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Experimental Investigation on Flexural Behaviour of Sandwich slabs with and without concealed beams

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Abstract: A sandwich panel is a lightweight structure, economical and having low thermal conductivity. It is made up of three layers in which the middle layer is low-density core bounded with a thin concrete layer at top and bottom. The main objective of this study is to find out the flexural behaviour of Sandwich slabs with concealed beams arranged in two different ways. The experimental investigation consists of four different slabs one in conventional reinforced cement concrete slab and the second model is sandwich slab and the third model is the sandwich slab with a concealed beam provided in one direction. The fourth model is a concealed beam provided in both perpendicular directions. To examine the flexural behaviour of sandwich panels, a loading frame of capacity 200 tons have been used. The Load versus deflection and crack pattern were observed and recorded by Linear variable differentiable transducers (LVDT). The results are obtained by varying parameters like direction and number of a concealed beam. There is a significant change in flexural behaviour of the sandwich slab with a concealed beam in both perpendicular directions compared to other specimens.

Index Terms: sandwich slab, concealed beams, flexural behaviour

I. INTRODUCTION

Construction of the building is a big challenge to the civil engineers and the government especially in developing countries throughout the world. This problem is due to an increase in the population and rural people are migrating to the urban areas and industrial centres that demand a better quality of life. It is a very difficult task to meet the challenges in the construction practices; however, it is a big challenge to the civil engineers to meet the housing demand in a short span without compromising on the quality. Traditional building construction is inadequacy so a new building system was developed at the beginning of the 20th century. So we have to use different alternative materials to decrease the concrete portion and to save the environment [1]. A Sandwich is a new construction technology which was used by William Fairbairn in the year 1849. In slabs, neutral axis is at centre but due to introducing of sandwich into the slab the axis is shifted to the compression zone due to this the stress and strain diagram may vary when compared to the conventional slab.

By introducing the sandwich into the slab we can reduce the concrete portion where the stress is zero it means where the concrete is ineffective under bending. At bottom of the slab that means in the tension zone, reinforcement should be provided [2]. The sandwich panel system is used around the world for low rise and high rise commercial structures. According to the architecture and structural point of view, the precast concrete sandwich panels are widely used [3]. The behaviour and strength of lightweight sandwich reinforced concrete (LSRC) slabs are the same as that of solid slabs. The values obtained from the shear capacity are compared with the design loads. AAC blocks are used as a sandwich material shape and size of AAC blocks depends on the shear capacity [4]. Many researchers [5] have studied the behaviour of precast lightweight foamed concrete sandwich panel (PLFP) under eccentric load. They have found that by using double shear truss connectors the load carrying capacity increases. And also they have compared their experimental results with the classical formulas developed by the previous researchers. [5]. An experimental and theoretical investigation was carried out on precast lightweight foam concrete foam concrete sandwich panel under flexure load [6]. The compressive strength and thickness are the influenced parameters while applying the ultimate flexure load. At the bottom wythe portion of the slab, cracks are developed with the increase in thickness ultimate load is increased [6]. In sandwich outer concrete layers in between insulation layer is placed. Different behaviours like non-composite, partially composite and fully composite are studied. By providing FRP bent bar connectors in the precast concrete sandwich panels gives more strength compared with the steel and concrete rib connectors [7]. In the sandwich panel if the grade of concrete is increased then deflection is decreased hence the grade of concrete plays a very important role in the sandwich panels. When compared with the experimental results the Finite element analysis (FEA) will get greater ultimate load due to the presence of micro cracks in the experimental specimen [8]. With the increase of slenderness ratio in the sandwich panels, the strength reduces. Experimental results are compared with the FEA analysis [9]. The crack pattern is similar to the PCSP slabs and conventional slab. By providing shear connectors the ultimate load is increased [10].

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II. RESEARCH SIGNIFICANCE

Sandwich panel is an eco-friendly material and having good thermal properties. Sandwich panel absorbs heat and it also acts as an insulation material. Sandwich panel is having similar properties as compared to precast wall panel in term of economical, durability, fire resistance and it can also be used as a shear wall, retaining wall and bearings walls. It can be used in the building expansion is needed. It is light in weight and easy to construct and it reduces the usage of concrete.

From the literature survey, it is found that there is no work on flexural behavior of sandwich slab with the concealed beam. So this is 1^{st} attempt to study flexural behavior of sandwich slab with the concealed beam.

III. methodology

In the experimental program, four slabs were cast and tested. Following flow, chat shows that the complete experimental procedure

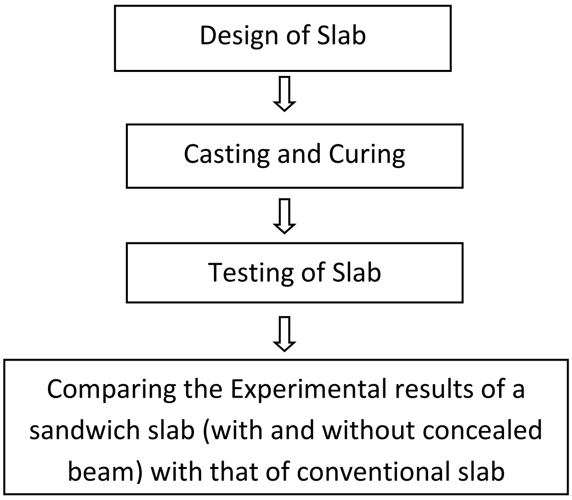

Fig. 1: Experimental Procedure

IV. MATERIALS USED

A. Cement

According to IS 12269: 2013 [11] ordinary Portland cement of 53 grade is used.

B. Fine Aggregate

Locally available sand conforming to Zone- II of Table 4 of IS 383:2016 [12] is used.

C. Coarse Aggregate

Locally available crushed granite coarse aggregate has been used.

D. Steel Reinforcement

Fe 550 grade high yield strength deformed steel bars are confirmed to IS 1786: 2008 [13] were used.

E. Extruded Polystyrene (XPS)

XPS is a non-toxic, insoluble, non-hygroscopic and chemically inert material. Bacteria and fungi cannot grow on it. XPS can be recovered and recycled and will resistant to moisture. In building construction, XPS insulation offers great compatibility, thermal efficiency and flexibility of a building envelope. XPS consist of closed cells with higher stiffness. The density of XPS is ranging from 28–45 kg/m^3. Thermal conductivity is between 0.029 and 0.039W/(m-K) depending on density and bearing strength.

V. EXPERIMENTAL SETUP

A. Beam Dimensions and Reinforcement

In this program, beam width and depths namely 230 x 150 mm designed to accomplish the experimental data. The clear cover of the beam is 25 mm for all the beams. 12 mm diameter bars are used as longitudinal reinforcement and 8 mm diameter bars are used as shear reinforcement.

B. Slab Dimensions and Reinforcement

The size of the slab is 1 m x 1 m x 0.15 m. The clear cover of the slab is 25 mm for all the slabs and 12 mm diameter bars are used as longitudinal reinforcement and transverse reinforcement.

C. Preparation of Test Slabs

Steel mold is used to cast the specimen the gaps are filled with wax to prevent it from leakages. M20 grade of concrete was used for all the specimens. The specimen was removed after 24 hours and then cured with wet jute bags for 28 days to obtain the required strength. After 28 days the wet jute bags are removed and then coated with white paint on both sides for clear visibility of cracks after testing. The casting, de-molding of the slab specimens is shown in Fig. 2-6.

Fig. 2: Slab Mould

Fig. 3: RCC slab

Fig. 4: Sandwich slab

Fig. 5: Sandwich slab with a concealed beam provided in one direction.

Fig. 6: Sandwich slab with a concealed beam provided in both perpendicular directions

The experimental work contains specimen 1 reinforced cement concrete slab and specimen 2 sandwich slab, specimen 3 sandwich slab with a concealed beam provided in one direction and specimen 4 Sandwich slab with a concealed beam provided in both perpendicular directions, these specimens were designed as two-way slabs of dimensions 1 m × 1 m × 0.15 m and 12 mm diameter reinforcement bars are provided along the longitudinal and transverse directions. The specimens were subjected to the flexural test. Before testing, the specimens were painted with a lime whitewash to identify the crack pattern due to the applied loadings. The setup was carried out with 200 tones loading frame and loading jack was fixed on the top of the slab to give the concentrated load on the slabs. The load cell was fixed to the tip of the jack by nut bolt system to measure the deflections of the specimen, LVDT gauge was kept under the bottom of the specimen. The load was applied with uniform increment up to the failure. The load versus deflection curves were plotted according to the load values given by the loading frame Deflections caused by these loadings were tabulated at each increment of loading. Crack patterns were developed due to loading, and finally, failure load was recorded. Fig. 7 shows the loading frame setup.

Fig. 7: Loading frame setup

D. LVDT Stand

Linear variable differentiable transducers (LVDT) stand was fixed at the bottom of the specimen. Fig. 8 shows the LVDT stand.

Fig. 8: LVDT stand

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E. Crack Pattern

The crack pattern was observed and recorded at the bottom. Cracks are developed first and at the middle portion and then propagated towards all the four sides. Fig.9-12 shows the crack pattern.

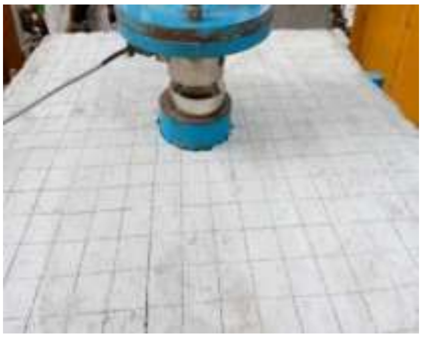

Fig. 9: Cracks on the slab after loading

Fig. 10: Cracks on the slab after loading

Fig. 11: Cracks on the slab after loading

Fig. 12: Cracks on the slab after loading

VI. RESULTS AND DISCUSSION

From Table 1, it is noticed that for control specimen (RCC) the first crack was developed at a load of 132 kN and the maximum deflection was at 14.53 mm and the ultimate load was at 208.7 kN. For sandwich slab first crack was developed at a load of 38 kN and the maximum deflection was at 18.06 mm and ultimate load was at 42.4 kN. For Sandwich slab with a concealed beam provided in one direction, the first crack was developed at a load of 90 kN and the maximum deflection was at 28.69 mm and the ultimate load was at 204.6 kN. For Sandwich slab with a concealed beam provided in both perpendicular directions, the first crack was developed at a load of 158 kN and the maximum deflection was at 13.44 mm and the ultimate load was at 267.7 kN. Fig. 13-16 shows the Load versus deflection graphs.

Table I: Load and Deflection Details

Specimen	Ultimate load (kN)	Maximum deflection (mm)	First crack load (kN)
Specimen 1	208.7	14.53	132
Specimen 2	42.4	18.06	38
Specimen 3	204.6	28.69	90
Specimen 4	267.7	13.44	158

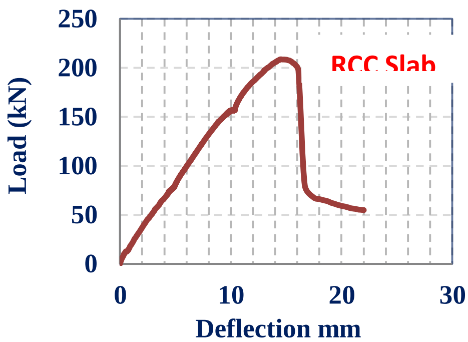

Fig. 13: Load vs. Deflection graph of reinforced cement concrete slab

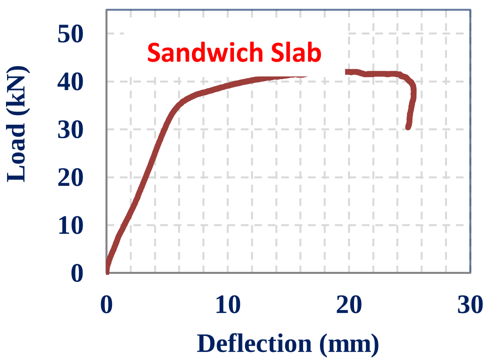

Fig. 14: Load vs. Deflection graph of sandwich slab

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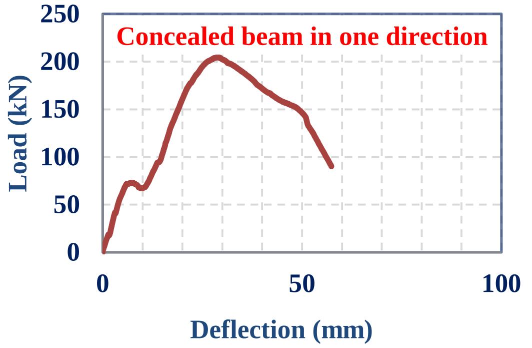

Fig. 15: Load vs. Deflection graph of sandwich slab with a concealed beam provided in one direction

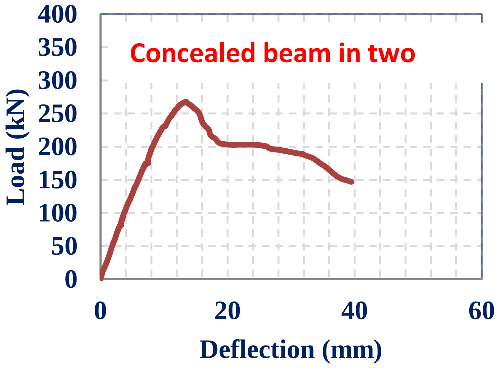

Fig. 16: Load vs. Deflection graph of Sandwich slab with concealed beam provided in both perpendicular directions

VII. CONCLUSION

Utilization of sandwich leads to the reduction in concrete and protects the environment.

From the experimental results, the following conclusions on flexural behaviour of sandwich slabs have been observed are:

1) It is concluded that sandwich slab and Sandwich slab with concealed beam provided in one direction have the same ultimate load but there is a significant change in ductility.
2) The results are obtained by varying parameters like direction and number of a concealed beam.
3) Cracks are occurred at the bottom of the specimen at first.
4) Sandwich slab with concealed beam provided in both perpendicular directions gives high strength and ductility.
5) Maximum deflection before failure is observed for the sandwich slab concealed in one direction.

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