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The Effect of Web Corrugation in Cold-Formed Steel Beam with Trapezoidally Corrugated Web

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Abstract: - The corrugated steel plate is a widely used structural element in many fields of application because of its numerous favorable properties. To increase the shear capacity of web of large steel plate girders, the web with different patterns such as tapered web, haunches, corrugations of different shapes are used. This paper presents the results of the experimental study on load carrying capacity of cold-formed steel section with trapezoid web. A total of six cold-formed steel beams with plain webs and corrugated webs were tested. The load carrying capacity of cold-formed steel beam with plain web is studied and compared with the load carrying capacity of beam with trapezoidal corrugated web having 30^0 and 45^0 corrugations. The specimens were tested under two point loading for its pure flexural behaviour. From the study, it is found that the cold-formed steel beam with trapezoidally corrugated web having 30^0 corrugation has higher load carrying capacity compared to the beams having plain web and 45^0 corrugated web.

Keywords: - *Cold-formed steel beam, Trapezoidal corrugated web, Load carrying capacity*

I. INTRODUCTION

A corrugated web beam is a built-up beam with thin walled corrugated web. The profiling of the web avoids the failure of the beam due to loss of stability before the plastic limit loading of the web is reached. The use of corrugated webs is a potential method to achieve adequate out-of plane stiffness and shear bulking resistance without using stiffeners.

An experimental and numerical study on lateral-torsional buckling behaviour of hot-rolled steel section with trapezoidal web and found that the steel beam with trapezoidal corrugated web section have higher resistance to lateral-torsional buckling than that of section with plain web[1]. Numerical analysis on the buckling resistance of cold-formed steel beam with sinusoidally corrugated web is studied and found that the bucking failure of the web is prevented by the corrugation[2]. The lateral-torsional buckling of hot-rolled steel plate girder with corrugated webs numerically analysis using ANSYS. It was concluded that the resistance to lateral torsional buckling is more for beam with a corrugated web when compare with the models without corrugation[3]. The efficiency of plate girder with corrugated web were analyzed numerically using ANSYS software and found that the plate girder with trapezoidally corrugated web with 30^0 corrugation has a higher load-carrying capacity compared with other corrugation angle[4]. Performed lateral torsional buckling tests on beams with normal flat web and beams with trapezoid web profile. The experimental results indicated a greater resistance in lateral buckling provided for beams with trapezoid web profile[5].

Extensive research has been done on the performance of hot-rolled steel girder with corrugated web. Hence in this investigation, the load carrying capacity of cold-formed steel beam with corrugated web was carried out experimentally. A total of six cold-formed steel beams with plain webs and corrugated webs were tested. Out of the six specimens, two controlled specimens were tested with plain webs and the other four specimens were tested with corrugated webs. The degrees of corrugation were the variables among the specimens. The specimens were tested under two point loading for its pure flexural behaviour.

II. EXPERIMENTAL INVESTIGATION

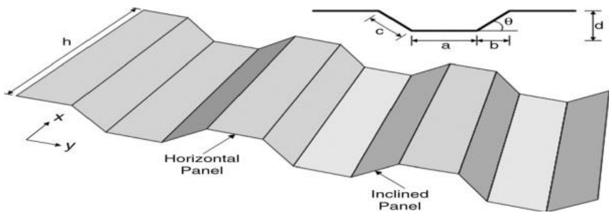
2.1 Test Specimen Details

The test specimen consist of cold-formed steel beams with plain web and trapezoidally corrugated web having 30^0 and 45^0 corrugations. The span of the beam was 2000mm and the cross section of the I-beams are 150mm x100mm x 2.5mm.The yield strength of steel used is 403 N/mm^2.The cold-formed steel beam is built up by welding the flanges and the web using intermittent welds of 4mm thick. A pair of stiffeners was provided at both the load points to minimize local effect due to concentrated loads. Table 1 shows the details of the specimens tested. A six lettered designation is given to the specimens. First 3 letters represents the nature of web whether the web is plain or corrugated, 4^{th} one indicate the degree of corrugation of the web, 5^{th} one represent the depth of the beam and the last one identify the specimen in a particular series as two specimens were tested in each series. Figure 1 shows the fabricated specimens.

Fig.1 Fabricated specimens

Table 1- Details of the specimens tested

SL.No	Beam Number
1	PWB 0^0, 150-1
2	PWB 0^0, 150-2
3	CWB 30^0, 150-1
4	CWB 30^0, 150-2
5	CWB 45^0, 150-1
6	CWB 45^0, 150-2



Trapezoidally corrugated web

2.2 Test set-up:

The testing was carried out in a loading frame of 400 kN capacity. All the specimens were tested for flexural strength under two point loading in the vertical loading frame. The specimens were arranged with simply supported conditions, centered over bearing blocks adjusted for a effective span of 1.8 m. Loads were applied at one-third distance from the supports at a uniform rate till the ultimate failure of the specimens occurred. Linear Voltage Displacement Transducers (LVDTs) were used for measuring deflections at several locations, one at mid span, two directly below the loading points and two near the end supports as shown in the Figure 2. Strain gauges and LVDTs were connected to a data logger from which the readings were captured by a computer at every load intervals until failure of the beam occurred. The beams were subjected to two-point loads under a load control mode. The experimental set-up for the test specimens are shown in Figure 3.

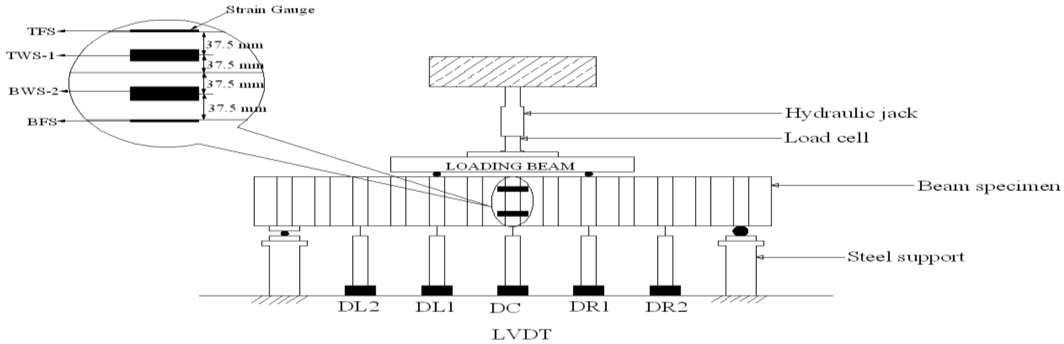


Fig. 2 Position of LVDTs and Strain gauges

Fig. 3 Experimental set-up for the test specimens

III. RESULTS AND DISCUSSION

3.1 Observed Failure Mode

The failure pattern of the test specimens is shown in Figure 4. Beams with plain web failed by shear buckling of web. In the specimens with 45^0 trapezoidally corrugated web, failure occurred by local flange buckling and further loading caused local shear buckling of corrugated web, but the specimens with 30^0 trapezoidally corrugated web failed by local flange buckling.

(a) PWB 0^0, 150-1

(b) PWB 0^0, 150-2

(c) CWB 30^0, 150-1

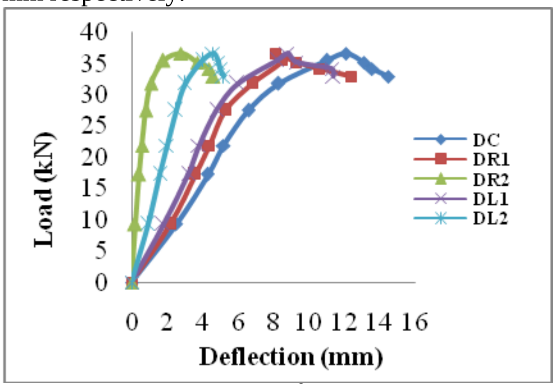
(d) CWB 30^0, 150-2

(e) CWB45^0, 150-1 (f) CWB 45^0, 150-2

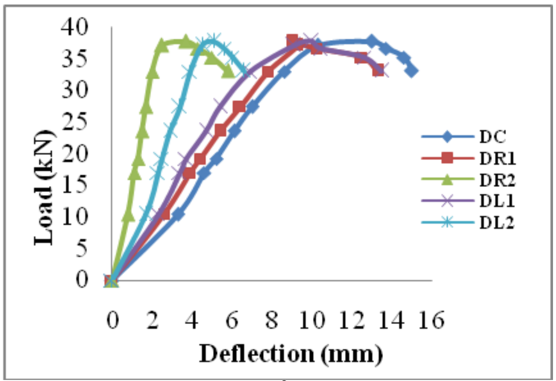
Fig. 4 Failure pattern of the test specimens

3.2. Load Versus Deflection Curves

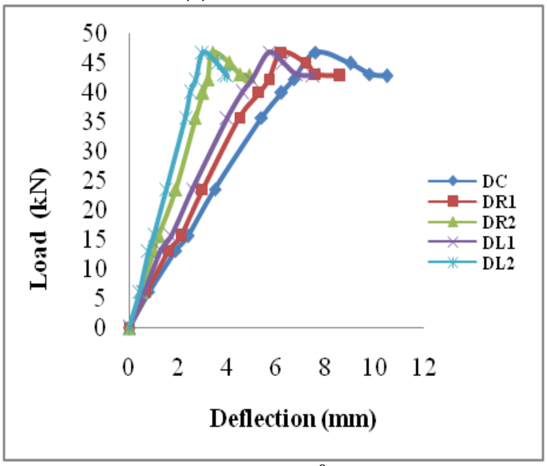
The experimental load-deflection curves of the cold-formed steel beams with plain webs and corrugated webs are shown in Figure 5. The specimens with plain web PWB 0^0, 150-1&2 failed at an average load of 37.15 kN with a central deflection of 12.5 mm and the other specimens CWB 30^0,150-1 &2 and CWB45^0,150-1&2 failed at an average loads of 46.55 kN and 45.55 kN with the corresponding average deflections of 7.85 mm and 8.55 mm respectively.



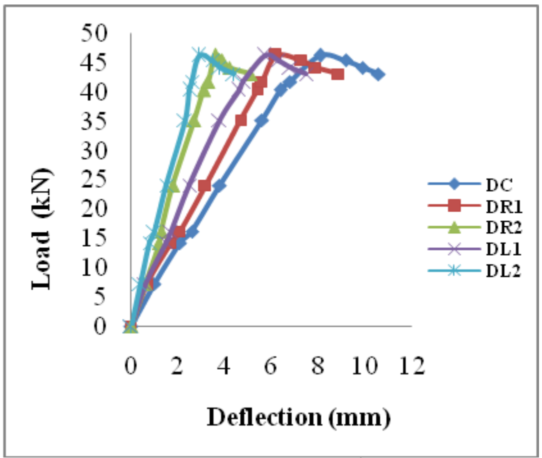
(a) PWB 0^0, 150-1



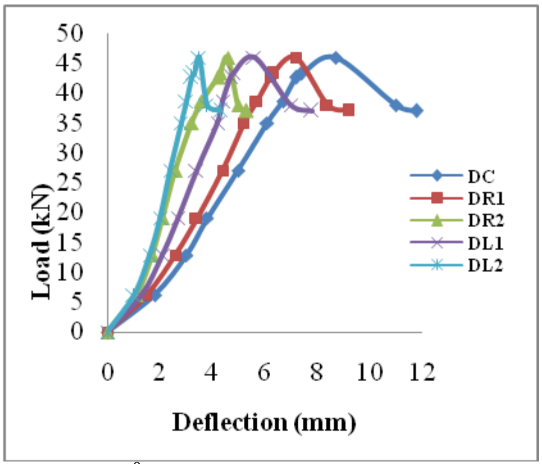
(b) PWB 0^0, 150-2



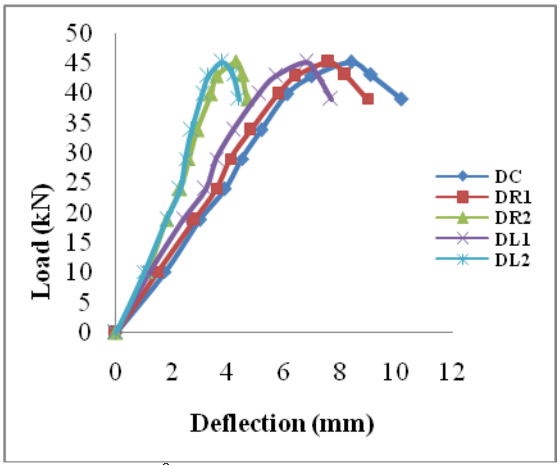
(c) CWB 30^0, 150-1



(d) CWB 30^0, 150-2



(e) CWB 45^0, 150-1

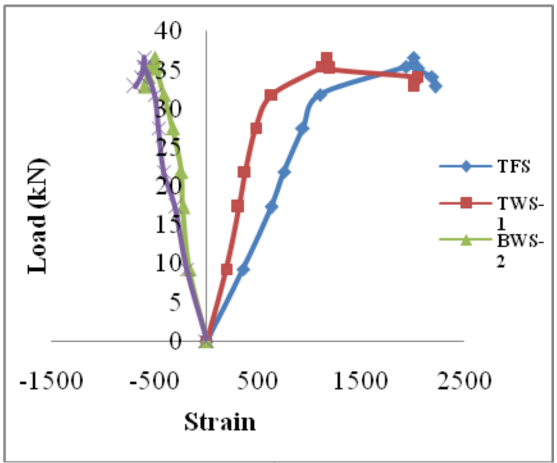


(f) CWB 45^0, 150-2

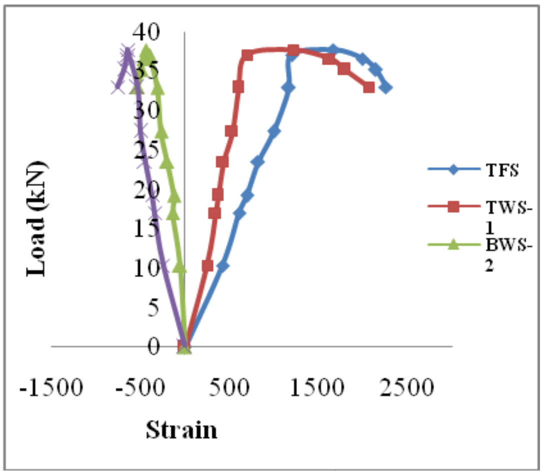
Fig. 5 Load versus deflection curves for the test specimens

3.3 Loads versus Strain Curves

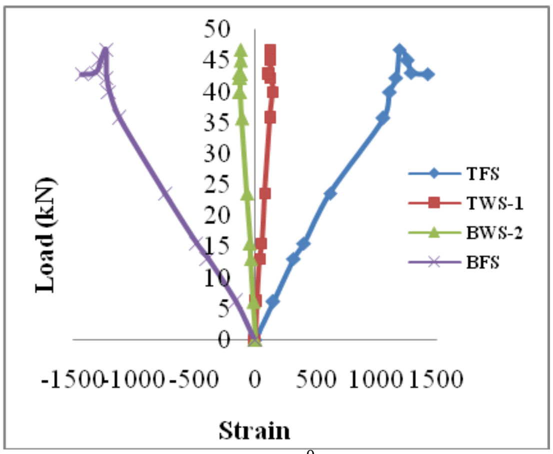
The strains were measured at the top flange, bottom flange and in the web portion . The load versus strain curves of the test specimens are shown in Figure 6. The measured steel strain at the top and bottom surface (TFS to BFS) at ultimate load varied from 1668 to 2010 & 603 to 643 respectively for plain web beams where as for a beam with 30^0 corrugated web varies from 1190 to 1320 & 1230 to 1376 and for a beam with 45^0 corrugated web varies from 1173 to 1330 & 1252 to 1703 respectively. From the results it is observed that the strain in the beams with corrugated web is more than that of the beams with plain web.



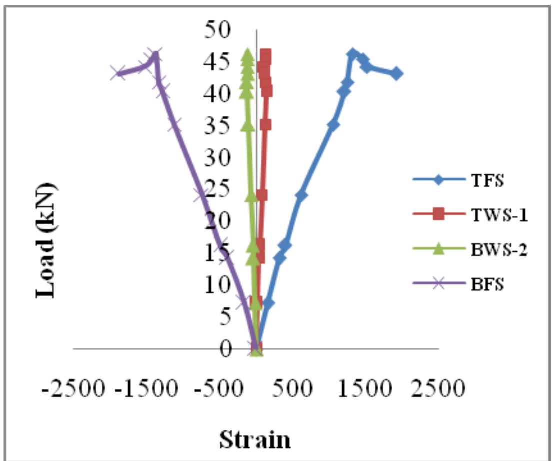
(a) PWB 0^0, 150-1



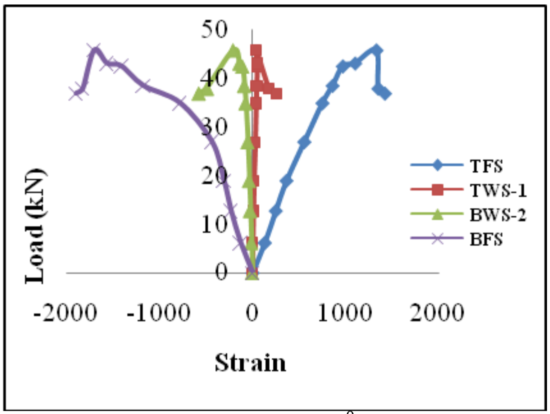
(b) PWB 0^0, 150-2



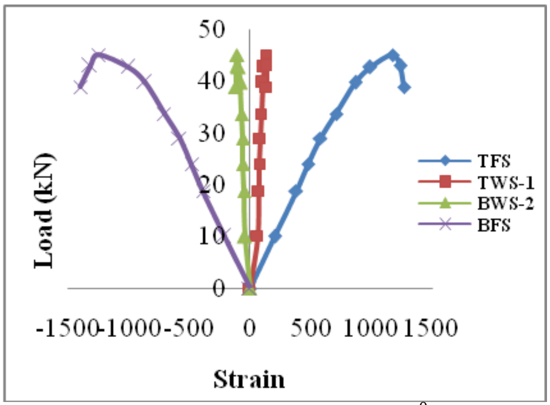
(c) CWB30^0, 150-1



(d) CWB30^0, 150-2



(e) CWB 45^0, 150-1



(f) CWB 45^0, 150-2

Fig. 6 Load versus strain curves for the test specimens

3.4. Strength Capacity of the Specimens

The trajectory of strength capacity of the specimens is shown in Figure 7. For the specimens with 150mm depth, the load carrying capacity of the beam having 30^0 corrugated web is 2.2% and 25.3% more than the specimens having 45^0 corrugation and plain web respectively.

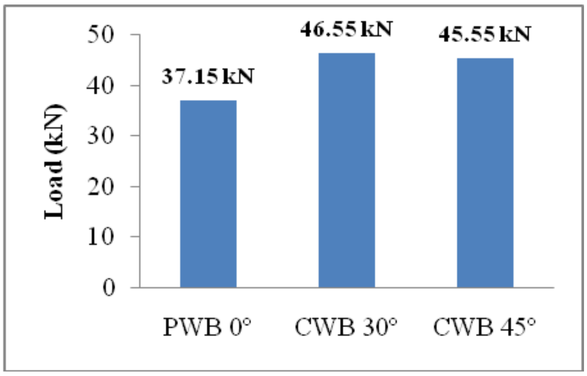


Fig. 7 Comparison of strength capacity of a specimens

IV. CONCLUSION

The following observations and conclusions can be made on the basis of the experiments conducted on the six cold-formed steel beams with plain and trapezoidally corrugated web.

1. The average load carrying capacity of cold-formed steel beams with 30^0 corrugated webs increases by 25% than the beam with plain web. But there is only a marginal increase in load carrying capacity of beam with 30^0 corrugated web than that of beam with 45^{0}corrugated web.
2. Beams with plain web showed shear buckling of web, but the failure due to shear in web could be eliminated by using corrugated web.
3. The strain in the beams with corrugated web is more than that of the beams with plain web.

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