Design of Steel – Concrete Composite Construction in Floor System

G. Sugila Devi[1], K. Banupriya[2], N. Rohini[3], V. Thesingarajan[4], R. Premadasan[5]
[1]Head of the Department, Civil engineering,
[2,3,4,5] Final Year Civil Engineering.
Nadar Saraswathi College of Engineering and Technology,
Theni

***Abstract*-This paper presents the structural behavior of composite concrete slabs with trapezoidal type profiled steel decking by experimental and theoretical studies. The slab is created by composite interaction between the concrete and steel deck with embossments to improve their shear bond characteristics .However, it fails under longitudinal shear bond due to the complicated phenomenon of shear behavior. Therefore, an experimental full-size tests has been carried out to investigate the shear bond strength under bending test in accordance to Eurocode 4 - Part 1.1. specimens are split into two sets of one specimens each in which all sets are tested for different shear span lengths under static and cyclic loadings on simply supported slabs. The longitudinal shear bond strength between the concrete and steel deck is evaluated analytically and compare the above results with the conventional concrete.**

Keywords—Composite slab, profiled steel deck, longitudinal shear bond stress, shear span length, partial shear connection method.

I. INTRODUCTION

A composite slab with profiled steel decking has proved over the years to be one of the simpler, faster, lighter, and economical constructions in steel-framed building systems. The system is well accepted by the construction industry due to the many advantage s over other types of floor systems. Cold-formed thin-walled profiled steel decking sheets with embossments on top flanges and webs are widely used in many composite slab constructions. 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.
Composite slab reinforced with profiled steel decking sheet means there is a provision in the system for positive mechanical interlock between the interface of the concrete and the steel deck by means of embossments.

The profiled decking sheet must provide the resistance to vertical separation and horizontal slippage between the contact surface of the concrete and the decking sheet. It also permits transfer of shear stresses from the concrete slab to the steel deck. The horizontal slippage between the concrete and the steel deck will exist due to the longitudinal shear stress when the shear force of the shear connectors reaches its ultimate strength.
Several full-size experimental tests have been proposed by past researchers to account for complex phenomenon of shear bond behavior between the steel deck-concrete interactions in composite slabs.

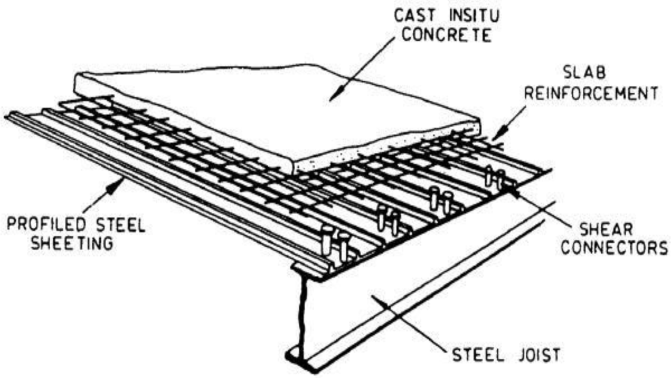

Fig 1.

a) Marimuthu and Seetharaman (2007) carried out 18 tests to investigate primarily the shear bond behavior of the embossed composite deck slab using trapezoidal profiled steel decking under simulated imposed loads and to evaluate the m-k values. The longitudinal shear strength of the composite slab calculated using m-k method is verified with the results obtained by partial shear connection method in Euro code 4 – Part 1.1 and is differed by about 26% in the average.

b) Mohammed (2010) carried out an experimental work to study the fresh and hardened properties of concrete containing crumb rubber as replacement to fine aggregate. The strength of composite slab lies within the bond between the concrete and the profiled steel sheeting; therefore, the use of lighter in weight and more ductile concrete such as CRC to toping the steel sheeting could produce a new composite slab system. Two sets of slabs, each set comprising three CRC composite slabs and one conventional concrete slab, have been tested with two shear spans. It is found that the shear bond capacity obtained by m-k method was slightly higher compared to the value obtained by partial shear connection method of the Euro code 4 – Part 1.1.

The review of literature shows that the strength of longitudinal shear bond achieved depends on many factors, among which include the shape of steel deck profile, type and frequency of embossments, thickness of steel decking, arrangement of load, length of shear span, slenderness of the slab, and type of end anchorage. However, an accurate determination of strength for a new steel deck profile type is possible only by full-size testing.

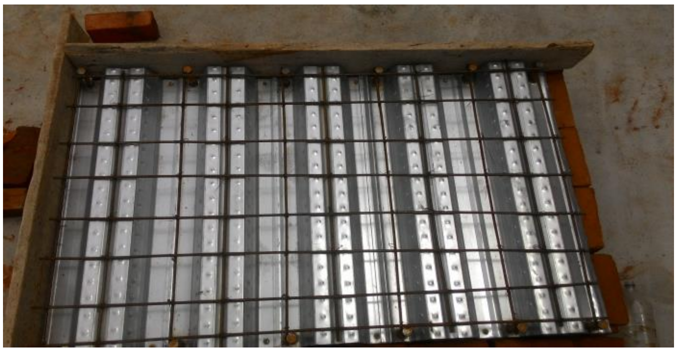

Fig 2.

2 MATERIALS

The following materials are using in composite construction. These materials are to be tested and their results are followed below.,

2.1 COMPARISON OF TEST RESULTS

A) SIEVE ANALYSIS**:** Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by 100. Generally sand having fineness modulus more than 3.2 is not used for making good concrete.TABLE 1

Sieve size	*weight retained in gm*	*Percentage of weight retained*	*Cumulative percentage of weight retained*
4.75mm	30	3	0
2.36 mm	160	16	3.0
1.18 mm	214	21.4	24.4
600 micron	282	28.2	52.6
300 micron	294	29.4	82
150 micron	19	1.9	83.9

***** Sieve analysis of river sand

Fineness modulus= Sum of cumulative percentage of weight retained/100 = 245.6/100

Fineness modulus = 2.456

TABLE 2

Sieve size	*weight retained in gm*	*Percentage of weight retained*	*Cumulative percentage of weight retained*
4.75mm	28	2.8	2.8
2.36 mm	63	6.3	9.1
1.18 mm	32	3.2	12.3
600 micron	272	27.2	39.5
300 micron	455	45.5	85
150 micron	60	6	94

***** Sieve analysis of M-sand

Fineness modulus= Sum of cumulative percentage of weight retained/100 = 242.7/100

Fineness modulus = 2.427

B) SPECIFIC GRAVITY OF CEMENT: To determine the specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. To determine the specific gravity of cement, kerosene which does not recent with cement is used.

Specific gravity of cement = 3.15

C) SPECIFIC GRAVITY OF RIVER SAND

Specific gravity of river sand = 2.60

Fig: 3 Specific gravity of River sand

D) SPECIFIC GRAVITY OF M-SAND

Specific gravity of quarry dust = 2.4

Fig: 4 Specific gravity of M-sand

E) INITIAL AND FINAL SETTING TIME OF CEMENT

a)INITIAL SETTING TIME OF CEMENT: Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Percentage of water added = 0.85 x consistency of cement
= 0.85 x 31 = 26.35

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TABLE 3

Sl. no	*Time in minutes*	*Weight of cement in gm*	*Percentage of water added*	*Volume of water added in ml*	*Penetration from bottom in mm*
1	0	400	26.35	105	0
2	5	400	26.35	105	0
3	10	400	26.35	105	0
4	15	400	26.35	105	1
5	20	400	26.35	105	2
6	25	400	26.35	105	4
7	30	400	26.35	105	6

***** Initial setting time of cement

Initial setting time of cement is 30 minutes.

b) FINAL SETTING TIME OF CEMENT

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression

TABLE 4

Sl. No	*Time in minutes*	*Penetration from the bottom*
1	10	0
2	15	1
3	20	2
4	25	2
5	30	3
6	45	4
7	60	4

*–Final setting time of cement

The final setting time of the cement is 10 hours

F) WORKABILITY TEST

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed.

- Slump is a measurement of concrete's workability, or fluidity.
- It's an indirect measurement of concrete consistency or stiffness.
- The dimensions are:

Top Diameter - 10cm
Bottom Diameter - 20cm
Height - 30cm

TABLE 5

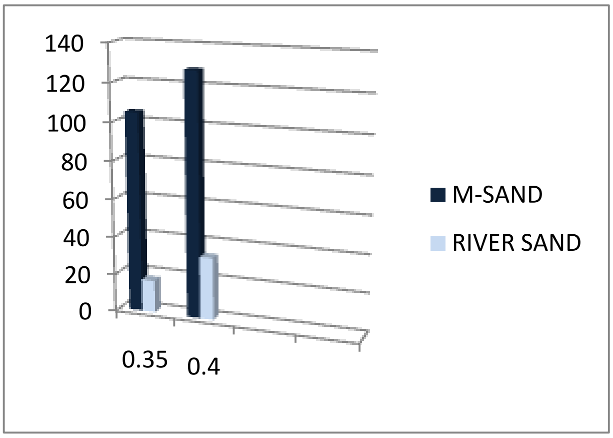
Sl. No	*Water Cement ratio*	*Weight of cement in gm*	*Volume of water added in ml*	*Slump value in mm*	*Degree of Workability*
1	0.35	2550	1020	17	True
2	0.40	2550	1147.5	33	True
3	0.45	2550	1275	58	True
4	0.50	2550	1402.5	84	Shear
5	0.55	2550	1530	111	Collapse

* Slump value of concrete for river sand concrete with out Super plasticizer

TABLE 6

*For M sand

Sl. No	*Water Cement ratio*	*Weight of cement in gm*	*Volume of water added in ml*	*Slump value in mm*	*Remarks*
1	0.20	2550	510	28	True
2	0.25	2550	625	57	True
3	0.30	2550	765	86	Shear
4	0.35	2550	892.5	105	Collapse
5	0.40	2550	1020	128	Collapse



2.2 PROFILED STEEL DECKING PROPERTIES

Thin-walled cold-formed profiled steel decks used to build the slab specimens are made of structural quality steel sheets conforming to IS 1079 (1994). A galvanized surface coating with an average thickness of 0.0254 mm is finished on each face of the steel deck. The total specimens are carried out with 0.8-mm thickness (20 gauge) which have a cross sectional area (Ap) of 839 mm2, a yield strength (fyp) of 250 N/mm^2, and second moment of inertia (Ip) of 0.364 ×106 mm^4.

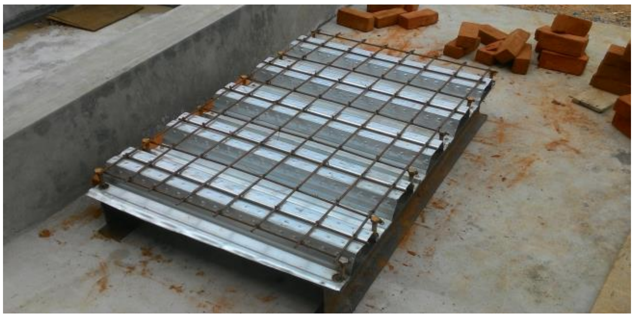


Fig 5.

2.3CONCRETE PROPERTIES

Concrete used for the specimen is of normal weight, Designed for compressive strength 25.984 N/mm^2. Concrete compressive strength is determined from concrete cubes 150 mm × 150 mm × 150-mm size according to IS 456 (2000) procedures. Three cubes are tested on the same day as the slab test to determine the concrete compressive strength. Course aggregate size used in the concrete is 20-mm down. Concrete proportion used in the mixture is 1:1.42:3.09 (cement/ fine aggregate/course aggregate).

Mix proportioning: The determination of relative quantity of materials like cement, fine aggregate, coarse aggregate and water is called the mix design of concrete M 20. For more structural work the concrete is designed to give compressive strength of 20 Mpa. Design adopted in this investigation as per Indian standard specifications is **1:1.5:3**(M 20).M-20 grade concrete has been designed according to IS 456-2000 and the mix proportion is shown in Table 1 & 2,

Table 2.2.3.1- Mix proportion for river sand

Description	*Cement (kg/m^3)*	*Fine Aggregate (kg/m^3)*	*Coarse Aggregate (kg/m^3)*	*Water (kg/m^3)*	*W/C*
RS CS }	325	2336	1162	186	0.45

Table 2.2.3.2- Mix proportion for m-sand

Description	*Cement (kg/m^3)*	*Fine Aggregate (kg/m^3)*	*Coarse Aggregate (kg/m^3)*	*Water (kg/m^3)*	*Super Plastizer (kg/m^3)*	*W/C ratio*
RS CS }	320	2291	1216	960	1.6	0.3

Fig 6.

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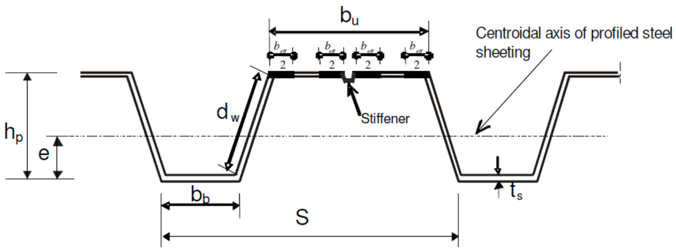
2.4 *PROPERTIES OF SLAB SPECIMAN*

Composite slab specimens are constructed with 150-mm nominal depth 930-mm width (b) and 1500-mm span the thickness of the concrete above the flange is 50 mm while depth of the profiled steel deck is 0.098 mm. All composite slab specimens are cast with full support on the plain surface concrete flooring in the Composite Testing Laboratory. Steel-decking surface is well cleaned before casting of the concrete. All slabs are constructed utilizing M20 grade of concrete obtained from a hand mixing method. Concrete test cylinders and concrete cubes are made at intervals while concrete is being placed according to IS 456 (2000) and cured in the same manner as the slab specimens.

3 DETERMINATION OF THEORETICAL LOAD CARRYING CAPACITY

RCC Slab



Ultimate Moment of resistance = 0.138 fck bd2
= 0.138 x 20 x 1500 x 51^2
= 7.178 kNm/m

For slab of span L and four point loading of W/4 with simply supported end condition, the Maximum B.M is = 3WL/20

Equating the Ultimate moment of resistance and the maximum BM and multiplying with the factor of safety, we get the theoretical ultimate load as 31.90 kN.

3.1 STEEL AND CONCRETE COMPOSITE SLAB ULTIMATE MOMENT OF RESISTANCE

The theory behind the calculation of ultimate moment of resistance is.

N.A within sheeting,

N_{cf} = bhc x 0.36 x fck

= 73x300x0.36x20 = 157.680kN

M_{pRd} = N_{cf} (dp – 0.42hc)

= 157.680x (0.098-(0.42x0.073))

= 107.12 kNm/m

Equating this with the maximum BM as explained for RCC the theoretical ultimate load obtained is

107.121 = (3wl)/20

W = (107.121x20)/3x1500

W = 1.5x47.186 = 70.78kN

3.2 SERVICEABILITY LIMIT STATES

- For simply supported composite beams the most critical serviceability Limit State is usually deflection.
- The effect of vibration, cracking of concrete, etc. should also be checked under serviceability criteria.
- In exposed condition, it is preferred to design to obtain full slab in compression to avoid cracking in the shear connector region.

3.3 STRESS AND DEFLECTION SERVICE

- Elastic analysis is employed to check the serviceability performance of composite beam.
- Concrete area is converted into equivalent steel area by applying modular ratio $m = (E_s/E_c)$.
- Analysis is done in terms of equivalent steel section.
- It is assumed that full interaction exists between steel beam and concrete slab.
- Effect of reinforcement in compression, the concrete in tension and the concrete between ribs of profiled sheeting are ignored.

3.4 *ADVANTAGES*

- Effective utilisation of steel and concrete.
- More economical steel section (in terms of depth and weight) is adequate in composite construction when compared with conventional non-composite construction.
- Enhanced headroom due to reduction in construction depth
- Less deflection than steel beams.
- Efficient arrangement to cover large column free space.
- Amenable to *"fast-track"* construction.
- Encased steel beam sections have improved fire resistance and corrosion.

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4 CONCLUSION

An experimental investigation carried out on reinforced concrete with & without profile sheets and shear connectors has been studied in this project work.

Based on the results of study, the following conclusions are drawn

TABLE 7

Slab Mark	**Load carrying capacity (kN)**	
	Theoretical	*Experimental*
RS	31.90	35.5

* For conventional concrete slab

TABLE 8

Slab Mark	**Load carrying capacity (kN)**	
	Theoretical	*Experimental*
CS	70.78	160

* For composite concrete slab

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