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Comparative Study of Conventional Reinforced Concrete Slab and Composite Slab with Profiled Steel Sheeting

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ABSTRACT: In India, consumption of steel is much less compared to other countries. On the other hand, India is the third-largest producer of steel. Thus, steel has great potential in the Indian Construction Industry and thus, not using it efficiently could be a great loss to the country. One such efficient method is steel-concrete composite construction. Composite slabs with profiled steel deck and concrete topping have gained wide acceptance as they lead to faster, lighter and economical construction. Steel encased with concrete does not only improve the strength of the composite members but protect the entire structure from adverse effects of fire, calamities, and corrosion. Many research works have been carried out to study the behaviour of composite steel deck slab. In that, most of the experimental studies on composite deck are performed on the full scale test. Analytical consideration of composite action on behaviour of slab and flexural strength is also far and few. In this study, a comparative experimental and analytical analysis has been carried out between reinforced concrete slab and composite slab with profiled steel sheeting. Composite and conventional slabs using steel decking were tested to failure under point loading test. The recorded results of the two different slabs were then used to plot a load-displacement graph and deflection profiles are to be analyzed and compared. The slabs were 150 mm deep and the deck profile was 60 mm deep and 1.5mm thick.

KEYWORDS: Steel-Concrete Composite Construction, Steel sheet profiled composite slab, reinforced concrete slab, flexural strength test.

I. INTRODUCTION

Composite construction is the general term used to describe any form of building construction involving two or more different materials that are bound together so strongly so they can act as a single unit. Generally, the materials used in composite construction are concrete/steel, timber/steel and plastic/steel. Composite structures integrate the structural properties of the two materials to produce stiffer, stronger and lighter structure due to the stiff connection between the materials. For concrete and steel, a shear bond connection between the materials is developed, so the materials can act as one unit. In composite construction using concrete and steel, the bending moment caused by applied load is resisted by the compressive force in the concrete and the tensile force in the steel. This action occurs in composite beams as well as composite slabs. Composite structures are generally cost effective from the constructional viewpoint, because they can be quickly erected especially when precast concrete units or profiled steel sheeting are used with the steel frame to facilitate the construction of the floors. The essential composite action between the steel decking and the concrete slab is generated by some form of embossments, which provide sufficient shear-bond, so that when the concrete gained strength, the two materials act together compositely with little slip. Today there is wide variety of profiled steel decks, in terms of depths and trough spacing, depend on the loading and the application of the decking. Deeper profiles allow decks to support loads with longer spans. The concrete/galvanised steel form of composite construction, considered in this study uses galvanized steel in the form of profiled steel decking. The steel decking is considered as the external reinforcement for the composite member.

II. RELATED WORK

Abdullah, Cole and Easterling [4] The research was conducted to analyze steel deck-concrete composite using non-linear dynamic finite element analysis ABAQUS/Explicit module software by the authors. A three-dimensional finite element modeling was performed which incorporated, tensile brittle cracking of concrete, horizontal shear

bond behavior between the concrete and the steel deck. Some of the input data were deduced from bending test. They developed the quasi-static analysis method which was capable of predicting the load-deflection behavior and the ultimate load of composite slabs.

U. Shah [6] modeled in ANSYS-15 by varying thickness, with and without embossments. The thickness of profile sheet has a considerable effect on the deflection and stress of the composite slab. Comparing the without embossments and with embossments, it was observed that the with embossment composite slab has less deformation by almost 34% to 41 % and less stress by almost 26% as the thickness is increased from 0.9 mm to 1.2 mm. Thickness of the decking sheet plays a significant role.

Baskar R. [16] studied the strength and behavior of composite slabs both experimentally and analytically. Ten composite slabs were cast based on with embossments, with embossments and end anchorages, without embossments. Both the experimental and analytical results were comparable. The load ratio between experimental and finite elemental values for without embossments, with embossments, with embossments and end anchorages groups were 1.02, 1.09, 1.16. The load carrying capacity of with embossments and end anchorages groups were found to be greater among the two. Embossments play a vital role in increasing the longitudinal shear capacity of slabs.

Namdeo Adkuji Hedaoo et al [17] casted a total of 18 full-scale composite slab specimen and tested to determine (1) the structural behavior and (2) the load carrying capacity. For partial shear connection method, analysis is based on actual measured strengths, and hence, it indicates a very less difference between actual failure load and design load. The m-k method results are weaker than the experimental method by 43%. This difference occurred since the design load values for m-k method are based on regression values reduced by 10% and the use of γ_{vs} of 1.25. From the design perspective of the composite slabs, partial shear connection method will give optimum design as compared to m-k method.

Gholamhoseini, [19] studied the longitudinal shear capacity of four types (two trapezoidal and two reentrant) of profiled decking that are widely used in Australia experimentally by using full scale load tests. The ultimate shear stress for each type of slab tested at shear span of (L/6) was greater than that obtained when the shear span was (L/4). A finite element model utilizing interface elements to model the bond properties between steel decking and concrete slab is described and used to investigate the behavior of the slabs throughout the full range of loading.

III. METHODOLOGY

Detailed study on materials used for the research and their properties were carried out. The cement, fine aggregate, coarse aggregate, water tested for its basic properties, which facilitates in arriving the mix proportion of concrete to be used. Basic characteristics of steel deck, embossments and reinforcing bars are also studied. Down scaled conventional slab was designed according to IS code 456-2000, while the composite metal deck slab was designed with European Code 4's (EC4) m-k method. Conventional slab and the composite deck both has the same dimension of 150 (D) x 500 (L) x 500 (W) mm. The reinforcement used was 8mm dia bars with 100 mm spacing. Concrete grade M25 was used for the slab tests which obtained from mix design. Specimens were casted and after 28 days when the slabs were ready for testing after having reached their final strength, the tests were carried out on a loading frame having capacity 150 kN. One point loading test was performed to obtain the flexural strength and load carrying capacity of the conventional and composite slab.

IV. EXPERIMENTAL RESULTS

1. Problem Statement

Casting of conventional reinforced concrete slab and composite profiled steel deck slab and testing under single point loading to obtain the flexural strength and load carrying capacity of the two slabs. Compare the results in the form of tabular and graphical representations to achieve the objectives by using trapezoidal galvanized steel profiled decking of 1.5mm thickness, 60 mm height, and M25 grade of concrete.

2. Mix Design Results.

Mix design calculated by referring IS456:2000 for M25 grade of concrete and calculated material quantity which is given in table 1.

Table 1. Mix Design Ingredient Quantity

S. No.	Materials	Quantity (kg/m ³)
1	Cement	425
2	Water	153
3	20mm Aggregate	765
4	10 mm Aggregate	546
5	Crushed Sand	721.7
6	Admixture	3.40

3. Test preparation and set-up for slabs

The steel deck pieces were cut to the suggested size using a metal grinder. The formwork system for the specimens was made from plywood. The plywood was cut accurately to obtain 500x500x150 mm size. Specimens were casted and tested after curing of 28 days. Slabs were simply supported and a spreader beam was placed in the middle of the slab in order to create an equal line load along the width of the slab. The loading was applied to the slab in deflection control and maximum load was recorded. Also the end slip for the composite slab was observed. Figure 1a and 1b shows galvanised steel deck used for the study and testing arrangement for the specimens respectively. The test results are shown in the table 2. And Figure 2 shows the Load vs. Deflection Curve.

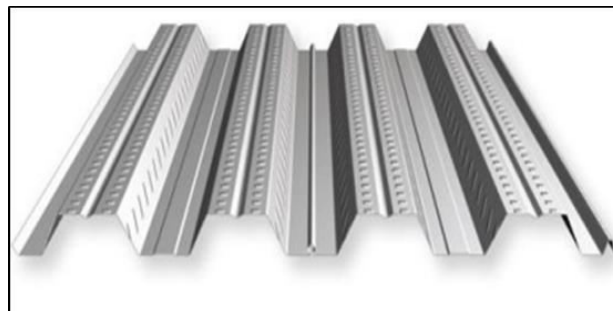


Figure 1a Galvanized steel deck



Figure 1b Testing of Specimen



V. RESULTS AND DISCUSSIONS

Obtained results by experimental study are discussed here.

5.1 Load-Deflection profile of Conventional and Composite Slab

The comparison between load carrying capacity, total deflection and flexure strength of normal concrete slab and composite steel deck slab in experimental investigation is done. Table 2 and Fig. 2 exhibits the overall combined results and load (kN) against deflection (mm) curve of the two specimens respectively.

Table 2 Comparison of results for conventional and composite slabs

Sr.No	Specimen	Load carrying capacity (kN)	Flexure N/mm ²	Deflection (mm)
1	Conventional slab	74.4	5.16	38.1
2	Composite slab	106.4	7.24	13.1

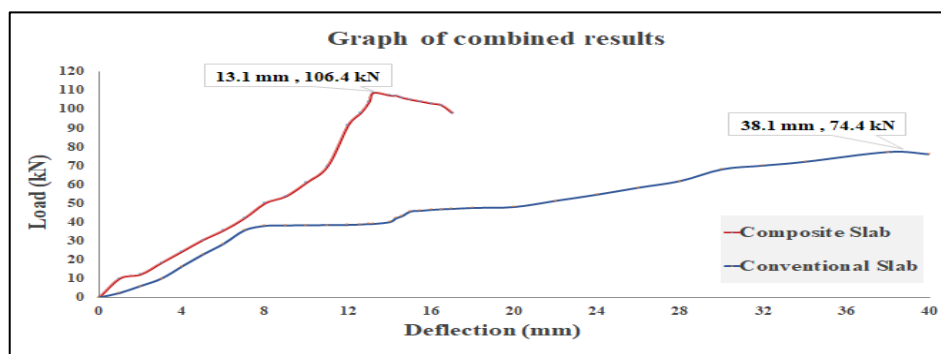


Figure 2 Load vs. Deflection Curve

Different behaviours shown between the specimens as specimens yielded and along plastic zone. As it is clearly seen from the table 2 above composite slab has the higher yield flexural capacity i.e. 7.24 N/mm² as compared to conventional slab with 5.16 N/mm². This simply indicates that flexural capacity of composite slab is higher than conventional slab by 40.3%. In addition, Fig. 2 shows that the conventional slab has the largest ultimate deflection 38.1 mm while composite slab has the smallest ultimate deflection 13.1 mm, this shows a decrease in deflection when comparing conventional to composite slab.

Also, composite metal deck does have a higher capability to withstand larger loading with little cracks. Load carrying capacity of the composite slab is 43.0% higher than conventional slabs. Composite metal deck with metal deck profile has higher serviceability.

5.2 Cracking pattern and mode of failure

Conventional slab failed by typical flexural failure at the middle of the slab below the loading point as shown in Fig. 3 (a). It is noticed that the crack happened very near to the loading point and the crack line continues to develop across the width of the slab while the load is increased gradually. The first flexural crack happened at 33.76.0 kN with the deflection of 6.33 mm at mid-span of the slab near to the concentrated loading point. The flexural cracks were then followed by crushing of concrete. Finally, the specimen failed at 74.37 kN.



Figure 3a Cracking pattern of conventional slab

On the other hand, the failure modes of composite slab can be categorized into 2 major modes under loading as shown in Fig. 3b which are flexural failure at mid span and bond or longitudinal slip failure. A bond failure results in slippage between the concrete and the metal deck, which can result in cancellation of the composite actions at interface. In flexural failure mode, the full steel section can yield in tension before the crushing of concrete in the upper section.



Figure 3b Cracking pattern of composite slab

VI. CONCLUSION

This research investigated the flexural strength behaviour of two different slabs, i.e. conventional slab and composite steel deck slab. In comparison with conventional slab, combining with steel sheet profile effectively increases the ultimate load capacity (increase of 43.0%) and ductility of the conventional slab remarkably. Besides, compared to the conventional slab with the same slab thickness, steel sheet profile allows the slab to withstand higher ultimate load under longer period of loading time. Moreover, the test results indicated that composite metal decks exhibited less deflection, higher ultimate load and ductility compared to the conventional slab. This suggested that composite metal decks show higher serviceability as compared to conventional slab. In general, the composite metal deck has flexural performance (40.0%) superior to that of the conventional slab.

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