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Experimental Investigation of Confined Steel Concrete Composite Beam under Bending

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ABSTRACT
A comparison study of a new type of composite beam known as Confined Steel Concrete Composite Beam (CSCC beam) is governed by welded stud T shaped shear connectors with different spacings such as 75mm, 100mm, 125mm, and 150mm. For this study, four CSCC beams were tested, and two point loading was used. The experimental and Finite Element Analysis (FEA) parameters of deflection and moment are compared using the ABAQUS software. All analysis values show that the composite beam with 75 mm spaced shear connectors has a high ultimate moment carrying capacity.

KEY WORDS: Composite beam, Cold formed steel sheet, Shear connector, ABAQUS.

I. INTRODUCTION

The current demand is for a cost-effective structure with high strength, dependability, and performance. This has resulted in the development of a new type of composite beam known as confined steel concrete composite. Shear connectors are used to limit longitudinal slipping and uplift at the element interface. The effects of bending of steel concrete composite beams have yet to be addressed in international composite steel-concrete construction standards such as Euro code 4 [1], the American Institute of Steel Construction, or Australian Standards AS 2327 [2]. The predictor corrector method was used to investigate and analyse the inelastic behaviour of steel concrete composite beams [3]. However, several assumptions were made, including a linear stress strain curve of steel in both the compression and tension regions, as well as a perfect bond between steel and concrete with no separation. In ABAQUS, a steel concrete composite beam was modelled [4] using a 2D truss element for the shear connector and shell elements for the concrete slab and steel. The behaviour of curved in plan structural steel-concrete composite beams was investigated. ABAQUS, a finite element package, was used. The proposed finite element model was validated by comparing computed values to experimental results. For beams of realistic proportion, an acceptable correlation has been observed between computed and experimental results [5]. The purpose of this paper is to discuss finite element modelling of the ultimate load behaviour of double skin composite (DSC) slabs. 12 simply supported DSC slabs were tested to failure in the experimental programme under a concentrated load applied at the centre. The finite element method was used to analyse these test specimens, and the results showed that these slabs had a high degree of flexural characteristics, ultimate strength, and ductility [6] [7]. Composite beams subjected to combined flexure and Torsion nonlinear analysis According to the findings of the analytical study, torsion-induced vertical slip is a significant issue, rendering the assumption that plane sections remain plane invalid. In addition, difference in span length greatly affected the flexure–torsion interaction relationship of the composite steel–concrete beams, whilst the partial shear connection did not affect the relationship [8]. The behavior of confined steel concrete composite beam subjected to combined bending and torsion and using a pair of 16 beams shuttered with the 1.2 mm and 1.5 mm thickness cold formed steel sheet and with the variation in the spacing of the bracings provided at the top of the beam [12]. This paper presents a study on flexural behavior of concrete filled steel tube. Numerical analysis has shown that for rectangular CFT's a good confining effect can be provided. Moment capacity results obtained from the ANSYS model are compared with the values predicted by Lin Han (2004) and different codes such as AISC-LRFD (1999) and EC4 (1994) [13]. The investigation on shear strength of stud shear connectors are influenced by the shank diameter of stud shear connector, compressive strength of concrete, and the slip on the interface of the steel beam was used shear connectors for composite steel beam. It is noted in results that shear connectors were responsible for a considerable increase in the load-bearing capacity and stiffness of the steel beams [14, 15]. The impact behaviour of non-reinforced concrete beams is investigated in this study both experimentally and using the finite element analysis. Members are tested in laboratory, and the ABAQUS software is used in the analysis. Accelerations, velocities, displacements, impact forces, and energy absorption capacities, have been obtained in the scope of these analyses [16].Impact loading which is a sudden dynamic one may have done may have destructive effects on structures. In this study, impact parameters as acceleration and impact force values of a reinforced concrete slab are obtained by using a testing apparatus and essential test devices. An analysis which is used to model different physical dynamics processes depending on several variables is performed in the numerical partof the study [17].

EXPERIMENTAL STUDY

To examine the viability of proposed technique for working on a definitive strength, four composite individuals with various separating of welded stud shear connector were utilized. The sketch of the shear connectors for the composite shaft is displayed in Figure.1. The Longitudinal and cross sectional subtleties of the pillars are displayed in Figures 2 and 3.The subtleties of example arrangement radiates are introduced in Table 1.The characteristics of beam are depicted in Table 2.

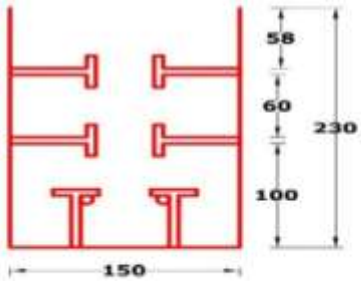

Figure 1. Sketch of stud shearconnector

Figure 2. Longitudinal section of confined steel concrete compositebeam

Figure 3. Cross section details ofstud shear connector

Table 1. Specimen Categorization

Specimen	Spacing of shear connector
A	75 mm
B	100 mm
C	125 mm
D	150 mm

Table 2. Characteristics of Beam

Parameters	Dimensions
Length of beam	2300 mm
Cross section of the beam	150 mm X 230 mm
Support conditions	Simply supported
Loading condition	Pure bending
Type of shear connector	Welded T Shaped stud shear connector
Diameter of shear connector	6 mm
Length of shear connector	80 mm
Number of shear connector	Vary
Length of the cold formed steel sheet	2300 mm
Thickness of cold form steel sheet	1.2 mm
Grade of reinforcement bars	Fe 415
Diameter of steel	8 mm
Number of tensile reinforcement	2
Grade of concrete	M30

Table 3. Materials for 1 m^3 of concrete

S.No.	Materials	Quantity [kg]
1.	Cement	413
2.	Sand	706
3.	Gravel	1117
4.	Water	186

Test Procedure of pure bending process

For unadulterated twisting test, four composite shafts with a successful range of 2.3 m were taken. The test set up is displayed in Figures 4 and 5.The place of the backings, inclinometer and dial checks focuses were set apart on the shafts. The point load was applied on the pillars for deciding unadulterated twisting interaction. Every one of the shafts were intended to just flop by flexure. To decide the arch of the pillars, the inclinometer readings were taken. For the measurement of deflections, dial gauges were located at seven places, one at mid-span, two under the load points, two at the bottom of the beams at 1/6 of the span and two at the top of the beams at supports The beams were tested at a loading rate of 30 kN/min. The test was carried out until cracks formed as a result of buckling of the beam sheets. The beams began to yield, and their behavior was closely monitored from the start until the beam collapsed. The propagation of cracks and failure of bracings connecting the sheet and concrete were carefully observed following the initial separation of the sheet. Following that, the beams were tested to determine their ultimate load carrying capacity by removing all dial gauges and the inclinometer setup until the beams failed.

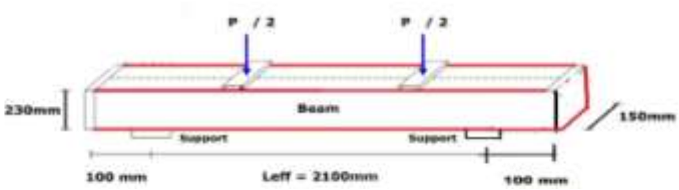

Figure 4. Testing specimen with Dimension.

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Figure 5. Testing SetupCompressive Strength of Concrete

After determining the material ratios for one cubic metre of concrete production, the required amount for the specimen moulding is calculated. Table 3 shows the material ratios per cubic metre of concrete. Figures 6 and 7 show the experimental setup for compressive strength of concrete and crack formation after applying load. Following crack formation, readings were taken from the experiment, and the results are shown in Table 4.

Figure 6. Test setup for Compressive Strength ofCube

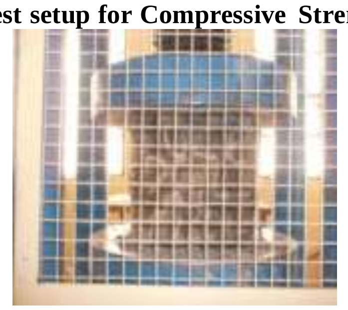

Figure 7. Crack formations during compressivestrength of cube

Table 4. Compressive strength of plain concretecubes

S. No	**Cubeseries**	**Load(kN)**	**f_{ck} (N/mm**
1		691	30.69
2	C	725	32.24
3	C	740	32.91
4	C	770	34.24
5	C	797	35.46
6	C	820	36.48
7	C	784	34.85
8	C		35.97
	Average Strength		**34.15**

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FINITE ELEMENT ANALYSIS

The finite element method is the most powerful numerical method to study the behaviour of the composite beams. This section describes the development of the 3D finite element model capable of simulating the behaviour of the confined steel concrete composite beam subjected to the pure bending using the software ABAQUS.

Material model for concrete

Concrete is a purely nonlinear material that behaves differently in compression and tension. Concrete's stress-strain curve is linearly elastic in compression up to its maximum compressive strength. Above this point, the stress gradually increases to the maximum compressive strength, then descends into a softening region, and finally crushing failure occurs at an ultimate strain cu. The stress-strain curve for concrete in tension is approximately linearly elastic up to the maximum tensile strength. After this point, the concrete cracks and the strength decreases gradually to zero.

Material model for steel

The Fe415 grade steel is used for the development of FEM model which is assumed to be an elastic- perfectly plastic material and identical in tension and compression. Poisson's ratio of 0.3 is used for the steel reinforcement in this study.

Material Types

- Material manager-create1-steel-mechanicalproperties
- Material manager-create2-concrete-mechanical properties

Modelling procedure using ABAQUS

The model made of cold form sheet with shear connector, which was subjected to load, had created mesh with 25 mm accuracy and the analysis was carried out. This is shown in Figures 8,9 & 10 and the deformation results obtained are shown in Figure 11. A perfect bond between steel and concrete interface is assumed here. By using merge option, the coinciding nodes of cold formed steel sheet and concrete are shared and thus composite action is achieved. The properties of the materials aredepicted in Table 5.

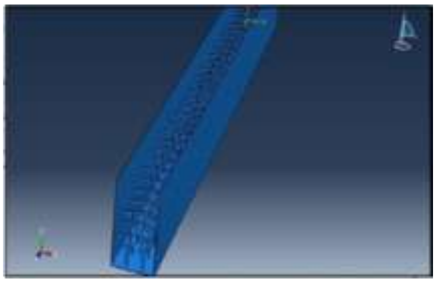

Figure 8. Geometry of composite beam model

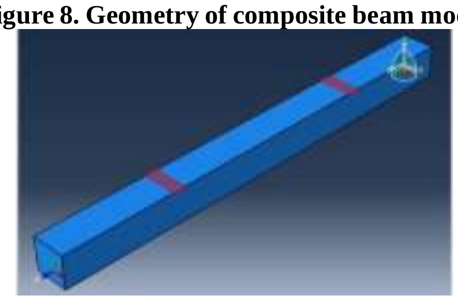

Figure 9. Application of load

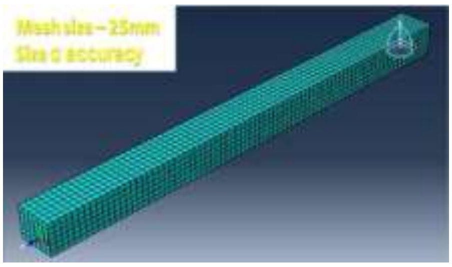

Figure10. Meshing.

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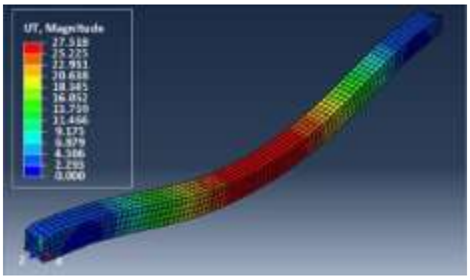

Figure 11. Deformation Result Table 5. Properties of Materials

Properties	**Values (N/mm^2)**
Bond stress between concrete and connector f_{BCC}	1.4 [10]
Bond stress between concrete and sheet f_{BCS}	0.187[11]
Actual stress in cold formed sheet f_s	158
Actual stress in the reinforcement f_Y	184
Compressive strength of concrete f_{ck}	30
Modulus of elasticity of steel E_s	2.1x 10^5
Modulus of elasticity of sheet E_{sy}	1. 8x 10^5
Modulus of concrete E_c	28.5 x10^3

From FEM analysis, it is observed that , a 75 mmspaced shear connector beam could withstand high

Figure 12. Failure Pattern of Beam in PureBending

When compared to other spaced shear connectors such as 100 mm,125 mm, and 150 mm beams, the ultimate bending moment is 150.02 KN-m. Table 6 summarises the findings. According to the simulation results, the maximum deflection for the ultimate moment is 27.518 mm, as shown in Figure 16..

II. RESULTS AND DISCUSSIONS

The CSCC has been put to the test in this study. A pure bending test was performed to determine the deflection and ultimate bending moment of the CSCC in order to estimate its performance. The failure began with the initial separation of the sheet in the form of waves due to local buckling, followed by beam yielding. The first crack was observed on the specimen, followed by the appearance of several cracks that propagated in an inclined manner as the load was increased further. Crushing of compression concrete, failure of bracings, and tension steel yielding were observed at failure. Figures 12 and 13 depict the failure pattern and beam crushing.The performance of load with deflection curve, determines that shear connectors with 75 mm spacing provides better strength compared to other spacing which is shown inFigure 14.

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Figure 13. Failure pattern by crushing ofconcrete in pure bending

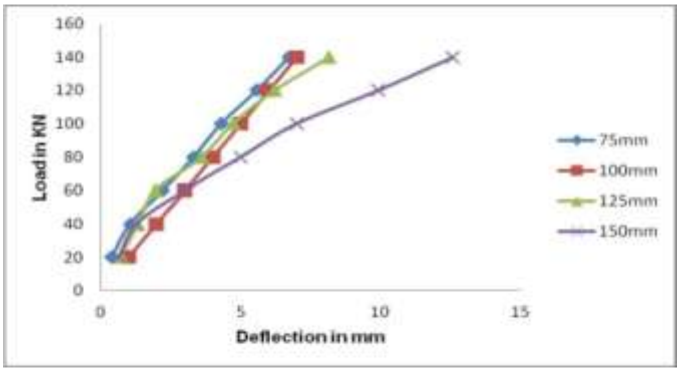

Figure 14.Load Vs Deflection in various spacing of Shear Connector.

Figure 15 shows a comparison of the ABAQUS and FEM results for various values of shear connector spacing. It can be seen from this that 75 mm spacing provides good ultimate beam strength. The reason for the enhancement in flexural stiffness is due to closely spaced shear connectors which contributed additional confinement. For beams with 75 mm spacing of shearconnectors the moment carrying capacity was found to be higher than the beams with 150 mm spacing.

Table 7. Comparison of ultimate of beams

Shear Connector (mm)	**Experimental Value (KNm)**	**FEM Analysis Value (KNm)**
75	129.84	124.02
100	111.38	106.45
125	107.28	102.49
150	102.68	97.23

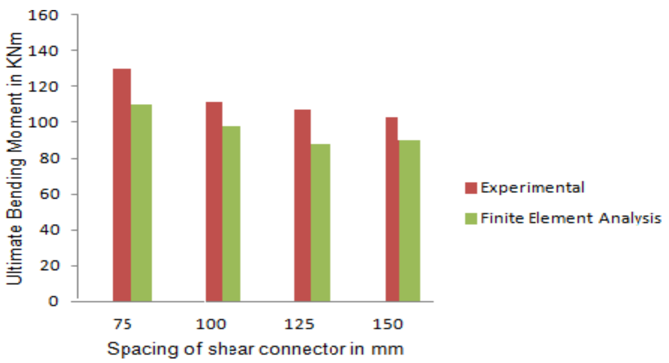

Figure 15. Comparison of Ultimate Bending Moment of beams in KNm

III. CONCLUSIONS

A detailed investigation was carried out on steel-concrete composite beams subjected to bending. The major conclusions are drawn as follows:

- The result indicates that ultimate moment capacity increases with decrease in thespacing of shear connectors.
- It is observed that the shear connectors connected with 75mm spacing provides higher ultimate strength.
- The experimental results, ABAQUS predicting moment capacity is almost same as that of experimental results.
- The failure of beams are caused by local buckling of sheet, formation of cracks and crushing

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