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Experimental Study on Minimum Tension Reinforcement for Sandwich Slab under Punching Shear

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***Abstract**: Sandwich components are multilayered materials made up of bond between high strength skins facing low density material. The primary target of this investigation was to discover flexural conduct of reinforced solid sandwich slab under punching shear. The experimental and numerical investigation is done on reinforced concrete sandwich slabs of dimensions 1000 mm x 1000 mm x 150 mm. The experimental programs were performed to assess the influence of same loading and support conditions. The sandwich slabs is provided with mesh reinforcement, extra reinforcement as spacing with variations of percentage of tension reinforcement (0.49%, 0.44%, 0.39% and 0.34%) and shear connectors has analyzed. The result shows 0.49% reinforcement gives better result when compared to other slabs.*

***Index Terms**: Sandwich, Composite, Punching shear and Shear connector.*

I. INTRODUCTION

Expanded Polystyrene (EPS) core Panel material is a new, efficient, safe and reliable construction system for the buildings. These panels can be used both as load bearing as well as non-load bearing elements. EPS core panel is a 3D panel consisting of 3-dimensional welded wire space frame provided with the polystyrene insulation core. Panel is positioned and filling with concrete on both the sides.

EPS panel consists of a 3-D space frame welded wire following a truss concept for transfer of stresses and stiffness. EPS panel is made up of reinforcing welded meshes of wire, diagonal wire and expanded polystyrene and concrete. Concrete is connected to the EPS sheet at the building site. It gives the bearing limit of the structure.

Fig. 1 shows the four components of EPS panel after concreting which are done to prepare the EPS panels and shows the transfer of stresses and stiffness.

The typical EPS panel is generally manufactured with dimensions of 1200 mm width,3000 mm length and over all thickness range of 80 mm to 230 mm. The panels are finished at the site using minimum 30 mm thick concreting of cement and coarse sand in the ratio of 1:4 applied under pressure. The concreting coat encases the EPS Core with centrally placed steel welded wire mesh.EPS used as a filling material for composite sandwich structure. Sandwich

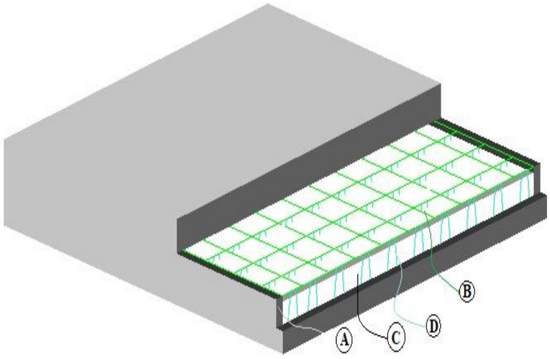

Fig. 1:Sandwich slab

A. The outer layer of concreting
B. Welded reinforcing mesh of high wire
C. The core of expanded polystyrene sheet
D. Diagonal wire (stainless or galvanized wire)

Structures are in different sorts of fillings and skin materials for an ideal plan to accomplish a particular execution target. Composite sandwich structures have great importance for weight sensitive structures in case of high flexural rigidity, due to the high specific stiffness, strength and light weight. Good thermal insulated, and the flexibility to be made into complex shapes [1].Lightweight concrete used for various purposes, such as a reducing self weight of structures with light cross sections. Light weight concrete developed for high rise buildings, having number of advantages: economical due to extra insulation not being required wide range of flexibility for structural engineers and architects [2]. EPS has the light weight with low strength having good energy absorbing properties. But, because of the light weight and their hydrophobic surfaces, EPS concrete may get affected by segregation while casting, which results in low workability and poor strength. To improve bond strength between concrete and EPS beds fine silica is used it also increases compressive strength as well [3], [4].Expanded polystyrene is used as early in 1957. EPS widely use the filling material due to low with good heat insulation property. EPS aggregates are available throughout world for commercial purposes. EPS concrete can be termed as an alternate for lightweight aggregate concrete [5], HPEPC with 40% EPs bulk ratio was suitable for high strength light weight concrete and exhibits good mechanical and thermal resistance compared to lightweight concrete and by testing structural results they concluded that the sandwich panel with an HPEPC core and UHPFRC face sheet can be used for high strength lightweight elements and

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can be used as structural lightweight concrete, has done his work on designing and comparison of samples of prefabricated concrete sandwich ceiling slabs with lightweight concrete core and concluded that it reduces the roof weight compared to conventional concrete slab about 44% and load on other components and structurally the roof that could be a conflict with the skeleton structure, the seismic oscillation provide structural stability are useable [6]. Precast concrete sandwich one way slabs under flexural loading and concluded that cracking behavior of fail in flexural mode in bottom of slab is similar to Ferro-cement, the truss shaped shear connectors are adequate to achieve composite action of the panels. The load deflection behavior, load strain, failure mode, failure load are affected in the rebar of bottom wythe [7]. Punching shear strength of composite construction on composite shells like cylinders and circular arches and they found it was difficult to separate their individual effects and to produce a comprehensive expression for predicting the punching shear strength [8]. Strengthened two-way flat slab using steel plates as horizontal reinforcement and steel bolts as vertical reinforcement and suggested that the rehabilitating steel plates and the number of steel bolts were sufficient to achieve positive results for the strengthening technique and the yield load and maximum load were increased due to strengthening process [9]. A new formula to calculate minimum flexure reinforcement for thick high strength concrete plates, the torsion moment factor is very important in determining the minimum reinforcement in calculation for thick two-way concrete plates and by using fracture mechanics concepts gives the reinforcement of flexural steel is size dependent [10]. The punching strength of reinforced concrete footings by developing the regression equation and analysis to flat plates and determined the lower bound values for the maximum punching shear capacity of footings [11].

II. RESEARCH SIGNIFICANCE

This project is to develop the sandwich 3D panel slabs to resist the loads that are coming on to the slabs in the structure as it is constructed and to reduce the load that are applied on the wall by the slabs. The Sandwich 3D slab are very economical and easy to construct when compared to the normal concrete slabs and undertake the high loads compared to the normal slabs that are constructed in the structural buildings. The sandwich 3D slabs are earth quake resistance structures that are lowly affected during earth quake. These are low weight structures compared to concrete structures and undertake high loads.

III. METHODOLOGY

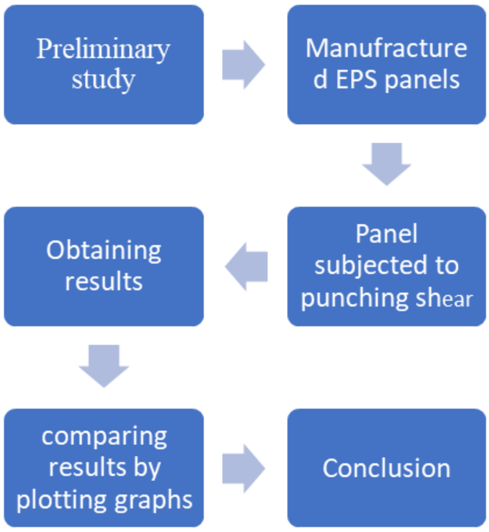

Fig. 2: Methodology for the EPS panels

Fig. 2 shows the methodology that has followed for the entire preparation of EPS panels, Casting slabs, results and conclusion for the use of EPS panels.

IV. Material properties

A. Expanded Polystyrene (EPS):

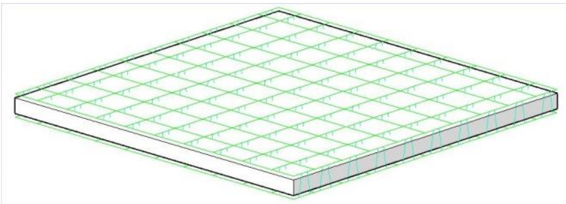

Fig.3:3D Sandwich Panel

Fig. 3 shows the 3D Sandwich Panel that is used to prepare sandwich slabs. Styrofoam often used for describing expanded polystyrene (EPS) foam while ‘Styrofoam’ is truly a trademarked word for cell closed extruded polystyrene foam produced for heat insulation as well as craft purposes. EPS foam is exact term for any kind of form using expanded polystyrene.

Expanded Polystyrene insulation is closed cell kind of insulation having less weight. Various kinds of EPS is available in order to handle different amounts of load and back fill forces. Closed cell structure has minimal absorption of water as well as low presence of vapor.

B. Concrete

Concrete was cast with coarse aggregates 6 to 10mm in size which is also called as baby chips is mixed with fine aggregates with water to make a homogenous mix . The mix proportion is 1:1.8:2.8 with water cement ratio 0.52.

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C. Steel Reinforcement

Panel available commercially comes with mesh. Fig. 4 shows the additional reinforcement of bars have 6mm diameter with four different reinforcement spacing in this case. Panels of four different reinforcement spacing are subjected to loads for obtaining results.

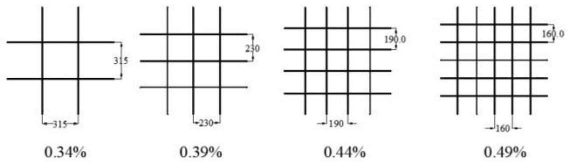

Fig. 4: Extra Reinforcement provided to sandwich slabs

Table I:Details of mesh reinforcement

Rod Ø	No. of Rods (Top &Bottom)	Area of Steel (MAs)
2.5mm	44	$215.98mm^2$

Table II: Details of extra reinforcement

Rod Ø (mm)	**No of Rods** (H,V)	**Spacing of Mesh** (mm)	**Area of Steel (EA_{St})** (mm^2)	**Total A_{St}** (mm^2)	**P_t** (%)
6	2,2	315	113.09	215.98+113.09=329.07	0.34
6	3,3	230	169.64	215.98+169.64=385.62	0.39
6	4,4	190	226.19	215.98+226.19=442.17	0.44
6	5,5	160	282.74	215.98+282.74=498.72	0.49

D. Loading

The load applied on the EPS slabs is punching shear kind of load. Punching shear causes failure in slabs and foundations due to concentrated loads acting on it. In most cases failure occurs due to load punches through the slab.Fig.5 shows the punching shear load was simulated by subjecting EPS slab subjected to concentrated load at the center of slab.

Fig. 6: Mould with cover Blocks

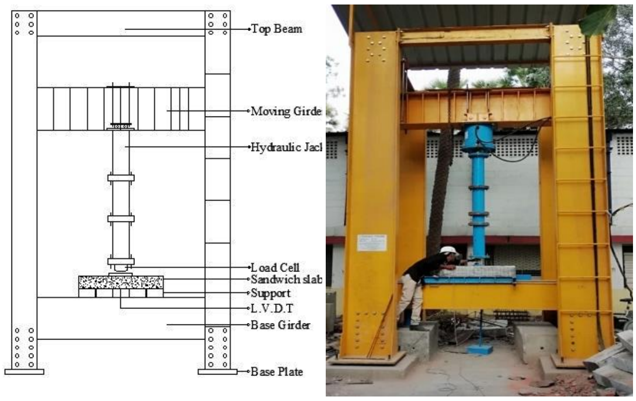

Fig.5: Loading Frame on Sandwich Slab

V. EXPERIEMENTAL PROCEDURE

Slab panel is cleaned from any leftovers and greased properly so that concrete poured in it won't stick to mould. Fig. 6 shows the concrete is placed in 40mm thickness in bottom layer for that place cover blocks in the mould. The concrete is poured in the form of layers into the mould. Fig. 7 shows the first fill 40 mm plain concrete is poured and compacted properly. After placing the bottom layer of concrete, remove the cover blocks. Fig. 8 shows the EPS panel is placed into the mould this is the second layer as core layer around the EPS layer 25mm cover was placed later. The EPS panel occupies 50mm width and is located in the middle of EPS slab sandwiched between plain cement concrete. Fig. 9 shows the panel in mould is forced to bond with concrete beneath it by external pressure. The rest of mould is filled with concrete up to 60mm depth and is the top layer of the EPS mould. The casted EPS slab is allowed to cure for 7 and 28 days by water curing. As we know that water containing dissolved salts or any unnecessary chemical constituents may lead to affect the durability of structure for the curing of concrete. After 7 and 28 days the mould is removed from EPS slab and the slab is placed under punching shear testing machine and subjected to load for obtaining result. Likewise, four EPS slabs are made each differ in the reinforcement of EPS panel. Same concrete grade and procedure for casting is adopted to compare all this four EPS Slabs.

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Table III: Details of Sandwich Slab

S.NO	Specimen	Size	Dimensions of core layer	Effective Span	Thickness of Top Layer	Thickness of core Layer	Thickness of Bottom Layer
		(L × B × D)	(L × B × D)	(ES)	(t_1)	(t_2)	(t_3)
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
1	Slab1	1000 × 1000 × 150	950 × 950 × 50	900	60	50	40
2	Slab2	1000 × 1000 × 150	950 × 950 × 50	900	60	50	40
3	Slab3	1000 × 1000 × 150	950 × 950 × 50	900	60	50	40
4	Slab4	1000 × 1000 × 150	950 × 950 × 50	900	60	50	40

Fig.7: Bottom layer of concrete

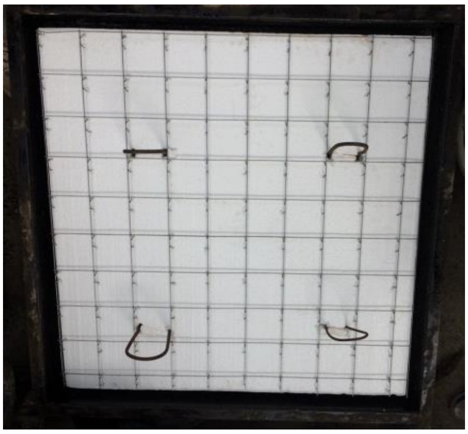

Fig.8: Core Layer (EPS PANEL)

Fig.9: Top Layer (EPS PANEL)

VI. RESULTS AND DISCUSSIONS

A. Crack and Failure Envelope

During the testing process the crack specimens has undergone same type of crack propagation on top and bottom layers. Initially flexural cracks are formed on the bottom surface of the sandwich slab and transferred from the centre towards the edges of the slab. With the increase in the load there is an increase in the radial cracks at the centre due to punching shear. These initial cracks are appeared at a load of 55kN and they are further propagated to the corners of the slab with the application of the load. Hence the specimens with less flexural reinforcement ratios having shear connectors showed higher deflections forming huge flexural cracks at the centre before punching shear. Fig. 10 shows that the cracks obtain in the sandwich slab after loading and the cracks obtain are shear cracks or normal cracks.

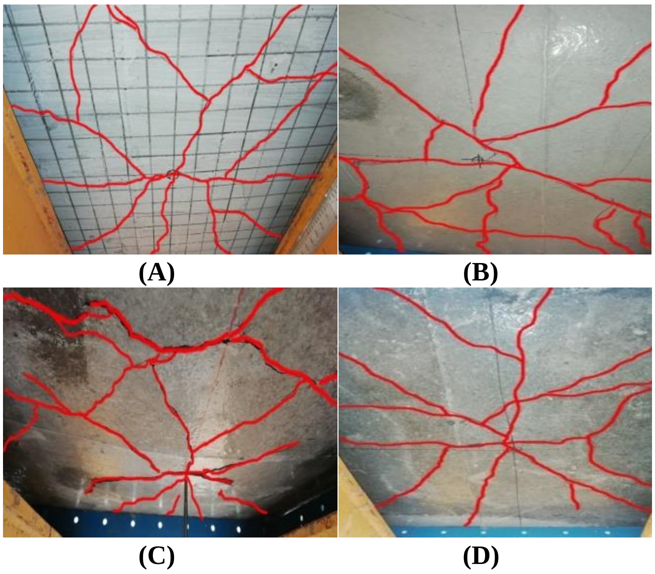

Fig.10:Final punching shear failure surface for tested specimens of Crack patterns (A) Slab1; (B) Slab 2; (C) Slab3 ;(D) Slab4 (images by author)

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B. Load- deflection

Correlation between the load displacement curves for the tested specimens plotted from the LVDT placed in the middle of the bottom surface of the sandwich slab. The load is subjected to increase at a rate of 1 kN/min until the peak load. It is important that increase in the slab flexural reinforcement ratio mainly affected the post crack in the slab. Failure is caused in a brittle manner rapidly soon after the peak load. Below figures shows that the load and deflection curve obtained after testing.

Fig. 11 shows the Load versus Deflection graph for the Slab 1 which was cast with plane concrete without sandwich panel placement.

Fig. 12 shows the Load versus Deflection graph for Slab2 which was provided with 0.39% of reinforcement.

Fig. 13 shows the Load versus Deflection graph for Slab3

which was provided with 0.44% of reinforcement.

Fig. 14 shows the Load versus Deflection graph for Slab4 which was provided with 0.49% of reinforcement.

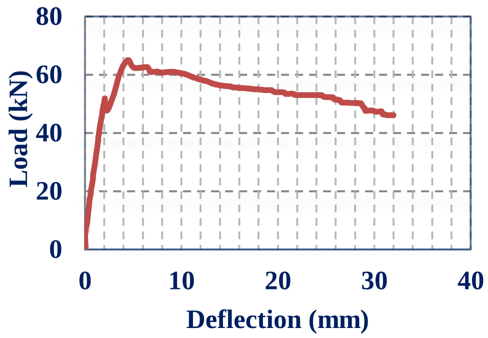

Fig.11: Slab 1 load versus deflection

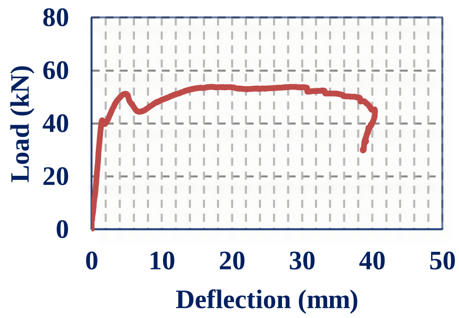

Fig.12:Slab 2 load versus deflection

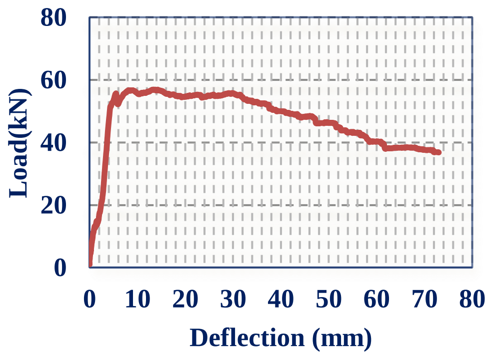

Fig.13:Slab 3 load Versus deflection

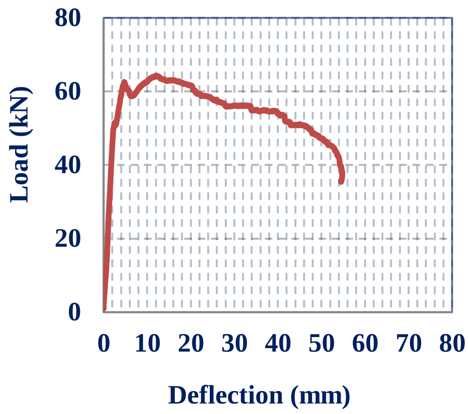

Fig.14: Slab 4 load versus deflection

C. Punching shear capacity

With the increase in the percentage of flexural reinforcement the punching shear capacity is increased.For 0.34% of reinforcement load is observed that the initial crack is formed at 55kN and the peak load of the slab is 60kN and it is gradually decreased due to crack propagation. The deflection is at maximum 51stsecond and it is linearly increased with respect to the tie.

VII. CONCLUSION

The following are the conclusions that are observed from the experimental works and the results that are obtained for the constructed slabs.

1. From the above results it is clear that the slab with 0.49% of reinforcement has the highest load carrying capacity and resistance to punching shear.
2. The deflection is more in the slab having 0.49% when compared with the 0.34%, 0.44% and 0.49% and also highly effected by the cracks with the application of punching load.
3. From the observed Load Vs Deflection graphs it is observed Slab 4 gives the highest load compared to remaining slabs and it concluded that it is the best load bearing slab.
4. Crack pattern shows that the cracks obtained in slab 3.
5. Punching shear is the best technique to observe slab capacity to uniformly varying load and it is concluded from the experimental work that the load is distributed throughout the slab while loading.

VIII. Abbreviations

A_{st}= Area of steel
M A_{st}=Mesh area of steel
E A_{st}=Extra area of steel
H=Horizontal
V=Vertical
P_t=Percentage of steel

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IX. ACKNOWLEDGMENT

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