EXPERIMENTAL STUDY ON THE BEHAVIOUR OF SANDWICH BEAMS USING STEEL AND CONCRETE

Thangasuriya.S[1], Ganga Lakshmi.C.J.[2]
[1]PG Student, [2]Assistant Professor, ME Structural Engineering,
Department of Civil Engineering,
Dr. Sivanthi Aditanar College of Engineering, Tiruchendur.

Abstract

A steel-concrete-steel (SCS) sandwich beam represents a special form of sandwich structure. It consists of steel face plates and concrete core which are connected together by means of a series of shear connectors. Sandwich comprises a central concrete core which is sandwiched between two steel skins to form a composite unit whose behavior is greatly influenced by the interfacial bond between the two materials. Many types of connectors have been developed and used in the SCS sandwich composite structure. In the first phase, the preliminary investigations were done for normal weight concreting materials. From the test results, all the material properties were arrived. Also the preliminary investigations were done for normal weight concreting materials. From that results, the mix proportions for normal weight concrete of M_{30} has been achieved. By using the mix ratio concrete cubes, cylinders and prisms were casted for attaining the desired strength parameters. All the tests were conducted for the hardened concrete, from that the results were obtained for compressive strength, split tensile strength and flexural strength of concrete. The cubes, cylinders, and prisms were cast. The compressive strength, split-tensile strength and flexural strength were found out respectively from the hardened concrete specimen. Then SCS Sandwich Beams of varying plate thickness of 3mm, 5mm were cast and made to pure bending test. The load deflection curve had been obtained to predict results.

Keywords: Sandwich Beams, SCS, Steel Concrete Steel, Flexure, Ultimate Load.

I. INTRODUCTION

The need for large structures with higher specific strength and stiffness is increasing. This is especially true of recent engineering structures where there is an interest in increasing payload to structure weight ratios. To deliver such structures, engineers can either find a new structural material or produce a new structural topology. Steel-Concrete-Steel (SCS) sandwich comprises a central concrete core which is sandwiched between two steel skins to form a composite unit whose behavior is greatly influenced by the interfacial bond between the two materials. During the past 30 years there have been many research and development in SCS sandwich construction. Due to its excellent cost-strength performances, it exhibits versatile potential applications in the building and offshore structures as building core, floors, submerged tunnels, offshore decks, ship hulls, and oil containment. Generally, cohesive material (e.g. epoxy) and mechanical shear connectors are the common measures to bond the steel and concrete. Compared with cohesive materials, the mechanical shear connectors exhibited advantages in providing transverse shear resistance to the structure. Many types of connectors have been developed and used in the SCS sandwich composite structure. SCS sandwich structure with overlapped headed shear studs was originally proposed for submerged tunnels. There are a number of types of shear connectors have being used in practice such as welded shear studs, friction-welded bar connectors. Welded studs terminate within

concrete and their prime functions are to resist longitudinal shear and plate / concrete separation.

II. EXPERIMENTAL PROGRAM

Experimental Investigations have been carried out on the specimens to ascertain the workability and strength related properties have been carried out to check the quality of concrete.

A. Materials Used

Cement is defined as the building material made by grinding calcined limestone and clay to a fine powder, which can be mixed with water and poured to set as a solid mass or used as an ingredient in making mortar or concrete. In this project, Ordinary Portland Cement (OPC) 53 grade was used.

The aggregate fraction from size 4.75 mm to 150 micron is termed as fine aggregate. The graded fine aggregate is represented by its zone. In this project, river sand belongs to zone – II conforming IS 383-1970 is used.

The aggregate fraction from size 80 mm to 4.75 mm is termed as coarse aggregate. In this project, crushed granular aggregate of 20 mm is used.

The steel plates are used as the top and bottom surface holding plates. The steel plates make desirable bond with the concrete core by the use of shear connectors. The tensile reinforcements are provided at both the ends of the SCS beams to prevent the separation of steel plates while casting.

B. Anti Corroding Coating

The corrosion of these steel plates is prevented by using any anti-corroding liquid or agent. In this project, the metal coating of PHENOLIC was used while the specimen immersed in water. The chemicals present in the agent resists the corrosion of steel plates.

III. MIX DESIGN

The concrete mix M30 is designed as per IS10262:1982, IS 456:2000 for the conventional concrete. Mix design are given below in table I.

TABLE I. MIX PROPORTIONS

Cement	Fine Aggregate	Coarse Aggregate	W/C
1	1.52	2.64	0.45

IV. SCS SANDWICH BEAMS

The design of SCS Sandwich Beam has been designed as normal RC Beam design without any reinforcement mesh. The SCS beam is sandwiched with M30 grade concrete between the top and bottom steel plates. The shear connectors were welded with the steel plates. The prime function of shear connectors is to prevent plate separation. The flexural test is carried out to study the flexural behavior of SCS Beams. The Steel-Concrete-Steel Sandwich Beams having the top and bottom steel plates of thickness 3 mm and 5 mm were cast and tested under two point loading. The headed stud shear connectors of 80 mm long were welded with the steel plates. The flexural test is carried out to study the flexural behavior of SCS Beams. The figure shows the beam detailing of SCS Beam.

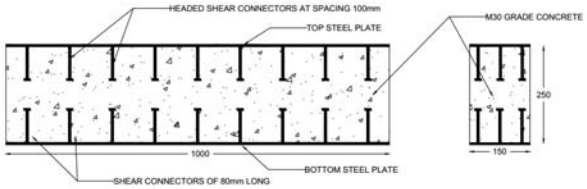

Figure 1. Detailing of SCS Beam

In order to investigate the effectiveness of proposed method for improving the ultimate strength, SCS sandwich beam members with different plate thickness of 3 mm and 5 mm plates with welded headed stud shear connectors were used.

V. METHOD OF EXPERIMENT

It is important that the constituent material of concrete remain uniformly distributed within the concrete mass during the various stages of handling and that full compaction is achieved and making sure that the characteristics of concrete with affect full compaction like consistency, mobility, compatibility are in conformity with relevant codes of practice. The tests were carried out in accordance with relevant IS standards. The fresh concrete was subjected to the slump test followed by casting of concrete in moulds for further investigations. All the mixes were prepared by mixing the concrete in laboratory mixer along with water.

VI. TESTS ON FRESH AND HARDENED CONCRETE

Workability tests such as slump test and compaction factor test were carried out for fresh concrete as per BIS specifications. The obtained slump value for controlled concrete was 100 mm. The obtained compacting factor value for controlled concrete was 0.8. The compressive strength tests were carried out on hardened concrete specimens of size 150 x 150 x 150 mm and split tensile strength tests were carried out on concrete specimens of size 150 mm diameter having 300 mm height also the Modulus of Rupture tests were carried out on concrete prisms of size 100 x 100 x 500 mm.

VII. RESULTS AND DISCUSSIONS

A. Tests on Fresh Concrete

The workability tests were carried out for concrete specimens. The slump test and compaction factor tests were carried out. The test results of workability are noted. The obtained slump value for controlled concrete was 100 mm. The obtained compacting factor value for controlled concrete was 0.8.

B. Tests on Hardened Concrete

The compressive strength tests were carried out on every concrete specimens of size 150 mm x 150 mm x 150 mm and the values were recorded for each control specimens and fiber introduced specimens. The average compressive strength values for each specimens are computed on the BIS standards after 7 and 28 days of curing. The average compressive strength values are given in table II.

C. Test Setup and Measuring

For pure bending test, two sandwich beams with a span of 1000 mm were taken. The experimental setup is shown in Figure 4. The position of the supports, dial gauge point were marked on the beams. The point load was applied on the beams for determining pure bending process. For the measurement of deflections, dial gauge was located at the mid-span of beams. The beams were tested at a rate of loading of 5kN/min. The test was carried out until the formation of cracks occurs due to buckling of sheets of the beams. The beams began to yield and the behavior of the beams was keenly observed from the beginning till the beam collapsed. A careful observation was made from the initial separation of sheet are propagations of cracks and failure of shear connecting the sheet and concrete. After that, the beams were tested for finding the ultimate load carrying capacity till failure of the beams. The specimen categorization and characteristics of SCS Beams were listed in table II, III.

TABLE II. SCS BEAM SPECIMEN CATEGORIZATION

Specimen	Beam Cross Section	Thickness of Steel Plate		Spacing of Shear connectors
		Top	Bottom	
BSC 1	150x250	3mm	3mm	100
BSC 2	150x250	5mm	5mm	100

TABLE III. CHARACTERISTICS OF SCS BEAMS

Description	Details
Length of the Beam	1000 mm
Cross section of Beam	150x250 mm
Tensile Reinforcement	6 nos per specimen
No. of Steel Plates Used	Top – 3mm, 5mm Bottom – 3mm, 5mm
Type of Connectors used	Headed Studs of 80mm long
Support Condition	Simply Supported
Type of Loading	Two Point Loading
Grade of Concrete	M30
Grade of Steel Plates	Fe415

The compressive strength, split tensile strength and Modulus of Rupture of Hardened Concrete Cubes, Cylinders, Prism were listed in table IV.

TABLE IV. STRENGTH VALUES FOR HARDENED CONCRETE

S.No.	Grade	Specimen Description	Average Strength
1.	M30	150 x 150 mm cubes @ 7 days of curing	19.62 MPa
2.		150 x 150 mm cubes @ 28 days of curing	32.39 MPa
3.		150 x 300 mm cylinders @ 28 days of curing	1.94 MPa
4.		100 x 100 x 500 mm prisms @ 28 days of curing	4.33 MPa

D. SCS Beam Testing Results

As the load was applied flexural cracks were initiated from the bottom of beam in the region of maximum moment. When the load beyond the yield strength of beam was applied, these cracks were widened and extended to the sides and new flexural cracks formed. As the applied load was further increased, cracks width increases and beam failed in flexure. The moment of resistance provided by the reinforcement was controlled by the anchorage (bond) of the bars and its magnitude was less than that provided by fully bonded reinforcement bars that yield at failure. The load carrying capacity of Beams were given in table V.

TABLE V. LOAD CARRYING CAPACITY VALUES OF BEAMS

Beam	Initial Crack Load	Ultimate Load
BSC 1	95 kN	145 kN
BSC 2	110 kN	155 kN

VIII. STATIC RESPONSE OF BEAMS

The static response of SCS beams of having steel plate thickness of 3mm, 5mm were exhibits more load carrying capacity when the load acting on the beams.

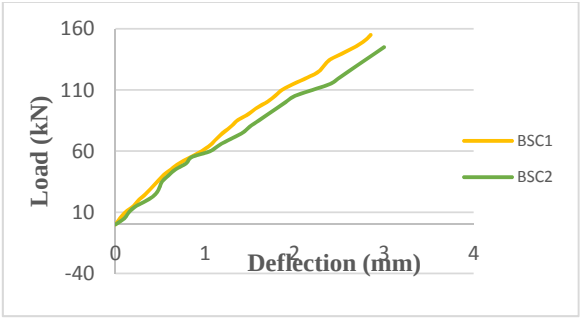

Figure 2. Load Vs Deflection Curve

IX. CONCLUSION

The innovative form of Steel-Concrete-Steel sandwich beams design, their mode of failures, their static responses had been thoroughly studied from the reputed journals for initiating this project. The preliminary investigations were done for normal weight concreting materials. From the preliminary test results, all the material properties were arrived. From that results, the mix proportions for normal weight concrete of M30 had been achieved. By using the mix ratio concrete cubes, cylinders and prisms were casted for attaining the desired strength parameters. All the tests were conducted for the hardened concrete. From that the results were obtained for compressive strength, split tensile strength and flexural strength of concrete. The average compressive strength of concrete cube is 32.29 N/mm^2 at 28 days of curing. The Modulus of Rupture of concrete prism is 4.33 N/mm^2. The Beam testing indicates the mode of failure of SCS Sandwich Beams with the load increasing manner. The initial crack load was found as 110kN for BSC2 is higher than the crack load of BSC1. Also the ultimate load carrying capacity was found as 155kN.

X. FUTURE SUGGESTIONS

Further expansion of this project work, regarding the strength parameters of SCS beams of varying spacing of shear connectors of desired beams can be cast and the mode of failure and their load deflection curve, moment curvature curve can be determined and also can investigate about the mode of failure in both steel plate, concrete core and shear connectors.

REFERENCES

1. Dr. Thaar Saud Salman, “Experimental Behaviour of Steel-Concrete-Steel Sandwich Beams with Truss Configuration of Shear Connectors”, Journal of Engineering, Vol.22, April 2016.
2. Foundoukos N., Xie. M., Chapman J.C., “Fatigue tests on steel-concrete-steel sandwich components and beams”, Journal of Constructional Steel Research, Vol. 63, pp.922-940, 2007.
3. IS 10262: 2009 “Indian Standard Code of Recommended Guidelines for Concrete Mix Design”, Bureau of Indian standards, New Delhi.
4. IS 456: 2000 “Indian Standard Code of Plain and Reinforced Concrete Code of Practice”, Bureau of Indian standards, New Delhi.
5. IS: 383-1970 “Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete”, Bureau of Indian Standards, New Delhi.
6. Jia-Bao Yan, J.Y.Richard Liew, Xudong Qian, Jun-Yan Wang, “Ultimate Strength behaviour of curved steel-concrete-steel sandwich composite beams”, Journal of

Constructional Steel Research, Vol.115, pp 316-328, 2015.
7. Jia-Bao Yan, Xue-Mei Liu, J.Y.Richard Liew, Xudong Qian, Min-Hong Zhang, "Steel-concrete-steel sandwich system in Arctic offshore structure: Materials, Experiments and Design", Journal of Constructional Steel Research Vol. 91, pp 111-121, 2016.
8. Jia-Bao Yan, Zhong-Xian Li, Jian Xie, "Numerical and Parametric Studies On Steel-Elastic Concrete Composite Structures" Journal of Constructional Steel Research Vol. 133, pp 84-96, 2017.
9. Richard Liew J.Y., Jia-Bao Yan, Zhen-Yu Huang, "Steel-Concrete-Steel Sandwich Composite Structures – Recent Innovations", Journal of Constructional Steel Research, Vol.130, pp 202-221, 2017.
10. Yu-Bing Leng, Xia-Bing Song, "Experimental Study on shear performance of steel-concrete-steel sandwich beams", Journal of Constructional Steel Research Vol. 120, pp 52-61, 2016.