Experimental Study on Cold-formed Steel Built-up Column Sections

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Abstract **- In construction of steel structures, based on the manufacturing process there are the two main types of structural members they are hot-rolled members and cold-formed members. Cold - formed steel cross sections have increased load carrying capacity and can be used to construct economical structures. This project describes the Analytical and experimental investigation on strength and behaviour of cold-formed steel built-up column sections under compression. Analytical investigation is carried out by using ANSYS software for finite element analysis. Comparative study is carried out by varying the web length and connection spacing. The local buckling of the specimens is observed in both analytical and experimental investigations. Due to local buckling, most of the specimen's experimental results are slightly greater than analytical results, whereas some specimen's experimental results are lesser than analytical results.**

Index Terms **- ANSYS, Cold-formed steel, compression.**

1.INTRODUCTION

In Steel structures, there are two types of structural steel member used: hot-rolled steel members and cold-formed steel members. Recently, the use of cold-formed high strength steel structural members has rapidly increased. Cold Formed Steel make its potential to reduce the weight of structures without decreasing their load capacity. This leads to the event of the theoretical and experimental investigations of such structures. The research works are steadily rising in the recent years. Cold-formed steel members find their extensive applications in automobile industries, aerospace and various secondary civil engineering structural elements such as purlins etc, especially when light weight members will be sufficient in achieving substantial economy. Cold-formed steel sections are less expensive in manufacturing and offer greater flexibility to produce any desired shape. Cold-formed steel sections can be used effectively as a structural element of light weight structures in cases where hot-rolled sections or others are inefficient. However, compression members may undergo Local buckling, Squashing, Overall flexure buckling, Torsional buckling and interaction between them or between the above buckling modes, the accurate prediction of the member strength becomes more complex.

Cold-formed steel members are commonly used in building construction either as a main structural element such as beams, columns, frames, etc., or as a secondary structural element such as roof purlins. Cold-formed steel structural members can lead to more economical design than hot-rolled members due to their high strength/weight ratio, light weight and their easy methods of fabrication and construction lead to more economical design than hot-rolled members.

Though several studies have been performed on the buckling behaviour of the cold-formed steel columns, few studies have been made on improving the efficiency cold-formed steel built-up sections which are used in the load carrying members. Depending on the height to width ratio and lateral support length of the members, cross-sections, shapes and dimensions, any of these buckling modes may be critical. From the above, it is observed that it is desirable to look for new shapes of cross-sections of cold-formed columns. This study helps in development of more efficient cold formed steel built-up sections by providing folded flanges with channel lip and EFG connections which is to improve its behaviour and to study the failure modes of proposed section.

2. DETAILS OF SELECTED SPECIMENS

The shape and size of the specimen are chosen in accordance to the Indian code specifications of IS 801-1975 and IS 811-1987. The thickness of the specimens is 1mm. the web length of the specimens are 100mm and 150mm with varying connection spacing for each web length. The details are given in the table 2.1.

Properties	Column Section	C 100 x 50 x 15 mm	C150 x 50 x 15 mm
Web depth		100 mm	150 mm
Flange width		50 mm	50 mm
Lip length		15 mm	15 mm
Height		1m	1m
Thickness		1 mm	1 mm
Type of connections		Spot welding	Spot welding
Connection spacing		300mm, 180mm, & EFG	300mm, 180mm, & EFG
Slenderness ratio		10	6.667
End Condition		Pinned	Pinned
Built-up type		Back to back	Back to back
Mass per unit length		3.31kg/m	6.50kg/m
Center of gravity		1.71mm	1.52mm
Shear center		4.29mm	3.97mm
Torsion constant		0.056cm^4	0.268 cm^4
Warp constant		312 cm^6	1240 cm^6

Table 2.1 Specimen properties

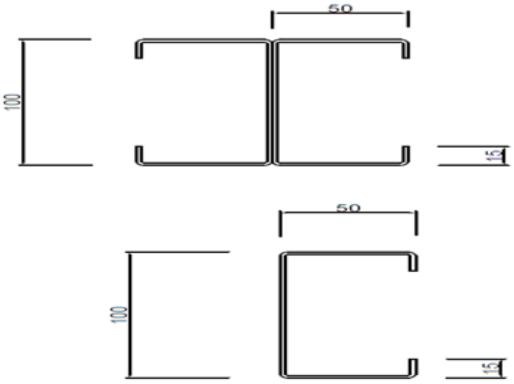


Figure 2.1 Section geometries- cold-formed steel built-up section C100X50X15 mm

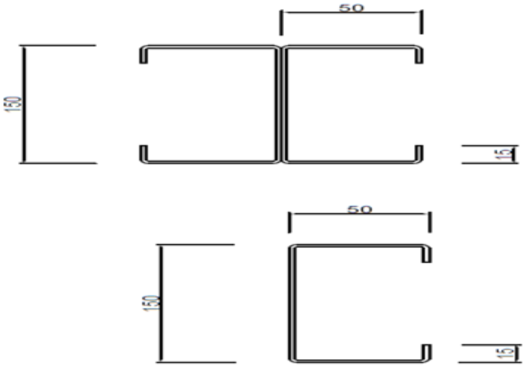


Figure 2.2 Section geometries- cold-formed steel built-up section C150X50X15 mm

3. FABRICATION

The fabrication of cold-formed steel built-up section formed from locally available cold rolled steel sheets. The cold rolled sheets are cut into the required dimension for the present study. The fabrication of the cold formed steel section is done in Press braking machine. The cold-rolled steel elements are welded together by spot welding by using a spot-welding machine. The type of connection chosen for this experiment is spot welding. Connections is done according to American code specifications AISI-S100 code. Regular spacing of the connections along with EFG is used. EFG means End Fastener Grouping. EFG means the connections are grouped together at the ends of the specimen within a specific length. According to the American code specification of AISI-S100(2016) at section I1.2(b) in page no. 76, the maximum length to which the EFG is allowed 1.5 times the width of the specimen.

Maximum length of EFG for specimen group C-100 = 150mm

Maximum length of EFG for specimen group C-150 = 225mm

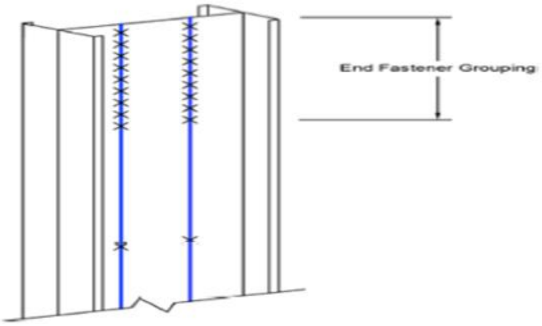
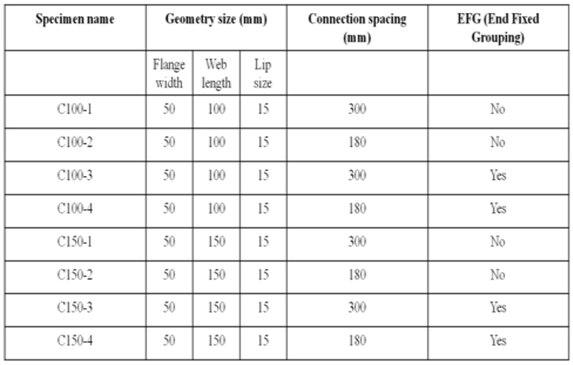


Figure 3.1 End Fastener Grouping

4. EXPERIMENTAL WORK

The test is carried out by using a loading frame connected to a hydraulic jack. The load is measured by using a proving ring in which for every 71.3 divisions is equal to 10KN. A plate is provided under the proving ring to provide a uniform load on the specimen. The deformation of the specimen is measured by using LVDTs. Two LVDTs are placed at a distance of L/3 from the ends of the specimen and one is placed at the centre of the specimen. The deformation is noted for every 10KN applied.

Table 4.1 Specimen specifications



Specimen name	Geometry size (mm)			Connection spacing (mm)	EFG (End Fixed Grouping)
	Flange width	Web length	Lip size		
C100-1	50	100	15	300	No
C100-2	50	100	15	180	No
C100-3	50	100	15	300	Yes
C100-4	50	100	15	180	Yes
C150-1	50	150	15	300	No
C150-2	50	150	15	180	No
C150-3	50	150	15	300	Yes
C150-4	50	150	15	180	Yes

Table 4.2 Load carrying capacity

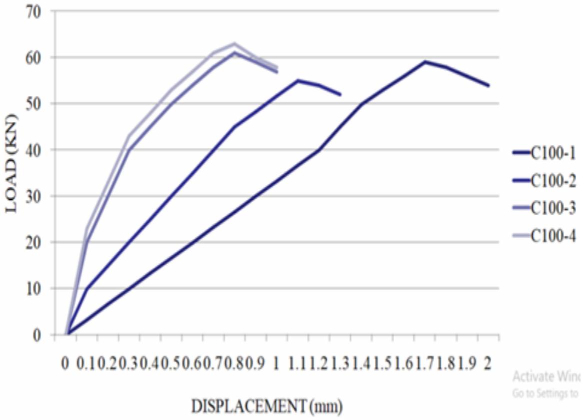
SPECIMEN	ULTIMATE LOAD (KN)	MODE OF BUCKLING
C100-1	60	LF
C100-2	55	LW
C100-3	61	LF
C100-4	63	LF
C150-1	35	LW
C150-2	40	LW
C150-3	36	LW
C150-4	33	LW

Where,

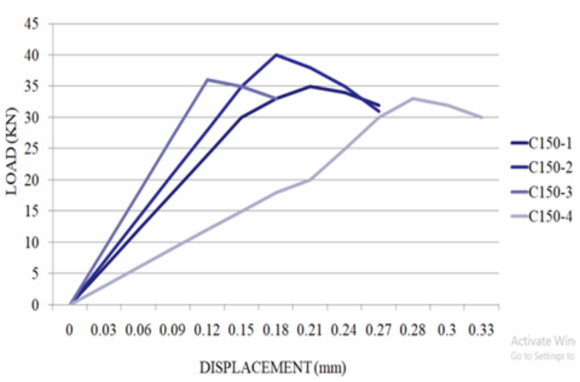
LW- Local buckling of web.

LF – Local buckling of flange.

From the Graph 4.1 the specimen group C100 all fail at lower loads due to local buckling of web or flange. From the Graph 4.1, it can be seen that load carrying capacity of the specimen C100-4 is greater due to the decrease in connection spacing and the presence of EFG. From the Graph 4.2 the specimen group C150 all fail at lower loads due to local buckling of web or flange. Comparing the Graph 4.2, with Graph 4.1, it can be found that load carrying capacity is lesser due to the increase in web length.



Graph 4.1 Specimen Group C100 Graph



Graph 4.2 Specimen Group C150 Graph

5. ANALYTICAL INVESTIGATION

There are many practical engineering problems for which one cannot obtain exact solutions. The inability to obtain exact solution due to either the complex nature of differential equations or the difficulties that arise from dealing with the complicated boundary conditions. The Finite Element Method (FEM) is a numerical technique to obtain approximate solutions to a wide variety of engineering problems. Finite Element Analysis converts the physical structure to a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. It has capability of both linear and non-linear analyses. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models include of stressing of the material past its elastic limits.

5.1) DEVELOPMENT OF FINITE ELEMENT MODEL

Cold-formed steel sections have thickness which is extremely small compared to the other two dimensions which are modeled as plate-shell elements. The commercial non-linear finite element analysis software ANSYS is used to predict load versus deflection behaviour, failure loads and failure modes of the built-up sections. There various steps involved in the finite element analysis.

If the section thickness is less than one tenth of an elemental dimension, then the section is modelled as shell elements. Since the cross section considered for the study has thickness much less than the least dimension in any direction a shell element is chosen for analysis. Material properties play a vital part in finite element analysis. Material properties required for elastic and nonlinear analyses are young's modulus of elasticity, yield strength and Poisson's ratio. Loading is the most important factor in deciding the behaviour of cold-rolled steel section. Here a uniform load is applied at the top of the model as shown in the ANSYS model figure 5.1.

Selection of the mesh density is an important step in finite element modelling. There are two types of meshing in ANSYS; they are

- Global meshing
- Local meshing

Global meshing is used to provide meshing of equal spacing to the whole model. Local meshing is used to provide meshing for a single element in a model. Here global meshing is applied to the model. While creating the model, the cross section of the column is generated. The cold-formed steel built-up column was tested between pinned end conditions. The end conditions are applied at the end faces.

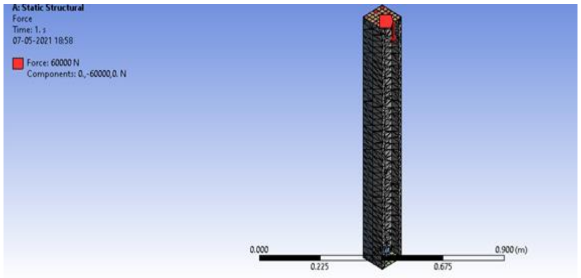


Figure 5.1

5.2) ANALYTICAL RESULTS

The finite element analysis is carried out on the proposed Cold formed steel built-up sections. Loading is applied as displacement and the amount of load applied are taken as total force reaction at the displacement location. The observations made from the analytical investigations are presented in the following.

Table 5.1 Load carrying capacity of specimens

SPECIMES	ULTIMATE LOAD (KN)
C100-1	45.89
C100-2	47.37
C100-3	53.68
C100-4	72.35
C150-1	42.11
C150-2	37.89
C150-3	33.68
C150-4	35.31

Table 5.2 Ratio of buckling capacity of specimens under various conditions

CONNECTION SPACING	SPECIMEN C100 (KN) (P1)	SPECIMEN C150 (KN) (P2)	RATIO (P1/P2)
300mm	45.89	42.11	1.09
180mm	47.37	37.89	1.25
300mm + EFG	53.68	33.68	1.59
180mm + EFG	72.35	35.31	2.05

5.3) ANALYTICAL INFERENCE

The ratio of the columns with connection spacing of 300mm and 180 mm is 1.09 and 1.25. However, with the addition of EFG the ratio from 1.09 to 1.59 for 300mm spacing and for 180mm spacing the ratio increased from 1.25 to 2.05. This indicates that the EFG increases the buckling capacity of a column by at-least 50%. Since the ratios are greater than 1.0, this indicates that increase in web length decreases the buckling capacity of the column.

6. RESULTS AND DISCUSSIONS

The various parameters considered for the study are Ultimate Load Carrying Capacity, Load-Deflection Behaviour. Behaviour of cold form steel built-up sections are investigated by analytical method and experimental method. From the table 6.1 it can be inferred that the experimental results are greater than analytical results by 5% to 30%. It can also be found that specimen C100-4 and specimen C150-2 have higher load carrying capacity of their respective group.

Table 6.1 Ratio of buckling capacity between tested and analytical results

SPECIMES	EXPERIMENTAL RESULTS (KN) (P_E)	ANALYTICAL RESULTS (KN) (P_A)	RATIO (P_E / P_A)
C100-1	60	45.89	1.3
C100-2	55	47.37	1.16
C100-3	61	53.68	1.13
C100-4	63	72.35	0.87
C150-1	35	42.11	0.83
C150-2	40	37.89	1.05
C150-3	36	33.68	1.07
C150-4	33	35.31	0.93

7. CONCLUSION

This thesis presents a detailed investigation on the buckling capacity of cold formed steel built-up sections. The buckling capacity of the proposed cold formed steel built-up sections is investigated using finite element analyses and experimental investigation to gain a thorough understanding in the compression behavior under pinned end conditions. Finite element models of the cold formed steel built-up columns are developed using the advanced finite element tool ANSYS. The tensile coupon tests are also conducted to obtain the material properties of steels that are used to make the test specimens. They are validated by comparing the load- deflection behavior and buckling modes from the experimental tests and from the finite element analyses. The following conclusions are drawn from the present investigation. From the experimental work it can be found that the specimens have undergone local buckling. Due to local buckling, most of the specimen's experimental results are slightly greater than analytical results; whereas some specimen's experimental results are lesser than analytical results. The load carrying capacity of the columns of specimen group C100, increases due to the addition of EFG under similar connection spacing conditions. Comparing the results of the specimen groups C100 and C150 it can be found that the load carrying capacity of the column decreases with increase in web length. Further study is needed for identifying the exact cause of the local buckling.

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