Experimental Study on Polypropylene Sandwich Composite Slab

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Abstract

In this paper, experimental study on the flexural behavior of Concrete Sandwich Composite slabs were reported. Single point flexure test on three slabs varying in core elements such as providing horizontal and vertical polypropylene sheets to the slab panel. The dimensions of the slabs are 1.00 x 1.00 x 0.15 m. These slabs are casted using self-compacting concrete.The experimental tests include the testing of panels under static loading. Load is applied using a 500kN hydraulic jack. Linear voltage displacement transducers with 50 mm gauge range are used to measure the transverse deflections.The test results includes theultimate load-bearing capacity, load-deflection profiles, typical modes of failure and cracking patterns under constantly increasing the loads were discussed.
Keywords: Sandwich Slab, Self-Compacting Concrete, Polypropylene Sheet

I. INTRODUCTION

In civil engineering construction, objective of using or selecting the material is to make full use of its properties in order to get the best performance for the formed structure. The merits of a material are based on factors such as availability, structural strength, durability and workability. Methods of improving material utilization can be classified into two categories. The first is to select appropriate materials mixed and the second dispersed to form a new product with desired properties, thus resulting in a composite material.

A sandwich composite slab is a three layer slab it consist of skin layer at top and bottom and core layer at middle. The core material is normally of light weight material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. The strength of the composite material is dependent largely on two factors such as outer skin and the interface between the core & the skin.

In this project one conventional and two sandwich slab have been casted, with one horizontal projection and one with vertical projection of polypropylene sheet which going to act as core material.

Sandwich slab unit is a relatively new and innovated form of construction in which the systemis increased bearing load, good insulations panels, easier to handle, material and labour cost reduction, quick and easy installation.

Polypropylene is highly impermeable to water. In a 24hrs soak test, the material absorbs less than 0.01% of its weight in water. Polypropylene is an adhesive material hence interaction between two different material is good in nature. It will resist many organic solvents, acids, and alkalines.

II. LITERATURE REVIEW

A. *New composite slab system for the structural rehabilitation of traditional buildings by M. Mastali, I.B. Valente, J.A.O. Barros.*

In this paper, a new generation of composite sandwich slab is proposed as a solution for rehabilitation of slabs in old masonry buildings. The new slab composite systemis composed of four elements that include High Performance Fiber Reinforced Concrete (HPFRC) layer, GFRP ribs, foam core and GFRP skin. In this an innovative GFRP-HPFRC hybrid solution has been developed, with a GFRP laminate on the bottom tension under skin layer, and an HPFRC layer on the top compression skin, preventing the occurrence of buckling, improving the resistance to the effects of impact and fire, providing a ductile behavior and allowing for an easy application of floor covering materials. GFRP ribs and foam core are able to transfer stress betweenskins. The design process of the proposed hybrid GFRP-HPFRC sandwich slab is presented. The effects of various parameters on the behaviour of the slabs are investigated by using both linear and material nonlinear analysis, with the aid of the software FEMIX. According to the obtained results, some criteria are established in order to choose the best slab solutions, which include design codes recommendations, serviceability criteria and economic aspects.

B. Performance of GFRP sandwich panels with corrugated GFRP sheets by Gautam SOPAL, Sami RIZKALLA, Greg SOLOMON.

In this study glass fiber reinforced polymer sandwich panel with GFRP corrugated sheet in addition to the through thickness fibers to enhance their structural characteristics. An experimental program is taken to determine the fundamental characteristics of these sandwich panels in tension, compression, and shear which are critical in the structural design of sthese panels for civil engineering application. The test result shows the addition of corrugated sheet is significantly increasing the flexure and shear modulus delayed the formation of cracks in the core foam and enhanced the fatigue resistance of the fiber insertions, therefore in addition of corrugated web improved the in overall structural performance of these sandwich panels.

C. Flexural performance of sandwich panels comprising polyurethane core and GFRP skins and ribs of various configurations by Amir Fam and Tareksharaf.

In this study flexural performance of panels composed of low-density polyurethane foam core sandwiched between two GFRP skins. A material testing program was first carried out on the constituents. Large scale panels with nominal dimensions of 2500, 660, 80 mm were tested in one-way bending under a simulated uniform load. Various configurations of internal and exterior GFRP ribs connecting the two skins were explored and compared to a panel without ribs. The study showed that, by integrating the ribs, strength and stiffness of the panels increased substantially, by 50–140%, depending on the configuration of the ribs. The strength was equivalent to the effect of doubling the core density in a panel without ribs. Shear deformation of the core contributed over 50% of mid-span deflection in the panel without ribs. The ribs were added flexure became more dominant and shear deformations of the ribs contributed only 15–20% of the total deflection. Analysis have been proposed, and captured these effects reasonably accurately. It was shown that ultimate strength of the panels were equivalent to those of similar size reinforced concrete panels with moderate to heavy steel reinforcement ratios of 0.6–2.0%, but sandwich panels were 9–14 times lighter in weight.

D. Failure behavior of aircraft sandwich panels under bending load by Syayuthi. A. Rahman, Haftirman, K.S. Basaruddin.

Failure behavior of aircraft sandwich panel under bending load has investigated in this study. In this study it focused in effect of support span length under bending load. Three point bending test was performed to the specimens with various span length 125 mm, 80 mm, 65 mm, and 55 mm. Standard test method and dimensions were adhere to the ASTM C393. Deflection and energy absorption of the sandwich panel have been characterized by the variation span length. It was found that the deflection and the energy absorption of the sandwich panel were strongly influenced by the length of support span. In the bending test of sandwich panels at 135 mm support span length, the panel show the lowest deflection at a critical load which is around 4.26 mm compared to the other support span length. The difference of the collapse load for 65 mm support span length is highly significant. The value of experimental was found at 1.74 kN whereas the theoretical value is 2.85 kN The ability to absorb energy of sandwich panel was affected by the collapse mechanism. It was found that the decrease of support span length increases the absorbed energy in aircraft sandwich panel.

E. Fatigue analysis of glass fiber reinforced polymer (GFRP) bridge deck panel by SaliniTheres N Kurian, Jiji Anna Varughese, Divya K K.

Reinforced Concrete structure deteriorates due to several reasons including steel corrosion. Once bond between the concrete and steel is lost then reinforcement become ineffective. There are several cases of failure of bridge due to defect of reinforced concrete. Glass Fiber Reinforced Polymer (GFRP) bridge deck panel is an alternative for conventional RC panel in bridge which remains unaffected by environmental attack. The paper discusses that result of the analytical study on the fatigue characteristic of GFRP bridge deck panel. Finite element software ANSYS used for modelling and analyzing multicellular GFRP bridge deck panel. The analysis showed good performance of GFRP panel under the fatigue load.

F. Effect of core topology on vibro-acoustic characteristics of truss coresandwich panels by M.P. Arunkumar, JeyarajPitchaimani, K.V. Gangadharan , M.C. Leninbabu.

This paper present the numerical simulation study on effect of core topology on vibro acoustic characteristic of truss core sandwich panels with metal facing. Free and forced vibration response of the panels that are obtained using finite element method which based on the equivalent two dimensional models. Sound radiation characteristics of the panel are obtained by Rayleigh integral. It is found that influence of nature in core topology of sound radiation is significant in low frequency. It is observed that when compared to trapezoidal, rectangular core and triangular core is suitable for low frequency application and it radiate less sound compare to trapezoidal and rectangular core.

G. A review on vibration control of composite slab using tuned mass damper by Krunal .V. Dholakiya, MazharDhankot.

Floors are highly susceptible to vibrations during its functional usage and owing to its lesser thickness as compared to the plan dimensions. The type of vibrations induced depends on the functionality of the floor. The induced vibrations can lead to serviceability issues and also can render psychological effects on the inhabitants. The services used in the building can also be badly affected due to the induced vibrations which can be due to machine running on the floors, walking, dancing activities and other human induced impact forces. This review has been undertaken to understand the ill effects caused by vibrations generated by various sources on floor systems. Many authors have worked to reduce these vibrations by installations of various control systems. A detailed study has been undertaken in this paper to study and understand the mitigations of these vibrations.

H. Structural performance of honeycomb sandwich panel by elzathomasukken, Beenab.r.

Honeycomb cores are one of the most structurally efficient core constructions, especially in stiffness-critical applications. The basic idea of honeycomb panel was to use the honeycomb as a shear web between two skins. It provides minimal density and high out-of-plane compression and shear properties. It has high strength to weight ratio and good impact resistance. Structural properties in honeycomb structure depend on lower and upper face sheet thickness, the core material thickness, cell diameter, cell angle and foil thickness. Debonding is one of the major failure modes of honeycomb sandwich panels. Material used for the honeycomb construction also has very important in its structural performance. This study focused on the dynamic and static performance of honeycomb sandwich structures and their applicability in bridge deck constructions. This study investigates the effect of geometric parameters on the structural performance of the honeycomb structures such as lower and upper face sheet thickness, the core material thickness, cell diameter, and core configuration.

III. EXPERIMENTAL INVESTIGATION

Following materials were used for the study is described in the following section,
1) Cement
2) Aggregate
3) Water
4) Polypropylene sheet
5) Ground-granulated blast-furnace slag (GGBS)
6) Conplast- 430

A. Material Specifications

Cement – OPC 53 grade
Fine aggregate – River sand
Coarse aggregate – (<10mm)
Polypropylene sheet – 10mm sheets

B. Test Conducted for Self-Compacting Concrete

1) Slump Flow Test

For this test about 6 litre of concrete is needed. The base plate and slump cone is moistened. Then place the base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly.

Fill the cone with concrete. Do not tamp, strike off the concrete level with the top of the cone with the trowel. Remove any surplus concrete around the base of the cone. Lift the cone vertically and allow the concrete to flow out freely. Simultaneou sly start the stopwatch and record the time taken for the concrete to reach the spread circle floatable test might be appropriate.
The T50 time is secondary indication of flow. A lower time indicates greater flow ability. The BriteEuRamsuggested that a time of 3-7 seconds is acceptable for civil engineering applications and 2-5 seconds for housing application.

In case of segregation many coarse aggregate will remain in centre of the pool of concrete, mortar and cement paste at the concrete periphery. In case of segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete.

Fig. 1:

Fig. 2:

Table - 1
Slump Flow Test

S.NO	*UNITS*	*MINIMUM VALUE*	*MAXIMUM VALUE*	*OBTAINED VALUE*
1	*Mm*	*2*	*5*	*4.5*

2) V Funnel Test

About 12 litresof concrete is needed for the test and sampled normally. Then set the V-funnel on ground and make sure that inside surface of the funnel is moistened. Use the trapdoor to allow any surplus water to drain. LaterClose the trap door and place a bucket underneath.

Then apparatus completely filled with the concrete without compacting, simply strike off the concrete top with the trowel.

Open within 10 sec after filling trap door and allow the concrete to fall out under gravity. Start the stopwatch when the tra p door is opened then record the time for the complete discharge. This is taken when light is seen from above through the funnel. The complete test has to be performed within 5 minutes.

Table - 2
V Funnel Test

S.NO	*UNITS*	*MINIMUM VALUE*	*MAXIMUM VALUE*	*OBTAINED VALUE*
1	*sec*	*6*	*12*	*11.5*

3) L Box Test

About 14 litres of concrete needed to test and sampled normally. Set the apparatus on ground ensure that the sliding gate can open freely and close it. Make sure that inside surface of the funnel is moistened and then remove any surplus water. Fill in the vertical section of the apparatus with concrete sample. Allow it to stand for 1 minute. Lift the sliding gate to flow out into horizontal section. Start the stopwatch and record the time for the concrete to reach the required level.
When the concrete stops running the distances ‘H1’ and ‘H2’ are measured. Calculate H2/H1 blocking ratio. The complete test has to be performed within 5 minutes.

Fig. 3:

Table - 3
L Box Test

S.NO	*UNITS*	*MINIMUM VALUE*	*MAXIMUM VALUE*	*OBTAINED VALUE*
1	*M*	*0.8*	*1.0*	*0.89*

IV. CASTING OF CUBES AND CYLINDERS

Casting of the specimens were done after preparation of materials, weighing of materials and casting of cubes, cylinder. The mixing and curing of concrete are done. Total of nine concrete cubes of size(150mmx150mm) are casted. One Conventional slab of size (1mx1m x 0.15m) and two sandwich slab have been casted with horizontal and vertical placement of polypropylene sheets with size (1mx1m x 0.15m).

A. Instrumentation and Test Procedure

The specimens were subjected for the following tests,
1) Compressive strength test - cube 150x150x 150mm (9 specimens)
2) Split Tensile strength test - cylinder 150x 300mm (9 specimens)

1) Compression Test

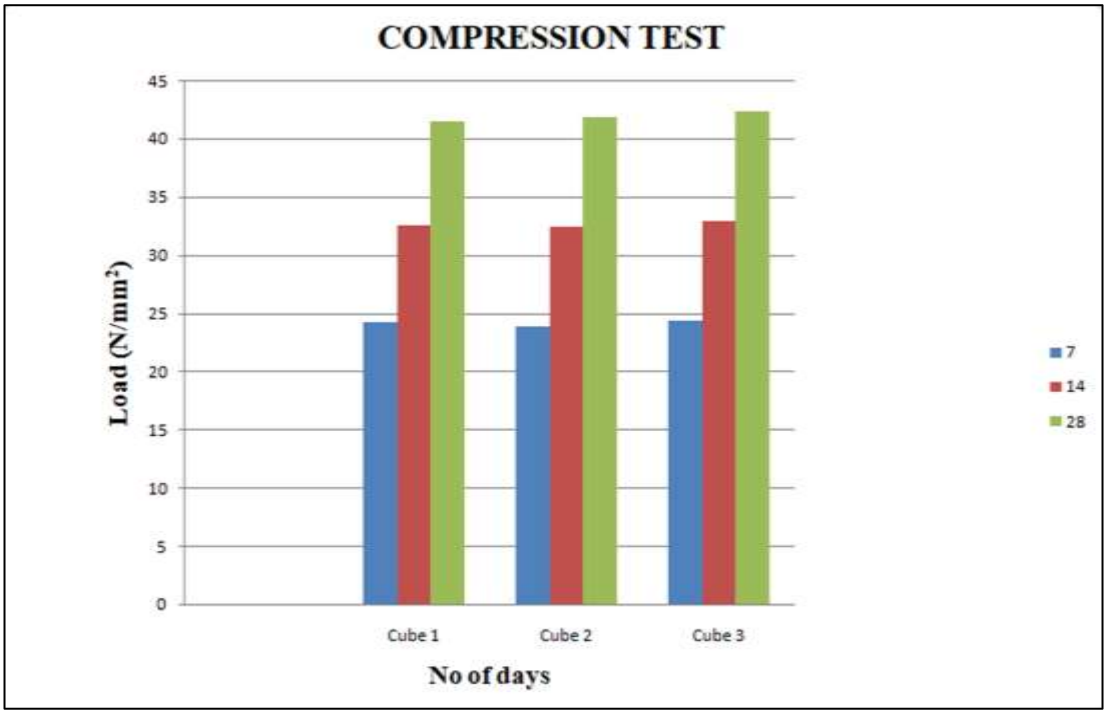
In this work cubical moulds of size 150mm x 150mm x 150mm are used. This concrete is filled in the mould and tempered properly so not to have any voids. After 24 hrs these moulds are removed then test specimens are put in water for curing. The top surface of specimen should be made even and smooth. These specimens are tested by compression testing machine after 7 days,14 days & 28 days curing. Load should be applied gradually at the rate of 13.7N/mm2per minute till the Specimens fails.
Compressive Strength = Load / Cross-sectional Area

Fig. 4:

Table – 4

Compression Test Results

DAYS	TRIALS	LOAD (kN)	COMPRESSIVE STRENGTH(N/mm^2)
7 days	Trial 1	539	24
	Trial 2	554	24.6
	Trial 3	548	24.3
14 days	Trial 1	805	35.7
	Trial 2	816	36.2
	Trial 3	819	36.4
28 days	Trial 1	898	39.9
	Trial 2	891	39.6
	Trial 3	922	40.9



2) Split Tensile Test

When the mixture is prepared it is poured into the oiled mould in layer which is approximately 50 mm deep. Then each layer is compacted either by hand or vibrator. Distributed bar stroke uniformly in order to compact it properly and minimum tamping bar stroke for each layer is 25. Then Penetrate strikes in to the underlying layer and apply the rod for the entire depth of bottom layer complete top layer compaction. Finally the surface of the concrete should be levelled with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation.

Split tensile strength $=\frac{2p}{\pi DL}$

Where p- compressive load on cylinder in kN

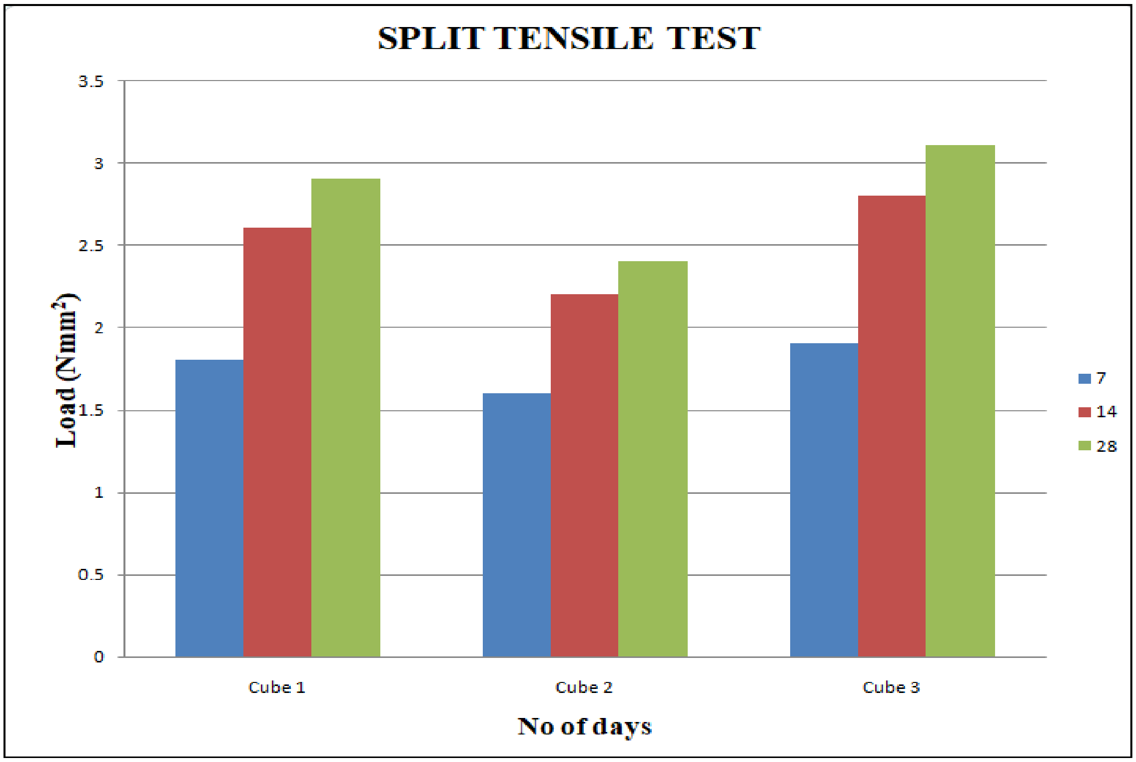
L-length of the cylinder

D- Diameter of cylinder in m

Table – 5
Split Tensile Test Result

DAYS	LOAD (kN)	OBTAINED AVERAGE TENSILE STRENGTH(N/mm^2)
7 days	120	1.7
14 days	184	2.6
28 days	191	2.7

Fig. 5:



3) Casting and Testing of Slabs

Totally there are 3 slabs of size(1m x 1m x 0.15m) casted and their experimental results are compared. The slabs are,

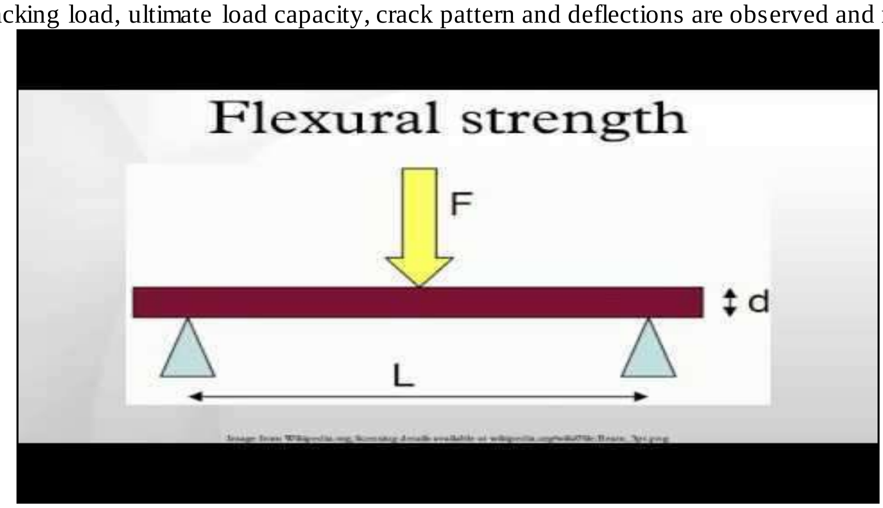
1) Conventional slab
2) Sandwich slab (horizontal placement of sheets)
3) Sandwich slab (vertical placement of sheets)

The slabs were tested using single point flexure tests and the results are observed and compared.

Fig. 6:

4) Testing of Slabs

After 28 days of proper curing the slabs are tested for single point bending flexure test.The single point load is applied at centre of the slabs and initial cracking load, ultimate load capacity, crack pattern and deflections are observed and noted.



5) Conventional Slab

Initial cracking load = 7.6T
Ultimate load capacity = 10.4T
Deflection = 3.18mm

Fig. 7:

6) Sandwich Slab (Horizontal)

Initial cracking load = 9.6T
Ultimate load capacity = 12.8T
Deflection = 3.43mm

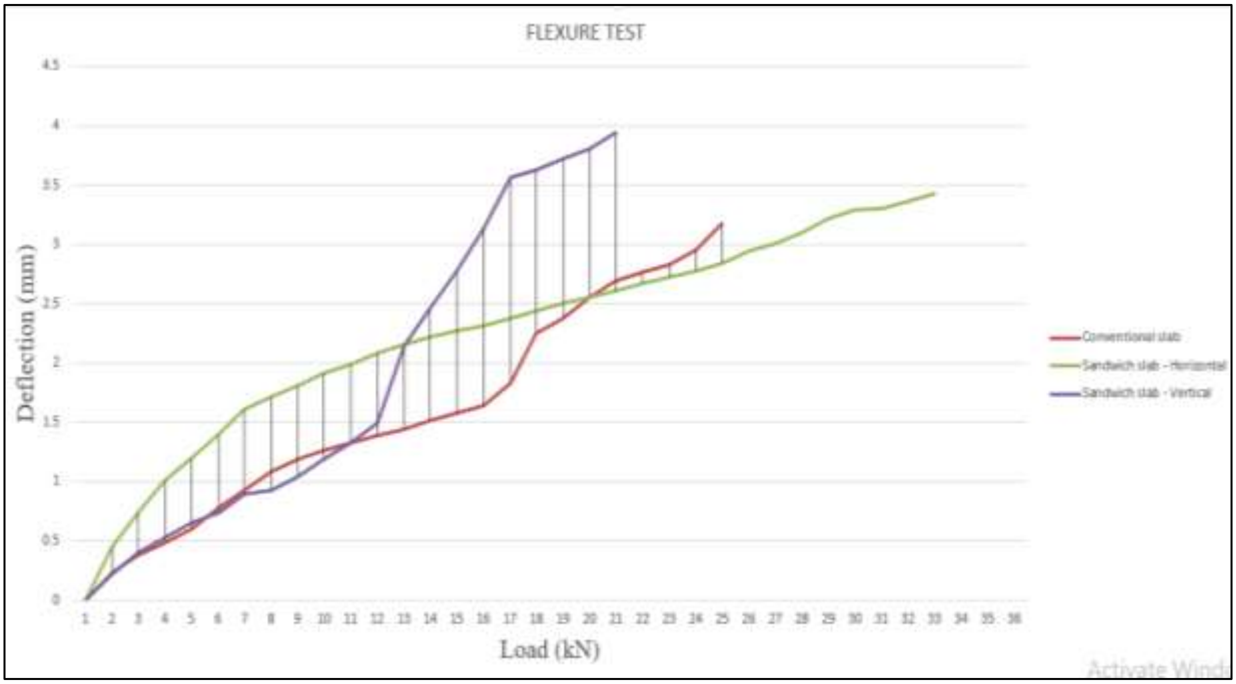
Fig. 8:

7) Sandwich Slab (Vertical)

Initial cracking load = 6.8T
Ultimate load capacity = 8.4T
Deflection = 3.94mm

Fig. 10:

8) Test Results



V. CONCLUSION

From the present study following conclusions are made

1) Mix proportion for SCC of M40 grade has been found outfrom various trial mixes.
2) Reduction in self weight of sandwich slab of horizontal layer and vertical layer comparing to conventional slab is found to be 11.5% and 8.4%.
3) Placing horizontal layer of polypropylene sheet as skin layer under point loading has showed high load carrying capacity to withstand 128kN.
4) Vertical layer placement of polypropylene sheets in slab under point loading shows less load carrying capacity of 84Kn.
5) Sandwich slab of horizontal layer, initial crack occur at 96kN and ultimate load of 128kN.
6) Sandwich slab of vertical layer, initial crackoccur at 68kN and ultimate load of 84KN.

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