# Adaptation of Corrugation Web in Cellular Beams with Hollow Flange

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**Abstract:- Nowadays Cold Formed Steel (CFS) sections are extensively used in structural engineering works replacing the conventional hot-rolled sections. It is due to the inherent advantages of the CFS. In industrial buildings and also in multi-storey buildings it is mandatory to provide web openings and they are generally provided in CFS roof and flooring systems to accommodate the pipelines and the building services, which leads to the reduction of floor heights. The disadvantage of placing web openings are, it will influence the shear behaviour reduce the strength and shear capacity significantly. The beam stiffness will decrease when web openings are placed, so it will buckle the beam easily when high seismic force or working loads are acted. Also shear failure will takes place. To prevent these hollow flanges are provided with straight beams. So very limited research studies have been conducted on hollow flange CFS beam with web openings. In this study to avoid shear buckling, use the method of implementation of corrugated webs. This study is about how strength and the shear capacity are improvising by implementing corrugated design in cellular beams. Two methods are used for improvising. First is with different type of corrugated shapes. They are square type corrugation, rectangular type corrugation and trapezium type corrugation. Second is with varying the thickness of the web. In this method instead of stiffening the web externally, they are inbuilding it by these corrugation design. The test conducting are shear and flexural test. By this it is expected that the moment of inertia of web and strength will increase, also the possibility of shear buckling decreases. The complete study is carried out using a finite element method in ANSYs software. The results details that the corrugated web hollow flange cellular beams has less weight and more strength than the flat web hollow flange. So the corrugated web cellular hollow flange beams have better performance than the flat web cellular hollow flange beams.**

***Keywords: Hollow Flange Beam, Web Openings, Corrugated Web, Cellular Beams***

## 1. INTRODUCTION

The installation of Cold-Formed Steel (CFS) components in contemporary construction is growing as a result of its benefits, including its light weight, high strength, flexibility, affordability, and ease of prefabrication. In Early in the 21st millennium, One Steel Australian Tube Mills (OATM) created a Hollow Flange Channel (HFC) section known as the Lite Steel Beam (LSB) by employing traditional cold rolling and then an electrical resistance welding technique. The hot-rolled conventional portions are heavier than the HFC sections, which are said to have a comparable bending strength. The LSBs are generally employed as structural components in structures for commercial, residential, and industrial buildings. Rectangular Hollow Flange Beams (RHFBs), a recently introduced steel member appropriate for extended span in many applications, are among the various open and hollow sections of CFS members.

Doubly symmetric RHFBs have better structural efficiency and buckling capacities than conventional CFS sections (Z-section and C-section) and hot-rolled I section. They consist of a central flat web plate with rectangular hollow flanges on the bottom and top of the section, as shown in Fig.1. Due to reduced web width and the absence of open edges, the section exhibits better local buckling capacity. Rigid hollow flanges further avoid distortional buckling caused by torsional effect. Fig.2. shows the hollow flange beam with circular web opening.

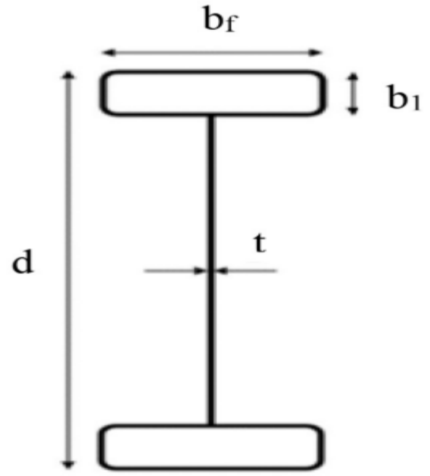


Fig.1. Doubly symmetric hollow flange beam [1]

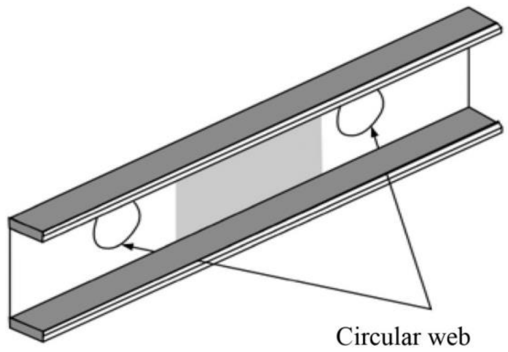


Fig.2. Monosymmetric hollow flange beam with circular web openings [1]

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*1.1 Web openings in CFS beams*

In order to lower the floor height by accommodating the building service conduits (electrical, plumbing, heating and ventilation), web openings in CFS beams are mostly employed in roof and flooring systems, as shown in Fig.3. The presence of web holes is found to significantly reduce the section's shear strength while having little to no impact on its flexural strength. The shear capacity of a CFS section with an unreinforced web opening may be influenced by a number of factors, including the section's size and shape, the web's slenderness, and the location of the web hole.

Fig.3. Service integration on beams through web openings [1]

*1.2 Corrugated web beams*

As an alternative to steel girders with flat webs or fabricated girders with a thin-walled corrugated web and flanges made of plate steel, hollow profiles, electric welded pipes, or reinforced concrete elements, corrugated web beams are welded I-sections with thin-walled sinusoidal corrugated webs. Corrugated web beams have a significant material cost advantage over hot-rolled or welded I-beams with flat webs, as well as completely automated production. Since corrugated web beams can frequently be loaded up to their plastic resistance without web reinforcing, they are lighter than flat web beams, assuming the same load-bearing capacity. Fig.4. shows the trapezoidal corrugated web beams.

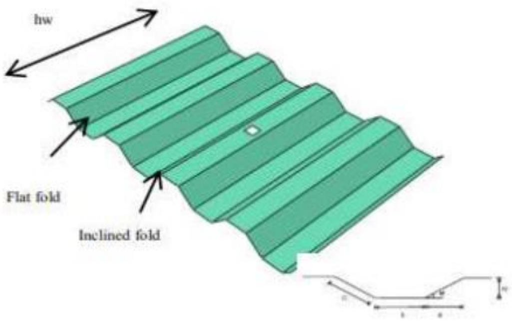


Fig.4. Trapezoidal corrugated web

## 2. FINITE ELEMENT STUDY

*2.1 General and Meshing*

The key objectives of this research are to evaluate the load carrying capabilities of the castellated beams and identify the predominant failure modes.

Material nonlinearities were incorporated into the finite element models throughout development in ANSYS workbench. Element type used is shell 181, element size is 10 mm and element shape of meshing is Qaud shape which is extensively used in earlier studies, was employed for modeling the beam.

The following are the geometrical characteristics of the cellular hollow flange beams (CHFBs) taken into account in this study:

| | | |
|---|---|---|
| 1. | Width of flange ($b_f$) | 55 mm |
| 2. | Thickness of flange ($t_f$) | 5 mm |
| 3. | Depth of web ($d_w$) | 90 mm |
| 4. | Thickness of web ($t_w$) | 4.7 mm |
| 5. | Overall depth (h) | 100 mm |

The definitions of the key words used in CHFB modelling are shown in Fig. 5. For this investigation, mild steel is used as the material. Steel has a yield strength of 329MPa, a density of 7850 kg/m3, a Young's modulus of 2x1011 N/m2, and a Poison's ratio of 0.3. The boundary conditions were simply supported, which means that one end had a roller and the other an end hinge.

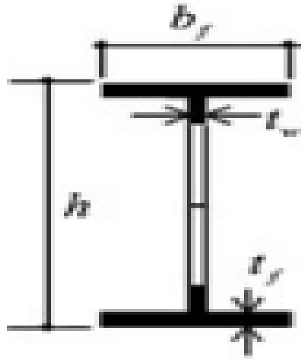


Fig.5. Terms used in the cellular beam.

## 3. VALIDATION

To confirm the numerous factors taken into account during the model development, such as the type of elements, mesh size, boundary conditions, and loading patterns, the generated model must be validated. This will make sure that the failure mechanism and ultimate capacity of RHFBs with web openings are accurately replicated. Keerthan & Mahendran conducted experimental research on LSB sections without and with web openings to estimate the shear strength also Dinesh Lakshmanan Chandramohan, Elilarasi Kanthasamy conducted numerical research on doubly symmetric hollow flange beam with web openings to estimate the shear strength. One model with web opening and without web opening is validated.

TABLE 1 COMPARISON OF VALIDATION RESULTS

| | Load (kN) | | Error percentage |
|---|---|---|---|
| | Experimental model | FEA model | |
| Without hole | 20.47 | 19.50 | 4.74 |
| With hole | 18.45 | 19.70 | 6.78 |

## 4. PARAMETRIC STUDY

A detailed parametric research was conducted to examine the impact of geometric parameters on the shear capacity

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and behaviour of CHFBs after the validation of FE modelling methods. The nominal dimensions of I sections with the model flat web hollow flange and with the corrugated web hollow flange (trapezoidal web) were represented in this study by three separate sections, each measuring 100X55X4.7, 125X55X4.7, and 150X55X4.7 all with a thickness of 5 mm.
To prevent combined shear and bending failure, the shear span aspect ratio (shear span /web depth) was kept at 10 while the web opening ratio ($D/d_w$) was changed as 8 and 6.667. As a result, a strength database containing the parameters mentioned previously was used to analyse the shear strength and behaviour of cellular hollow flange beam (CHFB) with flat web and also CHFB with trapezoidal web. Fig.6. shows CFHB with flat web and Fig.7. shows the CHFB with corrugated web. Fig.8. shows the geometry of CHFBs with corrugated web.
The beams are loaded with center-point loading. Based on the shear span to effective depth ratio, the load point was established.

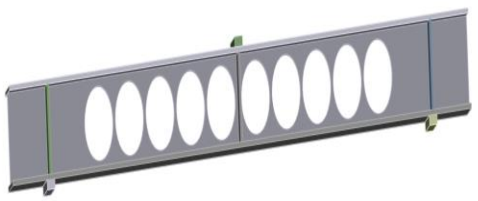

Fig.6. Model of cellular hollow flange beam with flat web

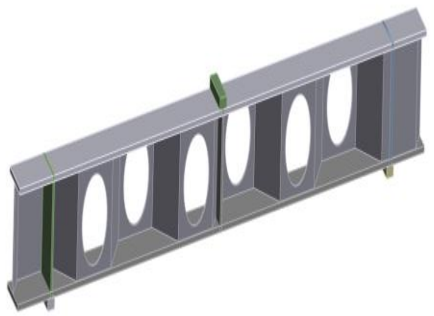

Fig.7. Model of cellular hollow flange beam with corrugated web

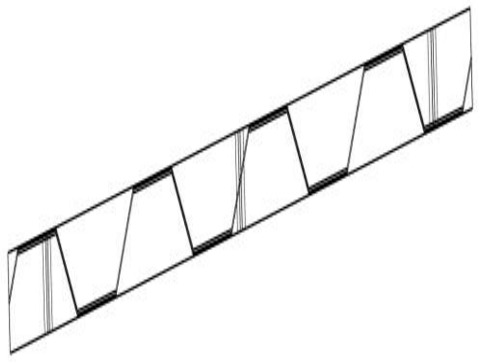

Fig.8. Geometry of corrugated web CHFB

## 5. RESULT AND DISCUSSION

This section examines how CHFBs that have flat web openings and corrugated web openings, which are the results of a parametric analysis, respond to shear. Table 2 demonstrates the ultimate shear capacity of the CHFBs with flat web for the sections 100x55x4.7, 125x55x4.7, 150x55x4.7 and table 3 demonstrates the ultimate shear capacity of the CHFBs with corrugated web for the sections 100x55x4.7, 125x55x4.7 and 150x55x4.7 respectively. Fig.17. shows the load comparison graph of flat web CHFB and trapezoidal web CHFB.

TABLE 2 PARAMETRIC STUDY RESULTS OF CHFBS WITH FLAT WEB

| Section $d \times b_f \times t_w$ (mm × mm × mm) | Mass (kg) | Thickness $t_f$ (mm) | $D/d_w$ | fy = 329 MPa Load (kN) |
|---|---|---|---|---|
| FLAT HT 100 (100x55x4.7) | 8.3278 | 1.5 | 10 | 15.999 |
| FLAT HT 125 (125x55x4.7) | 9.5827 | 1.5 | 8 | 26.722 |
| FLAT HT 150 (150x55x4.7) | 10.838 | 1.5 | 6.667 | 41.338 |

TABLE 3 PARAMETRIC STUDY RESULTS OF CHFBS WITH CORRUGATED WEB

| Section $d \times b_f \times t_w$ (mm × mm × mm) | Mass (kg) | Thickness $t_f$ (mm) | $D/d_w$ | fy = 329 MPa Load (kN) |
|---|---|---|---|---|
| TRA HF HT 100 (100x55x4.7) | 6.7373 | 1.5 | 10 | 20.849 |
| TRA HF HT 125 (125x55x4.7) | 7.4285 | 1.5 | 8 | 39.73 |
| TRA HF HT 150 (150x55x4.7) | 8.1197 | 1.5 | 6.667 | 42.811 |

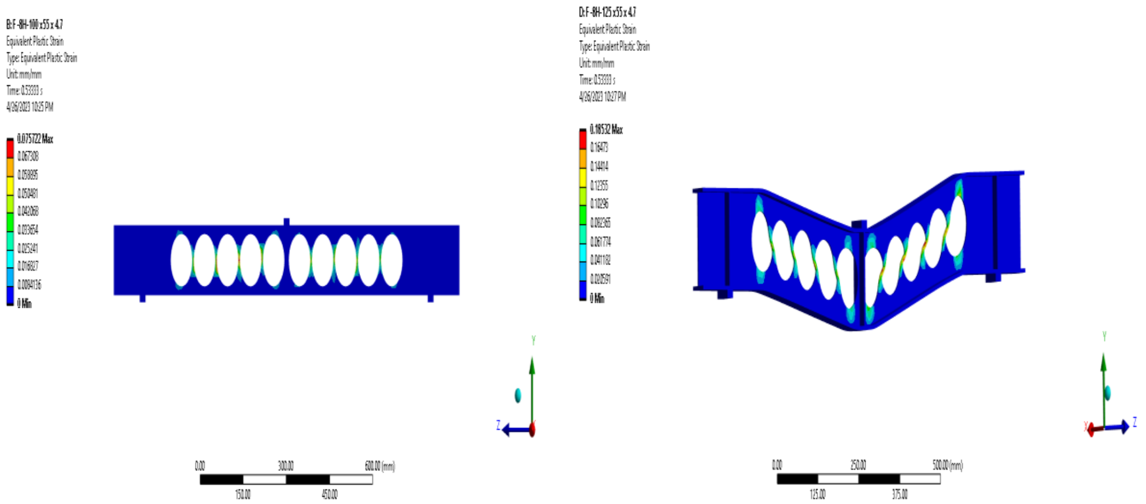

Fig.9. Equivalent plastic strain of flat web I section (FLAT HT 100 and FLAT HT 125)

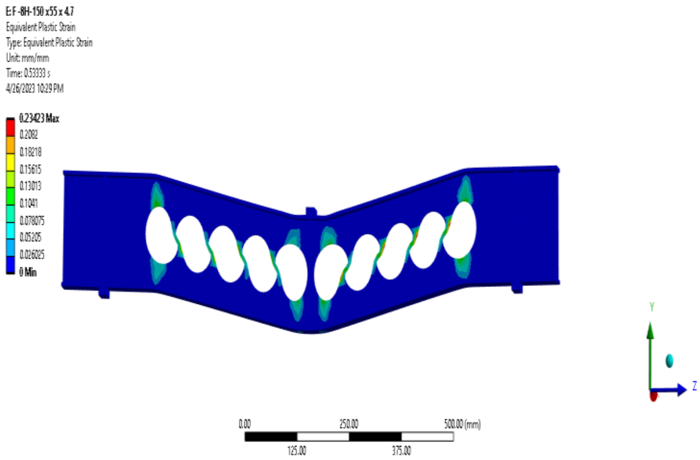

Fig.10. Equivalent plastic strain of flat web I section (FLAT HT 150)

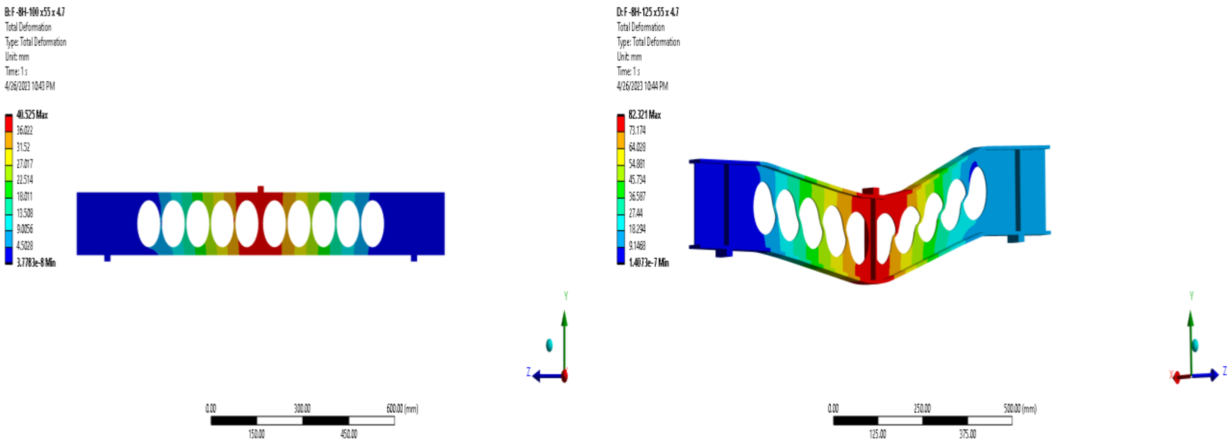

Fig.11. Total deformation of flat web I section (FLAT HT 100 and FLAT HT 125)

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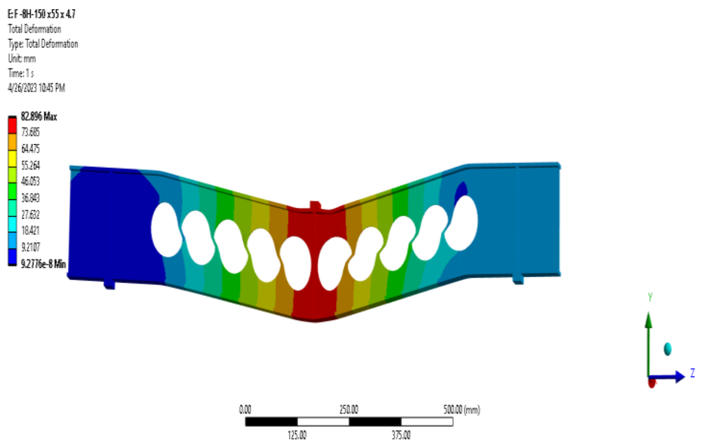


Fig.12. Total deformation of flat web I section (FLAT HT 150)

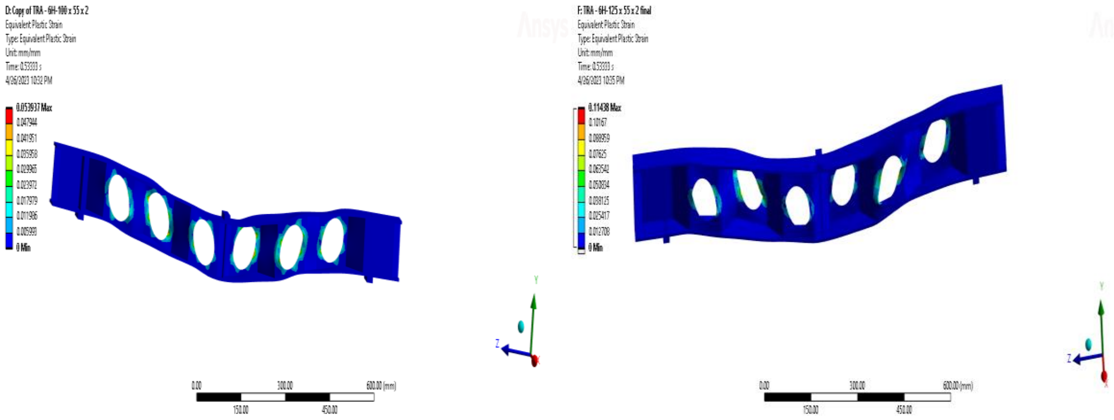


Fig.13. Equivalent plastic strain of trapezoidal corrugated web section (TRA HF HT 100 and TRA HF HT 125)

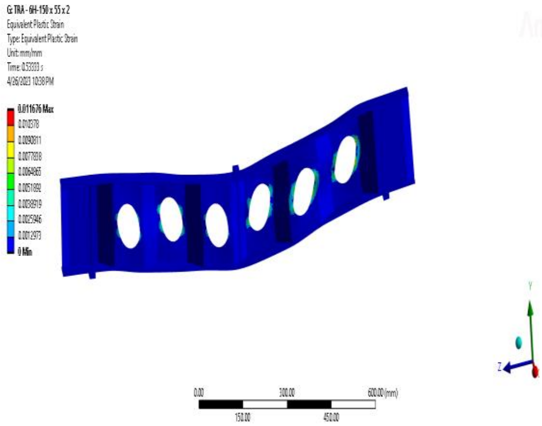


Fig.14. Equivalent plastic strain of trapezoidal corrugated web section (TRA HF HT 150)

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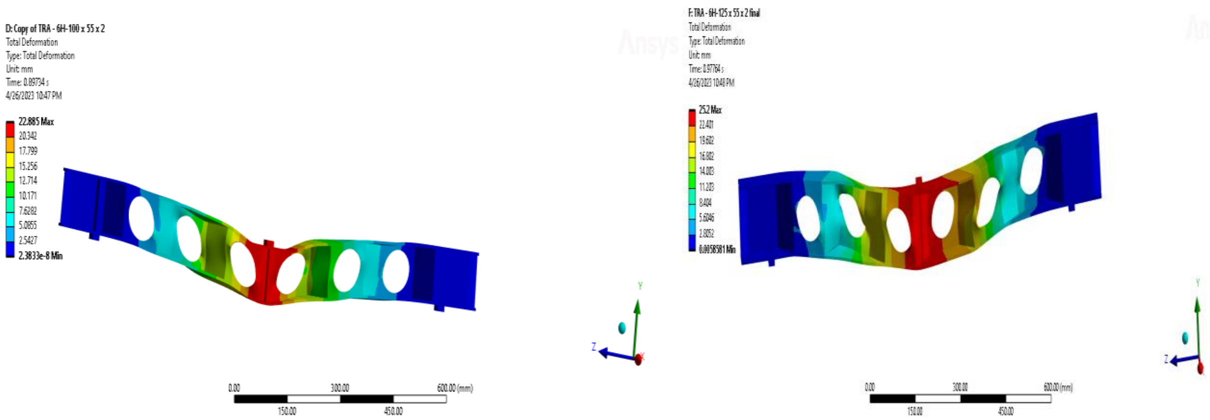

Fig.15. Total deformation of trapezoidal corrugated web section (TRA HF HT 100 and TRA HF HT 125)

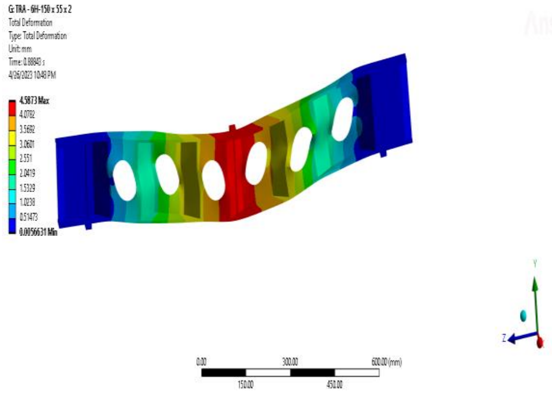

Fig.16. Total deformation of trapezoidal corrugated web section (TRA HF HT 150)

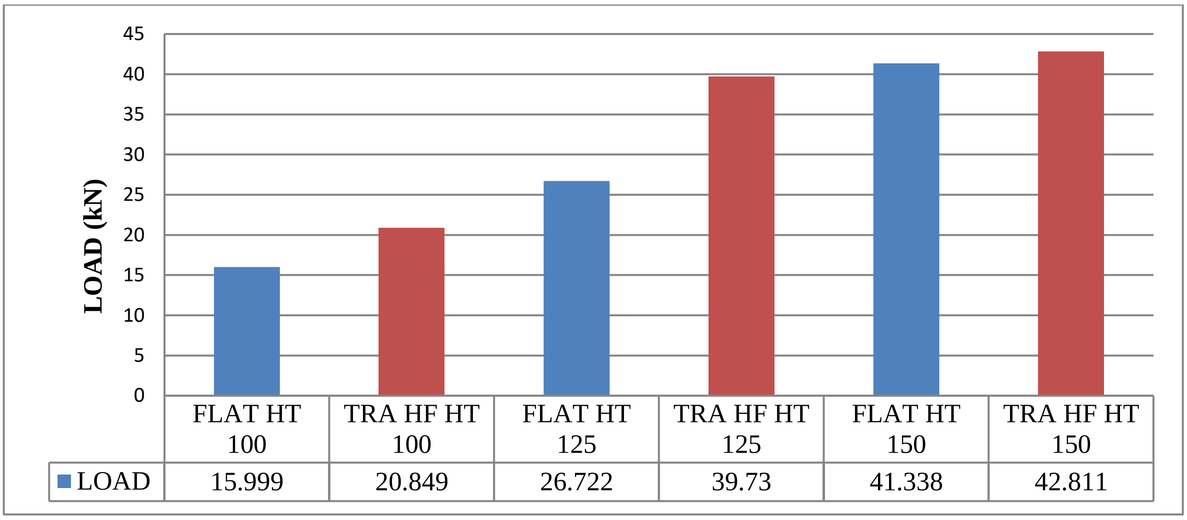


Fig.17. Load comparison graph of CHFB with flat web I section and CHFB with corrugated web

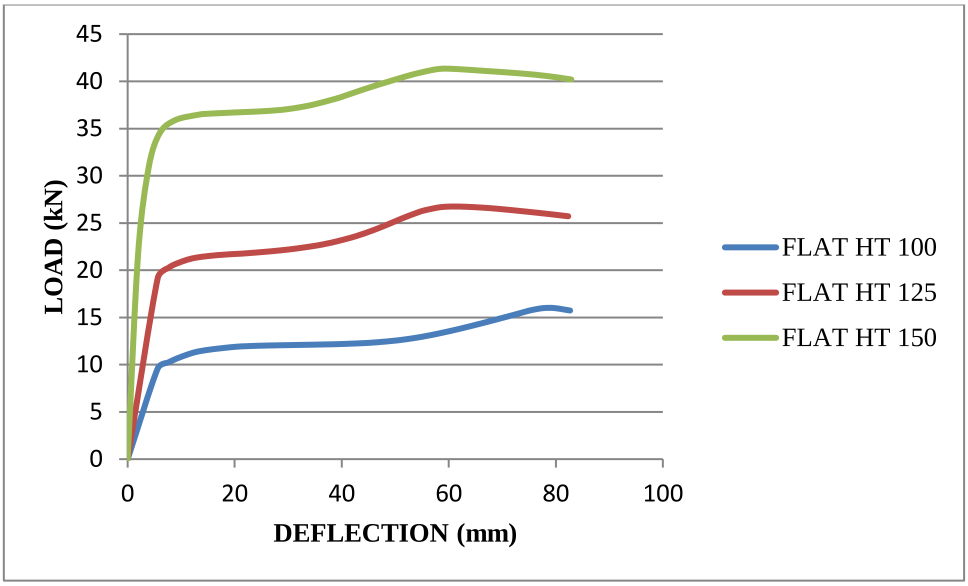


Fig.18. Load deflection curve of flat web I section

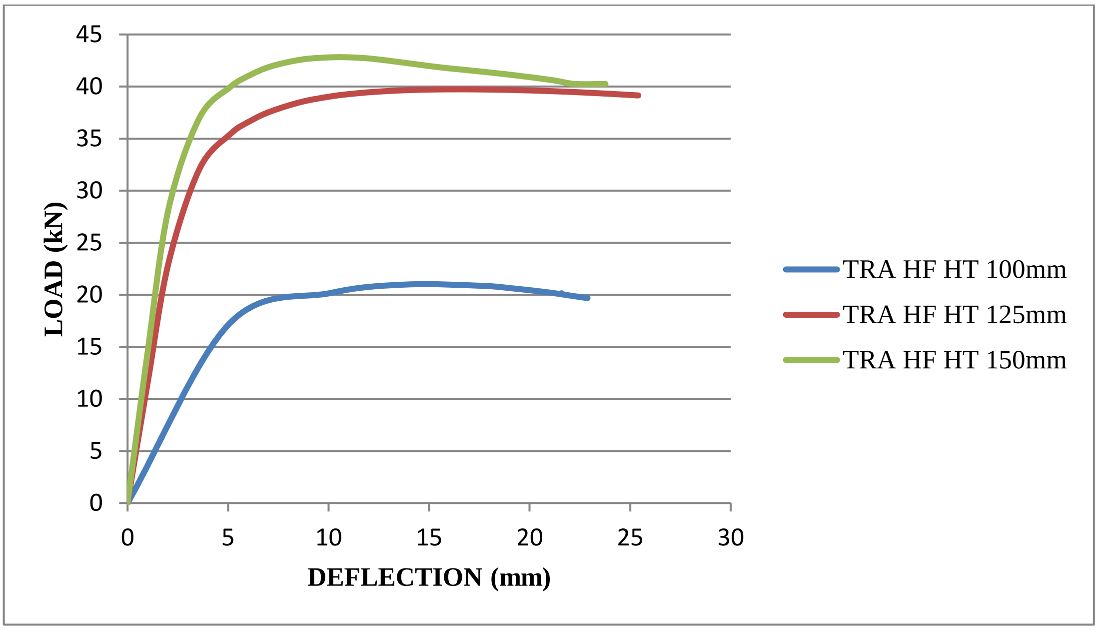


Fig.19. Load dflection curve of trapezoidal corrugated web section

## 6. CONCLUSION

The present study uses numerical analysis to offer a thorough examination into the shear behaviour of doubly symmetric RHFBs with circular web openings.

- Comparing the results of corrugated web and flat web, the corrugated web consumes lesser weight than the flat web with hole.
- Also have more strength than the flat web with web opening.
- The percentage of varying strength is 23.63% for 100mm height.
- Beyond 125mm height the performance of corrugated web is not much effective when compare with the flat web.
- Even though the weight is optimized but the performance is getting decreased when compared with the flat web.
- Trapezoidal corrugated web with web opening is giving better performance than the flat web with web opening.

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