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EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR OF STEEL-CONCRETE COMPOSITE DECK SLAB

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Abstract - *Composite steel-concrete slabs with profiled sheets are used in the construction of commercial multi-storey buildings, parking structures and industrial structures. The use of profiled deck sheet is economical as it plays the dual role of supporting the wet concrete load and construction loads during concreting and acting as the tensile reinforcement for the slab once the concrete hardens. In the present study, attempts are made to analyse the load carrying capacity, failure mode and deformation characteristics of the composite slab prepared with the commercially available profiled sheet. The steel-concrete composite deck slab is cast and subjected to four point bending test from which the behavior of the composite deck slab under flexure is studied.*

***Key Words*: Steel-Concrete Composite Slab, Deck Sheet, Flexure, Four Point Bending, Shear Bond Rupture**

1. INTRODUCTION

Composite structural forms are adopted to make use of the benefits of using different materials of construction, in combination. For slabs, the traditional choice has been between precast units and some form of in-situ concrete construction. In the last few decades, a new form of composite floor construction, consisting of profiled sheeting with a concrete topping has become very popular. The advantages of this form of construction include speed, safety and efficiency of construction. The structural behavior is the same as that of a reinforced concrete slab, with the steel sheeting acting as the tension reinforcement. Composite deck slabs comprise profiled steel decking as the permanent form work to support the underside of the concrete slab spanning between supporting beams. The steel decking supports the loads applied to it before the concrete has gained adequate strength. The decking can be easily handled, can be cut to the required lengths and openings can be formed. Shear connectors can be welded through the decking on to the beams. These factors help to cut down the construction periods and thus lead to significant economies.

2. REVIEW OF LITERATURES

Simon J, Visuvasam J and Susan Babu (2017) - Study on shear embossments in steel-concrete composite slab. A study on the presence of embossments in steel sheeting was carried out. The variation in the shear capacity and ultimate strength of the composite slab was analysed with changes in size, shape and alignment of the embossments using finite element modelling. It was observed that the ultimate strength and shear resistance of the composite slab increased due to the presence of embossments. From the study carried out, it was concluded that as the embossment size increased, the ultimate strength of the composite slab increased. The ultimate strength of the composite slab was high when the embossments were bigger and square shaped or smaller and rectangular shaped. As the size of the embossment increased, circular embossment showed quicker response to the increase of ultimate strength of the composite slab in comparison with square and rectangular embossments.

R.Amuthaselvakumar, R.Mareeswari (2016)- Experimental Investigation on Composite Slab. An experimental study was carried out to analyse the behaviour of composite slab. Also, the cost analysis was carried out for conventional slab and composite slab. Tests were carried out on conventional slab and composite slab which were simply supported. It was observed that the ultimate load carrying capacity of steel-concrete composite slab with profile decking sheet was similar to the load carrying capacity of the conventional slab. The material required for casting composite slab was 30% less than the material required for casting conventional slab. The energy absorption capacity of composite slab was observed to be more than the conventional slab. The use of formwork can be neglected in case of composite slab construction.

K. N. Lakshmikandhan et al. (2013) - Investigations on Efficiently Interfaced Steel Concrete Composite Deck Slabs: This investigation was attempted to arrive at a better, simpler interface mechanism between steel and concrete. Three types of mechanical connector schemes were identified and investigated experimentally. Out of these three shear connector schemes, the first type was proposed with fastening of 8mm diameter bolts with 100mm length at 300mm c/c distance on the web of trough profile. These bolts were placed perpendicular to the web in a staggered manner in the opposite webs to simulate equivalent dove tail action. These bolts were designed to transfer the bond separation forces in terms of longitudinal interfacial shear forces and the uplifting force of slab efficiently. The bolts were fixed by tightening the nut and this type of shear connector mechanism was designated as scheme 1. The second shear connector scheme was proposed with higher shear strength in both transverse shear and uplift force, separately. In this shear connector mechanism, the bolts were placed at the top flange of deck for the transverse shear force, and 8mm rod was inserted through the hole which is created at the middle height of deck web for uplifting force. The second shear connector mechanism was purposefully planned with higher shear capacity to achieve full shear interaction and it was designated as scheme 2 shear connector scheme. In the third shear connector scheme, 10mm steel rod was affixed to control both the transverse shear force and the uplifting force. In this shear connector mechanism, 10mm high strength deformed bars were inserted through the holes created at the deck web centre of steel deck in the direction perpendicular to the primarily reinforced direction. The steel rods were placed at 150mm from the edge of the web and 300mm distance between the adjacent rods. The composite slabs were prepared to be tested under two-point loading condition. From the experimental investigations, all three types of mechanical shear connectors performed well and neither slip nor uplifting between concrete and deck sheet was observed. The composite slabs with shear connectors exhibited full shear interaction with remarkable increase in the load carrying capacity. From the experimental results, it was concluded that (i) the composite slab without shear connectors slipped and reached failure at the earlier load level. The insertion of shear connector modified the brittle behaviour of the composite slab into ductile. (ii) Three mechanical shear connector schemes developed full shear interaction and not exhibited any visible de-lamination and slip. (iii) The insertion of steel rods at the middle of the deck web in scheme 2 and scheme 3, tied and integrated the metal deck. The integration improved the strength and stiffness of metal deck and reduced formworks and temporary supports. (iv) Steel rods present in the deck web could be efficiently tied and showcased for the two-way composite deck system. (v) The inclusion of shear connector enhanced the flexural capacity, stiffness, ductility, and energy absorption of composite deck system. (vi)The load carrying capacity was improved by about 110 percent when compared to that of the composite slab without mechanical shear connector with minimum/negligible cost escalation. The composite slab with mechanical shear connector carried about 60 percent additional load when compared to that of the reinforced concrete slab with same depth. (vi)The flexural capacity of composite deck slab with wire mesh was found to be competitive for shrinkage and temperature effects.

3. DETAILS OF THE SLAB SPECIMEN

Composite deck slab is constructed with commercially available GI deck sheet. This sheet has an overall depth of 75mm with embossments and indentations provided on the web of the profile. Also, this sheet is provided with grooves on the bottom flange of the deck sheet to enable better interlocking properties. Thickness of the sheet is 1mm.

Width of the slab	= 625 mm
Length of the slab	= 1450 mm
Overall depth of the slab	= 120 mm
Depth of concrete above the profile	= 45 mm
Grade of Concrete	= M_{25}
Interlocking mechanism with concrete embossments and indentations	=With

Fig-1: GI Deck Sheet Used for Deck Slab Construction

3.1 Construction of Composite Slab Specimen

Firstly, the surface on which the slab specimen is going to be cast is cleaned thoroughly and ensured that there is no moisture accumulation below the deck sheet. The surface is level and free from any obstruction. Then the mould is kept ready for the desired slab dimension. The mould is prepared from particle board planks. These boards do not absorb water from the concrete as they come with a layer of polythene sheet on main face. They also provide adequate support without bulging during concreting process.

3.2 Batching of the Constituent Materials

The concrete constituent materials are batched by weight. Mix proportion for M25 grade of concrete is 1:1.58:1.88 with water-to-cement ratio of 0.44. The concrete constituent materials namely cement, crusher sand and coarse aggregate are measured separately according to their proportion.

3.3 Mixing of Concrete

The site of concrete mixing is chosen very close to the place where composite slab is going to be constructed. The mixing surface is clean and free from any foreign matter. Water is sprinkled on the mixing surface one hour prior to mixing of concrete so as to ensure that there is no moisture absorption to the surface. Materials for concrete making batched previously are placed one layer over another in a uniform manner. Dry mixing of constituent material is then followed. Once the dry mixing is completed, the required water is added slowly and mixed simultaneously. Mixing is continued until uniform consistency of the green concrete is obtained.

3.4 Placing of Concrete

After thorough and uniform mixing of fresh concrete, it is then placed in the form work. Placing of concrete takes place in a steady rate and compacting is done properly to ensure that concrete attains its maximum density. Firstly the concrete is placed up to the top flange of the deck sheet and compacted well. Then concrete is placed to the rest of the desired height in a uniform manner.

3.5 Finishing of Concrete

Placing of concrete is carried out till the desired height of the slab. Then finishing is given to the concrete surface with the help of trowel and float. The surface is levelled using the float and final finishing is given with the help of trowel.

3.6 Curing of Concrete

Curing of the slab specimen is done by surface ponding method. For this purpose, bunds are constructed along the edges of the slab specimen. This takes place on the next day of casting of composite slab specimen. The bunds are constructed using lean cement mortar so that they can be chipped off from the slab surface after specified curing period. On the next day of construction of bunds, water is retained on the surface. Care is taken to ensure that there no side spillage of water. This prevents deck sheets from getting corroded excessively during the curing process. Curing is continued until 28 days from the date of first application of water.

4. EXPERIMENTAL SETUP

Experimental setup for the testing of composite slab specimen comprises supporting beams, 32mm diameter rods for distributing point load into line load, spreader beam, built up section to transfer load from actuator and 250 kN actuator to provide loading. The composite slab specimen shall be tested for flexure with two line loads applied at one-third spans. This is known as Four Point Bending Test. In this study, only static loading is applied.

Fig-2: Experimental Setup for Testing

4.1 Testing of the Composite Slab Specimen

To measure the mid span deflection, an LVDT is fixed at the mid span point with the help of a stand. As steel concrete composite slab elements exhibit de-lamination at the steel-concrete interface, it is necessary to measure the amount of end slip from the point of view of structural integrity. Therefore an LVDT is fixed at one end of the slab specimen to measure the slip between concrete and steel decking.

In the present study rate of loading is given as 3mm/min to the computer interface. Once all the inputs are given, load and displacement are kept zero by clicking the tare button. At this point of time, the readings shown by the LVDT are noted down. Then 'Initiate Loading' is clicked and the actuator starts applying the loading at the given rate.

The computer software records load-deflection values at regular intervals and also plots the graph representing the two parameters. In order to cross check the values given by the software, LVDT readings are noted at regular intervals for a particular range of load values. The deflection value when the first crack is encountered is noted. Then the loading continues until the slab fails by flexure. At this point of time, the actuator retracts and the loading gets stopped. The ultimate deflection before the withdrawal of the actuator is noted. The final reading of the end slip LVDT is also noted.

4.2 Load – Deflection Data

Table-1: Load-Deflection Data from the Four Point Bending Test

S.No	Load (kN)	Mid Span Deflection (mm)	Remarks
1	5	0.3	
2	10	0.7	Minor separation between steel-concrete interface
3	15.2	1.2	First Crack
4	20	1.3	
5	25	2.5	
6	30	2.8	
7	32.8	5.2	Ultimate Load

4.3 Load – Deflection Plot

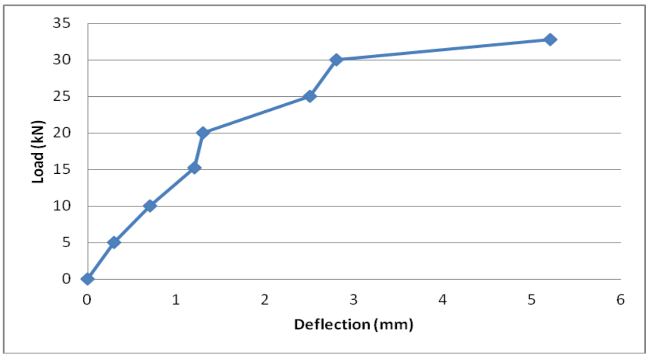

Chart -1: Load-Deflection Plot

4.4 Discussions on the Test Results

Composite Deck Slab Specimen underwent brittle failure as it is evident from the test results. As soon as the loading started, the specimen underwent deflection only up to 2.5 mm. Finally, at the ultimate load there is a jump in deflection from 2.5 mm to 5.2 mm. Before failure a sharp cracking sound could be heard. This is the result of complete de-bonding of concrete from the decking sheet. At this stage, the concrete in the compression zone underwent crushing at the mid span location.

Fig-3: Crack Formation under Flexure

As seen in Fig-3, 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 region.

4.5 Shear Bond Rupture

There was a minor separation between steel decking and concrete seen at around 10kN load. There was excessive end slip between steel decking and concrete at the failure stage. Composite slab constructed with GI deck sheet exhibited poor bonding and interlocking mechanism with concrete. This is evident from the end slip value observed at the end of testing. The end slip between steel decking and concrete at the end of testing was 3.6mm. At failure stage, the deck sheet separated from the concrete completely, and the concrete section failed suddenly.

5. CONCLUSIONS

From the Four Point Bending Test conducted on the composite deck slab, it can be concluded that –

- The ultimate load carrying capacity of the composite deck slab is 32.8 kN
- The failure mode of composite deck slab with commercially used deck sheet is of brittle nature
- This brittle failure is due to the early loss of bond between steel decking and concrete
- Load carrying capacity of the composite deck slab can be increased by enhancing bond characteristics between steel decking and concrete
- The shear bond capacity of the composite deck slab depends on the type, orientation, interval and height of the embossments and indentations

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