Experimental Study on Concrete Slab With Profiled Steel Decking

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***Abstract*— This paper describes an experimental study on concrete slab with steel decking. . The main objectives of this paper is to study the behaviour of composite slab (with and without embossment deck sheet) in flexure test; to determine the effect of bond strength between chemical bond and mechanical bond by end slip test and to analyse the behaviour of design mix and nofines concrete under composite action. In the composite slabs, mechanical interlocking in the form of embossments or shear connectors was used to transfer shear between the outer skin of the plate and the concrete core. For deck sheet without embossment it is necessary to generate bond between concrete and slab, hence chemical adhesive is used. In this experiment, the adhesive chemicals- Araldite-GY257 IN and Aradur-140 are used in a ratio 2:1 respectively. In the experimental programme, carried out, ten simply supported composite deck slabs are tested to failure under two point line loads at L/4 (Shear span) of the span. The flexural characteristics, ultimate strength and bond strength (end slip test) of composite slabs are determined.**

Keywords—composite slab, shear bond, decksheet, embossment, design mixconcrete, nofines concrete,ultimate load, end slip and bond strength.

I. INTRODUCTION

Composite construction is the term used for structures composed of two or more different materials. Generally in Structural Engineering, the materials may be concrete-steel, concrete-timber, timber-plastic, timber-steel, plastic-steel, etc. Composite construction integrates the structural properties of the two materials to produce stiffer, stronger and lighter members from the efficient connection between the two materials. The shear-bond connection between the two materials is a very important factor in ensuring they act as one unit.

Composite behaviour between profiled sheet and concrete shall be ensured by Mechanical interlock provided by deformations in the profile (indentations or embossments), Frictional interlock for profiles shaped in a re-entrant form, End anchorages provided by welded studs or another type of local connection between the concrete and the steel sheet, End anchorages by deformation of the ribs at the end of the sheeting and Natural bond between concrete and steel due to adhesion.

The concrete-steel type of composite construction considered in this work, uses steel in the form of profiled steel sheeting. Profiled steel deck performs two major functions that act as a permanent formwork during the concrete casting and also as tensile reinforcement after the concrete has hardened. The only additional nominal light mesh reinforcement bars that needs to be provided is to take care of shrinkage and temperature, usually in the form of welded wire fabric as shown in fig.1.1. For many reasons, the composite action may not be complete because the concrete does not completely confine the steel. This may give rise to incompatibility in the strain at the concrete-steel interface when horizontal slip has occurred at the interface in the longitudinal direction. Also, vertical movement (uplift) may occur due to lack of interlock at the interface in the vertical direction. So, a strong stiff connection at the interface is required for effective composite members.

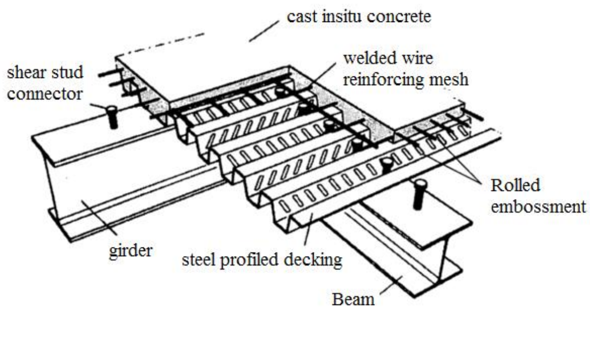
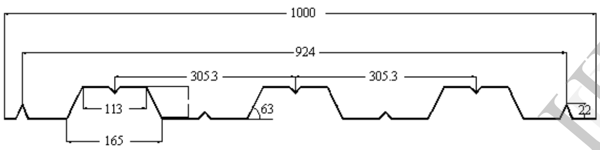


Fig.1 Concrete slab with steel decking

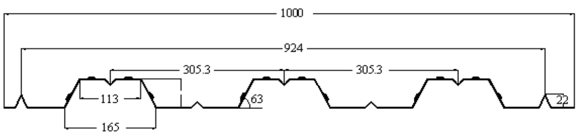
When rolled steel sections are used, as in composite beams, shear-connecting devices are required to increase the interface stiffness in both the horizontal and vertical directions. When profiled steel sheeting is used as the steel component in a composite element, it is impractical to weld shear connectors unless they are used on the supporting beams as end anchors. The steel material may be less than 1 mm thick, so shear connection is provided either by pressed or rolled embossments (indentations) that project into the concrete. This may be enhanced by giving the profiled steel sheeting a re-entrant shape, which prevents the vertical separation of the steel from the concrete, and can result in more effective mechanical connection from the embossments.

II. SPECIMEN DETAILS

Four test series were performed in the experiment. Series 1 and 2 consisted of testing three slabs and series 3 and 4 consisted of testing two slabs. Each slab are of span 1.5m and 1.0m width. The overall thickness of slab is 85mm, in which 52mm is the depth of profiled sheet and remaining 33mm is the depth of concrete above deck sheet. For series 1 and 2 the slab was casted using design mix concrete while for series 3 and 4, the slab was casted using nofine concrete. In all series, welded mesh of 3mm diameter spaced at 38.1mm (1.5 inch) centre to centre is used with a clear cover of 30mm. Mesh reinforcement is used to resist strains due to shrinkage and temperature effects. The profile deck sheet is of trapezoidal shape having 1 mm thick steel sheets with a galvanized finish for corrosion protection were used. Other properties are given in table 1. Details of the profiled steel sheeting are given below.



(a) Deck sheet without embossment



(b) Deck sheet with embossment

Fig.2 Cross-sectional details of deck sheet.

Table1. Properties of deck sheet.

Properties of deck sheet	
Chemical Composition	304 grade
Carbon	0.08 %
Manganese	2.00 %
Phosphorus	0.045 %
Sulphur	0.03 %
Silicon	1.00 %
Chromium	18.00-20.00 %
Nickel	l 8.00-10.50 %
Tensile Strength	579 MPa
Yield Strength	290 MPa
Elongation	55 %
Length	1.5 m
Width	1.0 m
Thickness	1.0mm
Type	Embossment and without embossed

Shear connection is provided either by pressed or rolled dimples as shown in figure 1.5 that project into the concrete, or by giving the steel profile a re-entrant shape that prevents separation of the steel from the concrete. In this study, embossments were introduced at the web portion of the deck sheet which acted as shear key between concrete and deck.

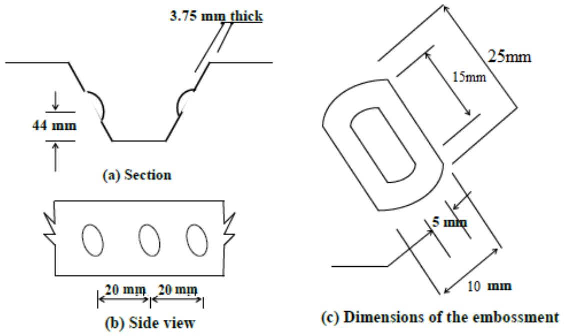


Fig.3 Details of embossment.

For deck sheet without embossment it is necessary to generate bond between concrete and slab, hence chemical adhesive is used. In this experiment, the adhesive chemicals- Araldite-GY257 IN and Aradur-140 (manufactured by Petro Araldite Pvt. Ltd. and marketed by Huntsman) were mixed in 2:1 ratio and applied over the sheet 15 minutes before casting. These chemical will take 24 hours to create bond between the materials. Araldite-GY257 IN and Aradur-140 are popularly used in connecting joints or bonding two materials in bridges and buildings.

Normal-weight design mixed concrete and nofines concrete was used in composite slabs. Six numbers of slabs (3 slabs with embossment and 3 slabs without embossment) was casted using ready mix concrete and similarly four numbers of slabs using nofines concrete. Following table 2 gives the mix proportion of M20 grade concrete (as per IS 10262 standard)

Table 2. Mix proportion of M20 grade concrete

Design mix proportion for M20 grade concrete	
Particulars	*Quantity per m^3*
Cement	320 kg
20mm Coarse aggregates	601 kg
10mm coarse aggregates	492 kg
Fine aggregates	769 kg
Water	170 kg
Super plasticiser	1.9 kg

For nofines concrete a mix proportion of 1:8 with water cement ratio 0.35 is selected. The specification of the composite slabs of different categories is given in table 3.

III. METHODOLOGY

Figure 4.6 shows the set-up used for testing the composite slabs. When slabs were ready for testing, having reached the required strength, they were lifted manually and positioned as shown in Figure 4.6. The middle of the slab been coincident with the centerline of the jack. All slabs were simply supported. A distance of 37.5mm was left between the centre-line of the supports and the end of the slab. A system of spreader beams was placed on the slabs so arranged to allow two equal concentrated loads at a distance of span/4 from each support. Fiberboard packing pieces were used between the supports and the lower surface of slabs, and between the spreader beams and the upper surface of slabs.

Table 3. Specification of the composite slabs.

Specification of the composite slabs			
Series number	*Concrete type*	*Bond type*	*Abbreviation*
Series I	Design mix concrete	Mechanical bond (with embossment)	SRE1
			SRE2
			SRE3
Series II	Design mix concrete	Chemical bond (with embossment)	SRC1
			SRC2
			SRC3
Series III	Nofines concrete	Mechanical bond (with embossment)	SNE1
			SNE2
			SNE3
Series IV	Nofines concrete	Chemical bond (with embossment)	SNC1
			SNC2
			SNC3

Fig.2 experimental set up.

The test configuration and loading procedure were according to recommendation of the IS code. All slabs were simply supported and tested with two symmetrically placed line loads figure4.2. A single hydraulic jack was used to apply load, which was distributed to the slab through a spreader beam system, which resulted in two line loads being applied to the specimen. It took approximately three days from the start of testing to failure of the last slab. Dial gauges were used to measure deflection and end-slip. Deflection at the mid-span was registered for one point. The end-slip between the steel sheet and the concrete slab was measured at single ends of the slab. The deflections and end-slip were recorded at each loading increment.

The loading of all slabs was of static loading. Testing started with static loading applied by the hydraulic jack to the spreader beams, and transmitted to the slab as a two concentrated line loads across the slab width at a distance of span/4 from each support which is equivalent to the uniformly distributed load case. The load was increased gradually in small increments (2.5 KN), and all the loads and displacement readings were taken at each increment.

IV. RESULTS AND DISCUSSION

A. Observation

The following are the observations made during flexure test;

i. In design mix concrete composite slab with chemical bonding and with embossment, the first crack was developed at the top right layer of the slab and also at this load one minor crack was developed at the centre back portion of the slab. As the loads increased, new cracks developed while the existing ones below or near the line load enlarged. After that gradually load applied major cracks were developed below the concentrated load and at mid span for an ultimate load. Also end slip was developed in right portion of the slab and vertical separation between two materials was also observed before failure.

Fig.3 Failure pattern of composite slab with design mix concrete.

ii. In nofine concrete composite slab with embossment, the first crack was observed at left and the second crack was developed at shear portion of the right side. End slip as well as buckling of profile was observed. The failure took place due to early bond failure in the slab.

Fig.3 Failure pattern of composite slab with nofines concrete.

iii. The nofines concrete composite slab with chemical bond showed better result and bond strength than mechanical bond. The first crack developed below the concentrated line load with minor cracks in flexure zone. At ultimate load apart from side cracks, central crack was formed.

B. Result of flexure test

The following tables the results of flexure test of various category slabs.

Table 4. Results of flexure test.

Results of flexure test				
Slab Specification	*Mass (in kg)*	*1st Crack Load (in kN)*	*Ultimate Load (in kN)*	*Maximum Central Deflection (in mm)*
SRE1	232.3	33.4	43.4	10.80
SRE2	232.1	30.9	40.9	10.60
SRE3	231.8	35.9	43.4	11.25
SRC1	232.4	35.9	43.4	10.60
SRC2	232.6	33.4	43.4	11.15
SRC3	233.1	35.9	43.4	9.80
SNE1	182.9	22.5	28.4	8.60
SNE2	183.2	25.9	30.9	9.35
SNC1	183.4	28.4	35.9	10.45
SNC2	183.8	28.4	35.9	10.70

Figure 5, shows load-deflection relationship of various composite slabs under flexure.

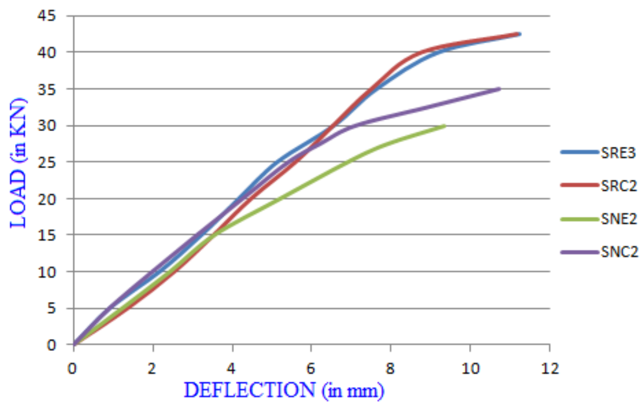


Fig.6 load-deflection relationship.

C. End slip test result

End slip is one of the parameters to estimate the strength of the shear bond between concrete and deck sheet. It is observed that the end slip load is around 75% to 80% of the ultimate load. But for nofines concrete with mechanical bond (with embossment) showed week bondstrength compare to Embossed sheet proves to be better shear bond for design mix concrete rather than nofines concrete which failed at early load. Whereas in composite slab with chemical bond (without embossment) showed better result in both design mix concrete as well as no fines concrete. Figure 7 shows load-end slip relation of various category slabs.

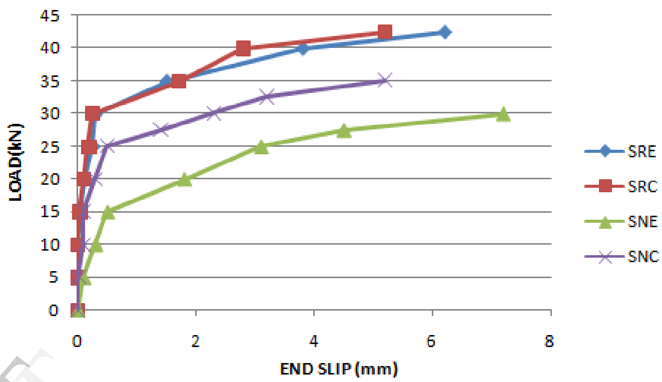


Fig.7 shows load-end slip relation of composite slabs.

CONCLUSIONS

The following are the conclusion drawn from the experimental results:

- Use of profiled deck sheet reduces 25% of concrete by volume.
- In nofines concrete composite slab, the slab with embossments attained early ultimate load due to the initialization of its delamination of deck sheets. Further, the delamination developed in the region between the two load points. The ultimate load carrying capacity of sheets without embossments (with chemical bond) is 14% more than that of sheets with embossments. Even though the increase in ultimate load carrying capacity was marginal, the chemical bond arrested the delamination of the sheets in the region between the two load points.
- In nofines concrete composite slab with chemical bonding, the maximum deflection at ultimate load of 35.9 kN (29.3 kN/m^2- equivalent udl) is 10.7mm.From load v/s deflection graph, the deflection of slab at 6.5 kN/m^2 and is 2.3mm.This deflection is within permissible limit (l/350) as per IS: 456-2000.
- In comparison with design mix concrete, nofines concrete (1:8 proportions) reduces 34% of cement,

100% of fine aggregates and 9% of total aggregates by mass per metre cube of concrete. Using nofines concrete there is reduction of 21% of self weight of slab.

- Design mix concrete slab with and without embossment shows almost same behavior in flexure. An ultimate load of range 40 to 43.4 kN was achieved and it is 20% more than nofines concrete composite slab.
- The longitudinal shear stress is not uniformly distributed over the shear span, and it is much smaller within the region between the two load points (or pure bending region) than that in the shear span. The longitudinal shear force is proportional to vertical shear force before the onset of shear-bond slip. The maximum load reached when the end-slips initiate for composite slabs. To overcome this situation, end anchorage by headed studs is provided to achieve extra substantial strength and ductility.
- The partial composite action between the concrete and the steel started after the loss of the chemical bonding and could be identified by the formation of the first crack and the beginning of end slip. In all the specimens, the end slip is observed from an early stage of loading, i.e., 75% to 80% of failure load

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