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STUDY ON BEHAVIOR OF CORRUGATED WEBS IN COLD FORMED STEEL SECTIONS WITH VARYING THICKNESS

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ABSTRACT

A cold-formed steel section is more sensitive to local buckling than typical hot rolled sections. It is characterized by light weight, high strength, economical, wide variety, smooth surface and accurate size. The web panels are used as stiffened plates that can receive both high shear and high moment in different sections or in the same section depending on the beam statical system. One of the methods of reducing the web thickness is the use of corrugated sheets as webs. However, they are suggestible to various modes of buckling including local and distortional buckling. The main aim of this thesis is to find the maximum load carrying capacity of the specimen and possible modes of failure under two point loading at the corrugated web in cold formed sections with varying thickness. Steel I section with the corrugated web having two flanges are welded with the web. The length of the specimen is kept constant for 1200mm and the thickness is varied from 0.7mm, 0.9mm, and 1.2mm.The results for a simply supported beam is subjected to a two point loading are examined. Finally, numerical analysis using ANSYS 15.1 results are analysed and justified with experimental results for an explanation.

Keywords: Corrugated webs; finite element method; load carrying capacity.

1. INTRODUCTION

The corrugated webs are used in steel buildings and highway bridges in Europe in the year 1960s using Abacas 2003.The I- girder with the corrugated web having the good shear strength and improved fatigue strength compared with conventional I-girders with flat webs are shown in past research [1]. General shapes of the corrugated beams having two flanges and a single web, the whole weight of the flange width at the middle or the narrow flange beam are contributed by the web having 30-40% respectively [2]. Steel I section with the corrugated web having two flanges are welded with the web. Normally, the profile of the

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web is of the trapezoidal shape, but it may also be rectangular, triangular, sinusoidal or any other repeating shape [3]. The corrugated webs are used for plates having less thickness, therefore, the carrying capacity will increases. Hence, it reduces the weight of the beam, the cost of fabrication and increased the fatigue life [4]. The failure modes of the beams under shear loading is due to the web buckling, where local and the global buckling in coarse and dense corrugation respectively [5].

Webs are one of the main components that act with flanges in hot rolled or built-up sections to form beam or girder members. The web may be subjected to elastic buckling from shear, bending moment and localized compressive stresses from reactions or concentrated loads [6]. The flat web losses it stability, when the stress in the compression side will exceed the critical point. The compressive stress in the web exceeds the critical point earlier than the yielding occurred. This type of failure will be enhanced by using corrugated web instead of the plane web, this introduces the higher stability and the strength and without the use of large thickness [7]. Under in-plane moment and the shear in the I-girder with web corrugation will deflect in the plane and also out of plane twist immediately. The conventional beam theory is used will analyse for the in-plane bending behaviour of the steel sections. And the flange transverse bending problem will be analysed for out of plane twisting behaviour of the steel sections [8]. The shear strength of the web steel plate will decrease and the web plate buckling will occur, while using out cuts in girder with corrugated webs [9].

Past researchers are investigated on I-girders with trapezoidal corrugation of hot rolled Section. The research on cold-formed steel (CFS) of I-beam is limited. For flexure member subjected to light and moderate load, I section of the thin flange and the web may be sufficient. The thin flange may be stiffened by providing lip. The thin web may be stiffened by using corrugation. In recent times, limited studies have been reported on I-beam with trapezoidal corrugation with varying thickness. This paper describes the details of such a study. The main aim of this paper is to study the buckling analysis of corrugated webs in cold formed sections by varying thickness under two point loading. In this study three specimens are experimented by varying thickness are investigated. Steel I section with the corrugated web having two flanges are welded with a corrugated web. Totally three specimens experiment. The length of the specimen is kept constant for 1200mm and the thickness is varied from 0.7mm, 0.9mm, and 1.2mm. The load is applied at the one-third distances from the full span. At the loading point and support, a stiffener plates are placed in order to avoid the bearing failure and distribute the load uniformly. The two point loading is subjected to simply supported beam is examined. The numerical model is developed using finite element software ANSYS 15.1 including both material and geometric nonlinearity are presented and compared to the experimental results for justification. The Maximum load carrying capacity is obtained from experimental results.

2. EXPERIMENTAL INVESTIGATION

The specimens are fabricated by locally available cold formed sheets. The CFS sheet of 0.7mm, 0.9mm and 1.2mm are used for both flanges and the web. Flanges and the web are connected by a continuous thin weld. The profile of the I-beam with the corrugated web is shown in Fig. 1. The corrugated web profile is shown in Fig. 2. At the loading point, stiffeners are placed in order to avoid the bearing failure and distribute the load uniformly throughout the section. Fabricated specimens are shown in Fig.3.The details of the specimens fabricated and their dimension details with labelling are given in Table. 1.

Table 1. Dimensions of specimens

Model no.	a mm	b mm	c mm	d_{max} mm	Θ Degree	t_w mm	h_w mm	b_f mm	t_f mm	b_1 mm	t_1 mm	L Mm
1.	100	50	50	25	45	0.7	300	150	0.7	20	0.7	1200
2.	100	50	50	25	45	0.9	300	150	0.9	20	0.9	1200
3.	100	50	50	25	45	1.2	300	150	1.2	20	1.2	1200

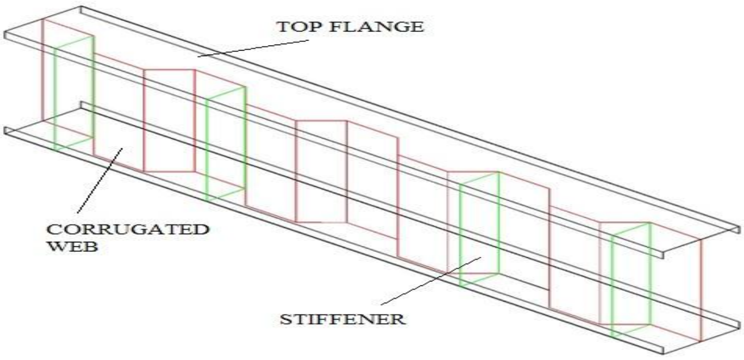


Figure 1. Profile of I-beam with corrugated web

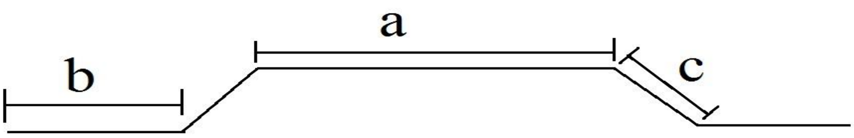


Figure 2. Corrugated web dimensions

Figure 3. Fabricated specimens

3. COUPON TEST

The material properties of CFS specimens are examined by tensile coupon tests confirming to the Indian standard IS 1608-2005 (Part-1). Coupon test specimen and dimensions details are shown in Fig. 4.The tensile strength of the specimen is obtained by coupon test. It consists of two regions, central part and two end regions where the failure is expected to occur in the central part. The end regions are clamped to the test machine.

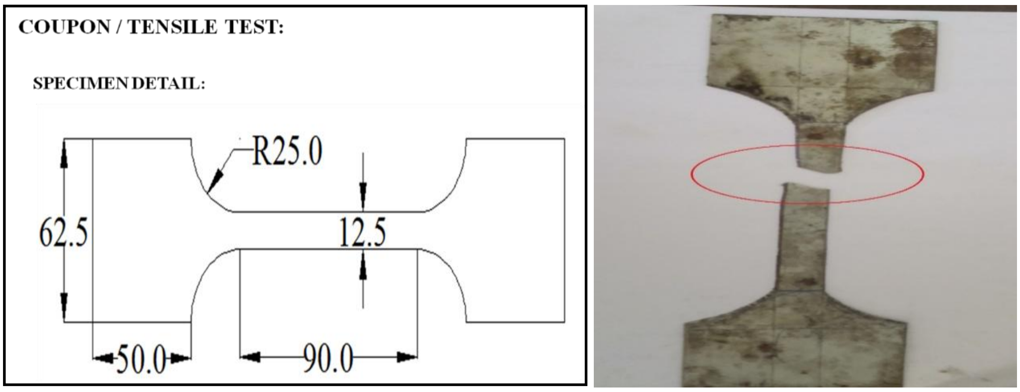


Figure 4. Dimensions details & specimen after testing

The corresponding strength values are listed in the below Table.

Table 2: Values obtained from coupon test

Description	Sp 1	Sp 2	Sp 3
Maximum Force (F_m)	4.413kN	5.013kN	5.550kN
Displacement at F_m	10.899 mm	11.437 mm	12.730 mm
Yield stress	190 N/mm^2	200 N/mm^2	210 N/mm^2
Tensile Strength	3.6 N/mm^2	4.2 N/mm^2	5 N/mm^2
Elongation	16.7 %	18.4 %	19.2 %

4. TEST SETUP

The specimens are tested in loading frames under two point loading at L/3 distance. The schematic diagram of the test setup is shown in Fig. 5. The specimens are simply supported by the loading frame. The load is transferred through the load cells, which measure the deflection and load increment in the specimens. All the data’s are recorded in data acquisition system.

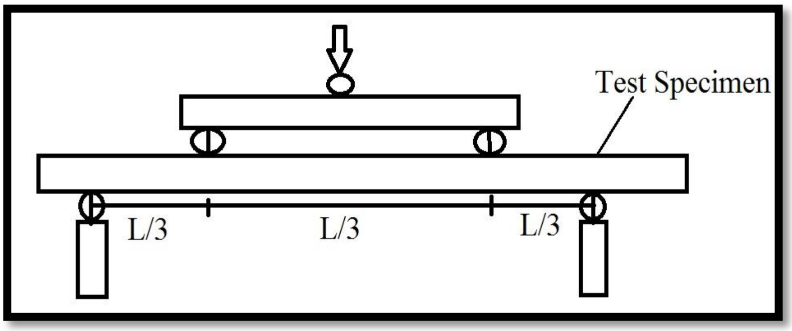


Figure 5. Schematic diagram of experimental setup

5. NUMERICAL ANALYSIS

The tested three specimens of I- beam with the corrugated web which is trapezoidal shape are analysed numerically using finite element analysis using ANSYS.15.1 software. An appropriate mesh size is chosen. The young's modulus of E=20000 N/mm^2 and the stress at yielding is (F_Y)=190, 200, 210 N/mm^2. The web and flanges are connected by coupling at each node throughout the section. By using geometric imperfection the modes of buckling shapes are created first. In the modelled finite element specimen, material and geometric nonlinearity are included. For all the specimens, the nonlinear finite element analysis is also performed and load carrying capacity can be obtained.

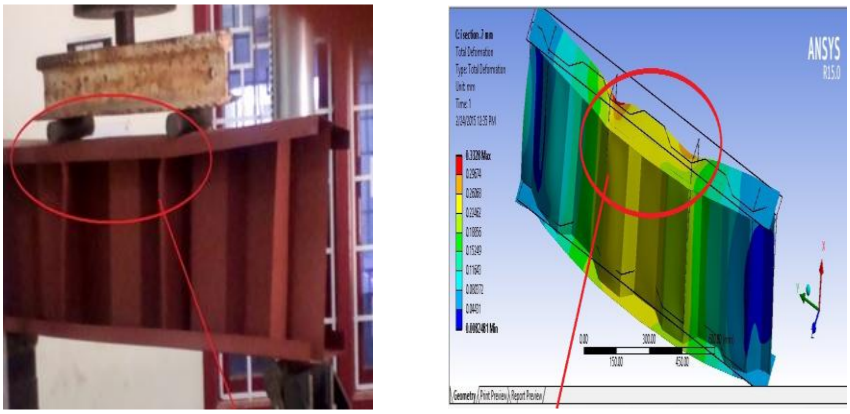
6. VALIDATION OF THE RESULTS

The loading carrying capacity of all three specimens of varying thickness is verified with numerical modelling. From the experimented results, load carrying capacity shows the good understanding with numerical results, especially in web portion. The mechanical behaviour of the specimen is changed because of applying the amount of weld at the joints. The load carrying capacity and failure modes of each specimen is mentioned in below table 3.

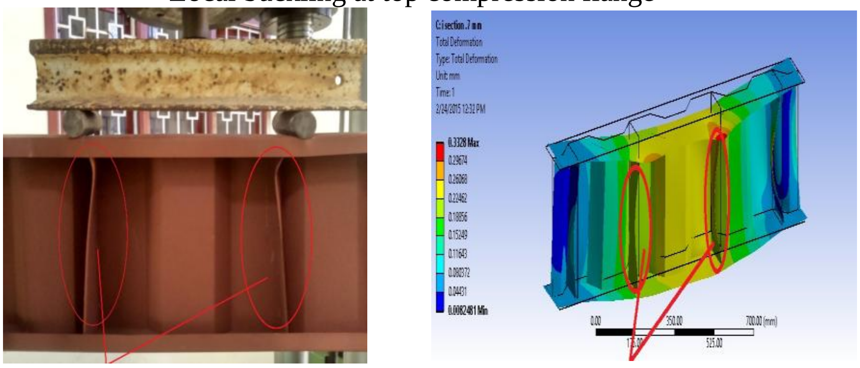
Table 3: Experimental results

Specimen name	Thickness	Failure mode
Sp 1	0.7 mm	Local buckling at top compression flange & Corrugated web followed by distortional buckling + Stiffeners fails at the loading point.
Sp 2	0.9 mm	Local buckling at top compression flange& Corrugated web followed by distortional buckling.
Sp 3	1.2 mm	Local buckling at top compression flange& corrugated web followed by distortional buckling.

7. MODES OF BUCKLING

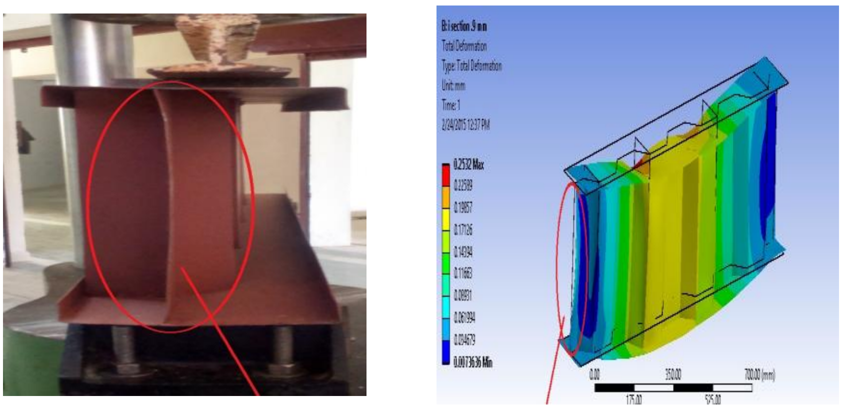


Local buckling at top compression flange

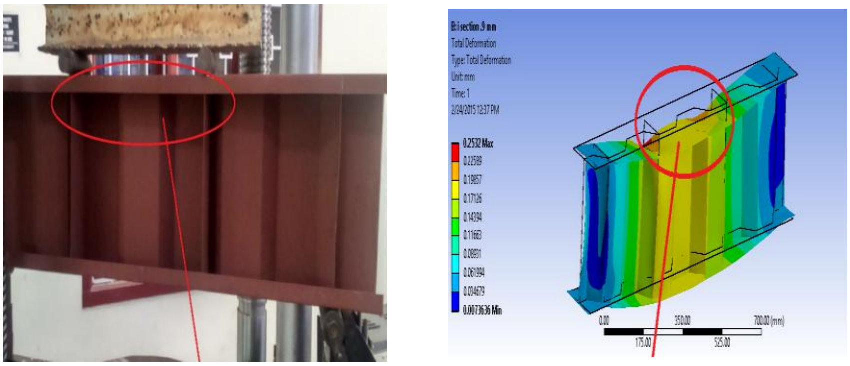


Stiffener fails at the loading point

Figure 6. Buckling modes for Sp 1

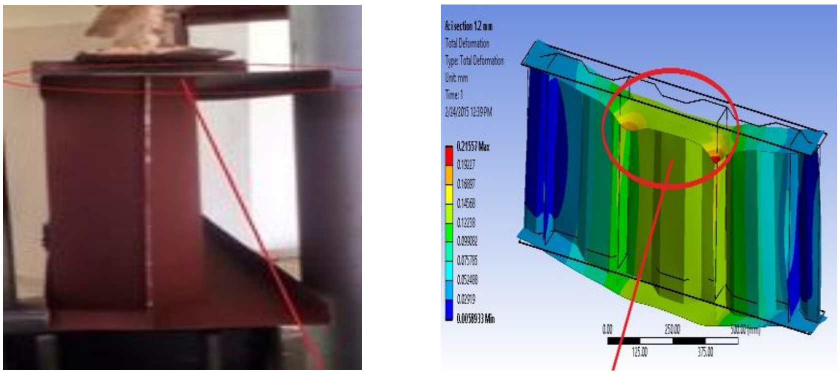


Corrugated web failure at the loading point



Local buckling at the top compression flange

Figure 7. Buckling modes for Sp 2



Local buckling at top compression flange

Distortional buckling

Figure 8. Buckling modes for Sp 3

From the results, all the specimens are initially failed by local buckling at the top compression flange followed by distortional buckling. Stiffeners are failed at the loading point in Sp 1. The deflected shape obtained from FEA is similar to the Experimental buckling modes of failure. From experimental and numerical results, we found that the load carrying capacity increases with increasing the thickness.

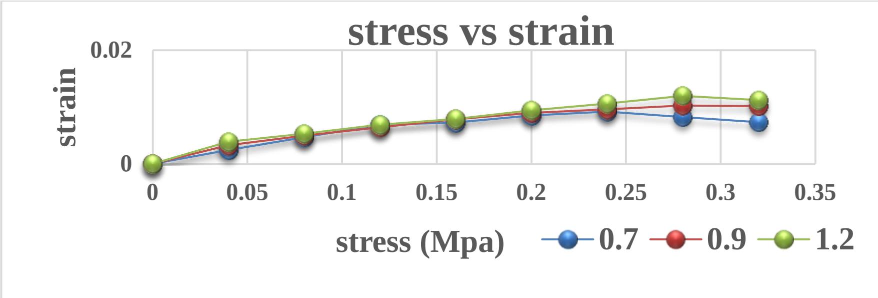


Figure 9. Stress-strain curve

These experimental values give stress-strain curve is shown in Fig.9. From this graph, Sp 3 show the maximum stress compared to all specimens. This Specimen is initially buckled local compression buckling followed by distortional buckling. The stiffness of the specimen also shows for Sp 3 has more stiffness has compared with another specimen because the thickness is increased. Load versus deflection, Stiffness versus thickness graph are shown in Fig. 10 and 11. Therefore, load carrying capacity also increases with increases in thickness.

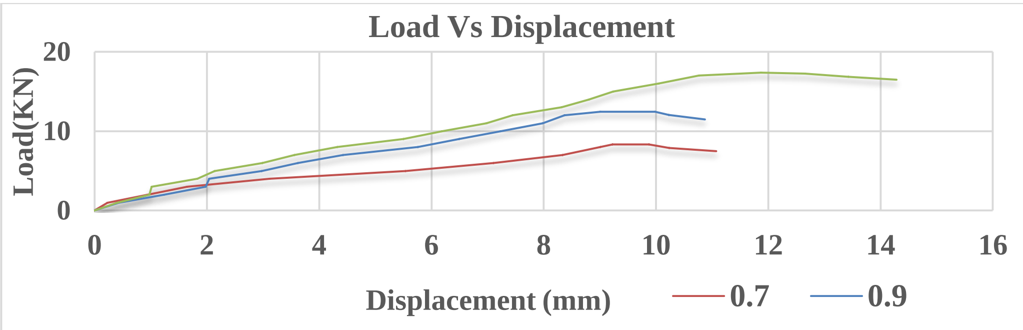


Figure 10. Load-Displacement curve

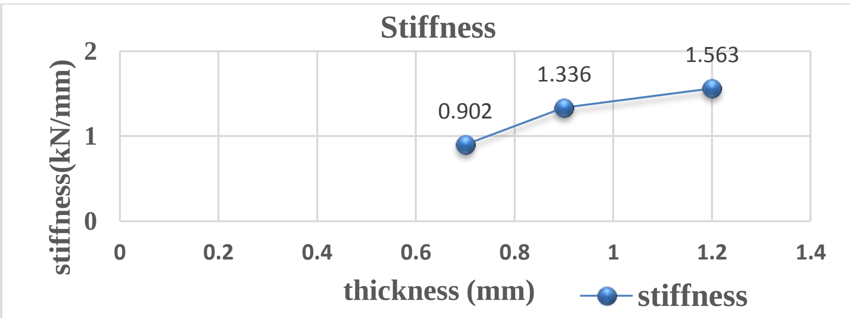


Figure 11. Stiffness curve

8. CONCLUSIONS

The detailed investigation on the structural behaviour of corrugated webs in cold formed sections with varying thickness is described in this paper. Both experimental and numerical analysis was examined for enhanced understanding of the behaviour of cold-formed members. Finite element model of tested specimen is prepared by using ANSYS 15.1.

Based on this investigation, the following conclusions are summarized below.

1. When thickness increases as well as the load carrying capacity is also increased in cold formed sections with the corrugated web.
2. Compression failure in the web is reduced due to corrugation in the web.
3. The connection between corrugated web and stiffeners gives efficient joint, because of providing point weld at regular intervals.
4. Finite element analysis is carried out to verify the experimented results, from this results gives better agreement with the experimented test results.
5. Compared with flat beams, corrugated web beams have reduced the weight of the beam.
6. Experimental results show that the failure of the section occurs mainly due to the buckling of flange plates and distortional buckling.

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