

# BUCKLING BEHAVIOUR OF COLD FORMED STEEL SECTIONS

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**Abstract** - Cold formed steel members are made from structural steel sheets by bending or forming into different shapes by roll forming the steel through a series of dies. The advantage of cold formed sections is that, no heat is required to form the shapes unlike hot-rolled members. CFS does not shrink or split, doesn't absorb moisture and also resists warping, termites and fire. The strength and ductility of CFS makes it ideal for construction in regions subjected to high speed winds and earthquakes. Different varieties of steel thicknesses are available that meet a wide range of structural and non-structural applications. According to National Association of Home Builders (NAHB) Research Centre, zinc coating on steel can protect it against corrosion for hundreds of years. With developments such as panelized systems, the usage of CFS has increased a lot. In fact it is becoming the material of choice of construction for student dormitories, assisted living facilities and hotels across the country. This project deals with the altering a channel section with provision of lip and comparing their buckling modes under axial load using the software CUFSM.

**Key Words:** Cold formed steel, buckling mode, channel section, lip, CUFSM.

## 1. INTRODUCTION

There are two main families of structural steel members. One is the familiar group of Hot-Rolled Steel (HRS) sections and other is Cold Formed Steel (CFS) members. The CFS members are widely used in various fields including the construction of buildings, bridges, storage racks, highway products, drainage facilities, grain bins, transmission towers, car bodies, railway coaches and various types of equipment. CFS members are more economical compared to hot-rolled members due to its high strength to weight ratio, ease of construction and sustainability for a wide range of applications. The thickness of steel sheets or strip generally used in cold-formed steel structural members range from 0.4 mm to about 6.4 mm. The materials used in cold-formed thin wall members have to satisfy certain criteria to be suitable for cold-forming and usually also for galvanizing. The yield strength is normally in the range of 220 to 350 N/mm<sup>2</sup>,

but also some high-strength steels with yield strength of over 500 N/mm<sup>2</sup> are used. In some cases, due to practical reasons such as transportation, handling etc., thickness of the material used in profiled sheeting is limited.

### 1.1 Benefits of Cold-Formed Steel sections

Generally, cold-formed steel sections have several advantages over hot-rolled steel section, timber sections and concrete. The main aspects are listed as

- Cold forming improves the yield strength of steel to some extent. The improvement of the yield strength is the consequence of cold working well into the strain-hardening range. The improvements in yield strength 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 design purposes, the yield stress may be regarded as having been enhanced by a minimum of 15%.
- Consistency and accuracy of profile: The nature of the manufacturing process: Cold rolling - enables the desired profile maintained and repeated for as long as it is required, in a very close tolerance. Moreover, the very little tools wears and the cold rolling process is ideally suited to computerized operation which assists to the maintenance of accuracy.
- Versatility of profile shape: Almost any desired shape can be produced by cold rolling, such as T-section, Z-section, Sigma-section etc.
- It could be pre-galvanized or pre-coated: The steel material may be galvanized or coated by plastic materials either to enhance its resistance to corrosion or as an attractive surface finish.
- Variety of connection and jointing methods: All conventional methods of connecting components, e.g. riveting, bolting, welding and adhesives are suitable for cold formed steel section.
- Speedy in construction and suitable for site erection: Generally the steel construction has eliminated the curing time which is inevitable in concrete construction; therefore it is faster than concrete construction. The cold formed steel may be more advantageous than hot-rolled steel since it can be cut and erected with very light machine and even only man power.

- Increase in yield strength due to cold forming: The cold forming process hardens the formed corners. This is called as local work hardening. This local work hardening may result in an increment of ultimate yield strength of about 25% from its virgin strength.
- Minimization of material: Since the material used can be very thin in comparison to the lower thickness limits of hot rolled steel sections, it allows the material usage for a given strength or stiffness requirement to be much less than that of the smallest hot rolled sections.

## 1.2 Manufacturing process

The CFS sections are cold-formed from carbon or low alloy sheet, strip, plate or flat bars in cold-rolling machines or by press brake or bending brake operations. Their manufacturing process involves forming steel sections in a cold state i.e., without application of heat, from steel sheets of uniform thickness. There are three methods to form any shape of CFS:

- Cold-roll forming
- Press brake operation
- Bending brake operation

### 1.2.1 Cold-roll forming

Cold rolling occurs with the metal below its recrystallization temperature (usually at room temperature), which increases the strength via strain hardening up to 20%. And also, it improves the surface finish and holds tighter tolerances. Sheets, strips, bars and rods are the most commonly manufactured cold-rolled products. Due to the smaller size of the work pieces, their strength to weight ratio is greater compared to hot rolled, four-high or cluster mills are used. Cold rolling cannot effectively reduce the thickness of a work piece as much as hot rolling in a single pass. Cold-rolled sheets and strips come in various conditions such as Full-hard, Half-hard, Quarter-hard, Skin-rolled. The thickness can be reduced by 50% by full-hard rolling, while the others involve less of a reduction. Skin-rolling involves the least amount of reduction: 0.5-1%. Smooth surface and uniform thickness can be produced and reduce the yield-point phenomenon (by preventing Luder bands from forming in later processing). It locks dislocations at the surface and thereby reduce the possibilities of formation of Luder bands. To avoid the Luder bands formation it is necessary to create substantial density of unpinned dislocations in ferrite matrix. It is also used in subsequent cold-working processes where good ductility is required. Other shapes can also be cold rolled provided the cross sections are relatively uniform and the transverse dimensions are relatively small. A series of shaping operations are required for the purpose of cold-rolling. It is done usually

along the lines of sizing, breakdown, roughing, semi-roughing, semi-finishing.

Roll forming is continuous process where, a series of paired roll tools progressively shape a flat strip of metal into a desired profile. This process is called 'Flowering'. A gradual change in shape appears on a continuous strip as it passes through different stages of the process. The process of cold roll forming process is shown below in the Fig. Cold roll forming is a continuous process which eliminates stage production, finishing and sub-assembly operations. Thus it holds an edge over the other production methods. It also offers the following advantages.

- Complex geometrical shapes can be produced.
- Better consistency and accuracy can be achieved.
- Versatility in thickness and length.
- Increased strength due to strain hardening.
- Lightweight and rigid which saves material and cost.
- Secondary operations can be combined in the continuous operation which speeds up the production.
- Both ferrous and non-ferrous metals can be formed by this method.
- Avoids secondary coating as galvanized, vinyl coating or plastic enclosed metal can be roll-formed.
- Increases manageability.
- Maximum straightness.
- Closer tolerances.
- Better surface finish.

### 1.2.2 Press brake operation

A brake includes parameters such as force, tonnage, working length. Some of the additional parameters that have to be considered in brake operation are amplitude or stroke, the distance between the frame uprights or side housings, distance to the back gauge and work height. The upper beam usually operates at a speed ranging from 1-15 mm/sec. There are many types of brakes which are classified by the means of applying force.

- Mechanical
- Pneumatic
- Hydraulic and
- Servo-electric

A typical specimen fabricated by the press brake operation is showed in below fig.

### 1.2.3 Bending press brake

Brake is a metal working machine that allows the bending of sheet metal. A cornice brake can produce simple bend and creases, while a box and pan brake can produce box and pan shapes. It is also known as bending machine or bending brake.

## 2. BUCKLING MODES OF FAILURE

The general failure associated with slender column is 'buckling'. As long as the load on such a member is relatively small, increases in the load result only in axial shortening of the member. However, once a critical load is reached, the member suddenly bows out sideways. This leads to large deformations, which results in the collapse of the member. The general buckling modes are

- Local buckling
- Distortional buckling
- Global buckling

### 2.1 Local Buckling

The plate elements of Cold-formed sections are generally thin higher plate slenderness ratio and hence they buckle locally before yield stress is reached. The cross sectional geometry (shape and dimension) and support conditions influences the local buckling mode of a given thin-walled member. But this does not immediately lead to failure. Additional load can be carried by the elements in the post-buckling strength before failure occurs. The post-buckling strength of elements having relatively large flat width to thickness ration may be several times the load that causes local buckling. Consequently all the cold-formed design specifications take in to account post-buckling strength.

### 2.2 Distortional Buckling

Distortional buckling also known as stiffener buckling or local torsional buckling is mode characterized by a rotation of the flange at the flange-web junction in numbers with edge stiffened elements. In the case of members with intermediate stiffened elements, displacement of the intermediate stiffener normal to the plane of the element characterizes the distortional buckling.

### 2.3 Global Buckling

Unlike distortional buckling, global buckling does not deform the cross-section of the element. Global buckling is consistent with classical beam theory.

## 3. REVIEW OF LITERATURE

Benjamin Schafer[1], on his paper proposed new definitions for different modes of buckling. Those definitions were based on simple mechanical assumptions

which can easily be applied in the context of any numerical method. The proposed definitions were deeply explained with the applications of Finite Strip Method.

S.Narayanan[2] has described about the buckling behaviour of innovative cold formed steel columns. Software such as THINWALL and ABAQUS were used to find out the buckling modes of the cold formed steel columns. B.W. Schafer[3] uses the software CUFSM to determine the buckling modes of the columns. CUFSM is a finite strip analysis software which is available for free. He has analyzed under general boundary conditions. Y.S. Tian[4] has analyzed channel sections with and without lip. The failure modes such as yielding, flexural buckling, torsional-flexural buckling, and local buckling were considered while the specimens were subjected to compression.

## 4. METHODOLOGY

The following flowchart illustrates the methodology adopted to determine the buckling behaviour of cold-formed steel columns.

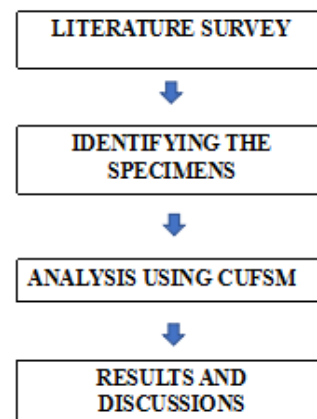


Chart -1: Methodology

The buckling behaviour of a channel section is analyzed by providing lip. Also the angle of the lip is altered and analyzed. A channel section of width 40mm and height 90mm is taken as the section to be altered. The sections are analyzed under simply supported conditions.

Table -1: Dimensions of the sections

Section	Web	Flange	Lip-1	Lip-2
S-1	90mm	40mm	-	-
S-2	90mm	40mm	20mm (inside) (90°)	-

S-3	90mm	40mm	20mm (inside) (90°)	10mm (inside) (57°)
S-4	90mm	40mm	20mm (outside) (90°)	-
S-5	90mm	40mm	20mm (outside) (90°)	10mm (outside) (57°)

S-1, S-2, S-3, S-4, S-5 are section 1, section 2, section 3, section 4 and section 5 respectively.

### 5. RESULTS

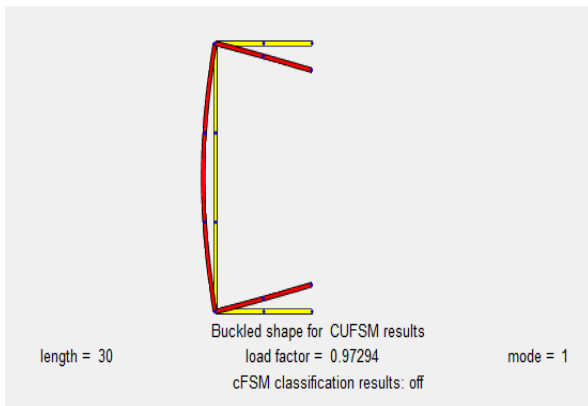


Fig -1: Buckled shape of S-1

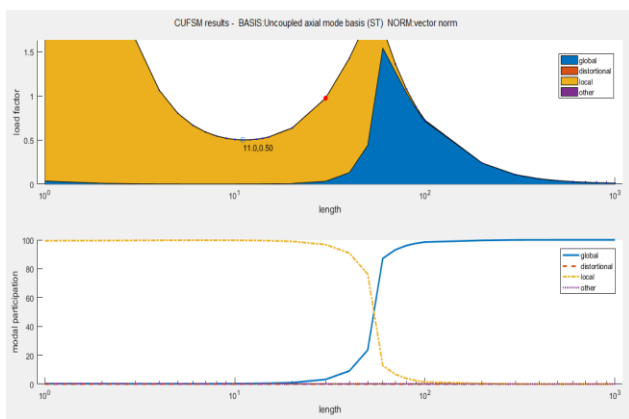


Fig -2: Modal classification of S-1

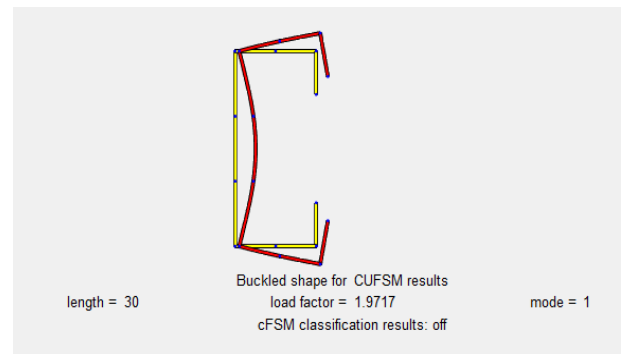


Fig -3: Buckled shape of S-2

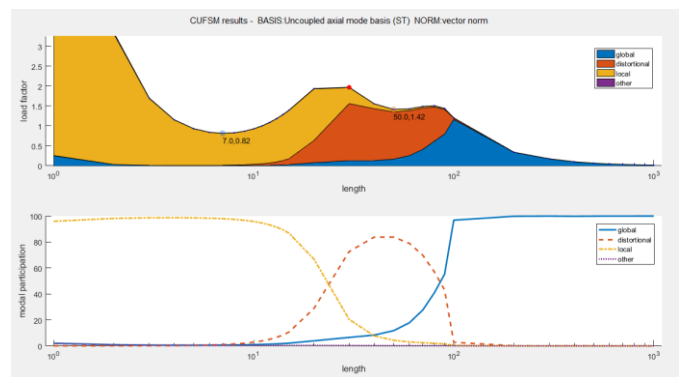


Fig -4: Modal classification of S-2

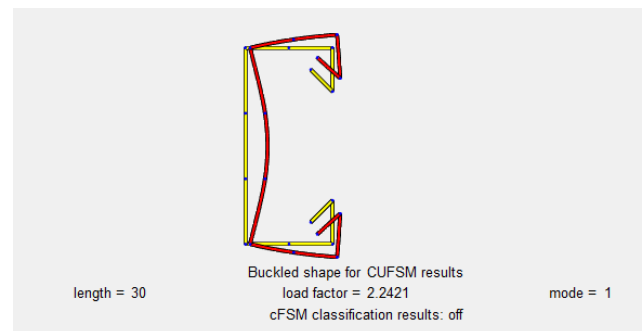


Fig -5: Buckled shape of S-3

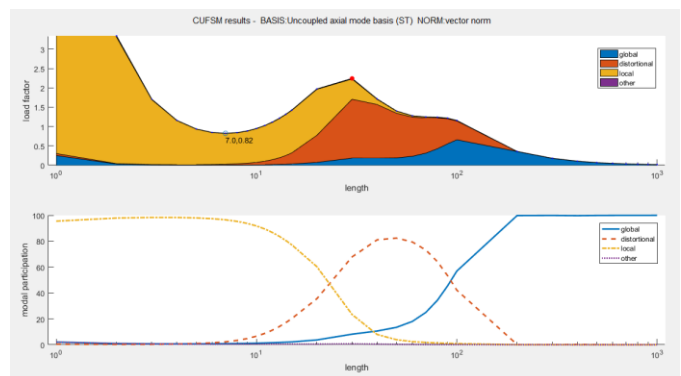


Fig -6: Modal classification of S-3

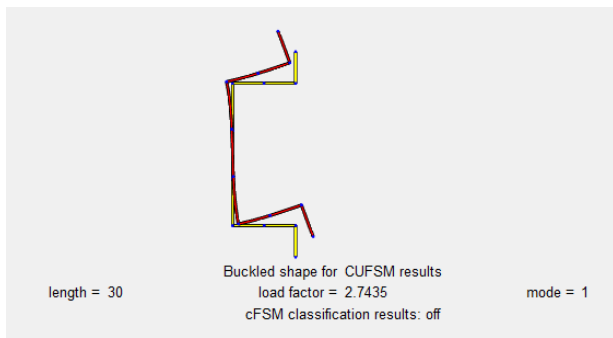


Fig -7: Buckled shape of S-4

From all the above results, it is seen that there is no distortional buckling taking place when there is no lip provided. Distortional buckling is seen in all the cases where lips are provided. But, the effect of distortional buckling varies with the position of lip as seen in the modal classifications shown in the figures. But these results are due to the provided boundary conditions. The results vary with different boundary conditions.

6. CONCLUSION

The buckling behaviour of the channel sections were effectively analyzed using CUFSM. It uses finite strip method which is comparatively less precise than finite element method. But still it provides acceptable results in a format that is easy to understand. Therefore we conclude that CUFSM is a reliable software that is available for free and with the help of it we could effectively analyse the buckling behaviour of columns.

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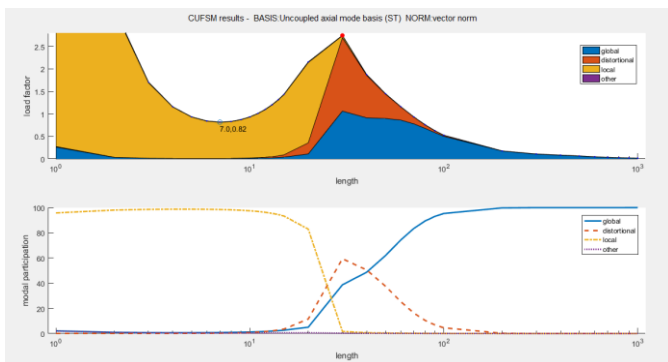


Fig -8: Modal classification of S-4

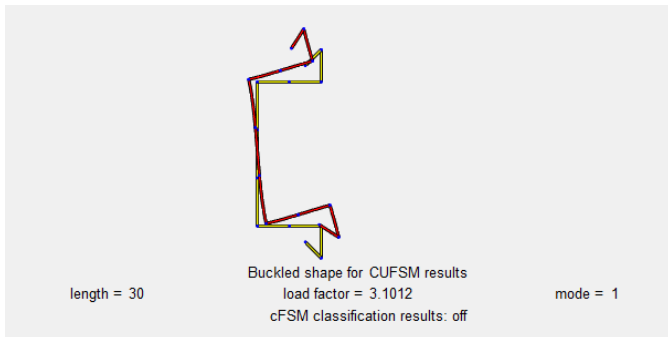


Fig -9: Buckled shape of S-5

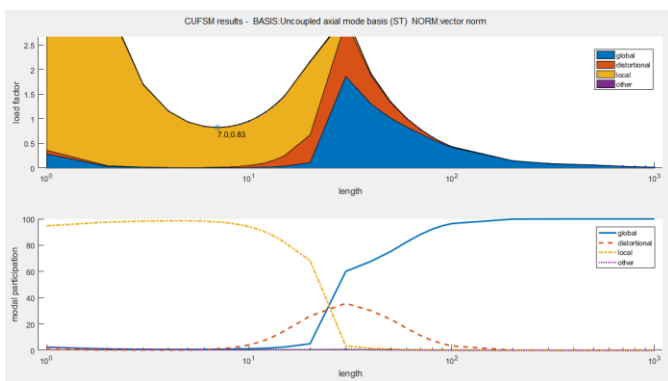


Fig -10: Modal classification of S-5