ABSTRACT
An experimental investigation is carried out on a newly developed composite beam called Confined Steel Concrete Composite Beam (CSCC beam) governed by welded T shaped shear connectors by considering a range of spacing 75 mm, 100 mm, 125 mm and 150 mm respectively. Two point loading method has been applied on four CSCC beams in order to evaluate the performance of the beam. The values of the parameters bending moment, angle of twist and rotation of the beam are calculated when applying entire load by combined bending and torsion. It is observed that the composite beam having 75 mm spacing shear connectors exhibits best ultimate strength over the beams having other spacing.

KEY WORDS: Composite beam, CSCC, Shear connector, Bending, Torsion.

1. INTRODUCTION
Economical structure having better strength, reliability and performance is desirable all over the world at present. This has led to the development of new type of composite beam namely confined steel concrete composite. The shear connectors are provided to restrict longitudinal slipping and uplift at the element interface. The effect of bending of steel concrete composite beams are yet to be addressed in the international standards on composite steel–concrete construction such as the Euro code 4 [1] the American Institute of Steel Construction and in the Australian Standards AS 2327 [2]. The inelastic performance of steel concrete composite beam was explored and studied using predictor corrector method [3]. On the other hand, more than a few assumptions were completed such as linear stress strain curve of steel in both the compression and tension area and in addition, there is a great bond between steel and concrete without any disconnection. Steel concrete composite beam were modeled [4] using two dimension truss element on behalf of the shear connector, shell elements used for concrete slab and steel in ABAQUS. The activities of structural steel-concrete composite beams curved in diagram were inspected. The numerical technique of FEA (Finite Element Analysis) package ABAQUS has been employed. The anticipated finite element model has been authenticated by evaluating the calculated values with accessible experimental results. An adequate correlation has been monitored between the computed and investigational results acquired for beams of realistic fraction [5]. This paper agreements with finite element modeling of the ultimate load behaviour of double skin composite (DSC) slabs. In the experimental analysis, 12 simply supported DSC slabs were checked to failure under a deliberated load applied at the centre. These test specimens were scrutinized by the finite element method and this investigation have exposed that these slabs presented a high degree of flexural individuality, ductility and ultimate strength [6] [7]. It is surveyed that the torsion stimulated vertical slip is an essential concern from the analytical study of nonlinear study of composite beams subjected to combined torsion and flexure. It creates the hypothesis plane sections remain plane unfounded. In accumulation, distinction in span length greatly affected the flexure–torsion contact bond of the composite steel–concrete beams, whilst the partial shear connection did not influence the relationship [8]. The behavior of confined steel concrete composite beam subjected to combined bending and torsion 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 horizontal bracings provided at the top of the beam [12]. In the study on flexural behavior of concrete filled steel tube, numerical analysis has shown that for rectangular CFT can provide a good confining effect. Lin Han (2004) compared Moment capacity results with the results generated from the ANSYS model using different codes such as EC4 (1994) and AISC-LRFD (1999) [13]. The investigation on shear strength of stud shear connectors were influenced by the shank diameter of stud shear connectors, compressive strength of concrete, and the slip at the interface of the steel beam. It is observed from the results that shear connectors were responsible for a sizable increase in the load bearing capacity of the steel beams in addition to stiffness [14, 15]. In another experiment, the impact behavior of non-reinforced concrete beams has been investigated by both experimentally and the finite element analysis such that displacements, velocities, accelerations, impact forces, and capacity of energy absorption have been obtained for the analysis [16]. Impact loading which is a sudden dynamic one may leads to destructive effects on structures. In this study, impact parameters such as impact force values of a reinforced concrete slab and acceleration are obtained by essential testing devices. An analysis which is used to model different physical dynamics processes depending on several variables is performed in the numerical part of the study [17]. From the literature review, it is found that less attention be paid on analyzing the CSCC using T-shaped shear connectors. In the present research, an attempt has been made in analyzing the flexural strength of CSCC beam.

2. Experimental Programme
For this experimental study, four beams of size 0.15m x 0.23m x 2.3m are cast. Along with the beams three cube companion specimens of size 150mm x 150mm x 150mm were cast to determine the compressive strength. In order to investigate the effect of the spacing of shear connectors in improving the ultimate strength of composite beams,
four composite members with different spacing of welded shear connectors are tested in this study. The details of the shear connectors in the composite beam are shown in figures 1 and 2. The Characteristics of beam is displayed in Table 1.

**Table 1 Dimensions of the Beam**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of beam</td>
<td>2300mm</td>
</tr>
<tr>
<td>Cross section of the beam</td>
<td>150mm x 230mm</td>
</tr>
<tr>
<td>Support conditions</td>
<td>Simply supported</td>
</tr>
<tr>
<td>Loading condition</td>
<td>Pure combined bending and torsion</td>
</tr>
<tr>
<td>Type of shear connector</td>
<td>Welded T Shaped shear connectors</td>
</tr>
<tr>
<td>Diameter of shear connector</td>
<td>6mm</td>
</tr>
<tr>
<td>Length of shear connector</td>
<td>80mm</td>
</tr>
<tr>
<td>Number of shear connector</td>
<td>Vary</td>
</tr>
<tr>
<td>Length of the cold formed steel sheet</td>
<td>2300mm</td>
</tr>
<tr>
<td>Thickness of cold form steel sheet</td>
<td>1.2mm</td>
</tr>
<tr>
<td>Grade of reinforcement bars</td>
<td>Fe 415</td>
</tr>
<tr>
<td>Diameter of steel</td>
<td>8mm</td>
</tr>
<tr>
<td>Number of tensile reinforcement</td>
<td>2</td>
</tr>
<tr>
<td>Grade of concrete</td>
<td>M20</td>
</tr>
</tbody>
</table>

2.1 Test Procedure of pure combined bending and torsion process

Four composite beams are tested for combined bending and torsion with an effective span of 2.3 m.

![Fig. 3. Testing specimen with Dimension](image)

**Fig. 3. Testing specimen with Dimension**

The test set up is shown in Figures 3 & 4. A, B, C and D specimens are subjected to 30% of ultimate experimental torque followed by the flexure till failure. The supports were fabricated in such a way that combined bending and torsion could be applied on the concrete beams. The ends of the beams are held by the torsion brackets with a loading truss. For applying torsion uniformly, a pair of hydraulic jacks is used. For applying flexural load, two point loading arrangement was made on the beam and the load is applied with the help of hydraulic jack attached to the loading frame. A proving ring of capacity 500kN (50T) is used to measure the load. The torque is found by multiplying the load on the truss by the distance between the point of application of the load and midpoint of the beam. Consideration of weight of the truss also included in the calculation of torque. Glass plates were attached on the top of the beam at both ends for measuring the, angle of rotation and the deflections are measured with the help of four deflectometers for different loadings.

![Fig. 4. Testing Setup](image)

**Fig. 4. Testing Setup**

3. Behaviour of the beams under torsion test

The crack first appears on the top face of the beam and then vertically both down. It is shown in Fig 5. For those beams tested under combined bending and torsion, in the initial stages the angle of twist and twisting moment increase linearly. However after the formation of cracks, the behavior is nonlinear. The length of the linear portion of the torque-twist relationship decreases when the twisting moment value increases. When failure occurs the sheets are separated from concrete and the bracing at the top delays the failure and consequently the crack are widen appreciably at failure. Rotation of beam at failure occurred at an axis near the top face. In some beams, upward deflection is well prominent.

![Fig. 5. Failure Patten in pure torsion](image)

**Fig. 5. Failure Patten in pure torsion**
From the readings of table 2, the values of torque, ultimate bending moment and twist moment are found. This is drawn as a graph figures, they are shown in figs 6&7. More resistances to twist are provided by the closely spaced bracing. This is because the brass acts as ties and carries combined bending and torsion that resist the torsional deformation. Thus, the bending and torsion carrying capacity of the beam have been enhanced.

**Table 2. Test Results for 30% Torque and Bending till Failure**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Beam ID</th>
<th>Dimensions (mm)</th>
<th>Spacing of bracing (mm)</th>
<th>30% of Ultimate Torque (kNm) average</th>
<th>Ultimate Bending Moment (kNm) average</th>
<th>Angle of Twist (o) (radians) x 10^-5 average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>150 x 230 x 2300</td>
<td>75</td>
<td>11.23</td>
<td>23.37</td>
<td>0.029</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td></td>
<td>100</td>
<td>13.41</td>
<td>26.18</td>
<td>0.032</td>
</tr>
<tr>
<td>3</td>
<td>C</td>
<td></td>
<td>125</td>
<td>15.45</td>
<td>29.97</td>
<td>0.037</td>
</tr>
<tr>
<td>4</td>
<td>D</td>
<td></td>
<td>150</td>
<td>19.57</td>
<td>37.69</td>
<td>0.047</td>
</tr>
</tbody>
</table>

4. OBSERVATION AND CONCLUSIONS

1. The behaviour of composite beams under pure combined bending and torsion with different loading conditions is calculated.
2. The result indicates that, the ultimate strength increases with the decrease in the spacing of shear connectors.
3. Resistance to the twist and deflection increases with the increase in the spacing of shear connector.
4. This study ascertain that these types of beams can be applied in combined bending and torsion test.
5. This test influences that all grade of beams can withstand maximum moment carrying capacity 75 mm spaced shear connectors.

REFERENCES


