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ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF BUILT-UP COLD-FORMED CHANNEL COLUMNS WITH BATTEN SHEETS

[1]Vaishakh Sekhar, [2]Sajin T. Babu, [3]Anima P.

[1,2] PG Students, Department of Civil Engineering, Universal Engineering College Irinjalakuda, Thrissur, Kerala, India,
[3]Associate Professor, Department of Civil Engineering, Universal Engineering College Irinjalakuda, Thrissur, Kerala, India

Abstract: This paper gives an analytical and experimental investigation on the web stiffened built-up cold-formed columns with batten sheets. Initially, the paper presents the axial compressive test result on 6 specimens under fixed-end conditions. It is shown that the batten sheets have a significant influence on the buckling and ultimate strength of the model under axial compression. The test specimens were also analytically investigated by the finite element program of ANSYS. The test result of finite element analysis is close to test results. The parameter studies were conducted by using the program of ANSYS. In which the effect of increasing height, width-thickness ratio, batten spacing were all investigated and it all concluded that the height, thickness-width ratio, batten spacing contribute to the column strength and mode of failure**.**

***Index Terms* - Cold-Formed Steel, Built-Up Columns, C-Columns, Buckling Behaviour, Web Stiffeners, Battens, CFS Sections, Thin Walled Steel**

1.INTRODUCTION

The cold-formed built-up column can be a compression member consisting of two identical parallel elements, the lengths of which are connected to each other in a few places by means of a connector such as lacing, battens or perforated plates. Economical formation process, excellent strength: Due to the weight ratio and ease of construction, cold-formed light-gauge steel structural members have been widely used in steel-frame residential homes, low-rise office buildings and industrial warehouses. Over the past few decades, much research has begun on the structural properties of cold-formed light-gauge steel sections, starting with the plain sections. Dual-channel sections are frequently utilized as built-up columns, which are associated with each other at few places by implies of battens. Cold- formed lipped channel columns may be subject to local, distortional and overall buckling.

1.1 Objective of The Project

- To study various modes of buckling occurring in cold formed steel members when subjected to axial loading
- To calculate the Load Carrying Capacity of a Cold formed steel columns with battens by experimentally and analytically
- To compare the Load Carrying capacity of a Cold formed steel Column as per software-based results obtained from ANSYS and experimental test results.

2. EXPERIMENTAL INVESTIGATION

2.1 Specimen Details

The specimens are manufactured by mild zinc-coated structural steel sheets. The sheets of nominal thickness of 1.5 mm for channels and batten sheets. The channels are connected by means of the weld. A total of 6 fixed-ended stub columns with a height of 650 mm were included in the test program. The test specimens were divided into 2 categories, namely, (i) Back to back C channel section (BB), (ii) Batten sheet with C back to back section (BBB) were selected to perform analysis by using ANSYS. All the models have same geometrical properties such as 180mm in web height (b), 650mm in depth (d), and 1.5mm thickness (t). Besides that, the details of models including the size of intermediate stiffener size are presented in figure 1. The columns are labeled such that the channel section shape, size of edge stiffener, and the column length can be distinguished from the label. For instance, the label 'BB – 650' defines a column Back to back C channel section without gap 'BB' followed by the length of the column in millimeter i.e. 650mm length.

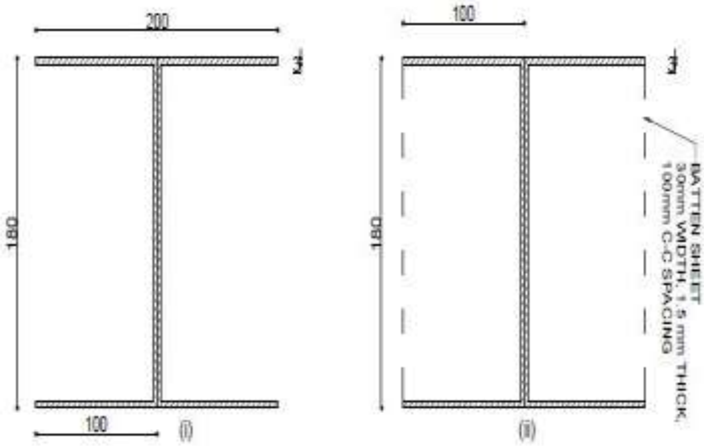

Fig-1: Cross Section of Specimen

(i) (ii)
Fig-2: Specimens Before Loading: (i) BB, (ii) BBB

2.2 Material Properties

The material characteristics of the test specimens were determined by tensile coupon tests. Tensile coupon specimens were extracted from the same batch of specimens used in the stub column tests for each cross-section. Three coupons were prepared and tested according to the IS 1608 – 2005 (Part – I). The dimensions of tensile coupons are shown in Figure 3. The mean of the three coupons test values, including the yield stress (fy), Young's modulus of elasticity (E) and Poisson's ratio (υ) are given in Table 1. The stress-strain curves and failure characteristics of the coupon test specimens are shown in Chart -1.

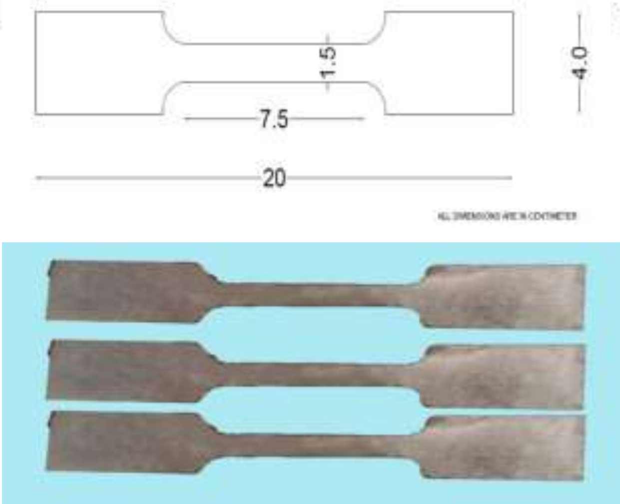

Fig-3: Tensile Coupon's

Table -1: Main Test Results of Steel Material Properties

Number of Coupons	Yield Strength, f_y (N/mm^2)	Young's Modulus, E (MPa)	Poisson's Ratio, υ
3	346.11	2.05×10^5	0.3

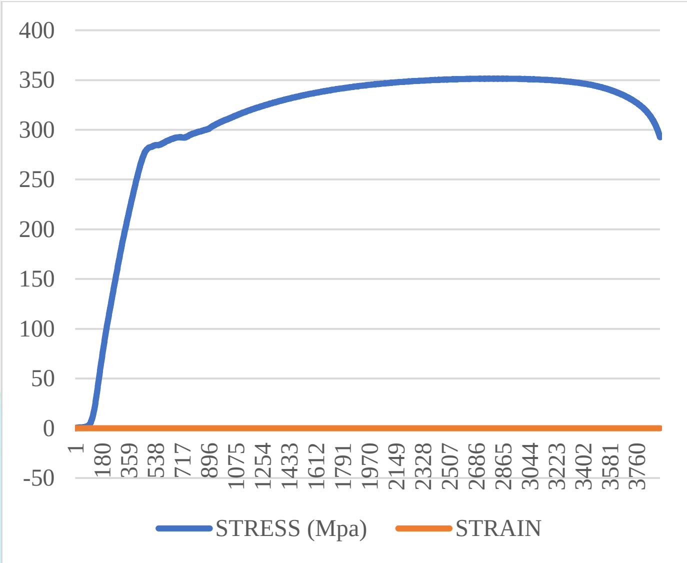

Chart -1: Stress-Strain Curve of Steel

2.3 Test Setup

The test setup is shown in figure 4. The specimens were loaded by a hydraulic universal testing machine of 30 TON capacity under axial load condition. Columns were tested under fixed ends supports condition. The axial deformation of the column was measured using a dial gauge which was kept on top of the jack and the readings were noted at every load interval until failure of the column.

Fig -4: Test Setup for Compression Test

2.4 Test Result

The ultimate load carrying capacities and failure mode of the specimen modeling are presented in Table 2. From the experiment result the specimen back to back C-section with batten sheet (BBB) obtain maximum ultimate load while compared to other specimens. The back to back C-section with batten sheet (BBB) had 112 % more strength compared to back to back C section without battens (BB). It can be obtained that the battens are the key factor influencing the axial bearing capacity and buckling mode of built-up cold-formed steel columns. Columns fails due to Local and distortional buckling. Due to the presence of battens, the distortional buckling was postponed.

Table -2: The Ultimate Load And Failure Mode of Each Specimen

Specimen Number	Plate Thickness t (mm)	Height (mm)	Ultimate Load (kN)	Failure Mode
BB-650	1.5	650	122.58	Local & Distortional
BBB-650	1.5	650	259.88	Local

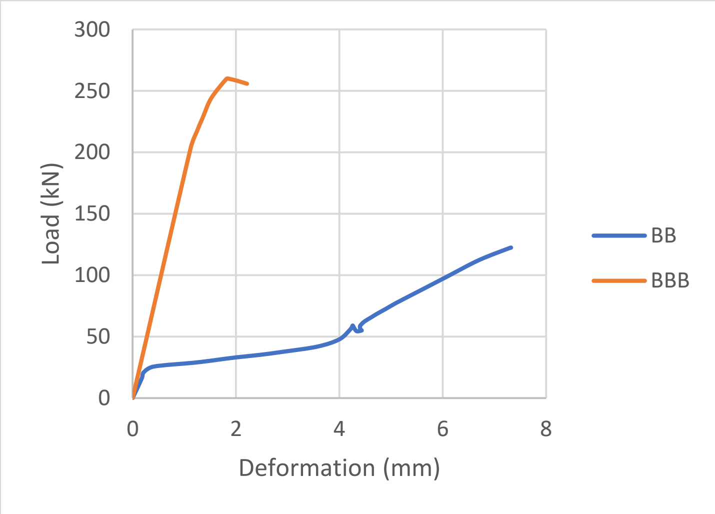

Chart -2: Load-Deformation curves

3 NONLINEAR FINITE ELEMENT ANALYSIS

3.1 Finite Element Model

Each test model was simulated by software ANSYS. Element Shell181 was chosen to simulate the column and tracks. The linear displacement of all nodes in the up-track plane at x and z directions Ux, and Uz is controlled, which is Ux=Uz=0. The linear displacement of all nodes in the down track plane at x, y, and z direction controlled, i.e Ux=Uy=Uz=0. A point-surface contact was made between the end of the column end and the track, a surface-surface contact was made between each element of the column. When loading the model, the Y-directional displacement of all nodes in the up-track plane was added to one node, and then the vertical displacement load was applied to the coupled node. The parameter values of the material properties were determined by the tensile coupon tests. Yield strength f_y = 346.11 N/mm2, Poisson's ratio v = 0.3, Elastic modulus E=2.05 × 105 N/mm2. The final models are shown in Figure 5.

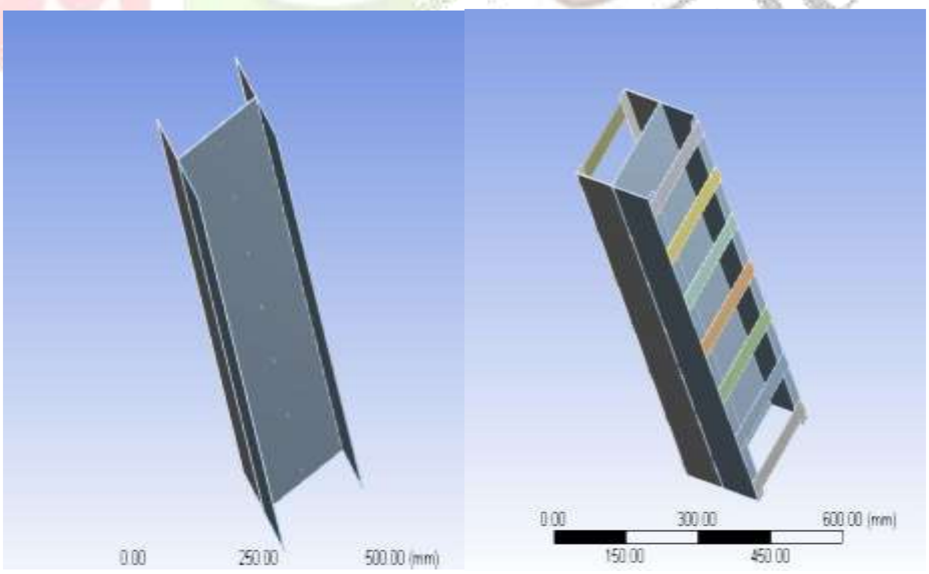

Fig -5: Finite Element Model

3.2. The Comparison of Finite Element Analysis and Test Results

It can be obtained that, according to test result, local buckling appeared at the initial stage of loading and with the increase of load the local buckling was also growing finally the specimen was destroyed. This test process was well simulated by ANSYS. The result of finite element analysis agrees well with the experimental results (see figure 6 and 7). According to Chart- 3 the load-deformation curve of finite element analysis agrees well with that of experimental results. The comparison of ultimate bearing capacity of built-up cold-formed stub columns based on FEA analysis and test are shown in Table- 3

Table -3: Ultimate Load of Test and FEA

Specimen Number	Experimental Ultimate Load, P_{ue} (kN)	Analytical Ultimate Load, P_{ua} (kN)	P_{ue}/ P_{ua}
BB-650	122.58	145.86	1.18
BBB-650	259.88	299.05	1.15

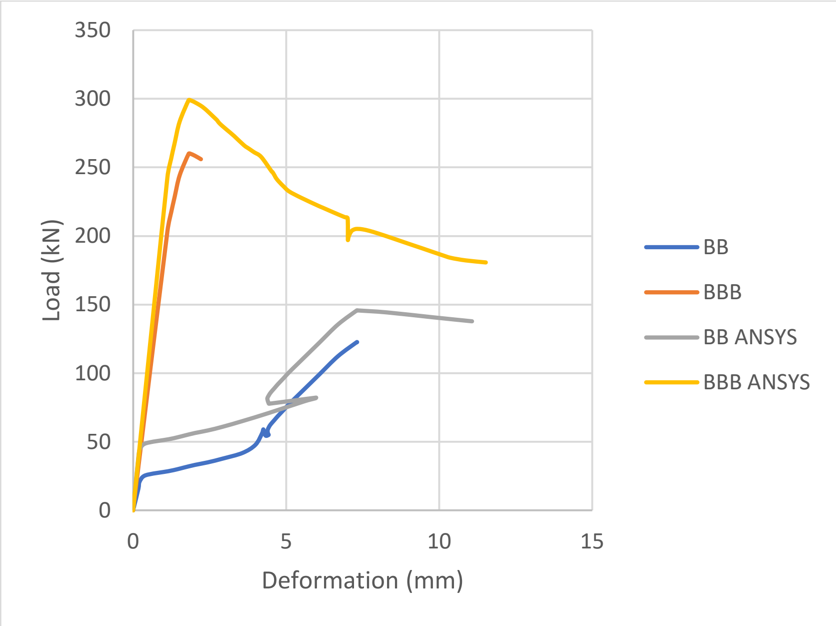

Chart -3: Comparison of The Load-Deformation Curve Obtained and Finite Element Analysis and Experiments

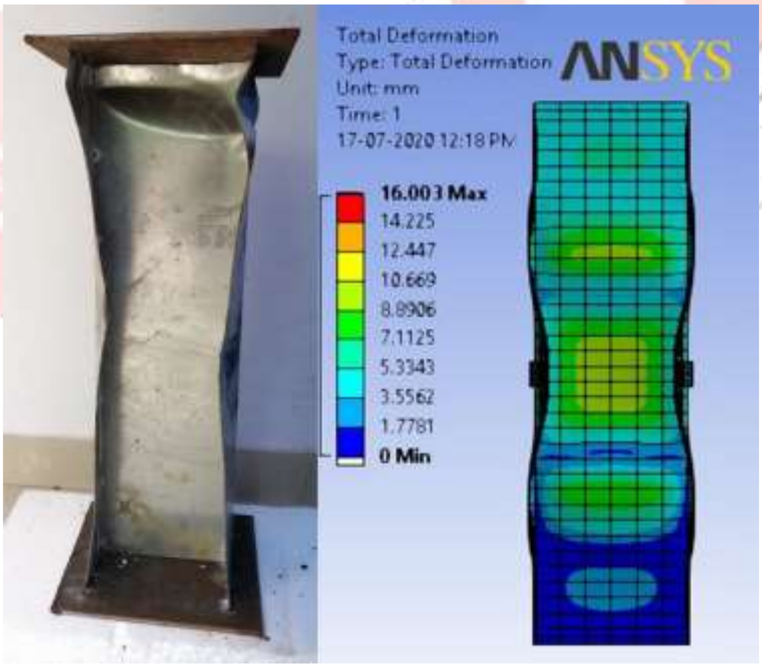

Fig -6: Comparison of Test Failure Modes and Finite Element Simulation Failure Modes of Specimens BB

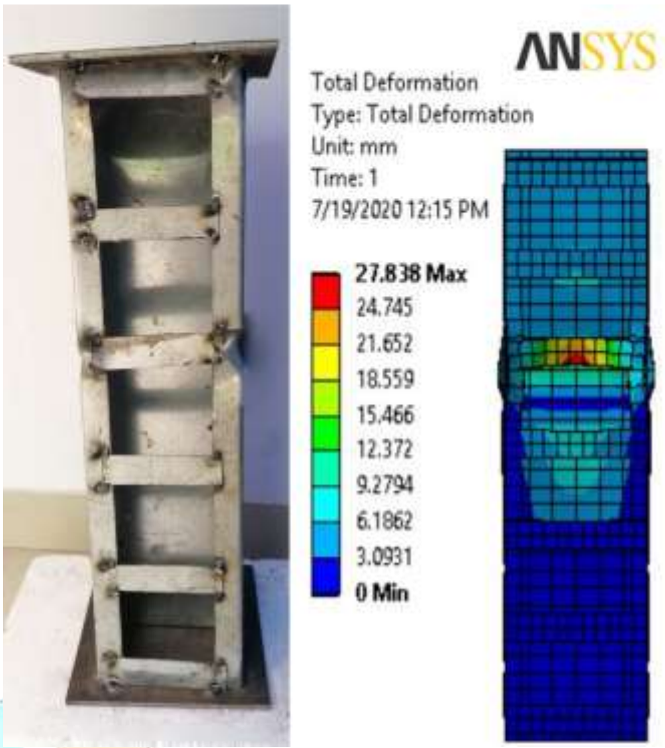

Fig -7: Comparison of Test Failure Modes and Finite Element Simulation Failure Modes of Specimens BBB

3.3 Parametric Study

The parametric studies are conducted on the best section obtained from the analytical studies i.e. column with back to back C section with battens.

3.3.1 Analysis of Width-Thickness Ratio

The length of multi-limbs built-up cold-formed steel stub columns in this section is 650mm, the numbers are as follow:
For instance, the label 'BBB-180-1.5-650' defines a column back to back C channel section with battens, the 180 represents the web height of basic component. The 1.5 represents the thickness of the plate, the 650 represents the length of specimen (units are mm). The load-displacement curve obtained by the finite element analysis of the columns with different width-thickness ratio of plates shown in Chart- 4. It can be seen from Table 4. that as the plate thickness decreased, the width-thickness ratio of plate increased, the ultimate load of the column was significantly reduced. The bearing capacity of the column with thickness t = 0.8 mm was 88% of that of the column with thickness t = 3.0 mm. It can be obtained that the maximum width-thickness ratio is the key factor influencing the axial bearing capacity of multi-limb built-up cold-formed steel column.

Table -4: Parameter analysis results with different width-thickness ratio

Specimen	Plate Thickness t (mm)	Width-Thickness Ratio	Ultimate Load (kN)
BBB-180-0.8-650	0.8	225	94.002
BBB-180-1.5-650	1.5	120	299.05
BBB-180-3-650	3	60	749.09

3.3.2 Effect of The Increasing Height of The Column

In this section, the height of column was changed in the finite element simulation analysis and find out the ultimate load and failure mode of different columns and thickness of columns are 1.5 mm. The load-displacement curve obtained by the finite element analysis of the columns with different height of column shown in Chart- 5. It can be seen from Tables- 5, that as the column height increased, the ultimate load of the column was significantly increased. The bearing capacity of the column with height 650mm was 30% of that of the column with height 2600mm. It can be obtained that the height of column is the key factor influencing the buckling mode of multi-limb built-up cold-formed steel column.

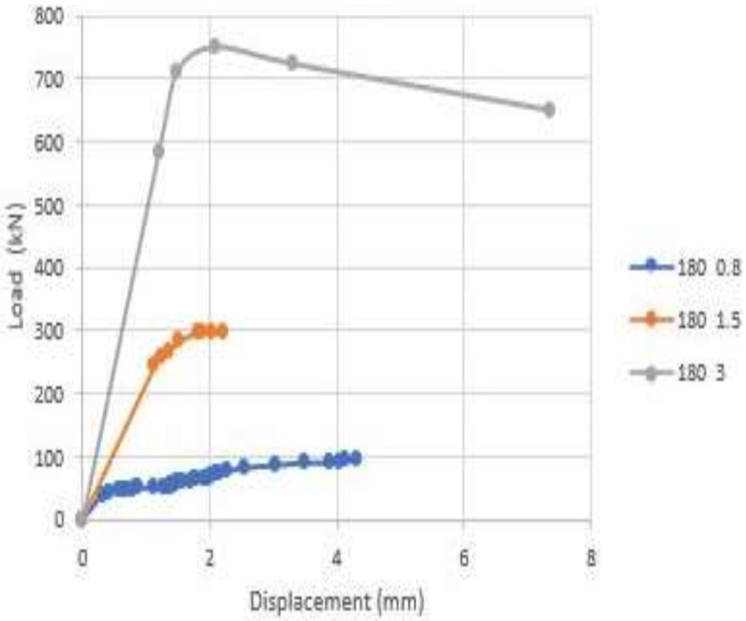

Chart -4: Load-Axial Displacement Curves of The Columns with Different Width-Thickness Ratios

Table -5: The ultimate load of specimen having different height

Specimen	Height (mm)	Ultimate Load (kN)	Failure Mode
BBB-180-0.8-650	650	299.05	Local buckling
BBB-180-0.8-1300	1300	258.82	Local and distortional buckling
BBB-180-0.8-2600	2600	427.86	Local buckling and flexural buckling

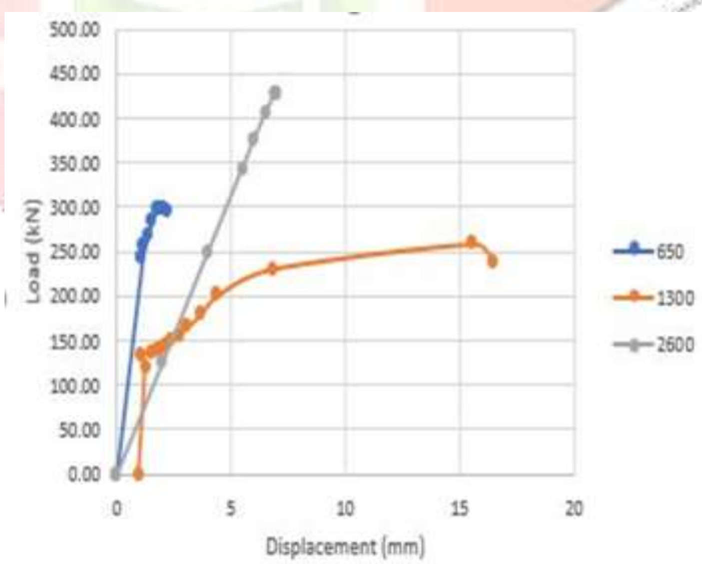

Chart -5: Load-Axial Displacement Curves of The Columns with Different Height

3.3.3 Analysis of Batten Spacing

In this section, the spacing of battens were changed, the length of column was 650 mm and thickness was 1.5mm. The load-displacement curve obtained by the finite element analysis of the columns with different spacing of battens of column shown in Chart- 6. It can be seen from Tables- 6, that the bearing capacity of column increase with increasing spacing of battens up to certain limit after a particular limit the increase in spacing of battens decrease the ultimate load carrying of column. The bearing capacity of the column spacing of battens 50mm was 18% of that of the column with spacing of battens 100mm. It can be obtained that the height of column is the key factor influencing the buckling mode of multi-limb built-up cold-formed steel column.

Table -6: Parameter Analysis Results with Different Spacing of Battens

Specimen	Thickness (mm)	Height (mm)	Spacing of Battens (mm)	Ultimate Load (kN)
BBB-180-0.8-650	1.5	650	50	253.34
BBB-180-0.8-650	1.5	650	100	299.05
BBB-180-0.8-650	1.5	650	200	239.86

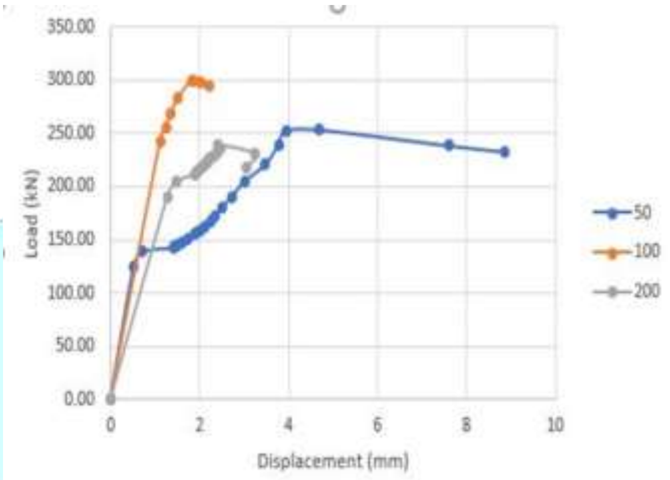

Chart -6: Load-Axial Displacement Curves of The Columns with Different Spacing of Battens

4. CONCLUSIONS

The experimental and Finite element analysis of built-up cold-formed channel strengthened by batten sheets have been presented. The batten sheets have significant influence on the specimen's failure mode. The columns buckling was postponed effectively or even prevented from happening due the presence of batten sheets

The batten sheet had little contribution on the columns ultimate load under the axial compression loading. It could efficiently enhance the ultimate loads for the columns under axial compression. The bearing capacity of the column without battens was 51% of that of the column with battens. The bearing capacity of column increase with increasing spacing of battens up to certain limit after a particular limit the increase in spacing of battens decrease the ultimate load carrying of column. It can be obtained that the maximum width-thickness ratio is the key factor influencing the axial bearing capacity of multi-limb built-up cold-formed steel column. The width-thickness ratio of plate increased; the ultimate load of the column was significantly reduced. The experimental process can be simulated exactly by the finite element analysis. The test results and finite element analysis results are in good agreement in failure mode and ultimate strength.

REFERENCES

[1] Boshan Chen, Krishanu Roy, Asraf Uzzaman, Gary M. Raftery, David Nash, G. Charles Clifton, Pouya Pouladi, James B.P. Lim, (2019), "Effects of edge-stiffened web openings on the behaviour of cold-formed steel channel sections under compression", *Thin-Walled Structures 144 (2019) 106307*

[2] Chungang Wang, Qinglin Guo, Zhuangnan Zhang and Yuting Guo. (2019), "Experimental and numerical investigation of perforated cold-formed steel built-up I-section columns with web stiffeners and complex edge stiffeners", *Advances in Structural Engineering 1–17*

[3] Essam A. Amoush, Mohamed A. Ghanem, (2018), "Axially loaded capacity of alternatively strengthened cold-formed channel columns with CFRP", *Journal of Constructional Steel Research 140 (2018) 139–152*

[4] Fangfang Liao, Hanheng Wu, RuizhiWang, Tianhua Zhou. (2017), "Compression test and analysis of multi-limbs built-up cold-formed steel stub columns", *Journal of Constructional Steel Research 128 (2017) 405–415*

[5] Husam Alsanat, Shanmuganathan Gunalan, Hong Guana, Poologanathan Keerthan, John Bull, "Experimental study of aluminium lipped channel sections subjected to web crippling under two flange load cases", *Thin-Walled Structures 141 (2019) 460–476*

[6] Jia-Hui Zhang, Ben Young b, 2019), "Experimental investigation of cold-formed steel built-up closed section columns with web stiffeners", *Journal of Constructional Steel Research 147 (2018) 380–392*

[7] Ji-Hua Zhu, Zi-qi Li, Mei-Ni Sub, Ben Young. (2019), "Behaviour of aluminium alloy plain and lipped channel columns", *Thin-Walled Structures 135 (2019) 306–316*

[8] Ju Chen, Man-Tai Chen, A.M. ASCE and Ben Young, F. ASCE. (2019), "Compression Tests of Cold-Formed Steel C- and Z-Sections with Different Stiffeners", *J. Struct. Eng., 2019, 145(5): 04019022*

[9] Jun Ye, Francisco J. Meza, Iman Hajirasouliha, Jurgen Becque, Paul Shepherd and Kypros Pilakoutas. (2019), "Experimental Investigation of Cross-Sectional Bending Capacity of Cold-Formed Steel Channels Subject to Local-Distortional Buckling Interaction", *J. Struct. Eng., 2019, 145(7): 04019064*

[10] Jun Ye, Iman Hajirasouliha, Jurgen Becque. (2018), "Experimental investigation of local-flexural interactive buckling of cold formed steel channel columns", *Thin-Walled Structures 125 (2018) 245–258*

[11] Kang He and Yu Chen, (2019), "Experimental Evaluation of Built-in Channel Steel Concrete-Filled GFRP Tubular Stub Columns under Axial