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Experimental Investigation of Cold-Formed Steel Section-Flexural Member with Triangular Web

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Abstract: *The present paper work dealt with the investigation on the behavior of cold form steel built up I - section with triangular web corrugation at varying depth. The effect of web corrugation and h_w/t_w ratio on the flexural strength of cold formed steel (CFS) lipped I section was presented in this paper. The length of the specimen was kept constant for 2000 mm and h_w/t_w ratio was varied from 166 to 250 keeping all other parameters as constant. In total three specimen were experimentally tested under two point loading with triangular web corrugation by considering simply support condition. The experimental results are verified with finite element analysis using ANSYS software. The results obtained from test experiments and ANSYS software were compared with the predicted Indian Specifications (IS 801- 1975). The experimental result shows that the flexural capacity of the triangular web was larger than flat web. Also the effect of h_w/t_w ratio on the flexural strength capacity was studied and discussed. Due to the provision of triangular web corrugation, there was no failure in shear zone or in web portion.*
Keywords: *Cold form steel, Triangular web, ANSYS, Flexural strength, Shear zone*

I. Introduction

One of the issues raised since the steel structure was introduced in the construction industry is how to reduce the weight and cost of the component parts such as girder and beams. Efficient and economical design of girders and beams normally requires thin webs.

However, extremely slender web will cause the web to buckle. To overcome this, the corrugated web can be used, which require no stiffening, so it permits the use of thinner plates with significant weight saving. Economical design of girders and beams normally requires thin webs. But if the web is extremely slender the problem of plate buckling may arise. Possible ways to reduce this risk are by using thicker plates; add web stiffeners or the latest innovative technique by strengthening the web by making it corrugated. Cold-formed steel members are widely employed in steel construction because they are lighter and more economical than traditional hot-rolled ones. Nowadays the easy availability and accessible cost of high-strength low-alloy steels, weathering steels, and zinc-coated steels have led to members with height/thickness ratios, rendering them even more susceptible to local buckling and to another buckling mode called distortional, Z sections, hat, rack, etc.Papia Sultana[1] has carried out a parametric study to investigate the influence of section depth, thickness, connection screw spacing, and the use of bearing plate at the support location, and material yield stress on the ultimate moment capacity of CFS built-up box girders.

Any resistance provided by the other members in the assembly depends on the efficiency of the connection components in transferring load. The theoretical and finite element analyses of the lateral–torsional buckling of I-girders with corrugated webs under uniform bending was studied by Jiho Moon et.al [2].

II. Coupon Test

The most common testing machine used in tensile testing is the universal testing machine (UTM). This type of machine has two crossheads, one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The strain measurements are most commonly measured with an extensometer, but strain gauges are also frequently used on small test specimen or when Poisson's ratio is being measured. Alignment of the test specimen in the testing machine is critical, because if the specimen is misaligned, either at an angle or offset to one side, the machine will exert a bending force on the specimen. So, provide punches on both sides it act as grips on the specimen. The Shape and dimensions as are per the recommendation of IS 1608 (part I) [3]. Thickness of specimen is 1.2 mm (approx. 18 gauge).The average value of Young's modulus and yield stress of three specimen is 1.98×10^5 N/mm^2 and 211 N/mm^2. The fig.1 represents coupon test specimen as per IS code.

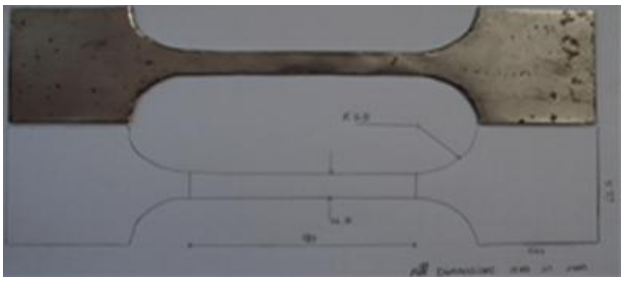

Fig. 1 Coupon test Specimen based on IS Code

III. Theoretical and Analytical Investigation

3.1 Theoretical Analysis

The calculation of the maximum load carrying capacity of the specimens was arrived by using code IS: 801 – 1975[4]. The Angle between the triangular webs is 90^0 for all the beams. The table 1 gives the details of corrugated beams. The details includes span (L), Flange thickness (t_w), web thickness (F_w),flange width (F_w), Lip distance (L_d) and depth of web (H) respectively.

Table 1: Details of corrugated beams

Specimen	Span (mm) L	Flange F_t (mm)	Web t_w (mm)	Flange F_w (mm)	Lip L_d (mm)	Depth of web H (mm)
CFD1	2000	1.2	1.2	100	15	200
CFD2	2000	1.2	1.2	100	15	250
CFD3	2000	1.2	1.2	100	15	300

Fig. 2 Cross section and cold form steel beams with varying web depth.

3.2. Analytical Analysis

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of Engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solution to problems rather than exact closed form solutions. The basic concept behind in the finite element analysis is discretization of structure, a structure is divided into a finite number of elements having finite dimensions and reducing the structure having infinite degrees of freedom to finite degrees of freedom. Then the original structure is the assemblage of these elements connected at a finite number of joints called Nodal points (Nodes). In this present paper work for finite element analysis an advanced software of ANSYS 14 was used. One end of the specimen was constrained in *X, Y and Z* directions and the other end of the specimen was constrained Y and Z direction. The nodes at the vertical side of the compression flange above, end stiffeners were constrained in the Z direction. The load was applied along transverse lines of the upper surface of the top flange above the stiffeners. The type of element chosen for finite element model idealization plays an important role in the prediction of actual behavior of the structure. The elastic properties of the material were assigned to create a model of triangular corrugated web beam. The value of Young's modulus 'E' is given as $1.98x10^5$ N/mm^2 .The Poisson's ratio is given as 0.3. The yield stress of the material is 210MPa. Density of the material is given as $7850x10^{-9}$. From the finite element behavior study it was finalized that element SHELL 63 (Four nodded thin shell elements) has to be used.

IV. Experimental Investigation

4.1 Test setup

The experimental arrangement consisted of a 1000 kN capacity UTM was used to apply loads. The load is applied axially along the centroid of the beam and it is distributed into two point loading by distributor (ISMB 150).i.e. load applying at l/3 distances. The deflection in the X and Z direction and the axial deformation in Y direction are measured by using dial gauge. The diagrammatic representation of test setup is shown in fig. 3. The fig.4 shows the experimental testing of cold formed steel beam with dial gauge and support condition.

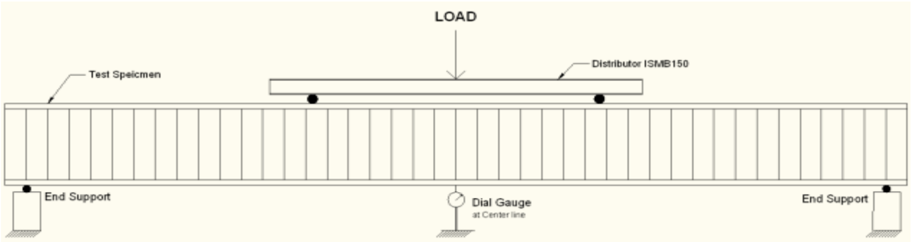

Fig. 3 Diagrammatic representation of test setup

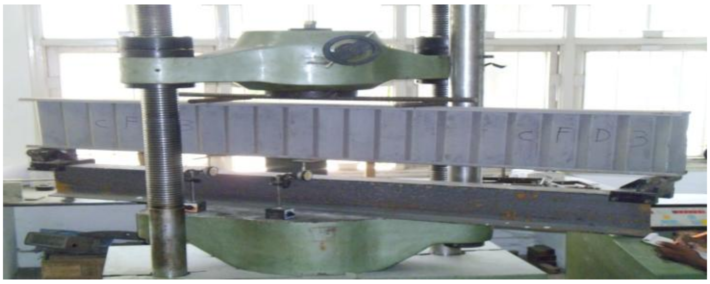

Fig. 4 Experimental testing of Cold formed steel beam.

V. Results and Discussion

Haiming Wang, Yaochun Zhang (2009) [5] studied the comparison of the bending strengths under the two bending states show that the bending strength under non-pure bending is higher than which under pure bending, but the increased magnitude is related to the buckling modes. The buckling mode is a key factor that influences the bending strength of specimens.

The experimental flexural moment are summarized in table.2. From the experimental results it was found that as the corrugation web depth increases the moment capacity also increases. All beams are crushed on top flange and Lateral torsion buckling was observed. Rate of loading for the specimen is 0.05 kN/sec. The load and deflection readings were taken out. Due to loading the beam start buckling, at the end of the test, failure mode were analyzed. The failure mode of test specimen are shown in fig.5 .

Fig. 5 Failure mode of test specimen- crushing on top flange.

Fig. 6 Failure mode of test specimen- lateral torsional buckling.

5.1 ANSYS result

The results obtained from the ANSYS analysis of I section with flat web and I section with corrugated web beam models are presented. Comparisons were made between the ANSYS and experimental results. Discussions were carried out with respect to the comparisons of load capacities and the mode of failure occurred. The fig.6 shows meshed test specimen with boundary condition and applied loads. The results of the experimental programme was tabulated in table 2. The fig.8 shows the comparison of test results.

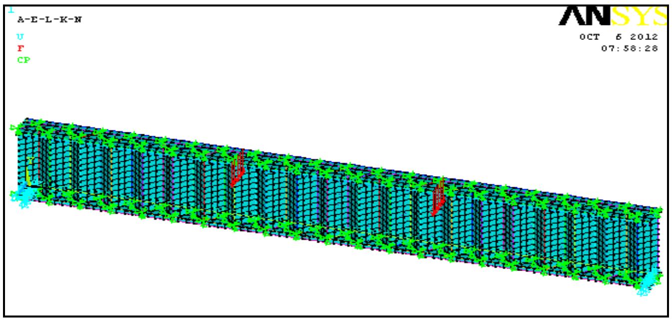

Fig. 7 Meshed test Specimen with boundary condition and loading.

Table 2. Result for corrugated beams

Specimen	Web Depth mm	ANSYS N	Theory N	Experiment N
CFD 1	200	13752	14550	14900
CFD 2	250	16498	16680	16500
CFD 3	300	19248	19500	19000

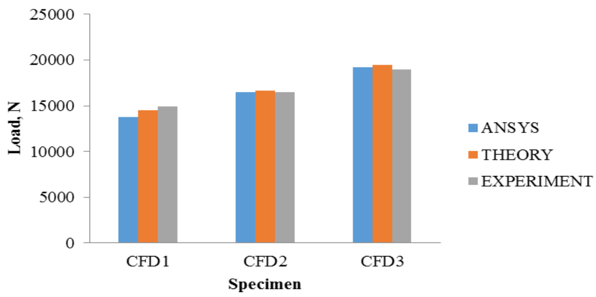

Fig. 8 Comparison of results.

VI. Conclusion

From the experimental investigation of cold formed steel beam the following conclusion were drawn:

- When the triangular corrugation web increases the flexural capacity also increases.
- All the specimens failed due to crushing on top compression flange and lateral buckling.
- Numerical Validation has been carried out to verify the appropriateness of the experimental results and found that they are quite closer to the corresponding test results.
- Due to the corrugation provision, there is no failure in shear zone or web portion.
- The code results are conservative.

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