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ANALYTICAL STUDIES ON BI- STEEL LIGHT WEIGHT CONCRETE SANDWICH BEAM

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ABSTRACT

This paper deals with study of static behavior of Bi-steel lightweight concrete beam (SLCS) which was simulated using a finite element model in Abaqus v6.1. During the course of analysis the lightweight concrete beam and SLCS beam, deflection and tension plate slip was observed. Due to the ductile nature and enhanced stiffness of the SLCS beam, the deflection of SLCS beam reduced by 43% from control beam. The slip of the SLCS beam was evaluated from the Contact open (C-Open) analysis. The variation between the load and C-Open was linear with negligible slip. Also very less Von Misses stresses was seen in the compression zone of the beam which gave good bonding of the shear connectors in the tension zone resulting in resistance to C-Open.

Key words: Bi-steel beam, Steel-lightweightconcrete-steel sandwich, Shear connector, C-Open, Shear span.

INTRODUCTION

Steel-concrete-steel (SCS) sandwich structures consist of a concrete core sandwiched between two steel skins. The composite structure combines the advantages of reinforced concrete (RC) and steel structure, with improved features in bearing capacity, ductility and integrity. It has also shown excellent performance in crack control, impact resistance and leakage prevention[1]. Transfer of forces between steel and concrete takes place through mechanical means called shear connectors[2]. Bi-Steel sandwich construction (Bi-Steel), and alternative SCS sandwich construction. They are different only due to the pattern of their shear connectors. The Bi-Steel form overcame some of the existing on site construction problems. Having the innovative prefabrication technique developed by British Steel, both ends of shear connector can be simultaneously fixed to steel face plates. As a result, it can minimize some construction problems on site[3]. The advantages of the system are that the external steel plates act as both primary reinforcement and permanent formwork,

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and also as impermeable, impact and blast resistant membranes therefore used in the offshore and onshore applications[4].

Initially, precast concrete sandwich panels became widely used as an appropriate system to construct structural shell applications for all building types. This prototype of composite sandwich panel applications was later developed and manufactured[5]. At the same time application of lightweight concrete significantly reduced the dead load of structures and relevantly reduced the cross-section of structural elements (i.e. columns, beam, braces and plate) and foundation size. Moreover, longer spans, thinner sections and better cycling load response can be obtained by using lightweight concrete[6]. Hence incorporating lightweight concrete in Bi- steel beam termed as Steel – Lightweight Concrete – Steel (SLCS) Sandwich beam can be found significant and its effectiveness can be analytically evaluated.

Finite element modelling

EXPERIMENTAL

The software used for the finite element analysis of SLCS beam was ABAQUS V6.1 and it was found in 1978. It is used for both modeling and analysis of mechanical components and assemblies and visualizing the finite element (FE) analysis result. The key features of the software are to find deflection, stresses, slip, contact, co-simulation and material library. The advantages of using this software is its efficiency in model generation, correlation between test and analysis result by simulating it to flexural loading and thermo-mechanical resistance with different end conditions.

Past research

N. Foundoukos et al.[7] performed static behavior of Bi-steel beams which was simulated using a finite element model. The authors have reported that the analytical results obtained from the FE model beams were in good agreement with the experimental results. T. M. Roberts et al.[8] investigated the behavior of Steel Concrete Steel Sandwich beam by subjecting them to different types of static loading with low span to depth ratios inducing high shear to bending ratios near supports and high span to depth ratios which induced low shear to bending ratios. The primary mode of failure of SCSS beam is tension plate yield and slips and also found out that stud connectors provided adequate transverse shear reinforcement Also the authors suggest a limiting longitudinal spacing of compression plate studs as 40 times the plate thickness. M. Xie et al.[9] experimented the static analysis of bi steel concrete beams and found out the tension plate yield and slip reporting the same behavior and mode of failure in the experimental and analytical study. Md Azreen Othuman Mydin et al.[10] has studied the experimental and analytical behavior of steel-foamed concrete-steel sandwich panels and derived the various parameters for foamed concrete.

In the past research only conventional concrete was used as core in Bi steel concrete beams while the present paper covers the use of Lightweight concrete as a core in Bi steel beams by reducing the dead weight of the concrete. The compression plate slip has not yet been studied.

Analytical investigations

Details of test specimen

The total length (l) of the SLCS beam is 2000 mm, wide (b) is 300 mm and depth (h) is 300 mm in size with lightweight concrete core (h_c) is 284 mm comprising of stud connectors connected both to tension and compression plate both longitudinally and transverse direction. Both the plates are 8 mm and longitudinal spacing of stud connectors is kept constant throughout beam with spacing (s_c) is 200 mm and transverse spacing of the stud connectors (s_t) is 100 mm with 16 mm dia rods of length 284 mm.

Material properties

The grade of steel used in the steel plates and stud connectors is Fe-415 with modulus of elasticity of (Es) 2.1 x 10^5N/mm^2 and Poisson's ratio of 0.5 and the grade of lightweight concrete is M30 with modulus of elasticity of (Ec) 17 kN/mm^2 and Poisson's ratio of 0.15.The coefficient of friction assumed between steel and lightweight concrete is 0.45.

Modelling

The FE model of SLCS beam is modeled as 3-D model with 50 mm size mesh for less computational time. In the unloaded configuration, the rod and steel plate nodes coincide. The lightweight concrete nodes are free to separate from the steel rods. Contact interaction is defined between the steel rods and the lightweight concrete core, lightweight concrete core and both steel plates as tie adjusted. The steel rod surface is restrained not to penetrate these surfaces. The friction coefficient μ = 0.45 was assumed between the steel and concrete contact surfaces. The models are developed with boundary condition as simply supported with symmetry at midspan. Continuum, three-dimensional, 8 and 10 noded, reduced integration (C3D8R and C3D10R). The meshing element for steel and plates are tetrahedron, hexahedron for concrete. Finally the FE modeled was analyzed and visualized.

Shear connectors

The shear connectors provided were of same steel grade providing more resistance to shear by holding the compression and tension plate firmly thereby reducing the slip to ensure adequate anchorage of steel plates at simply supported ends, it was taken care that at least 20% of shear connectors are located beyond the centre line of support.

Static load analysis

The static load analysis for SLCS is done by subjecting it to one point loading at mid span of the beam with simply support conditions, the load is applied on the nodes at mid span of the beam and analyzed to find the deflection, critical load and C-Open (slip).The deflection limit for static analysis of SLCS is assumed to be 0.3 mm, hence the load corresponding to it becomes the critical load. The SLCS is subjected to loading with an increment of 100 kN starting from 0kN to 1000 kN. Fig. 1 shows the sketch of analytical set up.

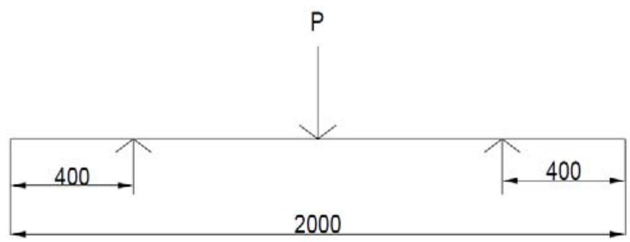

Fig. 1: Static load setup of SLCS beam

RESULTS AND DISCUSSION

Discussion of the analytical results

The results of the SLCS beam presented herein are compared with control beam and validated to find importance of adding steel plates to increase stiffness. The SLCS beam is analyzed with simply supported condition to find out the load v/s deflection graph which is quiet non-linear which is taken at the mid span of the beam. During the course of analysis the lightweight concrete beam and SLCS beam, deflection and tension plate slip was observed. From Table 1 and Fig. 2, it is observed that the deflection of control beam is around 43% more than the SLCS beam. This is due to the ductile nature and enhanced stiffness of the SLCS beam. From Figure it is seen that the critical load increases from 270 kN to 458 kN for the assumed critical deflection from conventional to SLCS beam. Fig. 3 and Fig. 4 shows the FE model of the deflected control Lightweight beam and SLCS beam.

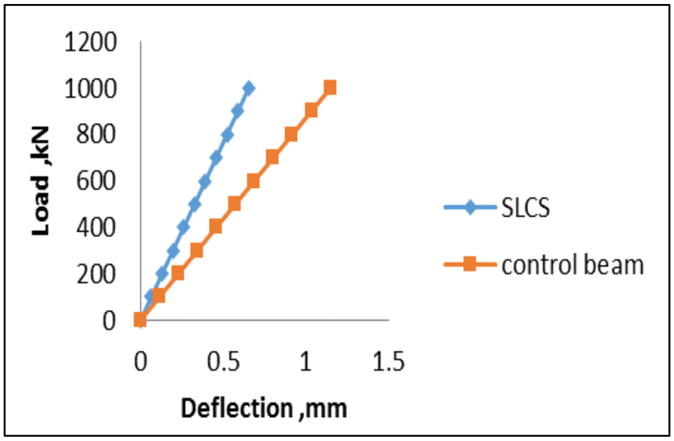

Fig. 2: Load-deflection graph between SLCS and control beam

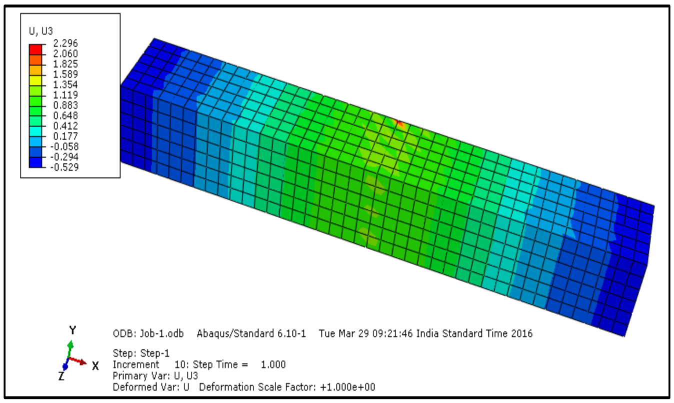

Fig. 3: Deflection contours of lightweight control beam

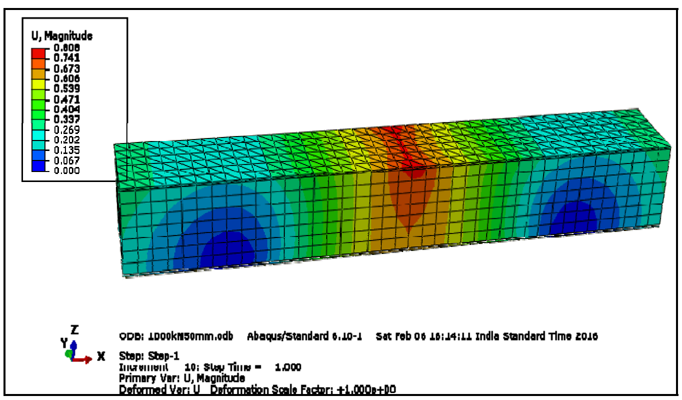

Fig. 4: Deflection contours of SLCS beam

Table 1: Comparison of deflection between control beam and SLCS

Load kN	Control beam deflection (mm)	SLCS Beam deflection (mm)
0	0	0
100	0.1146	0.0654
200	0.2293	0.1308
300	0.3441	0.1963
400	0.4589	0.2618
500	0.5738	0.3273
600	0.6888	0.3928
700	0.8039	0.4584
800	0.9191	0.5240
900	1.0343	0.5896
1000	1.1496	0.6553

In abaqus the slip of the SLCS beam were evaluated from the Contact open (C-Open) analysis. From Table 2 and Fig. 5, it is clearly evident that there was linear variation between the load and C-Open, but there was only negligible slip. The model generated for C-Open is shown in Fig. 6. This is because of the good bonding provided by the shear connectors. From Fig. 7, it is seen that very less Von Misses stresses were more on the compression zone of the shear connectors which is in the range of 66 N/mm^2. Also it was revealed that only eight number of shear connectors out of twenty were found to undergo this stress only in the shear span of the beam. This is the reason for resistance to contact open (C-open)

Table 2: Result of load v/s C-open of SLCS beam with simply supported conditions

LOAD kN	C-Open mm
0	0
100	0.000206
200	0.000413
300	0.000620

Cont…

LOAD kN	C-Open mm
400	0.000830
500	0.001042
600	0.001257
700	0.001476
800	0.001699
900	0.001925
1000	0.002155

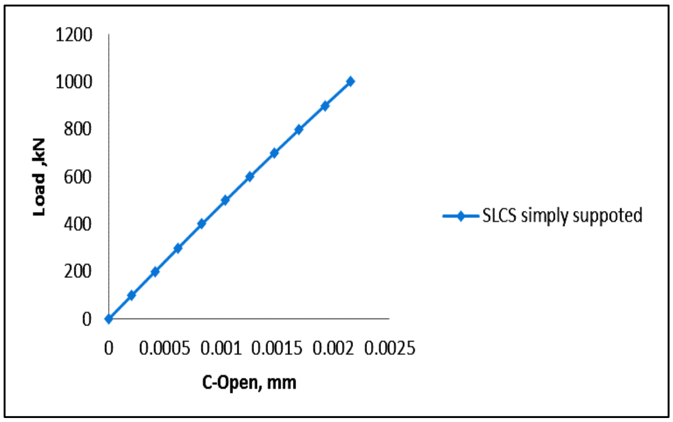

Fig. 5: Load from C-Open analysis graph

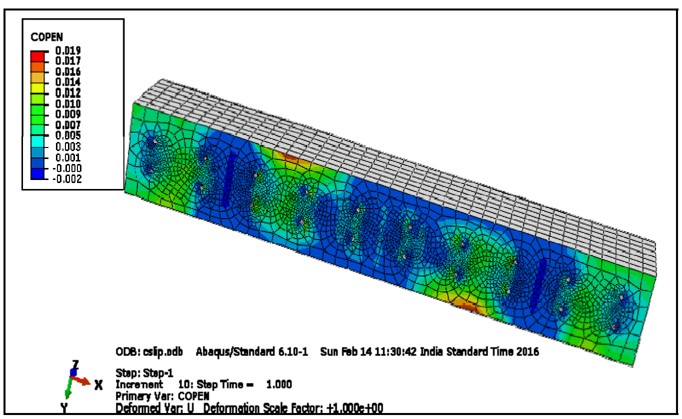

Fig. 6: C-Open contours seen by removing tensile steel plate

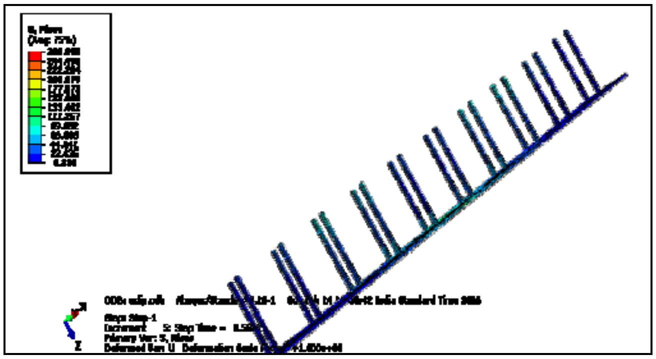

Fig. 7: Von Misses stress contours on shear connectors

CONCLUSION

(i) The analysis for deflection and C-Open of the Lightweight concrete beam and SLCS were carried out using the FE modeling in ABAQUS V6.1.

(ii) The flexural stiffness of the SLCS beam was found to be more than the control lightweight concrete beam having 43% more deflection than the SLCS beam.

(iii) Due to the enhanced bonding provided by the shear connectors the slip was almost negligible.

(iv) The resistance to C-Open was provided as the Von Misses stresses in the shear connectors were found to be very less and observed in the compression zone around $66N/mm^2$.

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