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# ANALYTICAL STUDY OF COLD FORM BUILT-UP SECTION WITH FOLDED FLANGE UNDER ECCENTRIC LOADING

**[1]Jigna Rabadiya, [2]K. A. Parmar**
[1]Post-Graduate Student, [2]Assistant Professor
[1]Department of Structural Engineering, L.D. Collage of Engineering, Ahmedabad, Gujarat, India
[2]Applied Mechanics Department, L.D. Collage of Engineering, Ahmedabad, Gujarat, India

***Abstract:*** In cold formed steel are several application where built-up I section are used to resist load induced in a structure when a single section is not sufficient to carry the design load. But in India, use of light gauge steel is not in trend for civil structures. Also, the structural behavior of these thin-walled steel structures is characterized by various buckling modes such as local buckling, distortional buckling or flexural-torsional buckling. These buckling problem lead to serve reduction and complication in calculation of their member strength. The objective of this study, built-up section with folded flange section having length varying 0.9 to 1.6 m also varying various parameter like thickness of section 1 mm to 2 mm, length of folded flange 15 mm to 45 mm, flange width 45 mm to 50 mm tested under concentric and varying eccentricity axial compression loading. In this paper, Study is focus not only on axially loaded columns, but also on eccentrically loaded columns. The perform experiment on particular section for software validation. Detailed parametric studies done in ABAQUS software for identify load carrying capacity and buckling behavior of built-up cold formed steel section.

***IndexTerms* - Built-up column, Cold form steel, Eccentric compression loading, Experiments, Finite element modelling**

## I. INTRODUCTION

There are two main categories of steel structural members, namely, hot-rolled and cold-formed sections. Hot-rolled sections are quite familiar. Cold-formed steel sections have been used in car bodies, railway coaches, equipment, transmission towers, and so forth. Cold formed members are generally known for their thin elements, buckling behaviour, and post-buckling strength. They have high strength-to-weight ratio and a thickness as small as 0.5 mm can be achieved. In the cold-formed family, many configurations such as angle, channel, I, Z, sigma, T, and tubes can be produced. Some of them are entirely composed of stiffened elements or unstiffened elements or a combination of both. Cold-formed steel (CFS) applications are increasing in the construction of various residential and industrial buildings. In conventional applications, CFS structural members are normally made of single channel or zed sections, which have limited load-bearing capacities due to their low torsional and flexural rigidities.

Figure 1 Conventional CFS profile

## II. LITERATURE REVIEW

**Mithum Peiris, Mahen Mahendran,** 35 lipped channel columns ranging in length from 0.6 to 1.5 m were evaluated under concentric and different levels of eccentric axial compression loads in this work. The failure mechanisms and load versus axial shortening curves that resulted were studied. The test findings were used to create and validate nonlinear finite element models of the tested columns. With increasing main axis eccentricity, the ultimate load capacities and stiffness of both short and intermediate-height components decreased (about 50 percent when eccentricity was increased to 50 mm).

**Qiu-Yun Li, Ben Young,** experimental research was carried out on cold-formed steel built-up open section members under eccentric compressive stress in this publication. Self-tapping screws were used to join two identical channels to create specimens with member lengths ranging from 300 to 1500 mm. To investigate the buckling behaviour of the newly designed built-up section members, thirty-three combined minor axis bending and compression tests were performed under pin-ended supports.

**P. Nivethitha, G. Vani, and P. Jayabalan,** This document shows cold-formed plain channel columns with various width-to-thickness ratios. The investigation is not limited to axially loaded columns, but also includes eccentrically laden columns. The ultimate load is observed to grow as the load approaches closer to the supported edge, and it is impacted by the unstiffened element's bf/t ratio. The findings from ABAQUS reveal that the ultimate loads derived using the direct strength approach are similar only for a narrow range of slenderness ratios when the columns are loaded axially (35 to 50). Only the sensitivity of the elastic buckling load and ultimate load with regard to non-uniform compression factor was investigated when the columns were loaded eccentrically. When the load was shifted closer to the supported edge, the ultimate loads were found to be greater.

**Sivakumar Kesawan, Mahen Mahendran,** The results of an experimental research involving more than 45 stub columns to evaluate the behaviour of built-up cold-formed steel hollow flange sections in compression are presented in this work. The hollow flange I- and channel sections were tested with either a single steel sheet or three steel parts. Hollow flange I- (HFI) and hollow flange channel (HFC) sections with web and flange components joined by screw/rivet fastening or spot welding were examined.

**Son Tung Vy, Mahen Mahendran,** in this paper local or distortional buckling affects the compression behaviour and capacity of built-up back-to-back cold form steel (CFS) channel sections. To investigate the impact of screw fastener qualities and configurations on the compression behaviour and capacities of back-to-back channel members that fail in local and/or distortional buckling. This paper presents the results of tests and FE analyses, on which the effects of screw sizes, screw spacing, and the number of screws per row are discussed. The compression capabilities of the BC87D-600-1S-150 (average 91.2 KN), BC87D-600-2S-150 (average 94.9 KN), and BC87D-600-2S-300 (average 90.7 KN) are almost identical (the differences are less than 5%), and are approximately twice that of the SC87D-600 (average 47.6 KN).

**Shao-Feng Nie, Tian-Hua Zhou,** Thirty specimens of built-up closed box sections made up of two cold-formed steel channels of varying cross sections, lengths, and thicknesses were subjected to concentric and eccentric axial compression in this work. Experimental and computational studies were used to evaluate the compressive behaviour of built-up closed box section columns made up of two cold-formed steel channels. Models based on finite elements (FE) were created and tested. The web and flange of each specimen subjected to con-centric axial compression experienced local buckling at first.

## III. PROBLEM DESCRIPTION

From above literature, we can conclude that here are several applications where built-up sections are used to resist load induced in a structure when a single section is not sufficient to carry the design load. The structural behavior of these thin-walled steel structures is characterized by various buckling modes such as local buckling, distortional buckling or flexural-torsional buckling. These buckling problems lead to severe reduction and complication in calculation of their member strengths. So that more research require to finding capacity and buckling behavior of cold form built up lipped channel section with folded flange under eccentric loading. The structural behavior of these thin-walled steel structure is characterized by various buckling. Also, in the current Indian standards (IS:801 Code of practice for use of cold formed light gauge steel structural members in general building construction, sp-6(5) Handbook for structural engineer), there is no guideline or design equation to calculate the load carrying capacity of built up section for eccentric loading.

### 3.1 Section Profiles

- Length of specimen: 900 mm, 1200 mm, 1600 mm
- Thickness of specimen (t): 1.0 mm, 1.2 mm, 2.0 mm
- Flange width (B): 45 mm, 50 mm
- Length of folded flange (b): 15 mm, 30 mm, full flange
- Flange lipped (h): 20 mm
- Connection: Bolting with diameter 4.8 mm @ spacing 100 mm

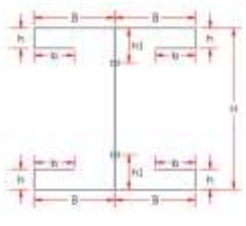

Figure 2 Section details

### 3.2 Data input

The column is made by connecting two C channels back to back having simply supported end conditions. Ultimate loading capacity will gives based on loading conditions. Height= 200mm, width of flange = 45mm, 50mm, thickness =1.0mm, 1.2mm, 2.0mm, length of column= 900mm, 1200mm, 1600mm, length of folded flange= 15mm, 30mm, full flange width. Coupon test for getting material property of specimen, $F_y$= 261.703 N/mm2, E=194790.5 N/mm2, density=7850 kg/m3

### 3.3 Analysis of section based on IS 801:1975

Step 1: Find section Property
Step 2: Check section effectiveness
Step 3: Minimum slenderness ratio
Step 4: Design of bolting connection

## IV. EXPERIMENT STUDY

The particular built-up section made by connecting two channel back-to-back through bolts for verifying FE analysis. Test was carried out on universal testing machine (UTM) for these specimens having simply supported end conditions. Strain rate = 0.2 mm/min applied up to ultimate capacity calculated. Buckling modes of specimen were observed during testing. At the end graph of load-deflection is obtained. Buckling behavior of specimen is studied and obtained load carrying capacity of specimen.

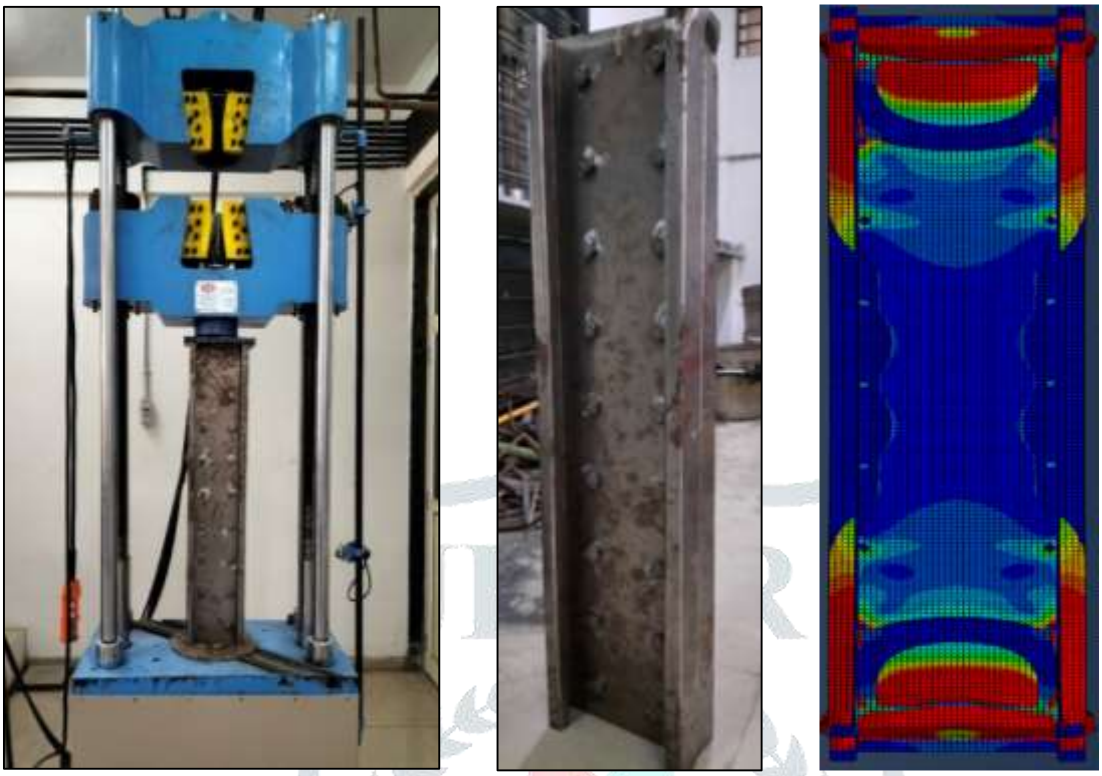

Figure 3 Test set up and buckling behavior of e=30 mm experiment study and ABAQUS software

Results are compared for particular specimen used in experimental study. Comparison of load carrying capacity and buckling behavior, FE analysis and Experimental study. Results are displayed in form of tables as shown below.

Table 1 Load carrying capacity comparision

| | Eccentricity (mm) | ABAQUS Result (KN) | Exp. Result (KN) |
|---|---|---|---|
| Load carrying capacity (KN) | 0 | 88.6 | 92.3 |
| | 30 | 87.2 | 81.5 |

Above values are compared for column having length 900mm, thickness 1.2mm, and length of folded flange 15 mm only for which experimental study is carried out.

## V. RESULTS AND DISCUSSION

Results are compare for experimental and FE analysis with good agreement. So the, varying parameter of section results of all models based on FE analysis in ABAQUS software are displayed in form tables as shown below.

Table 2 Varying length, thickness, flange width and FF=15mm

| | | Flange width= 45mm | | | Flange width= 50 mm | | |
|---|---|---|---|---|---|---|---|
| | Thickness | 1.0 mm | 1.2 mm | 2.0 mm | 1.0 mm | 1.2 mm | 2.0 mm |
| Length (mm) | Eccentricity (mm) | Buckling load (KN) | Buckling load (KN) | Buckling load (KN) | Buckling load (KN) | Buckling load (KN) | Buckling load (KN) |
| 900 | 0 | 56.32 | 88.60 | 211.27 | 57.50 | 89.89 | 212.69 |
| | 30 | 55.38 | 87.28 | 207.81 | 56.89 | 88.60 | 208.24 |
| | 50 | 53.83 | 85.07 | 202.35 | 54.24 | 86.42 | 203.59 |
| | 70 | 51.75 | 82.03 | 196.27 | 52.89 | 83.42 | 197.89 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1200 | 0 | 45.83 | 68.98 | 197.93 | 46.20 | 69.93 | 198.55 |
| | 30 | 44.66 | 68.07 | 195.72 | 45.95 | 69.10 | 196.22 |
| | 50 | 43.89 | 66.56 | 191.89 | 44.69 | 67.89 | 192.71 |
| | 70 | 42.20 | 64.54 | 186.41 | 43.25 | 65.03 | 187.55 |
| 1600 | 0 | 40.39 | 40.03 | 183.93 | 41.56 | 41.82 | 184.74 |
| | 30 | 39.94 | 39.56 | 181.82 | 40.95 | 40.75 | 182.56 |
| | 50 | 39.19 | 38.77 | 178.23 | 40.05 | 39.58 | 179.60 |
| | 70 | 38.25 | 37.74 | 173.22 | 39.55 | 38.44 | 174.56 |

Table 3 Varying length, thickness, flange width and FF=30mm

| | | **Flange width= 45mm** | | | **Flange width= 50 mm** | | |
|---|---|---|---|---|---|---|---|
| | **Thickness** | **1.0 mm** | **1.2 mm** | **2.0 mm** | **1.0 mm** | **1.2 mm** | **2.0 mm** |
| **Length (mm)** | **Eccentricity (mm)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** |
| 900 | 0 | 58.69 | 92.89 | 229.03 | 60.11 | 94.17 | 230.56 |
| | 30 | 57.74 | 91.53 | 225.36 | 58.75 | 92.84 | 226.14 |
| | 50 | 56.15 | 89.25 | 219.48 | 57.20 | 90.58 | 220.92 |
| | 70 | 54.03 | 86.11 | 212.91 | 55.04 | 87.48 | 213.58 |
| 1200 | 0 | 51.69 | 72.79 | 215.15 | 53.85 | 74.09 | 216.75 |
| | 30 | 50.30 | 71.85 | 212.75 | 51.29 | 72.69 | 213.52 |
| | 50 | 49.33 | 70.28 | 208.59 | 50.66 | 71.63 | 209.65 |
| | 70 | 47.54 | 68.18 | 202.65 | 48.20 | 69.45 | 203.89 |
| 1600 | 0 | 42.54 | 72.88 | 199.86 | 44.89 | 74.01 | 200.75 |
| | 30 | 42.07 | 71.93 | 197.58 | 43.08 | 72.58 | 198.54 |
| | 50 | 41.30 | 70.40 | 193.69 | 42.65 | 71.41 | 194.25 |
| | 70 | 40.33 | 68.48 | 188.40 | 41.30 | 69.05 | 189.65 |

Table 4 Varying length, thickness, flange width and FF=Flange width

| | | **Flange width= 45mm** | | | **Flange width= 50 mm** | | |
|---|---|---|---|---|---|---|---|
| **Thickness** | | **1.0 mm** | **1.2 mm** | **2.0 mm** | **1.0 mm** | **1.2 mm** | **2.0 mm** |
| **Length (mm)** | **Eccentricity (mm)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** | **Buckling load (KN)** |
| 900 | 0 | 169.32 | 196.80 | 342.29 | 177.37 | 204.89 | 350.34 |
| | 30 | 168.02 | 195.54 | 340.13 | 176.07 | 203.58 | 348.18 |
| | 50 | 165.98 | 193.45 | 336.48 | 174.03 | 201.43 | 344.73 |
| | 70 | 163.03 | 190.50 | 331.30 | 171.08 | 198.41 | 339.35 |
| 1200 | 0 | 130.02 | 135.62 | 322.76 | 138.07 | 143.71 | 330.81 |
| | 30 | 128.15 | 134.81 | 321.03 | 136.20 | 142.85 | 329.56 |
| | 50 | 126.29 | 133.42 | 318.06 | 134.35 | 141.92 | 326.58 |
| | 70 | 124.69 | 131.44 | 313.83 | 132.74 | 139.58 | 321.14 |
| 1600 | 0 | 77.62 | 133.99 | 314.14 | 85.65 | 142.04 | 322.89 |
| | 30 | 77.15 | 133.17 | 312.58 | 85.20 | 141.22 | 320.65 |
| | 50 | 76.34 | 131.78 | 309.34 | 84.39 | 139.83 | 317.58 |
| | 70 | 74.34 | 128.75 | 304.71 | 82.39 | 136.80 | 312.96 |

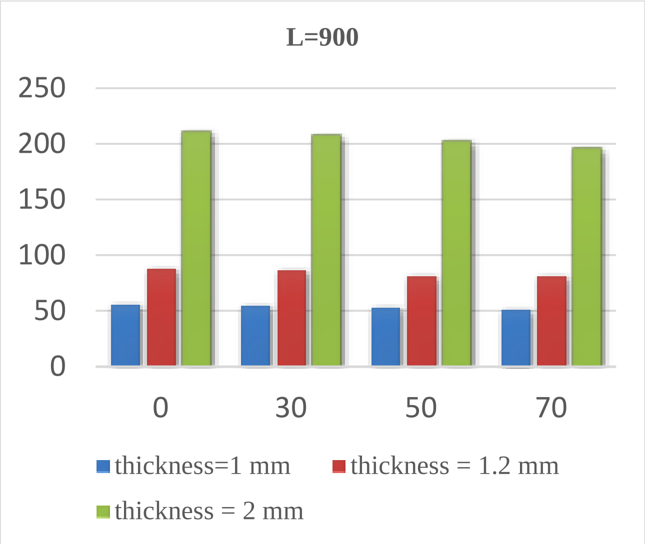


Figure 4 Load carrying capacity for L=900mm And varying thickness

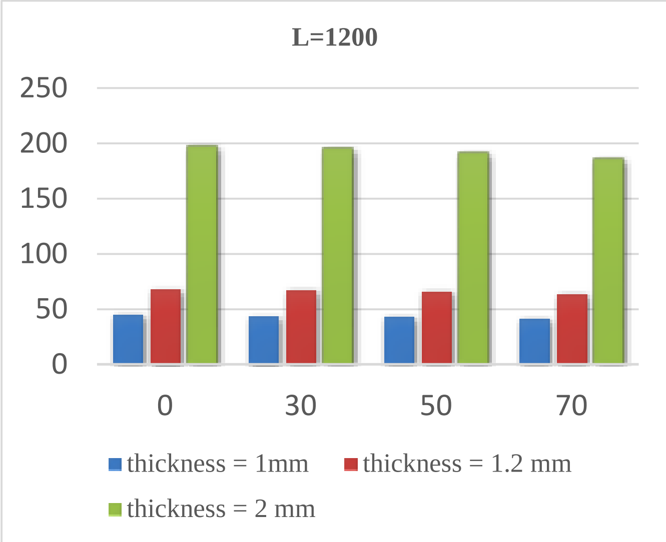


Figure 5 Load carrying capacity for L=1200mm and varying thickness

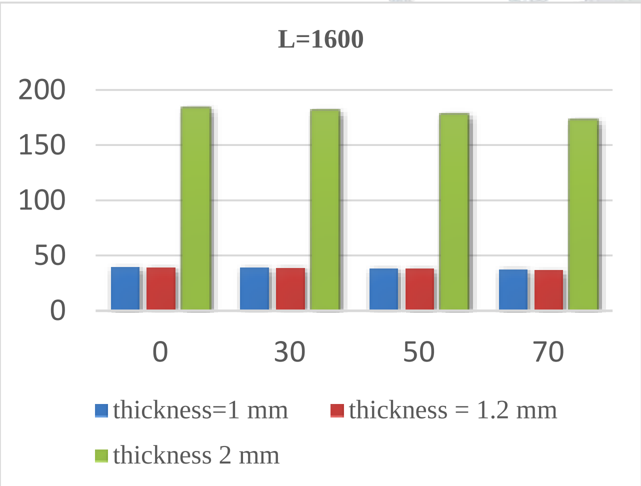


Figure 6 Load carrying capacity for L=1600mm and varying thickness

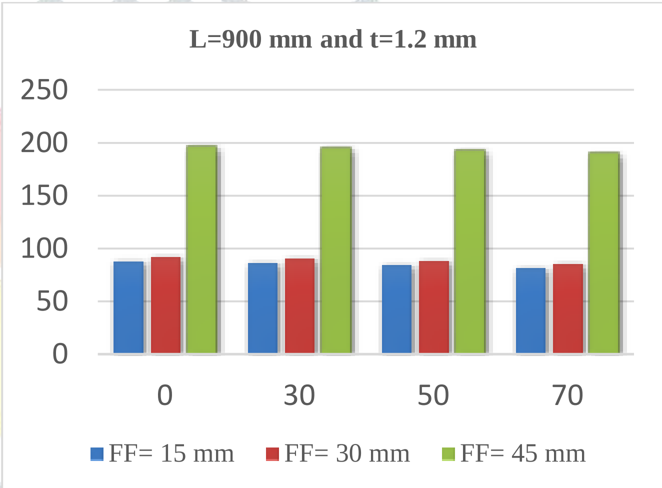


Figure 7 Load carrying capacity for L=900mm, t=1.2mm and varying FF

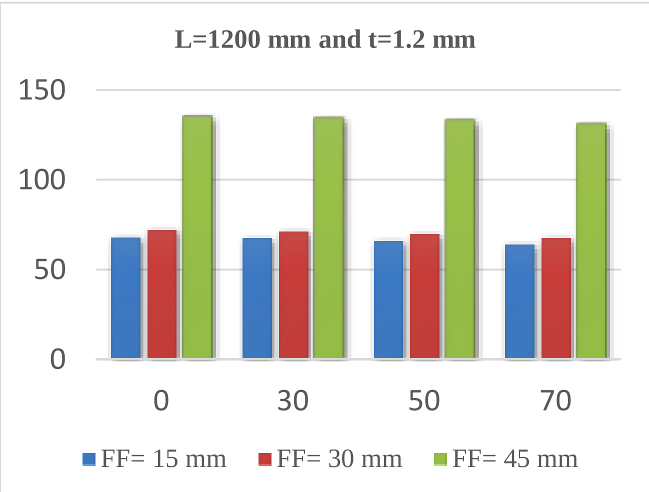


Figure 8 Load carrying capacity for L=1200mm, t=1.2mm and varying FF

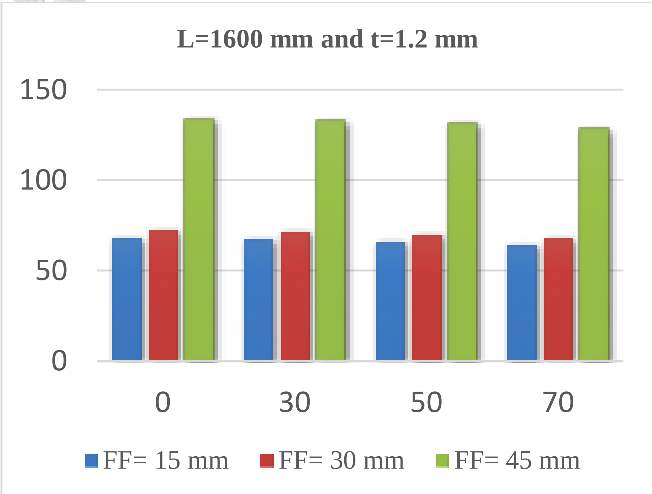


Figure 9 Load carrying capacity for L=1600mm, t=1.2mm and varying FF

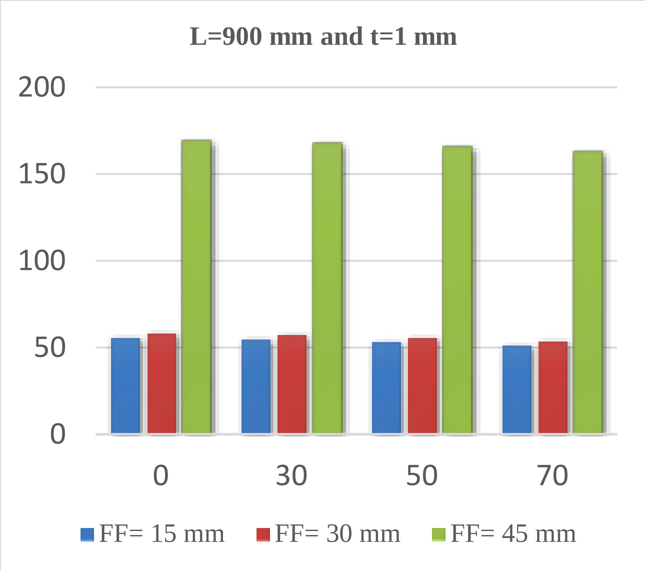


Figure10 Load carrying capacity for L=900mm, t=1mm And varying FF

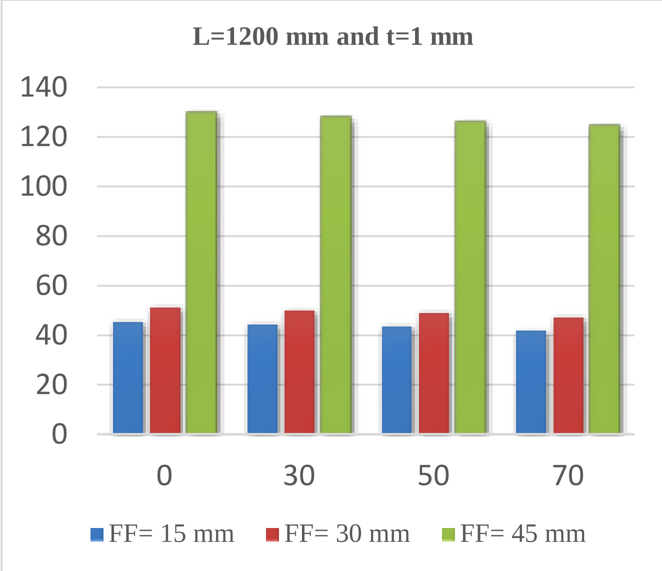


Figure 11 Load carrying capacity for L=1200mm, t=1mm and varying FF

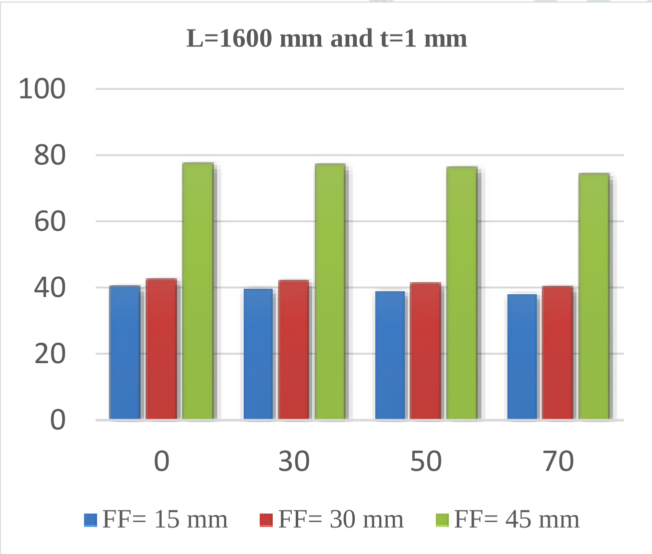


Figure12 Load carrying capacity for L=1600mm, t=1mm And varying FF

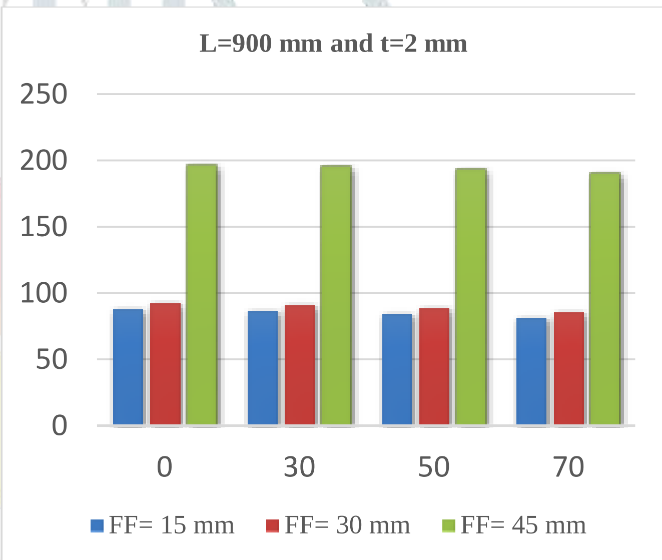


Figure 13 Load carrying capacity for L=900mm, t=2mm and varying FF

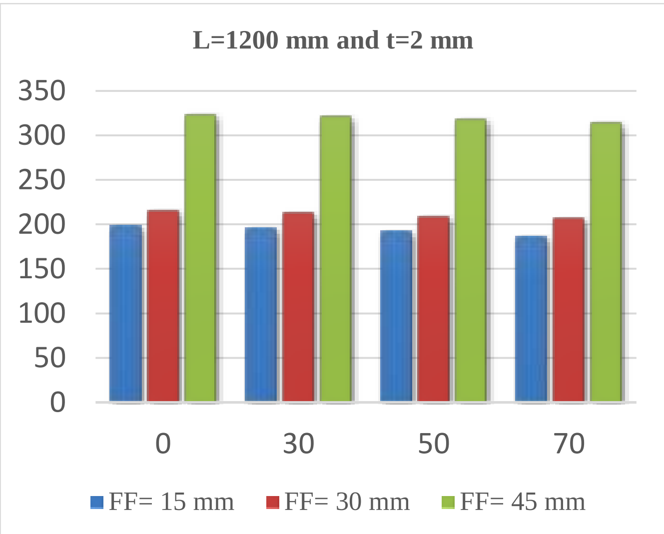


Figure 14 Load carrying capacity for L=1200mm, t=2mm And varying FF

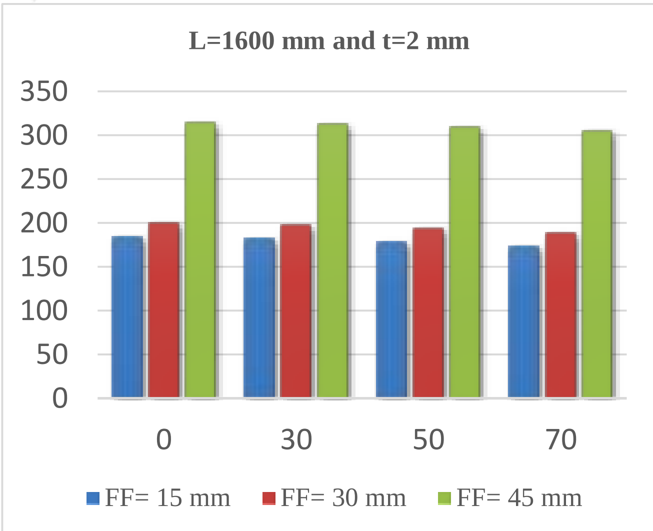


Figure 15 Load carrying capacity for L=1600mm, t=2mm and varying FF

## VI. CONCLUSION

From parametric study based on ABAQUS software, it can be concluded that:

- The load carrying capacity of section decreased by 1.62%, 4.5% and 8.5% respectively with increasing eccentricity by 30 mm, 50 mm and 70 mm.
- The load carrying capacity of section decreased by 18% and 28% respectively with increasing length from 900 mm to 1200 mm and 1600 mm.
- The load carrying capacity of section increased by 36% and 73% respectively with increasing thickness from 1 mm to 1.2 mm and 2 mm.
- The load carrying capacity of section increased by 5.6% and 54% respectively with increasing folded flange length from 15 mm to 30 mm and 45 mm.
- Section effectiveness increased by limiting value, strength capacity increased around 3.5%.

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