BEHAVIOUR OF COLD-FORMED BUILT-UP COLUMNS UNDER COMPRESSION

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ABSTRACT

Cold-formed steel sections are widely used due to their high strength, durability and resistance. In this paper, the non-linear behaviour of cold-formed steel battened columns placed back-to-back is considered. The channels are placed in four series with a back-to-back spacing of 25,50,75,100 mm. The behaviour of built-up columns under the effect of axial, eccentric and loading under temperature from ambient to 700 °C are considered. About 65 models are generated in ABAQUS 2019 with 2 models as validation. The effect of parameters like channel spacing, batten width, B1/D ratio, varying column length etc. was taken into consideration. The column strength, failure modes, deformed shapes, load vs. displacement, and ultimate loads at different temperature conditions were obtained. Furthermore, the column strengths obtained from the analysis were compared and obtained to a conclusion.

Keywords: *- Built-up columns, Cold formed, Finite model*

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1. INTRODUCTION

Cold-formed steels are used widely nowadays due to their high strength, corrosion resistance, easy installation, economic design etc. It was found that various investigations were reported on cold-formed steel single columns with symmetrical and asymmetrical cross-sections. Also, the majority of the experimental studies were carried out in hot-rolled steel sections. Muthuraman et al. [2], examined the axial loading of pin-jointed cold-formed steel column sections by numerical and theoretical analysis. About 44 models were modelled in Abaqus and were analyzed under axial compression. By considering different batten numbers and slenderness ratios numerical and theoretical studies were done. The ultimate loads for the lipped channels were analyzed using two methodologies for the lipped channel sections and were compared to obtain the effective section proposed. While considering the slenderness ratio from 20 to 60 from the direct strength method the buckling mode and the failure load were approximately showing good agreement with the FEM results. Thus, to study the behaviour of cold-formed built-up columns with battens experimental study was conducted by Dabaon et al. [8]. From the study, the effect of channel spacing, and local buckling length on the column strength was estimated. The study is conducted to develop a finite parametric study that considered column length, batten width, local buckling length and channel spacing to find out the effects on column strength. The behaviour of the column under the temperature loading condition by Gunalan et al. [10] was considered. The model was validated and studied the effect of the built-up columns under the temperature loading by adopting the properties, imperfections and boundary conditions. The parametric study was carried out to find the effect of channel spacing, local buckling length and column length on the ultimate load of columns. The behaviour of the column under eccentric loading was considered along with the parametric study on varying column length, channel spacing and batten width. The main objective is to find the behaviour of built-up columns under axial compression, eccentric loading and axial loading under the effect of uniform elevated temperature from ambient temperature to 700 °C.

2. AXIAL COMPRESSION

The objective of the study is to develop a finite element model to study the behaviour of built-up columns under the effect of axial compression. element model to study the behaviour of built-up columns under the effect of axial compression. At first, for validation, the dimensions for the specimen, non-linear properties, boundary conditions, and initial and overall geometric imperfections were adopted in the model. The deformed shapes and failure modes, load vs. lateral displacement obtained were validated against the results obtained from Dabaon et al. [9]. The parametric studies considered were column length, batten width, local buckling length and channel spacing to find out the effects on column strength.

2.1 Varying column length

For performing the parametric study based on column length 12 specimens were created in the ABAQUS 2019 software. The built-up columns were divided into 4 series C1B-25, C1B-50, C1B-75 and C1B-100. Column C1B25-300-L-600 denotes a built-up column formed by 2 channels placed back-to-back at a spacing of 25 mm (B25), local buckling length (Lz) of 300 mm and column length (L600). The dimension of the columns considered from the above journal. Fig 1 shows the built-up column is spaced back-to-back at a distance of 100 mm.

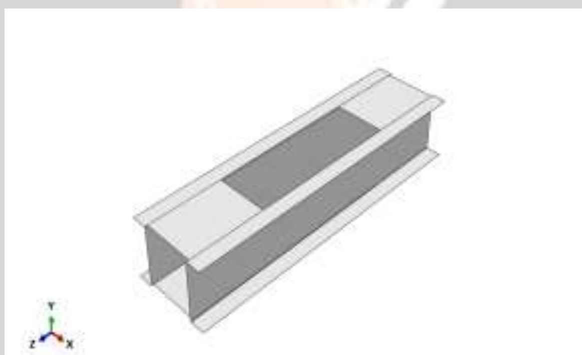


Fig -1: Model of the built-up column

Non-linear buckling analysis is carried out by the modified RIKS method available in the ABAQUS library with the Eigen load acting as load including geometric imperfections and material non-linearity. Fig 2 shows the linear and non-linear deformed shape of the built-up column in Fig 3.

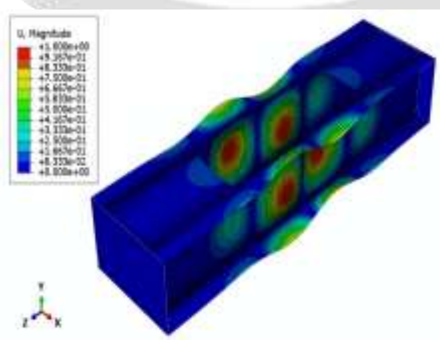


Fig -2: Deformed shape of the built-up column by linear analysis

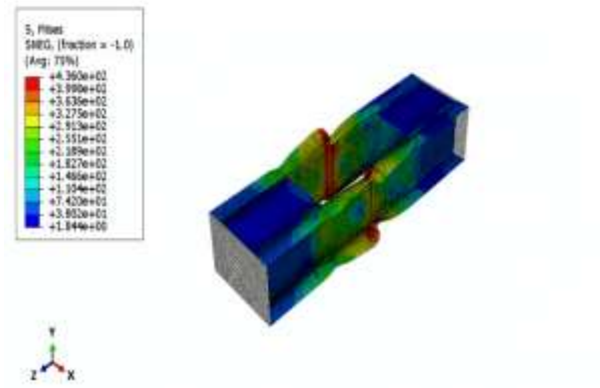


Fig -3: Deformed shape of the built-up column by non-linear analysis

2.2 Varying spacing between the channel sections

The non-linear analysis was carried out on the built-up columns with back-to-back spacing varying from 25 to 100 mm. The boundary condition was similar to the above parametric method.

2.3 Varying spacing of local buckling length (Lz)

To find the effect of local buckling length (L_z) or batten spacing on the strength of the column under axial compression the study was conducted. The buckling length is considered as 150, 300, and 400 mm. The dimension, meshing type boundary conditions and loading condition were the same as in the above analysis with a difference in the spacing between the battens. 3 models were developed to study the effect of buckling length on a 2200 mm length column.

3. ECCENTRIC LOADING

The study was conducted to find the behaviour of built-up columns under eccentricity loading. Several parameters like column length, channel spacing etc were considered to find their effect on the strength of the column.

3.1 Varying column length

For performing the parametric study on column length 12 specimens were created in the software. The built-up columns were created based on the dimension in table 1. The properties, loading and boundary condition etc were adopted from the above journals. The non-linear analysis was carried out.

3.2 Varying column length

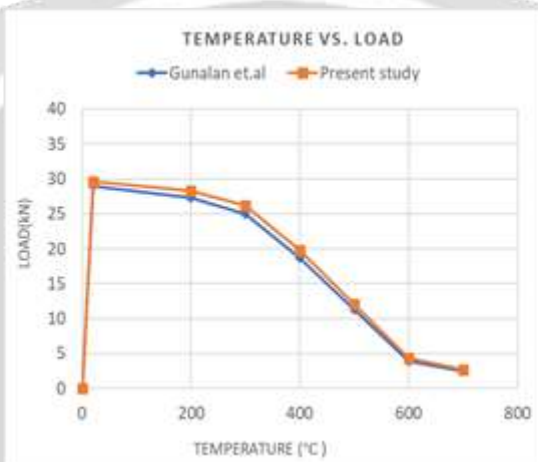
The non-linear analysis was carried out on the built-up columns with back-to-back spacing varying from 25 to 100 mm. The boundary condition was similar to the above parametric method.

4. THERMAL LOADING

In his journal, the authors conducted both experimental and numerical studies to investigate the local buckling behaviour of cold-formed steel sections of lipped and unlipped channels by varying the temperature from 20 to 700 °C. Finite elements were modelled in ABAQUS 2019 by referring to the dimensions adopted in the journal for validation. The material properties provided for the sections are listed below in Table 1. The analysis was carried out and the result obtained showed good agreement with the journal results as shown in Graph 1.

Table -1: Material property of the specimen

Temperature (°C)	E (MPa)	fy (MPa)
20	205000	615
200	174,189	609
300	146,56	584
400	118,921	427
500	91,246	240
600	63,571	67.7
700	35,896	43.1



Graph -1: Validation of the behaviour of channel under thermal loading

4.1 Varying channel spacings

To study the behaviour of built-up columns under the effect of elevated temperature loading analysis was carried out. To find the effect of channel spacing in the ultimate load of column 4 built-up columns of length 600 mm each were developed with the spacing of channels varying from 25 to 100 mm. The material properties provided were temperature dependent and were adopted from the validated journal. The concentrated load was provided at the upper-end plate which acts as the loading plate as shown in Fig 4. Along with it, temperature loading was also provided to the built-up column as shown in Fig 5. From the Eigenvalue analysis, the buckling modes obtained were different at different temperatures from 20 to 700 °C.

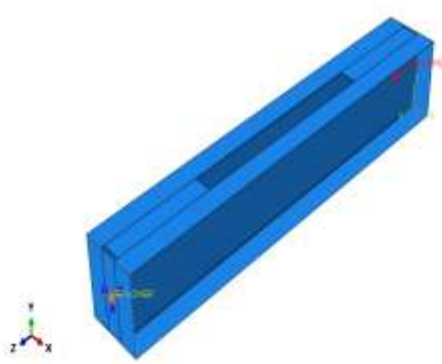


Fig 4: Concentrated load on the built-up column

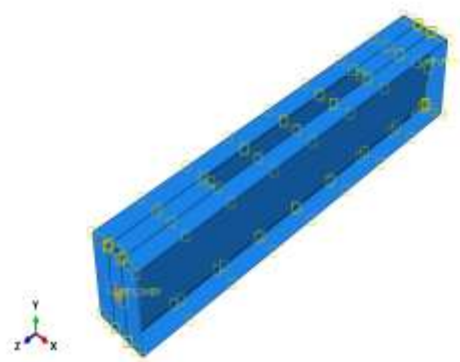


Fig -5: Temperature loading of the built-up column at 20°C

4.2 Varying column length

To find the effect of column length in thermal buckling of column 4 models were created in software and analysed. The built-up columns were divided into 2 series C1B-25 and C1B-50 in two built-up columns of each were generated with lengths varying from 600 to 1000 mm.

5. RESULTS AND DISCUSSIONS ON AXIAL LOAD

5.1 Varying column length

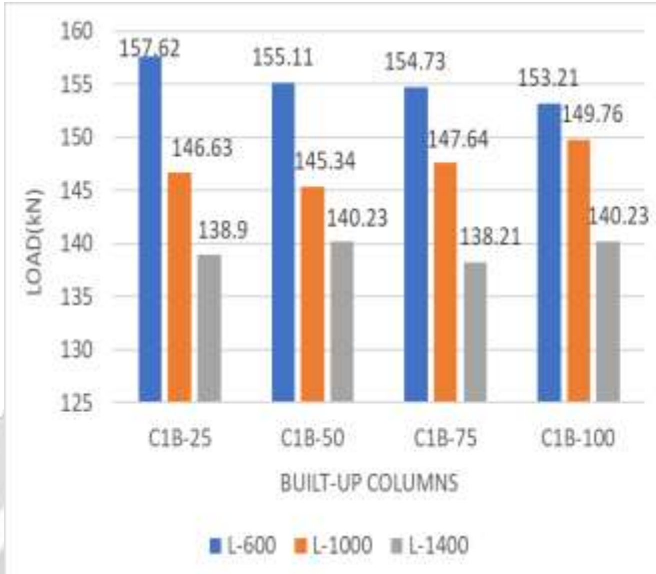
Table 2 shows the behaviour of built-up columns with varying the column length in 4 series. From each series, it is understood that with the increase in column length the strength of the column decreases gradually.

Table -2: Finite element results for the built-up cold-formed columns under axial loading

Series	Channel C/s D x b x t x r_i (mm)	L (mm)	Batten width (a_b) (mm)	Abaqus result (kN)
C1B-25	100x30x2x1	600	65	157.20
	100x30x2x1	1000	65	146.63
	100x30x2x1	1400	65	138.90
C1B-50	100x30x2x1	600	90	155.11
	100x30x2x1	1000	90	145.34
	100x30x2x1	1400	90	140.23
C1B-75	100x30x2x1	600	115	154.73
	100x30x2x1	1000	115	147.64
	100x30x2x1	1400	115	138.21
C1B-100	100x30x2x1	600	140	153.21
	100x30x2x1	1000	140	149.76
	100x30x2x1	1400	140	140.23

5.2 Varying spaces between channel sections

It is clear that in each series the column strength decreases with the increase in column length as shown in Graph 2. While considering the short, intermediate and long columns the column strength decreases in the short column with the increase in back-to-back channel spacing. Whereas in the case of both intermediate and long columns the column strength increases with the increase in channel spacing this is due to the effect of spacing to width (B1/D) ratio and the effect of batten width in greater channel spaced columns



Graph -2: Comparison of column strength with the effect of back-to-back channel spacings under axial load

5.3 Varying spacing of local buckling length (Lz)

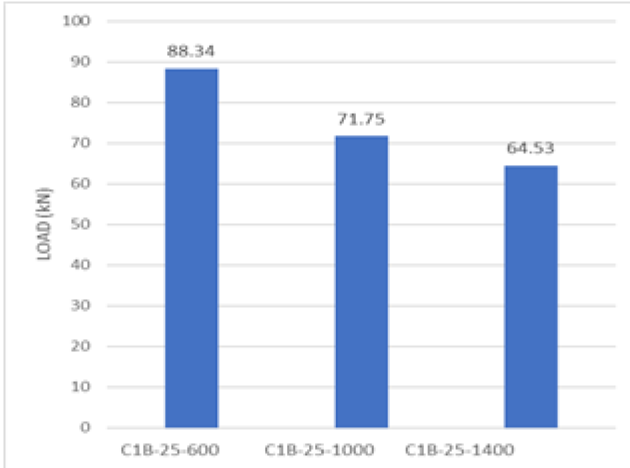
From Graph 3 it is visible that with the increase in the local buckling length (Lz) there is a reduction in the strength of the column by 4.57 and 7.96 % respectively.

Graph -3: Effect of the increase in the batten spacing on built-up column strengths

6. RESULTS AND DISCUSSIONS ON ECCENTRIC LOAD

6.1 Varying column length

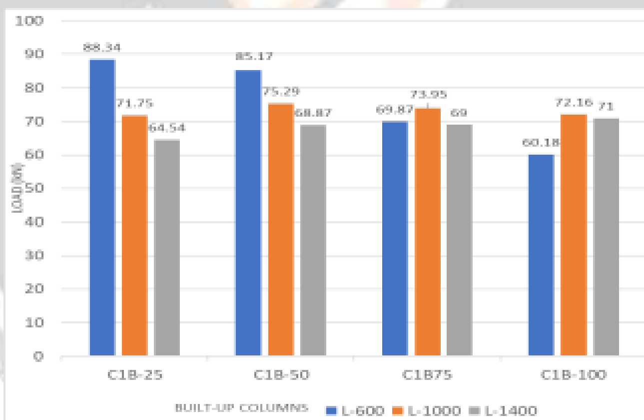
From the analysis, it is clear that the column strength decreases with the increase in column height. Graph 4 shows the column strength of the series C1B-25 with the lengths varying from 600, 1000, and 1400 mm.



Graph -4: Comparison of column strength with the height of columns under eccentric loading

6.2 Varying spaces between channel sections

It is clear that in each series the column strength decreases with the increase in column length as shown in Graph 4 While considering the short, intermediate and long columns column strength decreases in the short column with the increase in back-to-back channel spacing. Whereas in the case of both intermediate and long columns the column strength increases with the increase in channel spacing this is due to the effect of spacing to width (B1/D) ratio and the effect of batten width in greater channel spaced columns



Graph -5: Comparison of column strength with the effect of back-to-back channel spacings for eccentric loading

7. RESULTS AND DISCUSSIONS ON ECCENTRIC LOAD

7.1 Varying column length

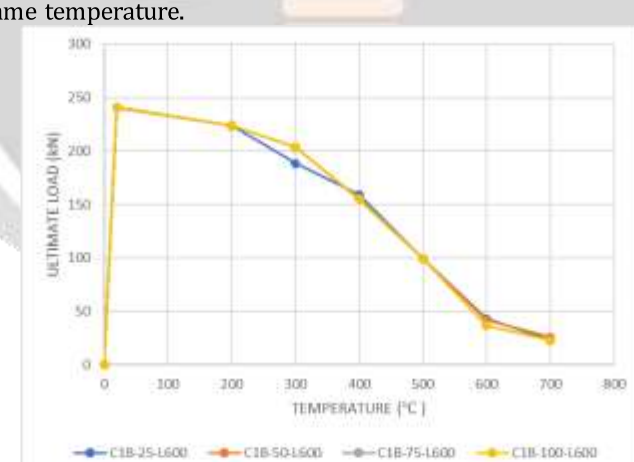
Table 3 shows the result of the behaviour of built-up columns with an increase in column length under temperature loading. From the tabular column, the ultimate load decreases with the increase in column length from ambient temperature to 700 °C. It is to be noted that the ultimate load increases with the increase in channel spacing at the same temperature for the built-up column with a length of 1000 mm. B1/d ratio and the batten width play a major role in increasing the ultimate load in the built-up column with 50 mm channel spacing. Also from the above graph, it is noticeable that the batten width and the B1/D ratio do not affect the ultimate load for shorter columns.

Table -3: Comparison of built-up columns with column length under thermal buckling

TEMPERATURE (°C)	C1B-25 Ult. Load (kN) L-600	C1B-25 Ult. Load (kN) L-1000	C1B-50 Ult. Load (kN) L-600	C1B-50 Ult. Load (kN) L-1000
20°C	240.95	218.60	240.68	234.97
200°C	223.82	194.10	223.86	220.71
300°C	188.37	168.37	203.34	202.23
400°C	159.38	133.28	155.16	153.14
500°C	99.24	62.76	99.13	95.91
600°C	43.08	33.40	41.65	42.99
700°C	23.09	21.08	26.03	21.31

7.2 Varying spaces between channel sections

Graph 6 shows the behaviour of built-up columns under the effect of temperature loading. The graph shows with the increases in the temperature the ultimate load decreases. Channel spacing has a lesser effect in shorter columns as values of ultimate loads was similar in all built-up columns with different spacing between channel at the same temperature.



Graph -6: Comparison of the behaviour of built-up columns of 600 mm length under thermal loading

8. CONCLUSION

From the study, it is found that with the increase in column length the strength of the column decreased. Increasing the channel spacing decreased the column strength for short columns while in the case of the intermediate and long columns the column strength increased with the channel spacing due to the effect of the B1/D ratio and the width of the battens in the columns. The column strength tends to decrease with the increase in local buckling length by 4.7 and 9.69%.

In eccentric loading, column strength decreased with the increase in the length of the column. The shorter column showed only little effect on the column strength with the increase in batten width and the channel spacing. In the case of intermediate and long columns with the increase in batten width and channel spacing the column strength increased.

In thermal buckling, even though the increase in temperature led to the decrease in the ultimate load of the built-up column. The increases in channel spacing did not affect the ultimate load in short columns and so drastic changes in the ultimate values were not obtained. Moreover, in the case of the intermediate and long column B1/D ratio and increased batten width with the increase in channel spacing helped to increase its ultimate load.

6. REFERENCES

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