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Experimental Studies on Flexural Behaviour of Steel-Concrete Composite Slab Panel Using Basalt Fibre

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***Abstract*— This Paper deals with an experimental investigation to understand the Flexural behaviour of a Composite Slab Panel (CSP) which are casted and tested without reinforcing bars using Basalt Fibre reinforced concrete (BFRC). Basalt Fibre (BF) is a new type of green material with excellent physical, chemical and mechanical properties. These are extensively used in the field of civil construction. The concepts of Composite Slab Panels (CSP) are widely used in developed countries for modern buildings and bridges. In the later case there is an occurrence of slip between the steel and concrete. In spite of that, composite slab construction became popular nowadays, it has been established as a pragmatic solution for tall buildings where conventional shuttering props were impractical. This method seems to be an excellent substitute for the conventional concrete (CC) slabs since there is an effective utilization of both steel and concrete and also it is fast in construction. Experimental test setup is designed as per the recommendations of Euro code 4 – Part 1.1.**

Keywords - Composite slab Panel (CSP), Basalt Fibre Reinforced Concrete (BFRC), Basalt Fibre (BF), Flexural Behaviour, Conventional Concrete (CC).

I. INTRODUCTION

In the day by day emergence of recent trends in construction industry, composite construction method has gained its popularity for its economical usage of materials and providing excellent sustainability than conventional concrete construction system.

The composite construction method is a widely used diaphragm strengthening method where two different materials perform a composite action. The composite action of the composite slab depends upon shear action between the corrugated steel sheeting on the hardened concrete. Structures made of two or more distinct materials are referred to as composite constructions. Typically, the materials used in structural engineering include concrete-steel, plastic-steel, and concrete-timber, etc. By effectively connecting the two components, composite construction includes the structural characteristics of both materials to create more rigid, stronger, and lighter members. In order for the two materials to function as a single unit, their shear-bond connection is crucial. In the Fig 1 shows the elements of composite slab.

Concrete is a composite material that has a low strain limit and poor tensile strength. The engineering qualities of concrete can be considerably enhanced by adding fibre to the mix. Fibre reinforced concrete (FRC) is frequently used as it has a good level of corrosion resistance, excellent ductility, and adequate durability. Steel or organic fibres, among other forms of fibres can be utilized in cement and concrete composite. In significant part to replace glass fibre and carbon fibre, basalt fibre reinforced composite materials have excellent strength, chemical stability, ductility and electric insulating capabilities. These materials are widely used in the aerospace, petrochemical, construction, automotive, and other industries. Melting process for basalt, there are no emissions of hazardous gases, non-industrial waste, or boron and alkali metal oxides, and the basalt fibre production process begins without harming the environment.

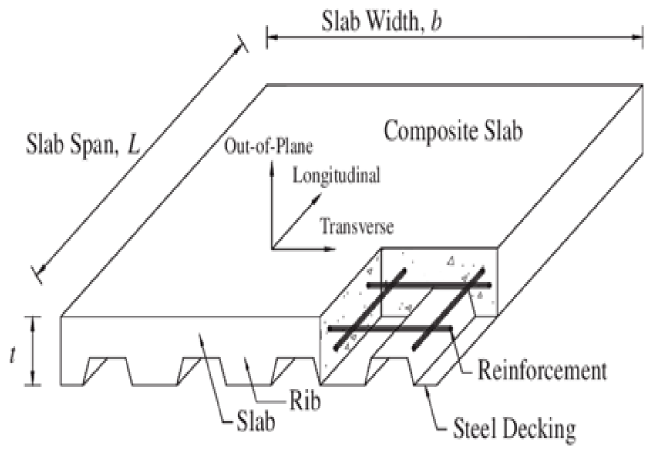

Fig. 1: Elements of Composite Slab

II. DESIGN AND DETAILING OF COMPOSITE SLAB PANEL

In this program, slab panels are designed and cast, which are experimentally tested. These slabs are designed as per Recommendations of EN 1994-1-1 2004. Slab panels are tested under flexural loads.

A Cold formed steel deck was identified to carry out experimental program on composite panels. It is having the length 1200 mm and width 795 mm and thickness of the profile sheet is 1mm. The percentage of cold formed steel sheet is 1.68%. In the Fig 2 shows the geometrical properties of profiled steel deck.

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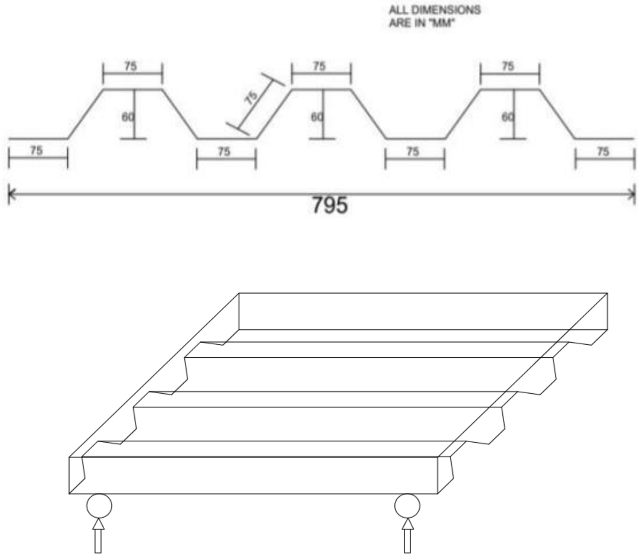

Fig. 2: Geometrical Properties of Profiled Steel Deck

III. MATERIAL PROPERTIES

A. Basalt Fibre Reinforced Concrete

In the casting of test specimen of composite slabs, Basalt Fibre Reinforced Concrete (BFRC) has been developed to get the characteristic compressive strength of M-25 grade concrete. For developing Basalt fibre reinforced concrete, ordinary portland cement (OPC) is used, Flyash 30% is used to reduce cement content, M- sand used as Fine Aggregate and 20mm and 12mm down sized Coarse Aggregate are used. For getting desired workability 0.6% Sikaplast-5132 super plasticizer (SP) is used and 1.0% Basalt Fibre as additive is used to improve the mechanical properties of the concrete.

IV. CONSTRUCTION AND TEST DETAILS

A. Specimen Design and Construction

The dimensions of the test specimens are 1200 mm length, 795 mm wide and configuration of panels are shown in Fig. 2. The compressive strength of concrete achieved was 35.13 Mpa.
The profiled steel sheet was connected with a shear connector of 8 mm thickness and 80 mm height with rubber washers to get a high grip between the nut and bolt. Totally 28 studs were required for one sheet. It helps to get a good shear bond between steel and concrete. In these specimens reinforcing bars were eliminated to know the structural behavior of panels under flexural loads.

The composite Slab panels with BFRC concrete were casted and cured and also these were tested at the 28th day after casting.

B. Test Set-up

The Experimental test set-up is shown in Fig. 3 and the procedure is as follows.

- The centre line dimensions are marked in the top and side of the slab as shown in the figure.
- Dial gauges and LVDT are placed at the bottom face of specimens at the centre portion of the Specimen to obtain the deflection of the specimen. Fig 4 shows the Dial gauge and LVDT.
- The Flexural load is applied in Two Points on the composite slab panel, slight deformation occurred.

Fig. 3: The Experimental test set-up

Fig. 4: Dial gauge and LVDT

C. General Observation on Test Specimen

The general observation on the test specimens are discussed here. At the beginning of the loading, specimen showed linear- elastic deformation with respect to the load. Under Flexural loading, the concrete experienced sudden brittle mode of failure.

As seen in Fig. 5 and Fig. 6, the flexural cracks continued to grow to the top surface of the slab upon increase in loading. The flexural cracks originated exactly below the point of application of line loads at two locations. At failure stage, the width of the already formed cracks increased without further development of additional cracks near the mid span.

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Fig. 5: Flexural Cracks formation of CSP – I

Fig. 6: Flexural Cracks formation of CSP - II

V. RESULTS AND DISCUSSION

With the use of basalt fibres in the M25 grade concrete, the Mechanical properties of Concrete are listed in Table.1 and it shows the improvisation in mechanical strength using basalt fibres compared to conventional concrete mix.

Table 1. Results of Mechanical Properties of BFRC and CC

No. of Days	Average compressive strength of cubes (N/mm²)		Average split tensile strength of cylinder (N/mm²)		Average flexural strength of prism (N/mm²)	
	BFRC	CC	BFRC	CC	BFRC	CC
7	22.07	20.74	2.83	2.66	2.93	2.75
14	22.66	21.30	2.91	2.73	3.86	3.62
21	28.16	26.75	3.13	2.94	5.73	5.38
28	35.13	33.37	3.43	3.22	6.80	6.39

The Composite Deck Slab Specimen undergoes brittle failure as it is evident from the test results. From the load Vs deflection curve it is observed that, at the begining stage load is linearly related to deflection and as the load increases, the first crack was developed at 57 kN and second crack at 86 kN and corresponding deflection observed upto 2.5mm. Also, it is observed that, the ultimate loads 153.5 kN with 16.8mm deflection and 155.8kN with17.5mm deflection for CSP-I and CSP-II respectively. Deformations of the specimens under flexural behavior are shown in Fig. 5 and Fig. 6.

With reference to Normal RCC Slab, the Composite slab structures are novel construction system where it is more economical and speedy construction for medium to high rise buildings.

A. *Load Deformation Response*

The flexural deformations of the composite slab panels, Deflections at mid-point and Rotations at end panels are shown in Fig.7, Fig.8 and Fig.9 for CSP-I and CSP-II respectively and the flexural capacities of the CSP-I and CSP-II are listed in Table.2.

Table 2. Results of Flexural Test

Results of Flexural Test						
Slab Specification	**Mass (Kg)**	**1st Crack Load (kN)**	**2nd Crack Load (kN)**	**Ultimate Load (kN)**	**Maximum Central Deflection (mm)**	**Maximum rotation (Degree)**
CSP-I	223.9	57	97	153.5	16.8	7.02
CSP-II	224.2	46	86	155.8	17.3	5.05

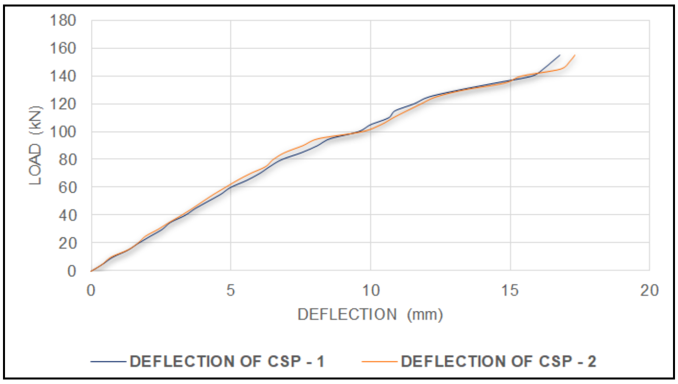

Fig. 7: Load v/s Deflection Curve for CSP-I and CSP – II

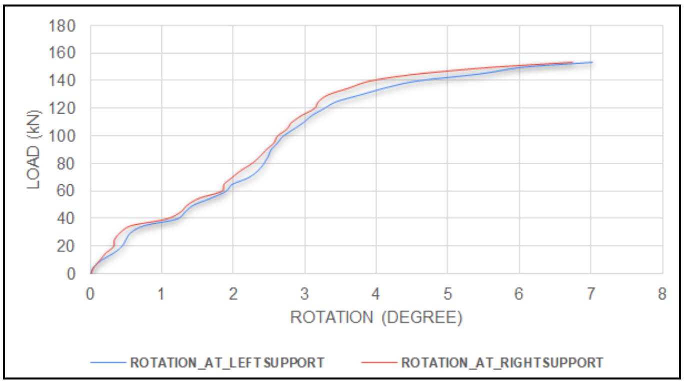

Fig. 8: Load v/s Rotation Curve for CSP-I

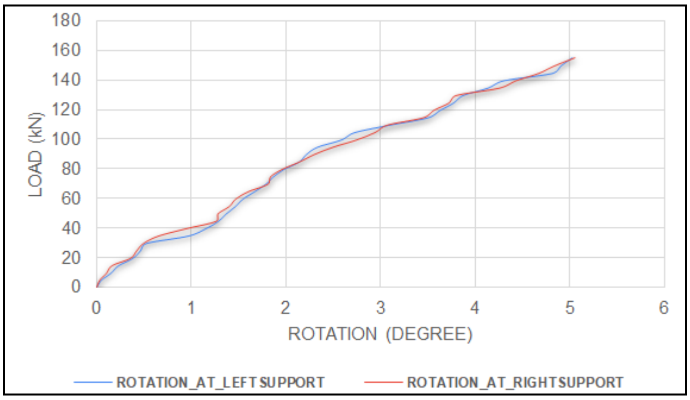

Fig. 9: Load v/s Rotation Curve for CSP - II

VI. CONCLUSION

From the above experiments, it is concluded that the mechanical properties of concrete can be improved with the use of Basalt fibres and also it can improve the strength of structural elements like Composite slab panels. Conclusion of the above experimental work are listed below-

- The use of 1% Basalt fibre as additive material in concrete improves 6 to 8 percent more strength compared to Conventional concrete (CC).
- Using Basalt Reinforced Concrete, the ultimate load carrying capacity of the composite slab panel - I is 153.5 kN and composite slab panel - II is 155.8 kN.
- The load carrying capacity and shear bond capacity between cold formed sheet and concrete are adequate with above mentioned shear studs or shear connectors (no slip observed).
- From this result analysis, these kind of composite slab panels can be used in the middle high rise buildings and commercial buildings using cold formed steel with shear connectors.

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