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Comparative Study on Cold Form Purlins for Distortional Buckling Behaviour

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Abstract

This paper presents the comparative study on cold form purlin sections under distortional buckling behaviour. The “C” purlins are now-a-days widely used in all industrial buildings. It is made up of steel sheets, thickness ranges from 0.8mm to 5mm and formed by cold process. It is extensively used for the advantage of lightweight, low cost and easy manufacturing. In the present study, an analysis has been made to understand the behaviour of cold formed “C” purlins for gravity and wind load conditions. In actual practice compression flanges and tension flanges are laterally restrained by roof sheeting in gravity and wind loading respectively. For this study, actual full scale model test have been conducted in laboratory, for above said boundary conditions. Uniformly distributed load was applied and vertical and lateral deflection was measured. In addition, a numerical study using finite element analysis was done for the above said case. For the analysis ANSYS 10.0 software was used. Finally a comparative study is made between theoretical and experimental results.

Keywords: cold form steel, finite element analysis, distortional buckling, simply supported beam.

Introduction

Steel has the advantages of strength and faster construction. The steel sections come in basic shapes of angles, channels, plates etc., since their dead loads are less and they are easy for transportation and erection. Workability is more since it can be easily cut or punched. It requires no formwork during construction stage. Hence in many situations steel can be alternate construction materials. Normally there are two main families of steel structural members. One is the familiar group of hot- rolled shapes and members built up of plates. The other less familiar but of growing importance, is composed of sections cold-formed from steel sheet, strip, plates, or flat bars in roll forming machines or by press brake operations .These are cold-formed steel structural members ranges from 0.38 mm to about 6.35 mm. Steel plates and bars as thick as 20 mm can be successfully cold-formed in to structural shapes. Cold formed light gauge steel members are used in structures subjected to light and moderate loads. For such structures the use of hot-rolled shapes is often uneconomical because the stresses developed are very low, the smallest available sections are more than sufficient. The advantage of light gauge lie in the ease of forming of variety of shape designed to use the material effectively and to simplify and speed up the construction operation. Substantial economy can be achieved with mass production of standardized structural members. In India, the application of cold-formed structural elements in building industry is gaining importance. The Bureau of Indian standards has also published many codes of practice IS: 801-1975 and IS 800-1984 are considered and sections available in IS 811-1987 and SP 6 (Part1) are used in the design.

Definition

The light gauge steel members are defined as structural members cold- formed to shape in rolls or press braked steel sheets or strips or plates or flats. The thickness of the steel sheets used in such members ranges from 0.38 to 6.35 mm.

Methods of Forming

Generally three methods are used in the manufacture of cold- formed sections

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

Advantages

In general, cold-formed light gauge steel structural members provide the following advantages in building construction: As compared with thicker hot rolled shapes, more economical design can be achieved for relatively light loads and/or short spans.

Unusual sectional configuration can be economically produced by cold- forming operation, and consequently favourable strength-to-weight ratios can be obtained. Load carrying panels and decks can provide useful surfaces for floor, roof, and wall constructions, and in other cases they can provide enclosed cells for electrical and other conduits. Load carrying panels and decks not only withstand loads normal to their surfaces, but they can also act as shear diaphragms to resist force in their own planes if they are adequately inter connected to each other and to supporting members.

Characteristics of Cold Formed Steel Structural Members

Compared with other materials such as timber and concrete, the following qualities can be realized for cold-formed steel structures members.

- Lightness
- High strength and stiffness
- Ease of prefabrication and mass production
- Fast and easy erection and installation.
- Substantial elimination of delays due to weather.
- More accurate detailing.
- Non- shrinking and non- creeping at ambient temperature.
- Form work unneeded.
- Termite proof and rot- proof.
- Uniform quality.

Combination of the above mentioned advantages result in cost saving during constructions.

Light Gauge Steel Flexural Members

The light gauge beams and bending members may be made of any of the cross section. The classification of beam sections is done according to whether the beam sections are laterally supported or unsupported. The strength of beam member of thin plates is defined as load carrying capacity of the member governed by one or combination of following types of failure:

1.Flexural failure.

2.Local buckling of thin plate web elements of the section between the flanges.

3.Over-all or primary beam buckling by bending in lateral direction over the unsupported length of the member.

4.Torsional buckling or twisting of the section about a longitudinal axis.

Need For The Present Study

Cold formed steel structural elements have emerged as a preferred economical solution for many roof systems for single storey commercial and industrial buildings at present days. The economy of these elements lies in buildings with short and intermediate length bays (i.e. 6-9m). A typical cold formed steel roof system is composed of a roof membrane that is attached to structural members. The membrane consists of interconnected panels formed from shut steel, with trapezoidal corrugations spaced 305mm on centre, formed from 24 gauge or 26 gauge thick shut steel. The individual panels are interconnected by either self drilling or self topping screws. The structural member or purlin commonly has a ‘Z’ or ‘C’ shaped in geometry. Member depth varies from 150 to 300 mm with thickness ranging from 1.5 to 3mm. The load span requirements dictate the actual member size and span conditions ie. Simple and continuous.

Accepted design practice is to assume for gravity loads, that the roof membrane is capable of stabilizing the compression flange in the positive moment region. Using this assumption, the member is sized to meet the provisions of the specifications for the design of cold formed steel structural members (IS 801). For the analysis a particular ‘C’ section for gravity load and wind force is considered. Studies have been made based on the experimental analysis. Theoretical analysis has been carried out based on the assumed section, boundary and loading conditions. Primary aim of this study is to find the ultimate load carrying capacity of assumed C-section for gravity and wind loading. Also the vertical deflection and horizontal deflection at regular interval of the span are noted. A comparative study has been made for study.

Theoretical Analysis

Introduction

Theoretical study involves analysis of a particular ‘Z’ shaped purlin section for its ultimate load carrying capacity for bending. Calculations and dimensions should satisfy the codal provisions laid by Indian Standard and by other international standards which is not covered by Indian standard. Based on the Trial and error procedure by balancing the allowable bending stress with actual bending stress, max Load carrying capacity is found out.

Load Carrying Capacity

Load carrying capacity of the section is calculated by the provisions Laid down by the following Indian standards.

- IS 801-1975
- IS 811-1987
- SP 6(5)
- IS 800-2007.

Generally wind Load is the criteria deciding the design of purlin for industrial structures. For the wind Load stresses, an allowance of extra 33% may be considered for design as per IS 800-1984. In the design of purlins, critical load combinations are worked out and the design is carried out. In general wind load is critical. After designing it should be checked for Dead and Live load combinations without giving any allowance for stresses. For getting ultimate load capacity, initially assumed a section and the calculations have been performed. Checked the design stress with the allowable stresses. If the actual stress is less than the allowable stress, slightly increase the Load on the beam until to get the zero difference between the allowable and actual stresses.

Section for Study

Depth of purlin	-	200mm
Width of Purlin	-	65 mm
Depth of Lip	-	20 mm
Thickness	-	3.15 mm
Length of purlin	-	8.0 m

Steps Involved In the Theoretical Analysis

It is a trial and error procedure to define the failure Load of the Beam. The procedure is as follows,

- Initially an Uniformly distributed Load Over the span is assumed.
- Calculation of the Maximum bending moment at mid span.
- Calculation of the sectional properties such as area, I_{xx}, Z_{xx}, I_{yy}, Z_{yy} etc.,
- Determination of the flat width of compression flange as per the provisions given by IS: 801-1975.
- Determination of the allowable bending stress and actual bending stress.
- Comparing the allowable bending stress with actual bending stress. Till to get the zero difference increase or decrease the load.

Finite Element Analsis

The ANSYS element library contains more than sixty elements for static and dynamic analyses, over twenty for heat transfer analyses and numerous magnetic field and special purpose elements. This variety of elements allows the ANSYS program to analyze two and three dimensional frame structures, piping systems, two dimensional plane and axi-symmetric solids, flat plates, axi-symmetric and three dimensional shells and non-linear problems including contact, interface and cables.

The analytical investigation consists of modelling and testing cold formed 'C' purlins of cross section 200 x 65 x 2.0 x 20 mm and 200x 65 x 3.15 x 20 mm sizes. Testing of length of specimens are 6m, 8m and 10m. The boundary conditions are one edge is pinned and the other end is roller. This is simulated in ANSYS, in one bottom edge Ux, Uy and Uz restrained and Uy is only restrained on other end. This supporting boundary conditions are common for both gravity and wind load cases. And for gravity load case top edge of the flange of 'C' purlin is laterally restrained by providing Ux restrained and for wind loading case bottom flange edge of 'C' purlin is laterally restrained by providing Ux restrained.

Model Generation And Analysis

The finite element models were created as single volume and meshing was performed using free mesh option. The total number of line elements varies from specimen to specimen due to the variation in the dimension. For accurate results the discretization requires very finer meshing.

The beams were simply supported at the support locations. Full scale model was created for the analysis. Step by step procedure was adopted to create the model like generation of key points, area and volume. After generation of area, it was extruded to required length. As stated earlier the boundary conditions were applied. To apply the uniformed distributed load, the total no of nodes were selected along the length at line of centre of gravity location and the uniformly distributed load is converted into equivalent point load and the loads are applied as in the laboratory. The deflections were measured at the middle of the span and tabulated for different loadings, thickness and boundary conditions. Static analysis was done.

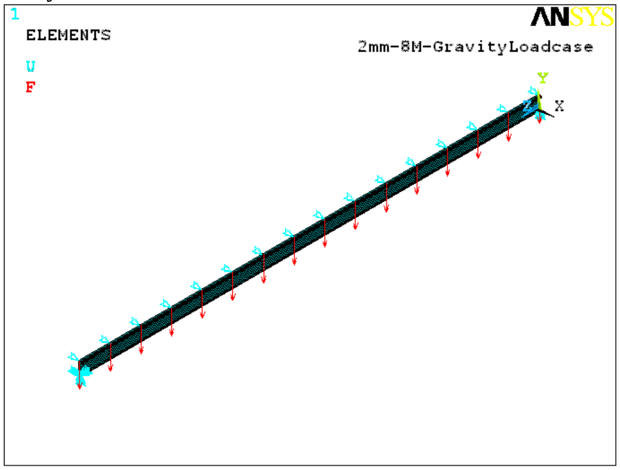

Fig.1.8m span 2.00mm tk (Elements)

Experimental Investigation

Introduction

Experimental setup is arranged in the laboratory. Effort is made to simulate the Loading and the boundary conditions as in the field. Generally the purlins will be analyzed and designed as a continuous beam and the continuity is created at the supports by means of overlapping of both sections. In our experiment the beam is analyzed as a simply supported beam and the experimental set up is also done accordingly.

Experimental Arrangement

The "C" purlin was made as a simply supported beam with a span of 8m and holes were made in the top and bottom flange of the "C" purlins exactly at the centre of gravity with an interval of 0.5m. Then the gravity loading and wind loading were done on the purlin as explained below.

CASE 1 (Gravity loading)

The lateral movement of the "C" purlin was restrained by tying the top flange (compression flange) of the "C" purlin with support tightly held in position placed at a distance of 2m on both sides with steel wires as shown in figure 3. The vertical loading was then applied at the centre of gravity upto 125kg/m with increments of 12.5kg/m each trial by tying the load (25kg sand bags) through the holes made at CG with steel wires. The maximum vertical deflection was measured by placing the dial gauges at a interval of 2m.

CASE 2 (Wind loading)

The lateral movement of the "C" purlin was restrained by tying the bottom flange (tension flange) of the "C" purlin with a support tightly held in position placed at a distance of 2m on both sides with steel wires as shown in figure 3a. The compression flange was fully free. The vertical loading was then applied at the centre of gravity upto 75kg/m with increments of 12.5kg/m each trial, By tying the load (25kg sand bags) through the holes made at CG with steel wires. The maximum vertical deflection was measured by placing the dial gauges at a interval of 2m.

Section Geometry

Depth of Purlin	-	200mm
Width of Purlin	-	65mm
Depth of lip	-	20mm
Thickness	-	3.15mm
Length of purlin	-	8m

Experimental Setup

Fig.2 Gravity Loading Case

Fig. 3 End Connection Details

Fig. 4 Loading Arrangement.(Sand Bags)

Fig.5 Deformation after Loading (wind loading).

Discussion of Results

Results from Theoretical Calculation

Results obtained by theoretical calculations based on the following assumptions.

- Simply supported at both the ends.
- Yield strength of steel is 250 MPa.
- Span of the beam is 8.0m.
- Beam is laterally supported at 0.5m intervals for gravity load case.
- Bending strength is defining the failure and not by shear strength.

Max Loads and Stresses

From the calculation, the ultimate load capacity is found to be 1.64 kN/m. Maximum bending stress calculated based on the above load is 150 MPa.

Results from Experimental Study

In this study, efforts have been made to obtain the deflections and Max load carrying capacity. In the first test (gravity loading) there was no lateral deflection since the compression flange is laterally tied at every 0.5m intervals. Lateral restraint is given to simulate the exact field condition. In the wind loading case compression flange was kept free and lateral deflections were measured. The observations are listed below for both the cases. Max bending stress observed was 145 MPa for gravity loading case corresponding to 1250 N/m loading and 101 MPa for wind loading case corresponding to wind loading case.

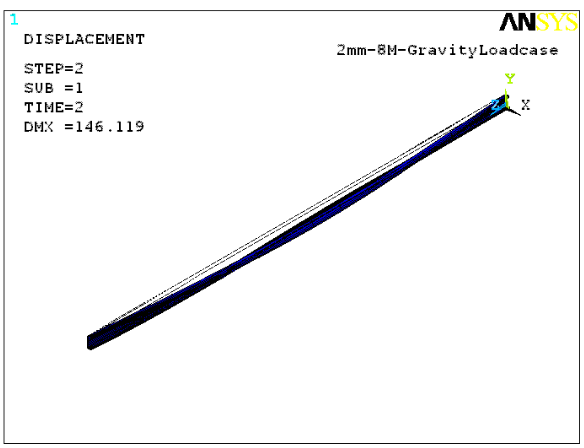

Fig. 6. 8m span 2.00mm tk (Gravity case max displacement)

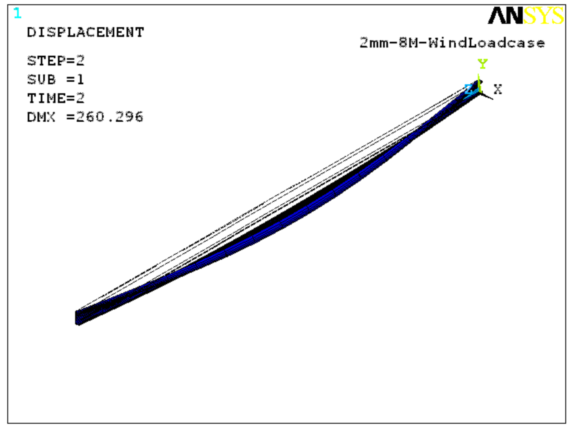

Fig.7. 8m span 2.00mm tk (wind case max displacement)

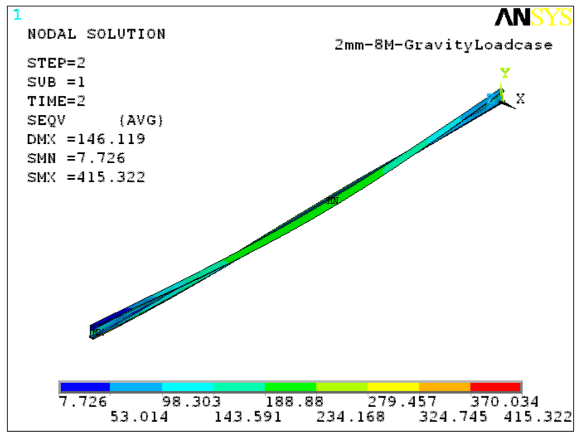

Fig.8. 8m span 2.00mm tk (Gravity case max von mises stress)

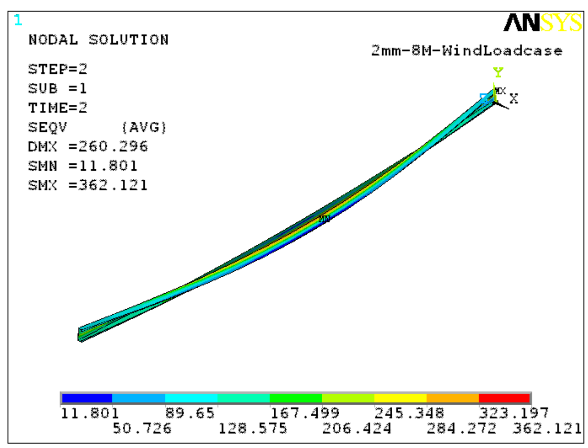

Fig.9. 8m span 2.00mm tk (wind case max von mises stress)

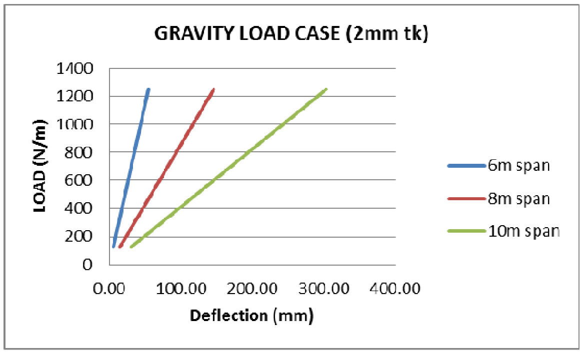

Fig.10. Gravity Load Vs Deflection (2mm tk)

Table 1. Gravity Load Deflection Details (2mm tk)

Gravity Load Case (compression flanges laterally restrained)			
load (N/m)	Vertical Deflection (mm)		
	6m span	8m span	10m span
125	5.47	14.61	30.37
250	10.94	29.22	60.73
375	16.42	43.84	91.10
500	21.89	58.45	121.46
625	27.36	73.06	151.83
750	32.83	87.67	182.19
875	38.30	102.28	212.56
1000	43.78	116.90	242.92
1125	49.25	131.51	273.29
1250	54.72	146.12	303.65

Thickness of the cold formed section is 2.00 mm

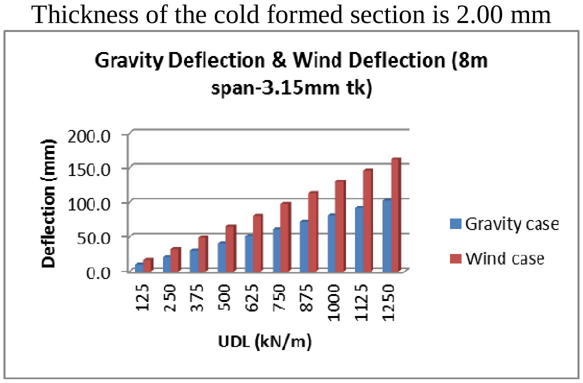

Fig.11. Actual Wind & Gravity Load Deflection (2.00mm tk)

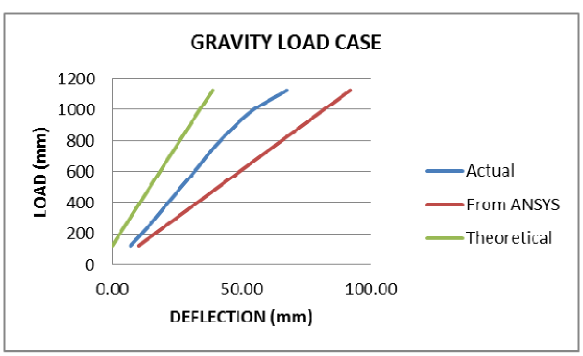

Fig.12. Deflection Vs Gravity Load (comparison)

Table 2. Deflection comparison for Gravity Loading case

load (N/m)	Vertical Deflection (mm)	
	Experiment	From ANSYS
125	7.02	10.22
250	14.03	16.82
375	20.27	21.33
500	26.51	29.82
625	32.92	35.85
750	38.93	40.41
875	46.10	48.02
1000	54.58	59.21
1125	67.54	70.77

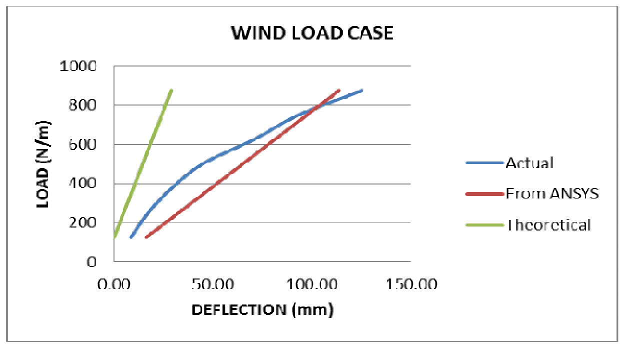

Fig.13. Deflection Vs Wind Load (comparison)

Conclusion

Keeping in mind, the practical problem faced in the construction industry, an attempt is made to analyze cold formed steel purlins for two common loading conditions with different boundary conditions. For theoretical analysis IS 801.1975 (Code Of Practice For Use Of Cold-Formed Light Gauge Steel Structural Members In General Building Construction) was used. From both the analysis, it may be concluded that,

- From the theoretical analysis the ultimate load carrying capacity for the assumed section with compression flanges restrained at 0.5m interval is found to be 1.64 kN/m and the corresponding allowable max bending stress is 150 MPa.
- From the results, it is very clear that, for the wind loading case, the compression flanges tend to buckle laterally and it undergoes lateral torsion buckling.
- When the compression flanges are arrested laterally, load carrying capacity may be considerably increased.

- Some modifications may be done to improve the load carrying capacity of purlins subjected to wind loading. The modification may be (i) by arresting the compression flanges laterally by means of sag rods at intervals. (ii) By modifying the purlin sections capable of resisting torsion. the section may be in the closed form like rectangular hollow sections.

References

[1] Ahmad Ali Ghosn, M.ASCE., Deflection of Nested Cold-Formed Steel Z-Section Beams: 10.1061/(ASCE)0733-9445(2002)128:11(1423).

[2] B. W. Schafer, M.ASCE., Local, Distortional, and Euler Buckling of Thin-Walled Columns.: 10.1061/(ASCE)0733-9445(2002)128:3(289).

[3] B.W. Schafer and T. Peko., Computational modeling of cold-formed steel: characterizing geometric imperfections and residual stresses, Journal of Constructional Steel Research 47 (1998) 193–210.

[4] Cao Hung Pham and Gregory J. Hancock.,, Experimental Investigation of High Strength Cold-Formed *C*-Sections in Combined Bending and Shear. Vol. 136, No. 7, July 1, 2010. ©ASCE, ISSN 0733-9445/2010/7-866–878/$25.00

[5] Cheng Yu and Benjamin W. Schafer., Distortional Buckling Tests on Cold-Formed Steel Beams. 10.1061/(ASCE)0733-9445(2006)132:4(515)

[6] Christopher T. Willis1 and Benjamin Wallace., Behavior of cold-formed steel purlins Under gravity loading. Vol. 116, No. 8, August, 1990. ©ASCE, ISSN 0733-9445/90/0008-2061/ Paper No. 24969.

[7] IS 801 -1975 code of practice for use of cold form light gauge steel structural members in general building construction.

[8] IS 811-1987 specification for cold form light gauge structural steel sections

[9] IS 800-2007 code of practice for general construction in steel

[10] Long-yuan Li., Analyses of distortional buckling of cold-formed sigma purlins using EN1993-1-3 Journal of Constructional Steel Research 65 (2009) 2099-2102.

[11] Mohammad Reza Haidarali and David A. Nethercot., Finite element modelling of cold-formed steel beams under local buckling or combined local/distortional buckling Thin-Walled Structures 49 (2011) 1554–1562

[12] M. Meiyalagan M.Anbarasu and Dr.S.Sukumar Investigation on cold formed C section long column with intermediate stiffener & corner lips – under axial compression, international journal of applied engineering research, dindigul. volume 1, no1, 2010.

[13] R. S. Talikoti and K. M. Bajoria., New approach to improving distortional strength of intermediate length thin-walled open section columns *Electronic Journal of Structural Engineering, 5 (2005)*

[14] SP 6 (5) -1980cold formed light gauge steel structures hand book.