COMPARATIVE EXPERIMENTAL STUDY ON FLEXURAL BEHAVIOUR OF COMPOSITE SLAB AND RCC SLAB

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Abstract

This paper is elaborating the comparative study between simply supported RCC slab and profiled steel concrete slab for their suitability at small scale applications like mezzanine flooring. Experimental study has been conducted on the design of composite concrete slabs and RCC slab. In this study full size simply supported slabs has been designed and tested for flexural to study the bending capacity and vertical shear strength of composite slab and the same is compared with bending capacity of RCC slab. 'm-k' method is used for the design of composite slab and experimental test setup has been done by following guidelines given by Eurocode 4 – Part 1.1 and IS 456-2000 is used for design of RCC slab. Six composite slabs are split into two groups of three slabs and tested under static and cyclic loading to get 'm-k' values and RCC slab is tested under static loading for flexural. As a result composite slab proved to be more efficient than R.C.C. slab for small scale use.

KeyWords: *Composite Slab, Flexural Behaviour, m-k Method, Mezzanine Flooring*

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1. INTRODUCTION

Building construction in our country shows variety of construction material in every region; according to type of building, location of building, function of building different materials has been observed. Reinforced Cement Concrete (R.C.C.) is the most widely used construction material for buildings and steel structures also available in large numbers for industrial buildings. Composite steel-concrete buildings have been observed in industrial areas due to its beneficial properties for optimal design and ease in construction activities for large span constructions. Composite material favorably used for industrial structures/buildings.

Composite construction method provides most advantageous construction technique than R.C.C. and steel structures for high rise structures. In Composite construction both materials are fully efficient together which results in the best economic design and in speedy construction. Complex behaviour in composite action of steel and concrete can be overcome if design parameters are properly configured, and thus structure can be highly durable with superior seismic performance characteristics (Panchal and Marathe 2011). Comparative study between R.C.C. framed, steel and composite high rise for their structural performance proved that composite structures provide great economic and efficient design.

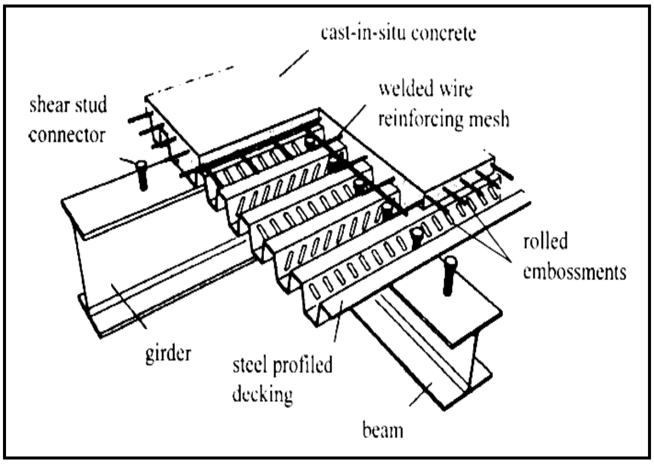

Fig – 1: Details of Composite Slab

For the commercial shops mezzanine floor at proper working level provides additional working space to the user. Generally R.C.C. slab panel is provided for the same in new construction or for the extension for mezzanine floor; but in the construction of mezzanine floor over existing structure will raise the problem to provide proper development length of reinforcing steel.

Under the proposed work the design and construction of composite slab is compared with the R.C.C. slab so as to provide the efficient and economical option for mezzanine flooring for small scale use in commercial shops. Already composite structures proved their ability for being safe, serviceable and economical for high rise constructions compared to steel and R.C.C. structures with great ease of construction. This study may provide the guidelines for use of composite slab construction for small scale application.

2. EXPERIMENTAL PROGRAM

Total seven slab specimens are designed and cast, which are experimentally tested. Six slab specimens out of seven are designed as simply supported composite slabs as per recommendations of EN 1994-1-1 2004. One slab specimen has been designed as simply supported R.C.C. slab. All seven slab specimens are tested under two point line loads with simply supported condition under reaction frame using single hydraulic jack. Under proposed work *m-k* method has been used for designing composite slab specimen. Experimental program for composite slabs consists of static and cyclic loading. This is needed for getting regression curves for determining '*m'* and '*k'* values as stated in EC-4. Thus six composite slabs bifurcated to two groups of three specimens for calculating their strength for regression curve. RCC slab is been tested for static load only.

3. MATERIAL PROPERTIES

3.1 Concrete

In the casting of test specimen of both composite slabs and RCC slab self-compacting concrete has been developed to get the characteristic compressive strength of M-25 grade concrete. For developing self-compacting concrete Pozzolona Portland Cement (PPC) is used and natural river sand used as a fine aggregates and 10 mm down sized crushed stone is used as a coarse aggregate. For getting desired workability 0.80 % super plasticizer (SP) is used and required flow of concrete is achieved by using 0.20 % viscosity modifying agent (VMA). These percentages are taken by considering weight of cement. Concrete mix proportion is 1:3.13:2.12 (cement : fine aggregates : coarse aggregates)

3.2 Profiled Steel Deck

Steel profile is manufactured from hot dipped zinc coated high strength with minimum 245 MPa, yield strength and coating mass of Z120 (min. 120 gm/m^2 total of zinc coating on both sides). The adopted thickness of steel deck is 0.80 mm. The steel conforms to AS1397 and BS EN 10147:2000. Its cross sectional area (*Ap*) is 1114.98 mm^2, yield strength of 245 MPa, moment of inertia is 593945.88 mm^4.

4. CONSTRUCTION AND TEST DETAILS

4.1 Specimen Design

RCC slab specimen is designed by limit state method as per IS 456-2000. RCC slab specimen is designed as simply supported one-way slab. Self-compacted concrete of M-25 grade and Fe-415 grade steel materials are used. Overall slab thickness (D_{prod}) of slab is 100 mm, # 8 @ 200 mm c/c reinforcement is provided as main steel and # 6 @ 230 mm c/c is provided as distribution steel.

A total of six full-size composite slab specimens are prepared of 100 mm nominal depth (ht), it has width of 965 mm (b) and specimen having total length of 2000 mm including bearing width. The thickness of concrete toping (hc) is 45 mm over the 55 mm depth of the profiled steel deck (hp). RCC slab specimen is cast of same dimension as that of composite slab.

4.2 Test Set-up

All seven specimens are tested with simply supported condition under two point symmetrically located line loads as per the specifications of EN 1994-1-1 2004. Span of test specimen has taken as 1800 mm with 100 mm support width on both sides. Loading will be applied by a single hydraulic jack system, which will apply the load on spreader beam section ISMB 150, below which 2 ISMB 100 are provided to transfer the jack load on specimen, and proving ring will be used for measuring load values.

Dial gauge will be used to determine vertical deflection at mid-span. Relative slip between concrete and steel deck will be measured by placing dial gauges on each side of specimens. Failure load of each specimen will be considered by adding self-weight of slab and weight of spreader beam and loading beam in the test values of static and cyclic loading.

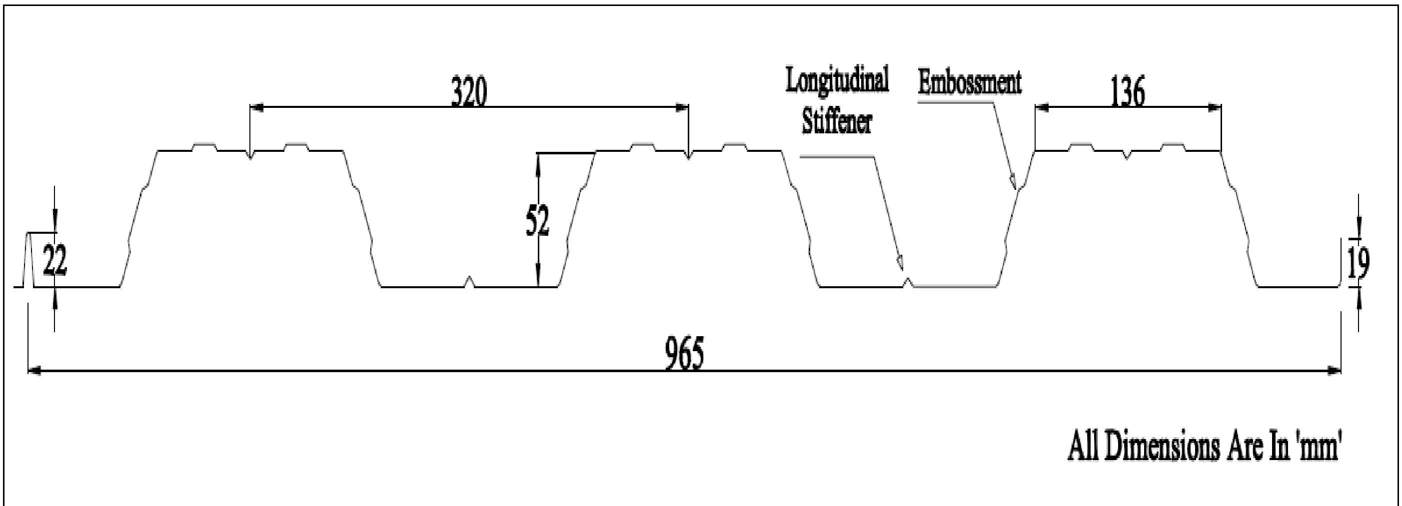

Fig – 2: Geometrical properties of profiled steel deck

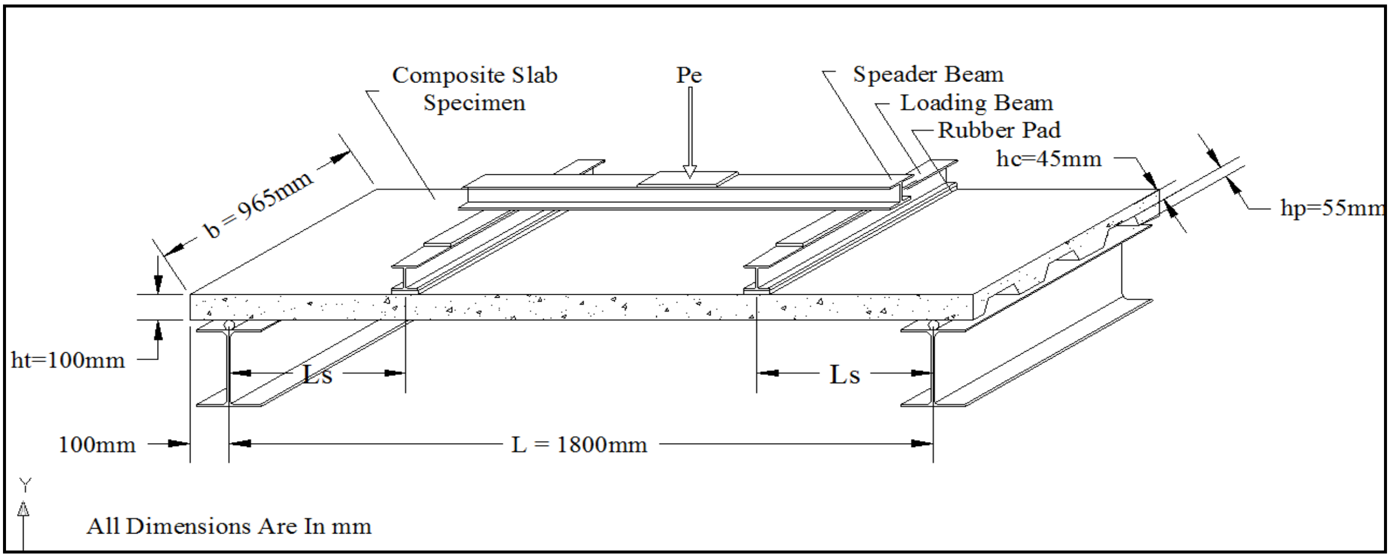

Fig – 3: Test set-up for composite slab specimen and R.C.C. slab specimen

5. RESULTS AND DISCUSSION

Fig – 4: Side-Slip of Slab CL300-B2

Fig – 5: Testing of ST-300-B1

5.1 Load Deflection Behaviour

Application of load on 'Region A' specimen for static loading failure initiated in the form of cracks observed at mid-span at bottom fiber of specimen. Progressive increase in application of static load results in widening of cracks towards top fiber and deflection rate goes on increasing. Cyclic loading applied on 'Region A' specimen only shown deflection same as that of static loading up to first cycle; as and when further loading cycles applied some more deflection shown for same loading which was given during earlier cycles. This behaviour is representing the removal of chemical bond between concrete and deck sheet.

When load is applied to 'Region B' specimen for static loading load-deflection behaviour has shown lesser deflection against initially applied load as compared to 'Region A' specimen behaviour. For statically applied load by loading beam was not have proper contact with specimen and shown surface crack along unsupported span, after filling the gap between loading beam and specimen, further deflection recorded. Under cyclic loading removal of bonding between concrete and deck sheet shown larger deflections compare to statically applied load.

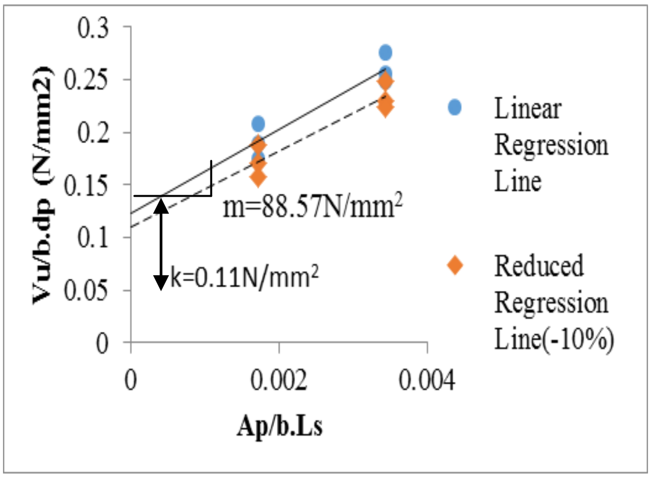

Chart – 1: Regression Curves for m-k Values

Total six composite slab specimens are tested and results are recorded in the table above. From obtained results regression curves are plotted as per BS EN 1994-1-1:2004. Mechanical bond strength parameter *m* is the slope of regression line with reduced values by 10% and from the same frictional bond strength parameter *k* is obtained.

Table – 1: Observation Table

Designation	Load at failure (kN)	Observations		
		Side Slip (mm)	Vertical Deflection (mm)	Remark
ST-600-A1	36.50	2.25	24.8	Composite slab under static loading started forming flexural cracks at mid-span; but ultimate failure occurred under one of the loading beam in shear.
CL-600-A2	33.20	3.15	24.9	With provided shear span of 'Region A', flexure cracks observed with progressive side slip and ultimate failure at loading point.
CL-600-A3	30.70	2.70	23.4	Cyclic loading removed the chemical bond between concrete and deck sheet and early failure observed in shear below loading points.
ST-300-B1	38.20	2.90	19.1	Crack along the unsupported span is observed due to improper contact of loading beam with specimen along throughout width of member. After providing filler material, ultimate failure occurred with shear cracks.
CL-300-B2	44.60	3.20	30.4	Shear cracks are formed below loading point with extended crack under ultimate load.
CL-300-B3	43.50	3.50	34.1	Shear cracks initiated with cyclic loading and flexural cracks observed after ultimate failure under progressive static loading after completion of cycles.
RCC-01 (L/4)	62	NA	42.1	Typical flexural failure occurred with yield line at mid-span for simply-supported one-way slab.

For the design of slab specimen as a mezzanine floor maximum shear force and maximum moment due to imposed live load and dead load determined are 11.60 kN and 3.915 kN.m respectively. Experimental tests provided ultimate load carrying capacity of the test specimens. These test results are used to calculate the shear carrying capacity and moment carrying capacity of the R.C.C. and composite slab From the desired strength requirement and experimental load carrying capacity of composite and R.C.C. specimen 'Over-Strength Factor' and 'Capacity Factor' has been determined.

Table – 2: 'Over-Strength Factor' and 'Capacity Factor' for Shear and Flexure

Designation	Design Shear Capacity (kN)	Design Moment Capacity (kN.m)	Experi-mental Average Vertical Shear Strength	Experi-mental Average Moment Capacity Mu_{act} (kN.m)	Shear Over-Strength Factor (Experi-mental/ Design)	Flexure Over-Strength Factor (Experi-mental/ Design)	Shear Capacity Factor	Flexure Capacity Factor
1	2	3	4	6	8	10	11	12
Composite Slab	11.60	3.915	15.77	4.80	1.36	1.23	1.97	2.18
R.C.C. Slab			31.00	10.46	2.67	2.67		

6. CONCLUSIONS

Following conclusions are drawn from obtained results after comparative experimental studies:

[1]. In experimental tests 'Region A' specimen with longest shear span has shown failure mode in flexure and 'Region B' specimen has shown failure with cracks under loading points in shear.

[2]. For 'Region A' specimens effect of cyclic loading has shown 12.88% lesser strength compared to static loading and For 'Region B' specimens cyclic loading shown 8.61% lesser strength compared to static loading.

[3]. According to conducted experimental tests *m* and *k* values are 88.57 N/mm^2 and 0.11 N/mm^2 respectively and these values used for determination of longitudinal shear strength as 0.337N/mm^2.

[4]. In the case of composite slab 'Over-Strength Factor' for shear and flexure results as 1.36 and 1.23 respectively for experimental results. These values show that, composite slab construction gives more

efficient strength which is near to the desired strength with suitable margin.

[5]. For R.C.C. slab 'Over-Strength Factor' are 2.67 and 2.67 for shear and flexure respectively for experimental results. These values are showing large margin between desired capacity and obtained capacity after experimental tests.

[6]. Design and comparative experimental study on R.C.C. and composite slab has shown that, shear capacity and flexural capacity of R.C.C. slab is 1.97 and 2.18 times greater than composite slab.

[7]. Construction of composite slab proved that there is saving in material i.e. volume of concrete reduced up to 27% in composite slab compared to RCC slab specimen.

[8]. Efficient design can be achieved by the construction of composite slab over R.C.C. slab at small scale applications.

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