man. By addition of EPS beads in the concrete as a replacement of aggregate, Saradhi et al has concluded that the concrete mix containing EPS beads with fly ash has gained good strength at 90 days when compared with OPC. Due to the addition of EPS beads the density also get reduceswhich is an advantage in case of composite sandwich panels. Abdulkadir and Ramazan investigated on cement to bead ratio and found that increase in ratio, there is increase in density and compressive strength.

EXPERIMENTAL TECHNIQUE:

EPS beads were purchased from local stores. The coarse aggregate from crushed granite were collected. The particle size used ranges from 10-12.5mm. River sand as fine aggregate was used to mix the concrete. Ordinary Portland cement and fly-ash was used for mixing of concrete and water was collected from laboratory.

Ratio of cement, Normal Sand, Quarry Dust, Coarse aggregate and Water/Cement ratio were of obtained through trial mix.

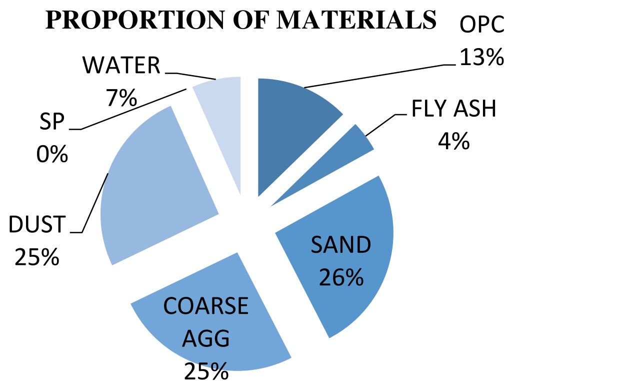

Fig 1 Mix Proportion of Materials for core.

Concrete cube sizes of 150x150x150 mm were cast for determining the properties of concrete. The mix proportion of 1:1.5:1.5:1.5 by weight of ordinary Portland cement, river sand, coarse aggregate and quarry dust were used to cast the specimens. The water/cement ratio of 0.52 was used for the mix. The water/cement ratio was maintained constant for all cubes. Super-Plasticizer named Con Plast is used to reduce the water content. All ingredients were mixed properly with use of pan mixture.

After mixing for three to 4 mins EPS beads were added slowly as shown in figure 2. It was checked that no lumps were formed during mixing. All specimens were left in mould for 24Hrs to set under ambient temperature. They were removed from the mould and transferred into the curing tank.

Fig 2 Adding EPS beads in the mixer

EXPERIMENTAL RESULTS

Test Setup

Compressive testing machine with a capacity of 3000kN were used. Rate of loading with 100N/s wasgiven to the cubes. Load Vs Displacement curve can be plotted from the data obtained from the CTM. Compressive strength test was carried out to find out the ultimate failure load, pattern of cracks.

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3a. Cube under compression 3b. Faiure pattern
Fig.3 Compression test on cubes

Results:

The stress results of specimen on 7th day were

Table 1 Specimen stress details and Results on 7th Day

S No.	Weight (kg)	Density (kN/m^3)	Load (kN)	Stress (N/mm^2)
1	3.1	918.53	10.25	0.45
2	3.2	948.15	14.2	0.63
3	3.1	918.53	10.6	0.47

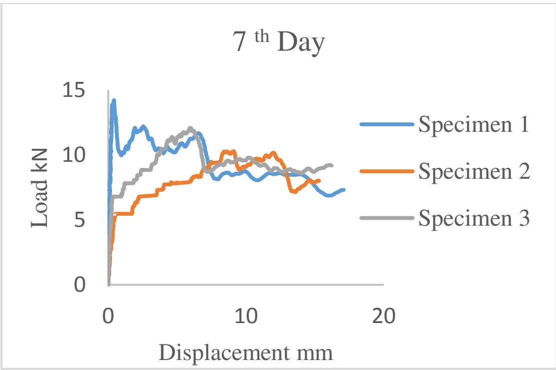

Fig 4 Load-Displacement graph of specimens on 7th Day

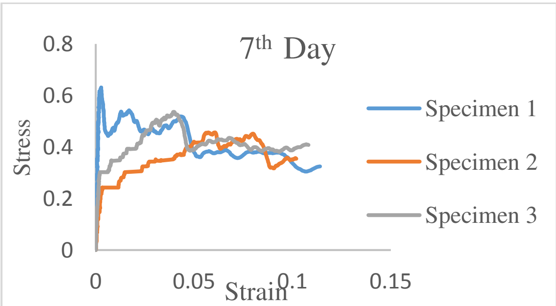

Fig 5 Stress-Strain Curve of specimens on 7th day

The stress results of specimen on 28th Day were

Table 2 Specimen stress details on 28th day

S No.	Weight (kg)	Density(kg/m^3)	Load (kN)	Stress (N/mm^2)
1	3.1	918.52	14.5	0.64
2	3	888.88	5.7	0.25
3	3	888.88	5.6	0.24

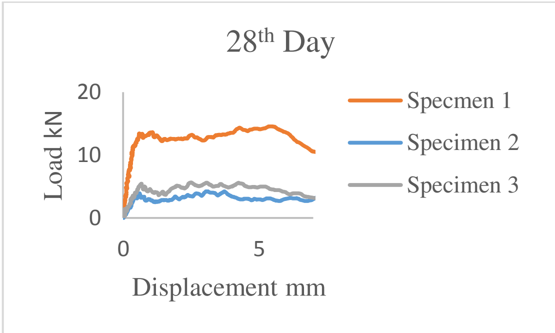

Fig 6 Load – Displacement graph of specimens on 28th day

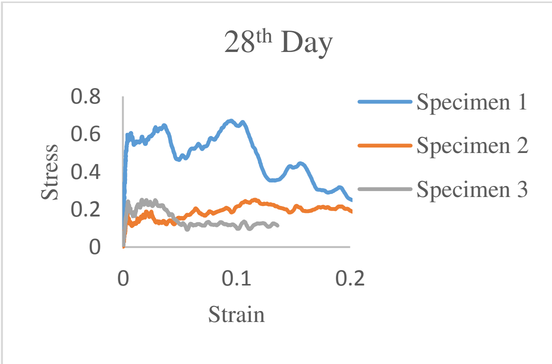

Fig.7 Stress – Strain graph of specimens on 28th Day

Based on the results obtained from the experiment conducted it was observed that the proposed material mix can be used as infill in the wall panels.

ANALYTICAL MODULATION:

The initiation of computers and the computer software simplified the behavioral prediction of any complicated structures. A general purpose finite element software ABAQUS/Standard is used for simulating the behavior of the simple cube with coconut infilled and normal cube. The ABAQUS has its own limitation in accurately modelling the complicated geometry. The panel of size 1m x1m was generated with EPS as core in one model and proposed material in another model.

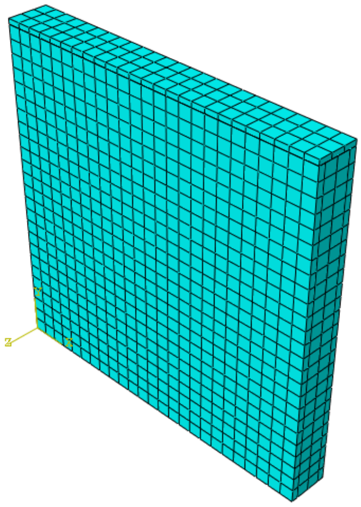

Fig 8 Meshed wall panel in ABAQUS

Material properties for all elements are specified; however, high-quality material data were difficult to obtain, particularly for the more complex material models like material damage properties. Concrete is a heterogeneous, non-linear and orthotropic material with relatively high compressive strength and significantly lower tensile strength. Modelling concrete is a difficult task which needs better understanding. Modelling concrete requires the density, elastic property and Poisson's ratio to define its behaviour at elastic range. The density of concrete is taken as 24 kN/m³ and the Young's modulus is taken as 25000N/mm^2 with Poisson ratio of 0.18 for outer Wythes (skin) of the panel and for core material properties are taken from the experimental results obtained. For steel provided density was taken as 7840 kg/m^3 and young's modulus was taken as 2x10^5 N/mm^2 with poison's ratio of 0.3.

The static risks method of structural analysis is carried out to overcome the issues related to instability point which normally may occur in the static general analysis. The history output request is made at the appropriate nodes. The deflection, stress and strains are observed from the analysis. The ultimate load of wall is calculated by multiplying the applied load with the maximum Load Proportionality Factor (LPF) from the history output.

ANALYTICAL RESULTS:

Nonlinear finite element analysis is conducted on the panels. The parametric study was conducted to study the compressive behaviour of the panel and also to know the load carrying capacity of the panel. The maximum deflection is observed as shown in fig 8.

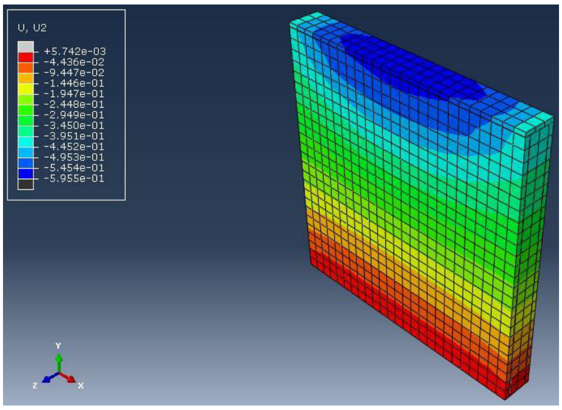

Fig 8 Deflection contour of the panel with Bead core

The Compressive Principle Stress distribution is obtained from Minimum Principle Stress plot as shown in Fig 9 and tensile stress distribution is obtained from maximum principle stress plots are shown in Fig 10 is observed in the reinforcement provided in the panel.

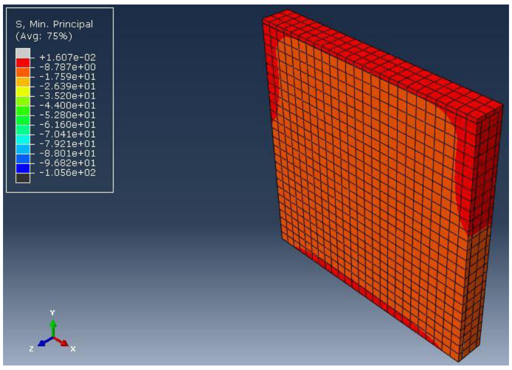

Fig 9 Compressive stress distribution of panel with Bead core

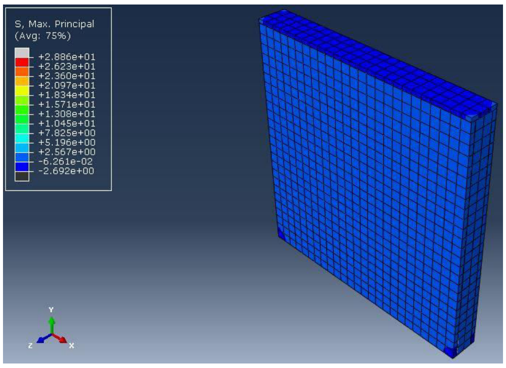

Fig 10 Tensile stress distribution of the panel with Bead core

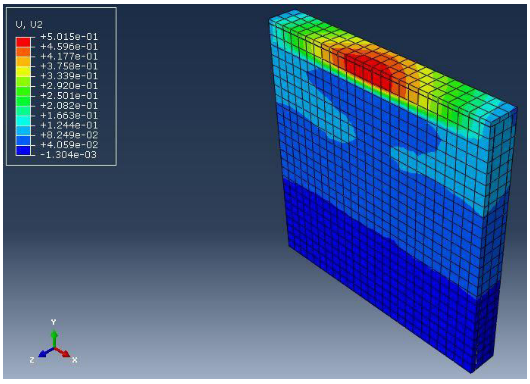

Fig 11 Deflection contour of the panel with EPS core

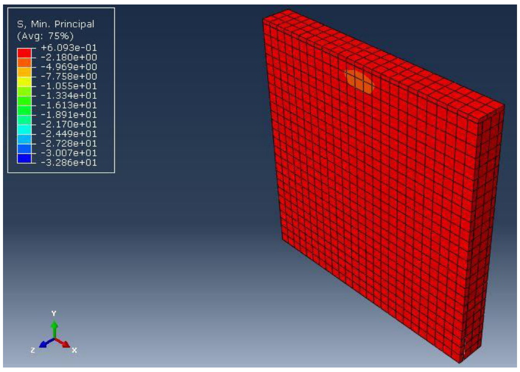

Fig 12 Compressive stress distribution of panel with EPS core

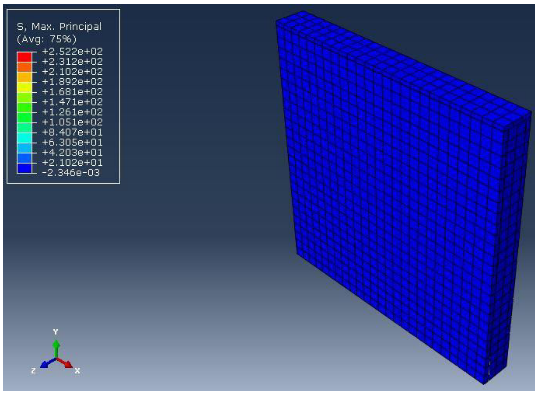

Fig 13 Tensile stress distribution of the panel with EPS core

The load distribution curve for the panel is shown in fig 14.

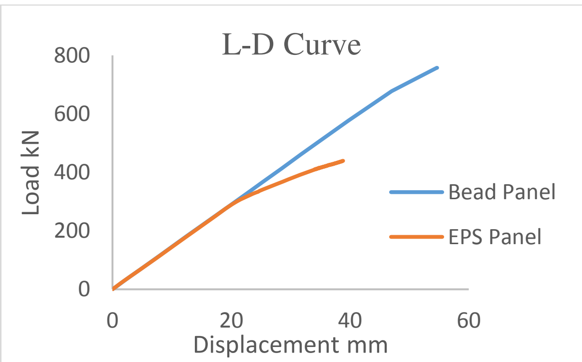

Fig 14 Load-Deflection curve for the panel (Analytical)

CONCLUSIONS:

The main Objective of this investigation is successfully accomplished through proper monitor and control during the casting and testing of light weight EPS concrete blocks. With the experimental and analytical investigations, the following conclusions were arrived,

- The EPS Bead concrete blocks are light in weight compare to the solid concrete blocks.
- The proposed concrete blocks weighs 40% less compare to the solid concrete blocks.
- From the experiment results it can be confirmed that the EPS Bead concrete blocks can be used as light weight concrete blocks.
- From the nonlinear finite element analysis of panel with EPS Bead concrete as core material and EPS as core panel, it can be inferred that the panel with Bead core has taken load of 756 kN.
- The study confirms that the EPS Bead concrete is light in weight and can be used as infill material in sandwich wall panels.

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