Experimental Study on Flexural Behaviour of Cold formed Hollow Flanged Z – Sections

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Abstract: *In general, types of loads acting on structures can be broadly classified as vertical loads, horizontal loads and longitudinal loads. The vertical loads consist of dead load, live load and impact load. The primary vertical load, which is the dead load of the structure is mainly due to self-weight of structural members. Therefor in any construction of building or a structure two major factors considered are safety and economy. If the loads are adjusted and taken higher, then economy is affected. If economy is considered and loads are taken lesser, then the safety is compromised. So maintaining a favourable benchmark compromising neither on safety nor on economy is crucial for any structure. In simple words, the structure which has higher load sustained by self-weight ratio is to be determined. In this paper, various Z - hollow flange cold formed steel sections are considered for the said purpose. Hollow flanged sections are selected for this study since they are used generally in roof trusses, where self-weight being the key concern. The sections are tested under flexural load and the load/weight ratio of the sections are found, for the rating the performance of the sections.*

Keywords: **Primary vertical load, safety and economy, Z – hollow flange cold formed sections, flexural load, load by weight ratio.**

1. INTRODUCTION

Cold formed steel as a structural material possess many benefits. It does not shrink or split, won't absorb moisture, and resists warping, termites, and fire. Cold formed steel sections are preferred due to its foremost properties such as light weight, high strength to weight ratio and any type of shapes can be fabricated. The cold forming on steel has increased effect of yield strength, since cold working is during strain hardening age. These qualities of cold formed steel make it valid for use, instead of the hot rolled steel sections in various structural members.

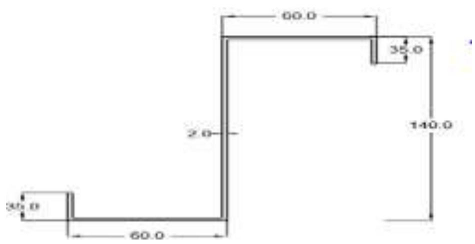
The 'Z' shaped section is considered, since it has higher moment of inertia about its major axis than the 'I' shaped sections. When cold formed steel section is used as a flexural member, the modes of failure are generally local buckling, distortional buckling and lateral buckling. Thus cold formed steel section needs special attention to improve its failure behaviour. This directs the research to introduction of high rigid sections in cold formed steel. With regard to that, an advanced cold formed steel section called hollow flanged steel section is introduced to replace the conventional cold formed steel sections. Thus the considered section for this study is the Hollow Flange Steel beams (HFSB) which are made of two torsionally rigid closed flanges and a slender web. This type of section can be more effectively used since the flanges provide most of the bending property and web provides the shear resistance. The hollow flange has more rigidity against buckling and torsional property, which makes it ideal for testing. The section strengths are determined based on the limiting deflection of the beam and its efficiency by the self-weight to load ratio. The stress vs strain curve aids in understanding the behaviour of the individual sections.

2. SECTION SPECIFICATION

The section with different cross section are considered for the experimental investigation. The 4 type of Z-section considered are, Rectangular Hollow Flange Beam (RHFB), Triangular Hollow Flange Beam type-1 (THFB-1) whose triangular flange apex is facing outward, Triangular Hollow Flange Beam type-2 (THFB-2) having its triangular flange apex is facing inward and normal z-section section.

The section specifications such as thickness, overall depth and the width of the Z - sections are based on the IS 811-1987: 'Code of practice for Cold formed light gauge structural steel section'. However, the flange depth is taken from the works done by [1] Mangala gowri [1], Karunagaran and Helen [2]. They proposed analytical results on the hollow flanged rectangular Z-section and its optimum benefit to resist large load and its effective flange depth for the same. As per that, the selected depth of flange should be one fourth of the total depth of the section.

The section specification for the Z - Sections and the hollow flanged Z-section are selected as follow the width of the flange as 60mm, the Depth of the flange as 35mm, total depth of the section is 140mm, thickness of the section is 2mm for the total span of 1000mm are used for the experimental study.



(All dimensions are in mm)

Fig1 - Normal Z-section Beam

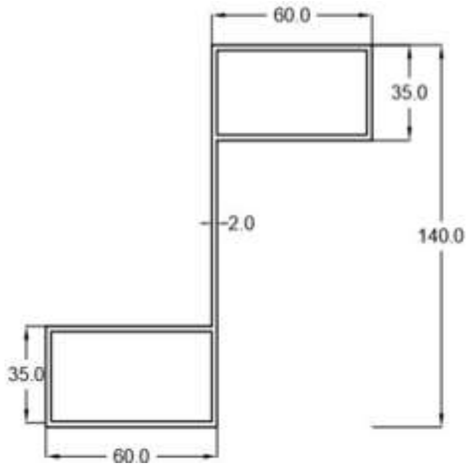


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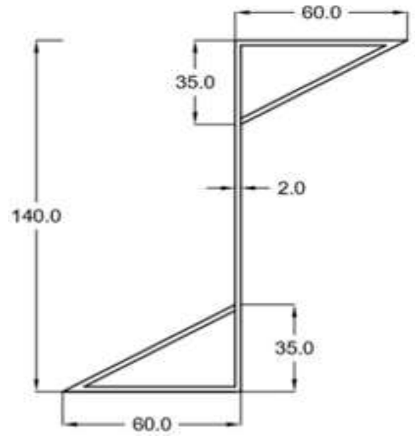
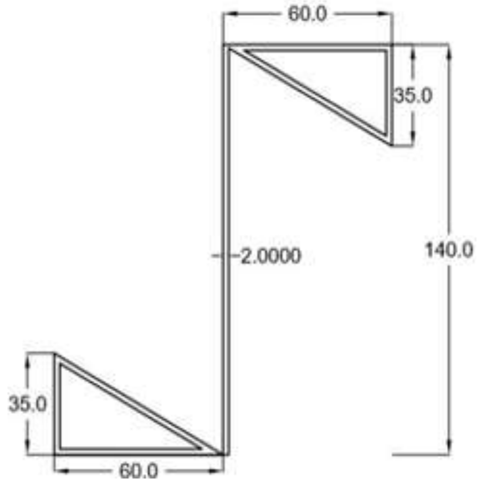
Fig 2 - Rectangular Hollow Flanged Beam (RHFB) Z- section



(All dimensions are in mm)

Fig 3 - Triangular hollow flange beam type-1 (THFB-1) Z-section



(All dimensions are in mm)

Fig 4 - Triangular hollow flange Beam type-2 (THFB-2) Z-section

3. EXPERIMENTATION

3.1 Fabrication

Cold formed steel, manufactured at room temperature with steel sheets of thickness 2mm. This is then fabricated into different shapes of specimen by two methods are cold roll forming and press breaking. The method adopted for fabrication of normal and HFB Z-section in this study is the press braking method.

Initially the 2mm thickness cold formed steel sheet of required length is bend into Z-section by press braking machine, then the hollow shapes are formed by electric resistance welding technique. This technique is used to weld the plate with the flange of Z-section to form triangular and rectangular hollow flanges. Finally, the full Hollow Flanged Z-section is fabricated at appropriate section specifications.

Fig 5 – Fabricated Test specimens

3.2 Loading Condition

The beam is loaded by two loads placed symmetrically between the supports. In this method there are four important points (two end supports and two loading points) along the span of the beam. Thus, it gives four-point bending. Hence, this method is called four-point bending.

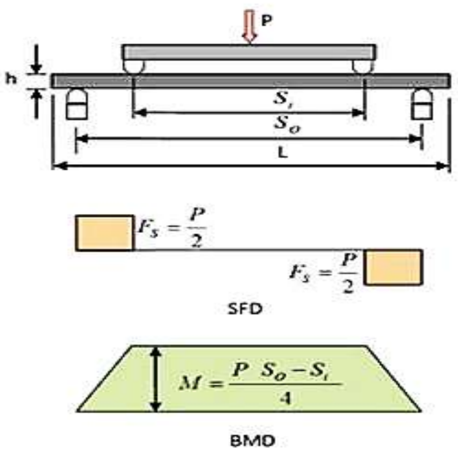


Fig 6 – Laboratory testing method

The S_0 is the clear distance between the two supports and S_1 is the distance between the loads which has taken as $S_0/3$ i.e. the distance between the loads is equal to the distance between the support and the load. For four-point bending there is uniform bending moment, and shear force is zero between the loading points. Thus, it leads to the pure bending loading. Such a state of stress is desirable in testing.

3.3 Supporting conditions

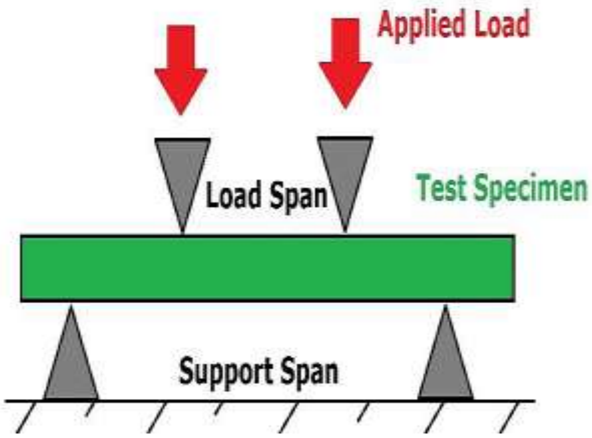


Fig 7 – Laboratory Support setup

The sections are supported on both ends under pinned condition and the span length of the all sections are maintained as 0.8 m with supports at L = 0 mm and L = 800mm.

3.4 Limiting criteria

The limiting criteria refers to a normalized scale or value, which is used to compare the results of the various sections to analyse the efficiency of the sections on a common scale. In this paper, deflection is used as a normalized value for comparing the load carrying capacity of the sections. The deflection limit is taken as span / 300 as per BS 5950-5:1998 "Code of practice for design of cold formed thin gauge sections".

4. RESULTS AND DISCUSSION

The flexural beam testing was carried out for four type of specimen in Universal testing machine of 200 tonne capacity contain movable supports suitable for required span. The load and the deflection obtained correspondingly are noted and extrapolated if required.

Linear Variable Differential Transformed (LVDT) is used to measure the deformation of the specimen. LVDT is placed at the center of the bottom flange to determine the deflection of the section. As the load is gradually increased by hydraulic jack the cold formed beam starts deflecting at the same time local buckling occur at the bottom of the load. The individual sections and its behavioural details are compiled.

4.1 Normal Z-section

The Z - section though having a lip at the flanges, has the least cross sectional area. This section is expected to carry the least load as well, since it has relatively lower moment of inertia about its horizontal axis.

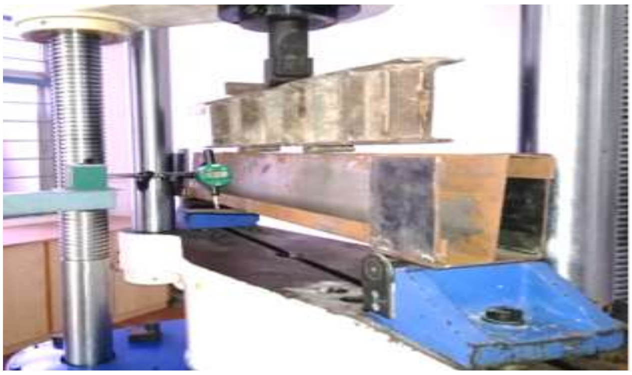


Fig 8 – Laboratory testing on normal Z – section

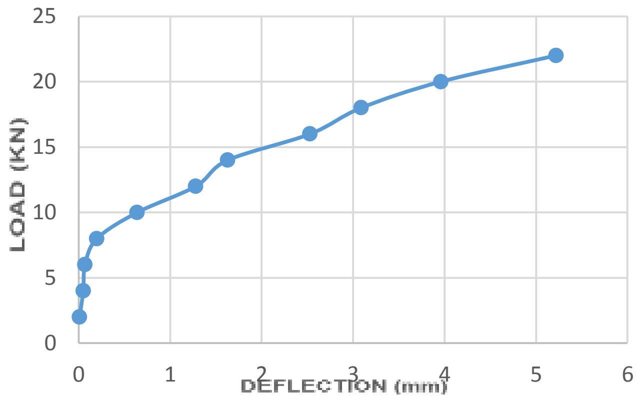


Fig 9 – Load vs deflection graph of normal Z – section

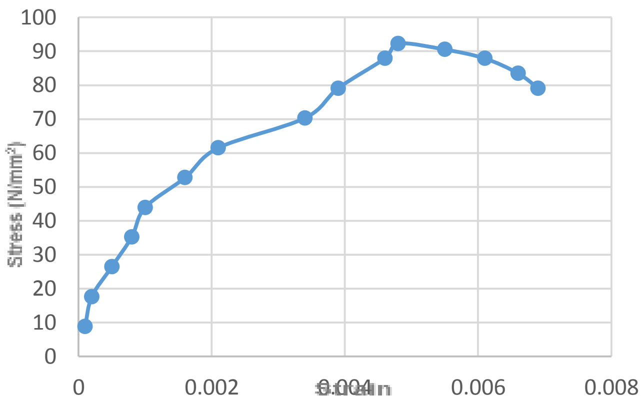


Fig 10 – Stress vs strain graph of normal Z – section

Inference – Normal Z-section

- The maximum load sustained by the normal Z-section is 21kN the beam undergone a deflection of 4.42mm.
- Yield stress of the normal Z-section is 70.306 N/mm2 and ultimate stress of the section is 92.3 N/mm2.
- Ductility factor of the section is 1.3

4.2 Triangular Hollow Flanged Z - section Beam type-1

This section has triangular hollow flanged cross section, with the apex of the triangular flange faced outwards from the section at flanges. Also the section has a higher moment of inertia than the conventional Z – section.

Fig 11 – Laboratory testing on THFB-1 Z – section

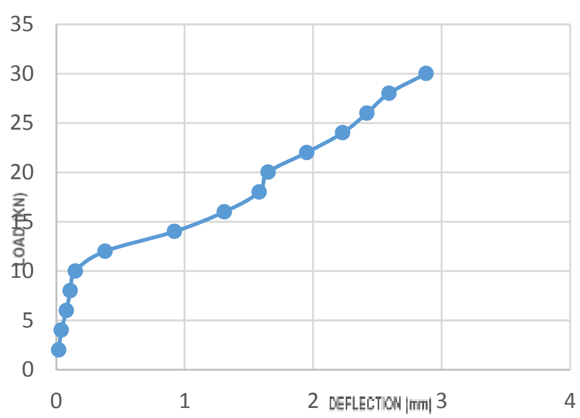


Fig 12 – Load vs deflection graph of THFB 1 Z – section

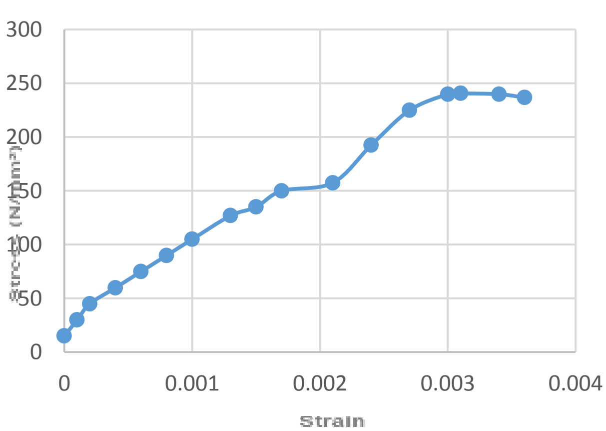


Fig 13 – Stress vs strain graph of THFB 1 Z – section

Inference – THFB 1

- The maximum load sustained by the triangular hollow flange type-1 section is 29kN makes the section deformation of 3.88mm
- The yield stress of the section is 157.35N/mm^2 and Ultimate stress of the section is 240.53N/mm^2
- Ductility factor of the section is 1.52

4.3 Triangular Hollow Flanged Z-section Beam type-2

This type 2 triangular hollow flanged section, is differentiated from the type -1 section by its triangular flange's apex faced towards the web of the section. This section would have higher cross sectional area than the type-1 section because, there is an extra member at the base of the triangle, place outward and parallel to the web.

Fig 14 – Laboratory testing on THFB-2 Z – section

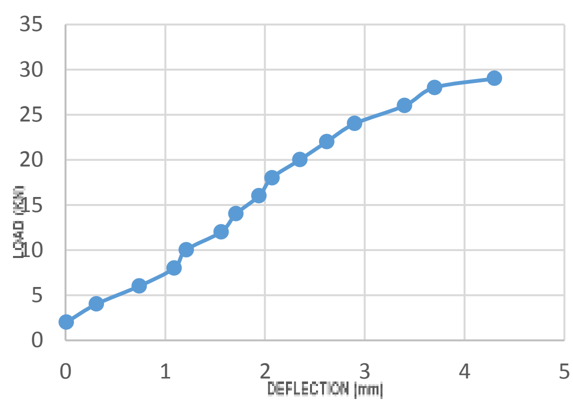


Fig 15 – Load vs deflection graph of THFB 2 Z – section

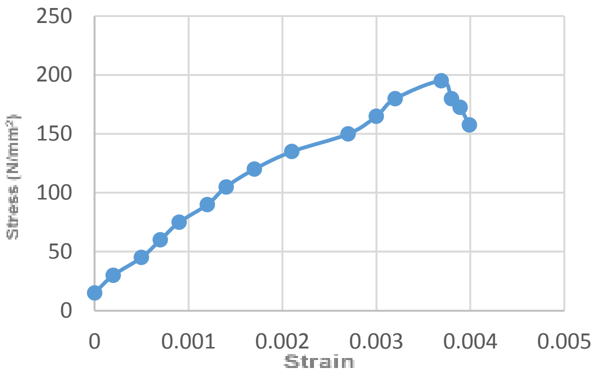


Fig 16 – Stress vs strain graph of THFB 2 Z – section
Inference – THFB 2

- The maximum load sustained by the triangular hollow flanged type-2 section is 29KN makes the section deformation of 4.3mm
- The yield stress of the section is 142.97N/mm^2 and Ultimate stress of the section is 194.82N/mm^2
- Ductility factor of the section is 1.36

4.4 Rectangular Hollow Flanged Z-section Beam

The rectangular hollow flanged section, has the maximum cross sectional area and maximum moment of inertia among all the considered sections. The depth and width of the hollow flange are selected as 35mm and 60 mm respectively, as per predetermined specifications.

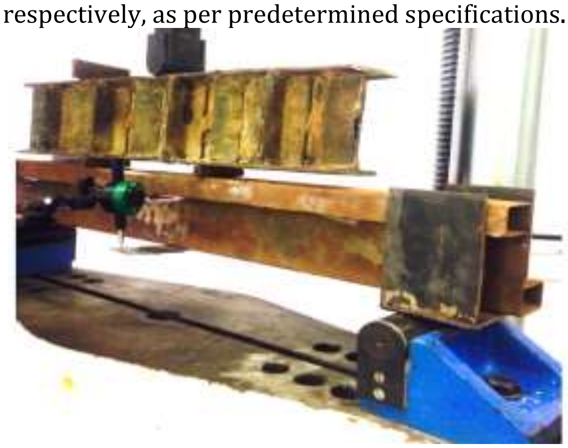


Fig 17 – Laboratory testing on RHFB Z – section

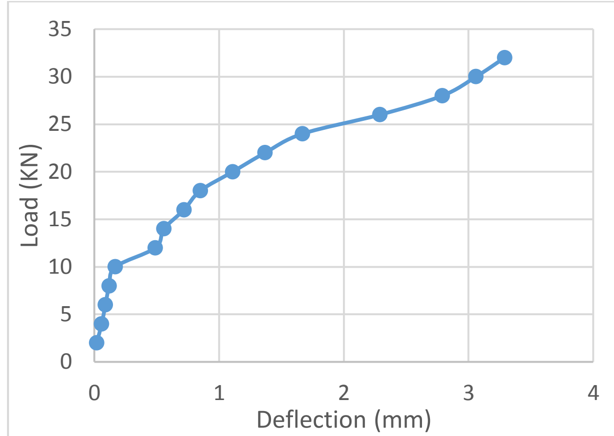


Fig 18 – Load vs deflection graph of RHFB Z – section

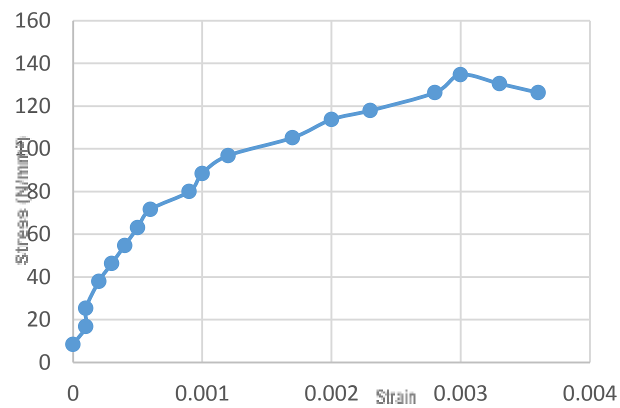


Fig 19 – Stress vs strain graph of RHFB Z – section
Inference – RHFB

- The maximum load sustained by the rectangular hollow flanged Z-section is 32KN makes the section deformation of 3.26mm
- The yield stress of the section is 105.24N/mm^2 and Ultimate stress of the section is 126.28N/mm^2
- Ductility factor of the section is 1.2

5. INTERPRETATION

The experimental studies are conducted and the results are attained. The steel adopted for the sections are mild steel with an average yield stress of 250 MPa and the young's modulus adopted is 2x10^5 MPa. As per the BS 5950-5:1998 "Code of practice for design of cold formed thin gauge sections" the deflection limit is 2.67mm (span/300) where the span in mm. The results of proposed four type of section are shown below. Load/Weight ratio is used as a tool for determining the efficiency of the sections. This ratio means that the amount of self-weight required to sustain per increase in load carrying capacity of the section, which means that higher the ratio, greater the performance of the section.

Table 1 - Test results for proposed specimens

Section types	**Ductility factor**	**Yield stress (MPa)**	**Load at Limiting Deflection (kN)**	**Weight (kg/m)**	**Ratio of Load at limiting deflection and its Weight**
Normal Z-section	1.31	70.3	15.5	5.18	2.99
RHFB	1.2	105.2	28.5	7.07	4.03
THFB1	1.52	157.4	27.5	6.26	4.39
THFB2	1.36	142.3	21.0	7.36	2.85

- When compared to the Normal Z-section, percentage of load carrying capacity increased by 83% for RHFB, 77% for THFB1 and 35% for THFB2 section.
- The Ductility factor of the Triangular Hollow Flange type-1 has 16% and type-2 has 3% is more than compared Normal Z-sections. Thus the THFB type-1 shows the good yielding behaviour before failure.
- On the basis of load/weight ratio the Rectangular and Triangular Hollow flanged Z-sections have higher efficiency than the Normal Z-section. Triangular hollow flange type-1 have the highest ratio among all the section.

6. CONCLUSION

Experimental investigation and the followed results shows that the built-up hollow flanged Z-section perform better than normal Z-sections.

- The load carrying capacity at the limiting deflection for the RHFB is 83% more than the normal z-section. RHFB has maximum load carrying capacity than all other type of Z-section.
- The THFB1 Z-section load carrying capacity shows only 6% less than RHFB Z-section.
- The Ductility behaviour before failure of the structural sections is better for THFB-1 with a maximum ratio of 1.0
- The load sustained by self-weight ratio of the THFB1 is 54% higher in comparison with the normal Z-section. Thus it indicates that material requirement is lesser for the maximum load sustain.

On over all comparison of the sections, the Triangular Hollow flanged beam type-1 (THFB1) section shows better performance as a flexural member with increased cost efficiency.

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