Study on Ultimate Strength and Buckling Modes of Cold Formed Steel Structures

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Abstract. Stronger construction material is category from one of the steel structure are attain higher strength with stand the resistance of steel by natural as well as it could made in different shapes. The exact shape of steel structure and its profile are precisely designed from cross section to ensure Indian Standard along with mechanical and chemical characteristics. All over the country’s most of the industrialization is precise on sizes, shapes; strengths, storage practices and its composition of steel structure are used as per standards. cold-formed steel is effect with rolling of thin gauge steel sheet increasing the yield strength whose products are widely used in construction industries, as well as structure like columns, beams, joists, studs, floor decking, built-up section, telecommunication towers, electricity transmission steel tower, multi-storied steel structures, etc., due to its stronger and reduction in dead weight cold-formed steel is used. The dies are series of making various section of cold-formed steel structural member with different section and shapes by cold roll forming the steel to attain the preferred shape. As per the standard, nominal minimum yield strength of sheet steel rolled in cold-formed section is 250 N/mm². However, user trend use of greater strength, but it could be lesser as 230 N/mm².

1. Introduction
In construction building now days the rapid increase in use of cold-formed steel members [1]. In 1950s the use of cold-formed steel structural members are initiated with construction building in several countries [2], [3], and [4]. Frequent requirement of shapes as per cross sectional member cold-formed to intimate acceptances, which can be implement reliable. Preferred shape along with length could be creating on cold roll as per design [5], [6], and [7]. Pre-coated member can be formed to achieve for good-looking besides the finish metal along with corrosion resistance structure [8], [9], [10]. In cold-formed steel rolled structures the weight ratio and greater strength is achieved [11]. For the purpose of transportation and erect in different places of cold-formed steel is made easy by thin structural member ease of construction. [12]. The industrial materializing process of making material methods adopted by press braking operation and cold rolling are these two methods followed.

1.1 Comparison of cold rolled steel and hot rolled steel
The comparative values of standard hot rolled section against the standard cold formed precise steel dimension section are given in the table 1.
From the above table 1, it indicates that for the various sections having same cross-sectional area, [13] the section modulus and the moment of inertia is greater for the cold rolled sections which will be capable of resisting greater bending moments as shown in the figure 1 and figure 2.

Table 1. Comparison of hot rolled section with various cold formed sections.

| Parameters                  | Notation | HRS ISA 60 × 40 | CFS 100 × 50 | HRS ISA 55 × 55 | CFS 70 × 70 |
|-----------------------------|----------|-----------------|--------------|-----------------|--------------|
| Thickness (cm)              | t        | 0.60            | 0.40         | 0.5             | 0.4          |
| Sectional Area (cm²)        | a        | 5.65            | 5.66         | 5.27            | 5.26         |
| Weight per meter (Kg)       | w        | 4.40            | 4.44         | 4.10            | 4.13         |
|                             | Ixx      | 19.90           | 60.30        | 14.70           | 25.7         |
| Moment of Inertia (cm⁴)     | Iyy      | 7.00            | 11.00        | 14.70           | 25.7         |
|                             | Iuu      | 22.80           | 64.80        | 23.50           | 41.9         |
|                             | Ivv      | 4.00            | 6.49         | 5.90            | 9.43         |
| Section Modulus (cm³)       | Zxx      | 5.00            | 9.41         | 3.70            | 5.09         |
|                             | Zyy      | 2.30            | 2.72         | 3.70            | 5.09         |
| Product of Inertia (cm⁴)    | Ixy      | 6.80            | 15.60        | 8.60            | 16.2         |

Figure 1. Comparison of hot rolled section and cold formed section of unequal angles.

To enhance the strength of cold-formed steel effect it range from 15 % - 30% of yield stress increase. The minimum of 15 % yield stress could be considered as strong to enrich for design purpose [14].
Figure 2. Comparison of hot rolled section and cold formed section of equal angles.

1.2 Characteristics of cold formed steel sections
By relating with timber and concrete materials, it recognized that quality steel structure along through quantities of cold-formed members is light in weight, stronger and durable, forbearance of pre-casting and more fabrication, rapid installation with erection, significant delay based on weather could be eliminated, non-shrinking and creeping at ambient temperature, not required of formwork, excellence in uniform along with cost effective during transportation and handling.

2. Literature review
Behavior of cold-formed steel approach along with tilt in angle of column studied under axial load. Limitations of geometric chosen for three section as per (AISI S100 – 2007) based on North American conditions. The existing experimental values of finite element analysis work were validated by ABAQUS [15]. Confrontation along with performance of resistance based application for flange/ web toughness on plain cold-formed steel to adhere improve in torsional buckling [16]. The knowledge behind shape and thickness of cold-formed steel is easy method for industrial design with huge number on various structures formed constrained to economical [17], [18], [19]. Approach on flexural behavior of torsional buckling, finite element analysis, radius of gyration for cold-formed steel direction are as per (AISI S100 – 2007) calculated cited based on North American conditions [20], [21]. Alternative method of cold-formed steel columns substantiation from existing experiments provides the inconsistency on design along methodical miscalculation error [22]. A proposed innovative method for calculation of thin walled columns behavior of buckling predictions based on design of effective thickness is reliable to analysis [23]. The prominent role of uncertainties behavior complicates the design based on thin wall columns is compared with conventional method [24]. Buckling modes are revealing fewer than three categories by local, distortional and Euler [25], [26]. Behavior on cross-section and typical thin walled columns under elastic buckling are performed [27], [28].

3. Theoretical analysis
The typical cross section of the cold formed steel column section taken for analysis is shown in the Fig. 3 and the dimensions are represented in mm.
3.1 Cross section of cold formed steel column specimens of varying thickness

On providing the geometrical data to input window of the CUFSM software the cross section of varying thickness 1.00 mm, 2.55 mm, 3.15 mm and 4.00 mm are obtained as shown in the figure 4, 5, 6 and 7 from which the section is being analysed.

Figure 3. Typical Cross section of cold formed steel column specimen.

Figure 4. Cold formed steel section thickness of sample 1.00 mm.

Figure 5. Cold formed steel section thickness of sample 2.55 mm.
The software determines the various section parameters by means of the inbuilt programme and is validated by the known values. The section of any thickness can be analysed by the limiting values of analysis and is determined by the flat width ratio of the members as per the IS codes.

3.2 Section properties calculated using CUFSM software
The Section Properties of the cold formed section of varying thickness derived from CUFSM Software is given in table 2.

| Sl. No | Description | Symbol | Value |
|-------|-------------|--------|-------|
| 1     | Area of the Section (mm²) | A  | 265.43 | 676.84 | 836.09 | 1061.71 |
| 2     | Centre of Gravity X Axis (mm) | Cgx | 27.21 | 27.21 | 27.21 | 27.21 |
| 3     | Centre of Gravity Z Axis (mm) | Cgz | 42.50 | 42.50 | 42.50 | 42.50 |
| 4     | Moment of Inertia XX Axis (mm⁴) | Ixx | 273332.5 | 696997.7 | 860997.2 | 1093329.7 |
| 5     | Moment of Inertia ZZ Axis (mm⁴) | Izz | 177811.9 | 453573 | 560296.4 | 711487.4 |
| 6     | Shear Centre X Co-Ordinate (mm) | Xs | -35.32 | -35.32 | -35.32 | -35.32 |
| 7     | Shear Centre Z- Co-Ordinate (mm) | Zs | 42.50 | 42.50 | 42.50 | 42.50 |
8. Warping Torsion Constant (mm$^4$) $C_w$ 299×105 763×106 943×106 119×107
9. Torsion Co-Efficient (mm$^4$) $J$ 136.12 1467.04 2765.38 5662.43

3.3 Calculation of ultimate load carrying capacity of the section
Load carrying capacity of different section under ultimate load with varying thickness and length for cold formed steel column section is given in table 3.

$$P_{a1} = \text{Flexural Torsional Stress } \times \text{Cross Sectional Area}$$

$$P_{a1} = 127.418 \times 265.43 \quad P_{a1} = 33.820 \text{ kN}$$

Ultimate Load = Factor of Safety $\times P_{a1} = 1.667 \times 33.820 = 56.38 \text{ kN}$

| Sl. No | Thickness (mm) | Length (mm) | Ultimate Load Carrying Capacity of the Section (kN) |
|--------|----------------|-------------|---------------------------------------------------|
| 1      | 1.00           | 500         | 56.38                                             |
|        |                | 1500        | 55.82                                             |
|        |                | 2500        | 52.48                                             |
|        |                | 3500        | 47.66                                             |
|        |                | 5000        | 38.08                                             |
| 2      | 2.55           | 500         | 146.69                                            |
|        |                | 1500        | 142.47                                            |
|        |                | 2500        | 134.77                                            |
|        |                | 3500        | 124.918                                           |
|        |                | 5000        | 109.44                                            |
| 3      | 3.15           | 500         | 181.21                                            |
|        |                | 1500        | 176.10                                            |
|        |                | 2500        | 167.22                                            |
|        |                | 3500        | 156.83                                            |
|        |                | 5000        | 142.70                                            |
| 4      | 4.00           | 500         | 230.11                                            |
|        |                | 1500        | 223.84                                            |
|        |                | 2500        | 213.92                                            |
|        |                | 3500        | 203.90                                            |
|        |                | 5000        | 192.78                                            |

Table 3. Ultimate load carrying capacity of the cold formed steel column section.

4. Experimental Study
An experiment study on under ultimate load, varying lengths and thickness of different modes with ANSYS output results were change in buckling nature is good.

4.1 Study on variation of ultimate load with varying lengths
From the figure 8 it’s clear that ultimate load varying based on length and the thickness of member of 1 mm, 2.55mm, 3.15mm, and 4 mm respectively. From 1 mm to 2.55 mm the load resistance increase to 100 kN. Similarly, 3.15 mm to 4 mm load increase to 50 kN.

Figure 8. Comparison of ultimate load with varying length (t = 1.00,2.55,3.15 and 4 mm).
4.2 Study on variation of ultimate load with varying thickness

Similarly the plot is drawn on taking the varying thickness along the XX axis and the graphs obtained are as shown in the figure 9.

![Figure 9. Comparison on ultimate load with varying thickness along length.](image)

5. Results and discussion

The validated results helps to extend the study to vary the parameters of the section for the thickness of 1.00 mm, 2.55 mm, 3.15 mm and 4.00 mm and various lengths of the specimen. The extended section is analysed for ultimate load using the IS method and ANSYS software to obtain the theoretical and numerical results. And these results are compared to match each other with little variations table 4.

| S. No | Thickness (mm) | Length (mm) | 500 | 1500 | 2500 | 3500 | 5000 |
|-------|----------------|-------------|-----|------|------|------|------|
| 1     | 1.00           |             | 103.890 | 105.354 | 103.399 | 98.028 | 92.834 |
| 2     | 2.55           |             | 102.025 | 101.506 | 99.566 | 99.402 | 97.734 |
| 3     | 3.15           |             | 102.236 | 103.444 | 100.302 | 98.623 | 97.222 |
| 4     | 4.00           |             | 101.308 | 101.838 | 98.978 | 98.788 | 97.963 |

From the obtained values the variation of ultimate load from the both numerical and theoretical methods are further extended for the study on getting the fine result against the experimental values. The variation of ultimate load from the both numerical and theoretical analysis are plotted as shown in the figure 10, 11, 12 and 13 and it is evident that the results are appropriate in the analytical method of analysis.
Figure 10. Percentage variation of ultimate load by numerical and theoretical methods for the thickness of 1.00 mm.

Figure 11. Percentage variation of ultimate load by numerical and theoretical methods for the thickness of 2.55 mm.
6. Conclusion

- The ultimate strength of cold formed steel section is determined by the both numerical and theoretical methods for the various section parameters.
- The section is analysed for the different buckling modes for the various section parameters.
- The finite element model is extended for the study of ultimate load carrying capacity and buckling modes for the varying thickness of 1.00 mm, 2.55 mm, 3.15 mm & 4.00 mm and also for the varying length to 500 mm, 1500 mm, 2500 mm, 3500 mm & 5000 mm.
• The relation among local, distortional and universal buckling induces reduction in ultimate strength of cold formed steel columns.
• Both the theoretical and numerical analysis results concluded that,
• Load increases with the increase in thickness of the section at the rate of 37.44% for every 1.00 mm rise in the thickness
• Load decreases with the increase in length of the section at the rate of 5.77% for every 1000 mm rise in the length.

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