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Numerical study on strength and behaviour of cold formed steel built-up battened columns

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ABSTRACT

This project deals with the investigation on behavior of Cold formed steel Built-up Battened columns The built-up column is fabricated using two lipped channel sections placed back to back. The cross sectional dimensions are selected based on the limitations for prequalified section in AISI S100-2007 for single section. Spacing has been chosen such that to have moment of inertia about major axis equals with the 1.5 times moment of inertia about minor axis ($I_{XX} = I_{YY}$). This project deals with the Numerical, Theoretical study on Built-up columns.

INTRODUCTION

The use of hot-rolled steel sections become uneconomical for the steel structures subjected to light and moderate loads and for the structural members of short span lengths(e.g., joists, purlins, girts, roof trusses, complete framing of one and two storey residential, commercial and industrial structures). So the study on behaviour of cold formed steel framing members is unavoidable to reduce the cost of a building made up of steel structures.

Cold forming has the effect of increasing the yield strength of steel, the increase being the consequence of cold working well into the strain-hardening range. These increases are predominant in zones where the metal is bent by folding. The effect of cold working is thus to enhance the mean yield stress by 15% - 30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15%. Some of the other advantages are high load resistance, long span capability, long term durability, lightness, ease of prefabrication.

For large loads and for efficient use of material, built-up columns are often used. They are generally made up of two are more individual section such as angles, channels, or I-section and properly connected along their length by battening, spacers, lacing so that they act together as a single unit. incorporating the applicable criteria that follow.

Finite Element Method (FEM)

The finite element method (FEM) is a numerical procedure for analyzing structures and continua. FEM originated in structural engineering, and has been used in the fields of heat transfer, fluid flow, electric and magnetic fields and many others. FEM is the principle applicable to any boundary condition, geometry and material variation. The finite element method has been proven as an efficient and powerful approach to calculate the elastic buckling load and ultimate strength of cold-formed steel (CFS) structural

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members. A successful static analysis of the unstable collapse and post-buckling behavior of CFS members requires the nonlinear solution method consider geometric nonlinearity, material nonlinearity, boundary nonlinearity and residual stresses of the physical objects, as well as have the capability to deal with convergence, locking and other difficulties related to implementing the numerical algorithm. There are numerous commercial programs developed based on the Finite Element Method. Few of the commercial programs are ABAQUS, ANSYS, etc., The basic design methods for CFS members are formally available in design specifications in North American specification AISI-S100:2007.

- Direct strength method
- Effective width method

Direct Strength Method (DSM)

Direct strength method considers the gross section properties and the elastic buckling behaviour of the cross-section, instead of considering the section as individual elements adopted in the conventional effective width method. In this method all the three important buckling modes i.e. Local, distortional and lateral-torsional buckling modes are considered to evaluate the design strength of the section. Direct Strength Method includes the interaction between adjacent elements and makes the calculations simpler in obtaining the bending strength of complex cross-sections. Shorter half-wave length buckling modes such as local and distortional may interact with long half-wave length modes such as lateral-torsional buckling. The interactions between the buckling modes are also considered. This method has been used successfully to predict the distortional buckling strength of flexural and compression members. It also predicts the elastic local buckling stress of the whole section with appropriate design curve for local buckling.

The main objective of this project work is to study the behaviour and ultimate capacity of the built-up cold-formed steel battened columns and to develop safe and economical design rules for the section and member ultimate capacities relating to the local buckling and overall buckling effects, respectively.

Cold-formed steel built-up sections are commonly used as compression elements to carry larger loads and over longer spans a single individual section is insufficient, so we are going for a built-up section. However, not much research has been done on built-up sections with batten plates.

The proposed work aims to systematically study the behaviour and ultimate capacity of the built-up cold-formed steel battened columns. Battens are the lateral members that used to connect the chord of the built-up member. This study used the square plates as battens connected by using the self driving screw attachments.

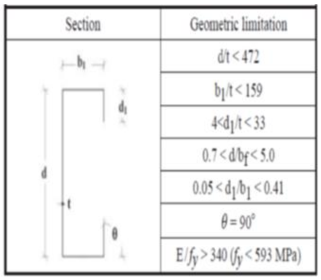
SELECTION OF SECTION AND ITS PROPERTIES

Selection of section

As per North American Specification for the design of cold-formed steel structural member-2007 Edition, the geometric limitations are available for single section only. Based on the single section back to back Built-Up section is selected.

The single section dimensions were selected based on North American Specification for the design of cold-formed steel structural member-2007 Edition. The conditions for geometric limitations are shown in table 1

Table 1 Geometric limitations

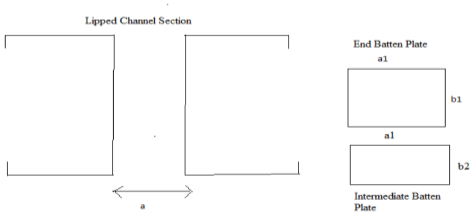


Section	Geometric limitation
	$d/t < 472$
	$b_1/t < 159$
	$4 < d_1/t < 33$
	$0.7 < d/b_f < 5.0$
	$0.05 < d_1/b_1 < 0.41$
	$\theta = 90°$
	$E/f_y > 340$ ($f_y < 593$ MPa)

Sections considered for study

The section considered for study is shown in figure 1

Table 2 Section geometric details



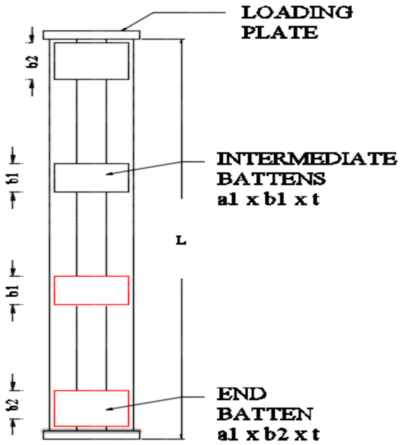


Fig.1.Specimen details

Selection of spacing

Two different types of prequalified cross sections were selected for this thesis work based on the limitation specified in North American & EURO Code Specifications. The spacing between the chords was fixed to have I_{xx} equals to I_{yy}. The centre to centre spacing between the depth of the spacers are fixed based on the IS codal provisions for hot rolled sections.

The spacer spacing along the length of the columns were investigated in accordance with the modified slenderness ratio in clause D1.2 of the AISI specifications (AISI S100-2007). The batten spacing within and beyond the conservative spacing requirement stated in the clause D1.2 of the AISI specifications were investigated. The conservative spacing requirement is expressed as:

$S/ry \leq 0.5(KL/ry)o$

Here S is the spacer spacing, ry is the minimum radius of gyration, and (KL/ry)o is the overall member slenderness ratio of a built-up section.

Numerical analysis

Section Details	b_f	b_w	b_l	T	S
120-50-15-1.6	50	120	15	1.6	80
150-60-15-1.6	60	150	15	1.6	105

The finite element method is a numerical analysis technique for obtaining approximate solutions to wide variety of Engineering problems. Most of the engineering problems today make it necessary to obtain approximate numerical solutions to problems rather than exact closed form solutions. The basic concept behind the finite element analysis is that structure is divided into a finite number of elements having finite dimensions and reducing the structure having infinite degrees of freedom to finite degrees of freedom. The original body of structure is then considered as an assemblage of these elements connected at a finite number of joints called Nodes or Nodal points. This method of analysis has an advantage of that it can take care of any boundary and loading conditions.

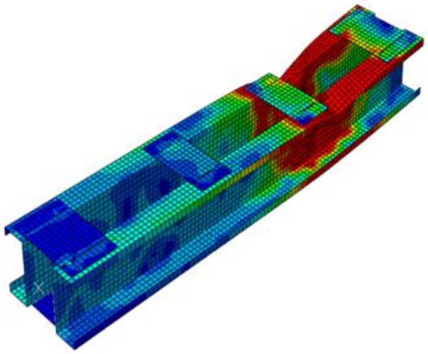
It is aimed to establish accurate finite element models for cold-formed steel long column subjected to pure axial compression. The column section of the FE models were based on the centre line dimensions of the cross-sections together with the plate thickness and rounded corners.

The Finite Element Program ABAQUS was used to simulate the experimental behavior of pin ended cold formed built-up columns. The columns were modeled shell S4R5 elements with sharp corners neglecting the corner radius according to the clause 3 of ENV1993-1-3(1996). The residual stresses of the sections were not included in the model. The strain hardening of the corners due to cold forming is neglected. A bilinear elastic-perfect plastic behavior for material was considered. The material and geometric nonlinearity was included in the finite element model.

A linear elastic buckling analysis was performed first to obtain the buckling loads and associated buckling modes. This was followed by a non-linear ultimate strength analysis to predict the ultimate load capacity. In the nonlinear analysis, initial geometric imperfections were modeled by providing initial out-of-plane deflections to the model. The first elastic buckling mode shape was used to create a geometric imperfection for the non-linear analysis.

Procedure for analysis

- The model of the section is generated through active cross section.
- Center line dimension of section were entered to form a cross section
- The material properties like young's modulus; shear modulus and Poisson's ratio are defined created and section were assembled

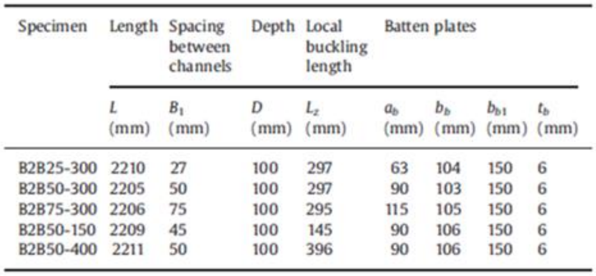


- Reference points(C G) of section were entered in the intension of axial load.
- Boundary conditions of the section were constrained
- Meshing is carried out for the different sizes for different element. Mesh size line mesh tool is used to mesh the individual elements into different number of elements
- Coupling was carried out for the coincidence node for joining the spacer to the specimen at lip and the all degree of freedom must be constrained.
- The type of element is then chosen is Shell S4R5

Validation of literature

Finite element method (ABACUS) procedure is validated through the literature "Experimental investigation of built-up cold-formed steel section battened columns", Mohamed Dabaon, Ehab Ellobody, Khaled Ramzy,2015.Table 3 shows the geometric details of the section.

Table 3 Geometric Details of Section



Specimen	Length	Spacing between channels	Depth	Local buckling length	Batten plates			
	L (mm)	B_1 (mm)	D (mm)	L_z (mm)	a_b (mm)	b_b (mm)	b_{b1} (mm)	t_b (mm)
B2B25-300	2210	27	100	297	63	104	150	6
B2B50-300	2205	50	100	297	90	103	150	6
B2B75-300	2206	75	100	295	115	105	150	6
B2B50-150	2209	45	100	145	90	106	150	6
B2B50-400	2211	50	100	396	90	106	150	6

Theoretical analysis

The theoretical study involves the analysis of a cold formed steel built-up column for its load carrying capacity. Direct Strength Method by North American Specifications (AISI S100-2016) and Effective width method by AS/NZ code specifications are carried out below.

The Direct Strength Method (DSM) is an alternative method of design located in Appendix 1 of the North American Specification for the Design of Cold-formed Steel Structural Members 2007 (AISI S100-2016).

DSM may be used in lieu of the Main Specification for determining nominal member capacities. Specific advantages include the absence of effective width and iterations, while only using known gross-sectional properties. In this thesis work Direct Strength Method is done in two namely DSM 1, DSM 2.

In DSM 1, the load factor is taken from GBTUL and the load carrying capacity of section is calculated by normal procedure.

In DSM 2, the load factor is taken from ABAQUS linear analysis and the load carrying capacity of section is calculated by normal procedure.

In this method, the load carrying capacity of the column is the minimum of the nominal member capacity for Flexural, torsional or flexural-torsional buckling (Pne), Local buckling (Pnl), and Distortional buckling (Pnd).

Parametric study

The parametric study was done with the help of Abaqus software by varying the slenderness ratio.

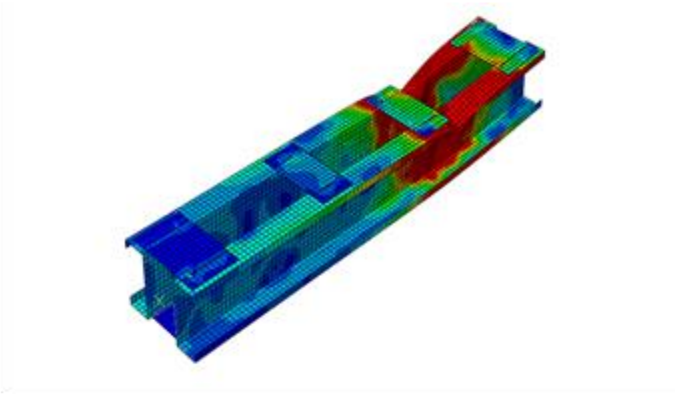


Fig.2. Failure Mode of Section

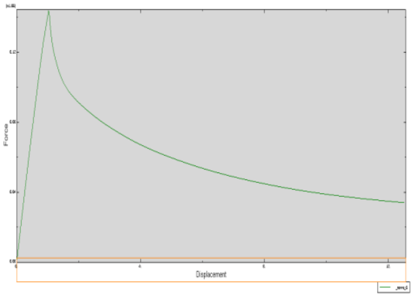


Fig.3.Load vs. Displacement curve from ABAQUS software

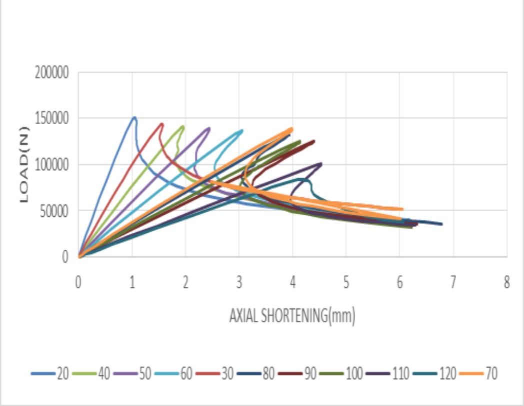


Fig.4.Load vs. Axial shortening curve for 120x50x15 section

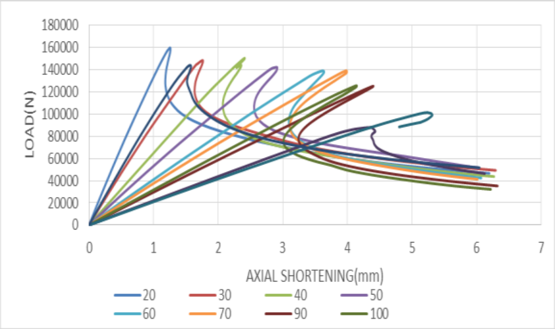


Fig.5.Load vs. Axial shortening curve for 150x60x15 section

RESULTS AND DISCUSSION

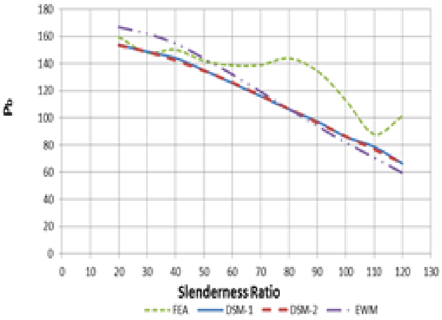


Fig.6 Load Vs Slenderness ratio for 120x50x15 section

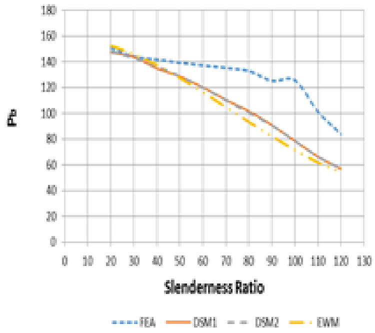


Fig.7 Load Vs Slenderness ratio for 150x60x15 section

CONCLUSION

- In general, the ultimate load decreases by increasing the slenderness ratio.
- More results are required to propose a design equation for columns failing by global buckling.
- A design equation has been proposed for columns with local buckling.
- The loads calculated from DSM-1 and DSM-2 based on code predicts conservative values when compared to FEA results.
- In built-up column-1, for all lengths loads from DSM-1, DSM-2 and Effective width method gives closer values. For Slenderness ratio between 20 to 40, the loads from code matches with the loads from FEA. For remaining slenderness ratio the code predicts conservative values.
- In built-up column-2, for all lengths loads from DSM-1, DSM-2 and Effective width method gives closer values. For Slenderness ratio between 20 to 50, the loads from DSM-1 and DSM-2 matches with the loads from FEA. But when compared with Effective Width Method, the code predicts unconservative values. For remaining slenderness ratio the code predicts conservative values.

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