Experimental Investigation of Composite action of Steel Concrete slabs

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Abstract:- *The aim of this project is to design the composite slab which is connected using shear connectors. The used of steel-concrete composite construction has been widely applied in building construction. The steel-concrete composite slabs and construction; to explain the action of the two different materials and to show how the structural members are used, particularly in building construction. The two complementary materials, structural steel and reinforced concrete are introduced and it is shown how composite action is achieved in the case of composite slabs, beams and columns. The use of composite construction for buildings, bridges, bus stop, railway platforms, and industrial sheds is several typical examples; its main advantages are also illustrated by comparison with structures of steel and concrete used independently. These materials can be used in mixed structural systems, for example concrete cores encircled by steel tubes, as well as in composite structures where members consisting of steel and concrete act together compositely.*

Key Words Steel Profiled Deck sheet, Shear connectors, I-beam, Construction stage, composite stage.

1. INTRODUCTION

To introduce steel-concrete composite members and construction; to explain the composite action of the two different materials and to show how the structural members are used, particularly in building construction. Composite design is when a structural member composed steel and concrete material joined together and acts as a single unit. The use of steel in construction industry is very less in India as compared to many developing countries. The experiences of other countries indicate that this is not due to the lack of economy of Steel as a construction material. There is a great potential for increasing the volume of Steel in construction, especially in the current development needs in India. Steel is an alternative construction material and not using it where it is economical is a heavy loss for the country. Also, it is evident that now-a-days, the composite sections using Steel encased with Concrete are economic, cost and time effective solution in major civil structures such as bridges, industrial sheds and high rise buildings. The most important and most frequently encountered combination of construction materials is that of steel and concrete, with applications in multi-storey commercial buildings and factories, as well as in bridges. The composite slab have almost the same thermal expansion; they have an ideal combination of strengths with the concrete efficient in compression and the steel in tension; concrete also gives corrosion protection and thermal insulation to the steel at elevated temperatures and additionally can restrain slender steel sections from local or lateral-torsional buckling.

A. Composite Structures

Composite Steel-Concrete Structures are used widely in modern bridge, factories, bus stops and building construction. A composite member is formed when a steel I-beam, is attached to a concrete floor slab or bridge deck. In such a composite I-beam the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. The fact that each material is used to full advantage makes composite Steel-Concrete construction very efficient and economical. The real attraction of such construction is based on having an efficient connection of the Steel to the Concrete, and in this connection that allows a transfer of forces and gives composite members their unique behavior.

B. Definition for Composite Beams

Composite beams are flexural members made of two or more longitudinal members which are constrained in their relative longitudinal displacements at the interface by means of a shear connection of the members.

Composite Construction

Composite construction refers to any members composed of more than one material. The parts of these composite members are rigidly connected such that no relative movement can occur.

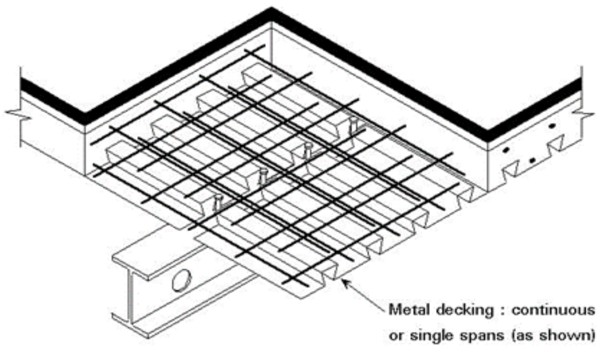

Fig.1 Composite Construction

C. Need of Steel - Concrete Composite Section

Steel concrete composite construction combines the compressive strength of concrete with the tensile strength of steel. Over the years, this specialized field of construction has become more and more popular in the western world and developed into a multifaceted design and construction technique. Apart from composite beam, slab and column, options like composite truss, slim-floor etc. It is also being explored in the field of composite construction. Building with steel and composite elements experienced a renaissance during the 1980's, resulting in a profusion of new construction concepts and structural details. Single composite elements, such as isolated beams, columns and slabs, whilst they are of high quality and resistance, they are also, in many cases, expensive. This is the case particularly for buildings with small column spacing's, floor beam spans well below 9 m and low loadings. On the other hand, composite floor construction is highly competitive if spans are increased to 12, 15 or even 20 m. There is, of course, a demand for larger column-free spans in buildings to facilitate open planning or greater flexibility.

Composite Construction in Buildings

Fig.2 Composite Construction in Buildings

D. Composite Beam Action

Composite beams, subject mainly to bending, consist of a steel section acting compositely with one flanges of reinforced concrete. The two materials are interconnected by means of mechanical shear connectors. It is current European practice to achieve this connection by mean of headed studs, semi-automatically welded to the steel flange.

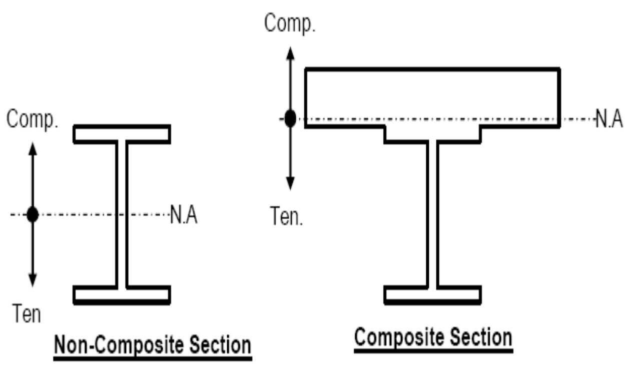

Fig.3 Composite Beam Action

Typical Beam Cross Sections

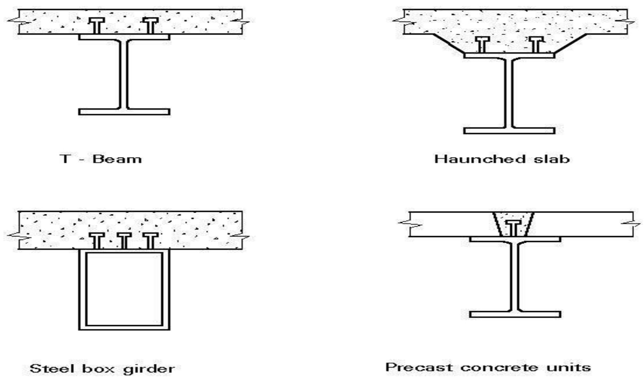

Fig.4 Typical Beam Cross Sections

Composite Steel Beam-Concrete Slab Interaction

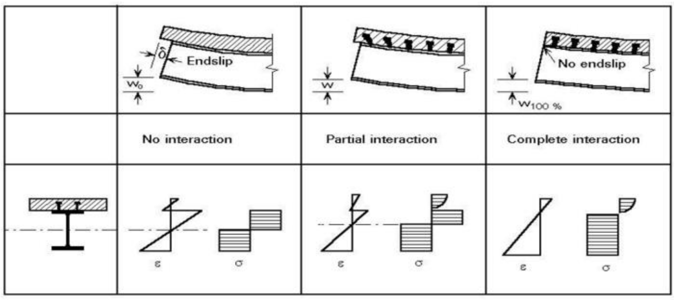

Fig.5 Composite Steel Beam-Concrete Slab Interaction

2. LITREATURE REVIEW

These studies relate to the behavior of conventional concrete slab over a steel I – beam. The concrete frame construction has until recently been traditionally undertaken using plywood formwork for all structural elements and so no inherent advantages have been achievable during the construction phase. This has been overcome by the development of composite profiled beams which employ a permanent formwork system consisting of profiled sheeting for concrete framed construction.

Chapman and Balakrishnan S.(2005) earlier investigations started with well-known work on composite beams by the authors who concerned about the shear connectors in the overhanging region of the simply supported composite beams. They aimed at the sensitivity of the overall response of the beams with respect to the material strength fibre reinforced polymer (CFRP) and steel plates, are implemented in different combination.

Xinpei Liu,et.al (2017) Composite beams comprising of concrete slabs and beams joined by conventional headed stud shear connectors are commonly used in modern steel framed building construction. The headed stud shear connectors are welded onto the flange of steel beam and cast into the in situ concrete slab.

Mahbue Suhani,et.al (2018) Due to the partial interaction between steel concrete slab, axes in a steel-concrete composite formed, sometimes even at . As a result, both the soffit of the slab and beam can be in tension if slip is allowed in the composite beam which is a common case for numerous composite beams. While most the previous studies emphasized on the strengthening of the steel beam only, this study investigates the effect of strengthening both the concrete slab and steel beam.

3. METHODOLOGY

Aim of the Project

- To observe the behavior of steel-concrete composite beam slab subjected to pure bending, with particular regard to their behavior at failure.
- The effect of shear connectors on the ultimate strength of beam slab.
- The effect of CFRP material on composite slab without profiled deck sheet.
- To compare the deflection of steel-concrete composite beam slab with conventional concrete.
- An approach is made to conduct number of experiments to observe the behavior of the beam slab under pure bending.

Elements of Composite Building

A. Shear Connectors

Shear connections are essential for steel concrete construction as they integrate the compression capacity of supported concrete slab with supporting steel beams / girders to improve the load carrying capacity as well as overall rigidity. Though steel to concrete bond may help shear transfer between the two to certain extent, yet it is neglected as per the codes because of its uncertainty. All codes therefore, specify positive connectors at the interface of steel and concrete.

Shear Connectors

Fig.6 Shear connectors

B. Profiled Deck

Fig.7 Profiled deck sheet

Composite floors using profiled sheet decking have become very popular in the West for high-rise buildings. Composite deck slabs are generally competitive where the concrete floor has to be completed quickly and where medium level of fire protection to steel work is sufficient. There is presently no Indian standard covering the design of composite floor systems using profiled sheeting. In composite floors, the structural behavior is similar to a reinforced concrete slab, with the steel sheeting acting as the tension reinforcement. The main structural and other benefits of using composite floors with profiled steel decking are:

- Savings in steel weight are typically 30% to 50% over non-composite construction
- Greater stiffness of composite beams results in shallower depths for the same span. Hence lower stored heights are adequate resulting in savings in classing costs, reduction in wind loading and savings in foundation costs faster rate of construction.

Profiled Sheet Decking

The steel deck is normally rolled into the desired profile from 22G (0.70mm) to 16G (1.6mm) galvanized coil. It is profiled such that the profile heights are usually in the range of 40 – 60 mm whereas higher depth of 85mm is also available. The typical trough width lies between 150 to 350mm. Generally, spans of the order of 2.5m to 3.5m between the beams are chosen and the beams are designed to span between 6m to 12m.

Design Considerations

Composite floors are designed based on limit state design philosophy. Since IS 456:2000 is also based on limit state methods, the same has been followed wherever it is applicable. The design should ensure an adequate degree of safety and serviceability of structure. The structure should therefore be checked for ultimate and serviceability limit states.

The main economy in using profiled deck is achieved due to speed in construction. Normally 2.5 to 4.0m spans can be handled without propping and spans in excess 4m will require propping. The yield strength of decking steel is in the range of 220 to 460 N/mm2. Though light – weight concrete is preferable both from reducing the effect of ponding deflection as well as increasing the fire resistance, the normal practice in India is to use concrete of grade M 20 to M 30.

The profiled deck depth normally available ranges from 40 to 85mm and the metal substrate thickness 0.7mm to 1.6mm.

The normal span/depth values for continuous composite slab should be chosen to be less than 35. The overall depth of the composite slab should not be less than 90mm and thickness of concrete, hc, shall not be less than 50mm.

Beam Size: ISMB 100 @ 8.9kg/m

- Depth of section (D): 100 mm
- Width of flange (bf): 50 mm
- Thickness of flange (tf): 7 mm
- Thickness of web (tw): 4.7 mm
- Depth of web (dw):h1: 64.8 mm
- Ixx: 183x104 mm^4
- Zp: 36.6x103 mm^3

Composite Slab Size: 2000 mm x 400 mm

- Depth of slab:50 mm +50 mm deck =100 mm
- Clear cover of composite slab = 15 mm

Materials

A. Steel beam

The I section is used for the push-out test was the ISMB 100@8.9kg/m. The height of the steel beam was 100 mm, and the centroid of the I beam was 50 mm. The modulus of elasticity, yield stress and tensile strength of the I section is 200 GPa, 450 MPa and 500 MPa, respectively.

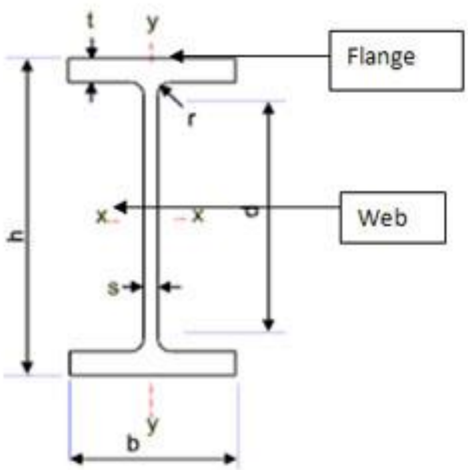

Fig.8 ISMB-100 section

B. Concrete

The concrete slab for the push-out test was constructed similarly as the concrete slab used for the composite beams. Accordingly, the thickness of the concrete slab was set at 50 mm. Due to the small thickness of the concrete slab; maximum size of the coarse aggregates was selected as 7 mm. The water cement ratio for the concrete was 0.38.The width of the concrete slab were 400 mm. The concrete slab was cured for 28 days by covering with gunny bags. Also, three concrete cube were casted to determine the compressive strength of the concrete.

Design mix proportion for M20 grade concrete (1:1.5:3)	
Particulars	***Quantity per 0.3 m^3***
Cement	129.20 kg
Sand	194.88 kg
Aggregates	403.5 kg

C. Shear connector

M8 high strength (grade 8.8) bolts were used to provide connection between the steel beam and concrete. The length of the bolt was 50 mm which enables a clear concrete cover of 10 mm. One bolt was used on center of the steel beam. Therefore, the bolt was placed at the center of the concrete slab. The yield stress and tensile strength of the shear connector are 660 and 830 MPa, respectively.

D. Casting Process

a) *Material Collection*:

Cutting Process

Fig.9 Cutting process

Welding Process

Fig.10 Welding process

Concreting Process

Fig.11 Reinforcement

Fig.12 Concreting

Curing Process

Fig.13 Curing process

Test Setup

Fig.14 Flexural test setup

Fig.15 Flexural test

4. RESULTS AND DISCUSSION

Observation

The following are the observation made during flexural test;

i. In design steel concrete composite slab with profiled deck sheet, the first crack was developed at the top layer of the slab and at this load one minor crack was developed at the center portion of the slab. As the load increased, new cracks developed while the existing ones near the line load enlarged. After that gradually applied load major cracks were developed below the concentrated load.

ii. During testing I have used one point central loading condition and observed that central deflection in composite slab was less than normal concrete beam slab.

iii. The end slip was developed in corner portion of slab and vertical separation between two materials was also observed before failure.

iv. Local buckling was not observed in any composite slabs.At the time of the failure diagonal shear crack was observed as shown in fig.15

v. Compressive strength of concrete cube in 7 days curing.

Table.1 Results of compressive strength tests

Details	*Samples*		
	Specimen 1	*Specimen 2*	*Specimen 3*
Compressive Load (kN)	375 kN	383 kN	370 kN
Compressive Strength (N/mm^2)	(375000/22500) = 16.66 N/mm^2	(383000/22500) = 17.02 N/mm^2	(370000/22500) = 16.44 N/mm^2
Average Compressive Strength	16.70666667 = 16.70 N/mm^2		

Table.2 Results of flexural tests

Results of Flexural test				
Slab specification	***Slab***	***1st crack load (in kN)***	***Ultimate load (in kN)***	***Maximum central deflection (in mm)***
I-Beam+ heet+RCC Slab	S1	32.30	44.08	10.11
	S2	35.20	48.05	10.34
I-Beam+CFRP+RCC Slab	S3	38.70	45.70	11.25
	S4	36.30	43.20	11.73
RCC slab +RCC Beam	S5	28.40	35.09	9.23

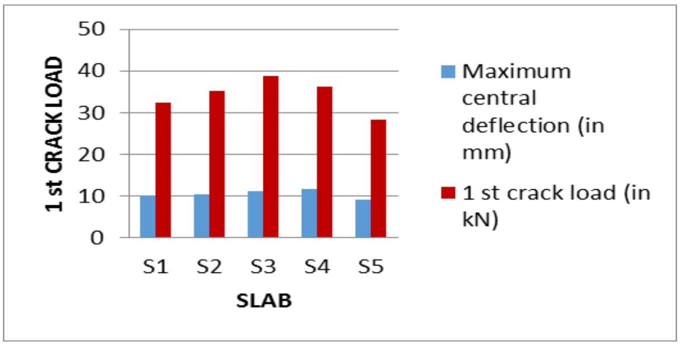

Fig.16 1st Crack load-deflection

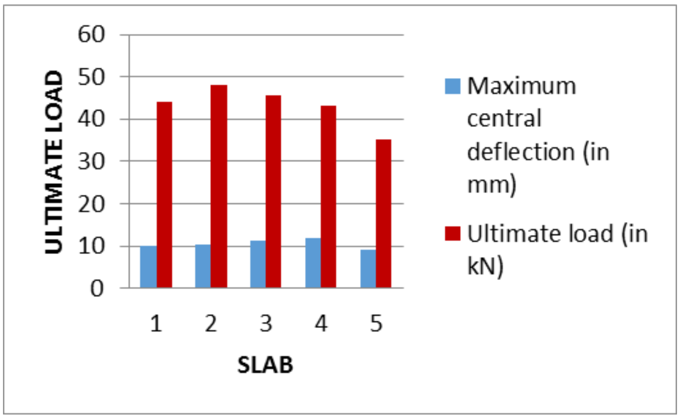

Fig.17 Ultimate load-deflection

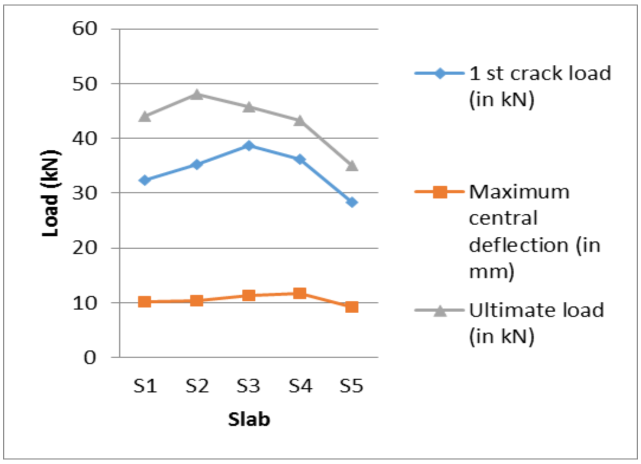

Fig.18 load-deflection relationship

5. CONCLUSIONS

The following are the conclusion drawn from experimental results:

- The deflection in composite slab is less than as compare to normal RCC slab.
- The weight of steelwork required in composite construction is less than if the materials were used independently.
- Use of profiled deck sheet reduces near about 25% of concrete by volume.
- Composite construction, particularly that using profiled steel sheeting, allows rapid construction.
- The steel reinforcement required in composite construction is less than normal RCC construction.
- In composite slab using profiled deck sheet, then the depth of composite slab was reduced.
- There is no need to construct formwork because used of profiled deck sheet.

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