Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 10(X), 2022:
http://dx.doi.org/

Numerical investigation on cold formed steel angle section portal frames.

Investigación numérica sobre pórticos de perfiles angulares de acero conformados en frío.

Devika Santhosh[1], Lakshmi Prassad[2]

Department of Civil Engineering, Saint Gits College of Engineering, Kottayam (Kerala), India

Corresponding author mail id: devika.secm1921@saintgits.org; devika.secm1921@gmail.com, parvathykrishnan101@gmail.com

ABSTRACT

Cold formed steel portal frames are widely used as alternative to traditional portal frames made from hot rolled steel sections. Load-displacement response of cold formed steel single C-section portal frames is available. C- section portal frames undergo significant deformation before reaching their ultimate loads. In this study, cold formed steel angle portal frame is analyzed using finite element analysis in order to find the load-displacement response. Bolt pressure is applied at the location of physical bolts in ANSYS.

Keywords: Cold formed steel portal frames, fasteners, bolts, connections, Numerical modelling.

RESUMEN

Los pórticos de acero conformados en frío se utilizan ampliamente como alternativa a los pórticos tradicionales hechos de secciones de acero laminado en caliente. Se encuentra disponible la respuesta de carga-desplazamiento de los pórticos de una sola sección en C de acero conformado en frío. Los pórticos de sección en C sufren una deformación significativa antes de alcanzar sus cargas finales. En este estudio, el pórtico en ángulo de acero conformado en frío se analiza utilizando un análisis de elementos finitos para encontrar la respuesta de carga-desplazamiento. La presión de los pernos se aplica en la ubicación de los pernos físicos en ANSYS.

Palabras clave: Pórticos de acero conformado en frío, sujetadores, pernos, conexiones, Modelado numérico.

INTRODUCTION

Cold-formed steel (CFS) portal frames are increasingly used as a viable alternative to traditional portal frames made from hot-rolled steel sections for low rise commercial, light industrial and agricultural single-storey buildings of spans up to 30m. Members of the portal frame are connected at the eaves, apex and at the base. The thickness of steel members ranges from 0.4mm to 6.4mm. Their large strength to weight ratio, versatility, non-combustibility with appropriate measures and ease of production has attracted architects, engineers, builders and manufacturers of building products with the promise, that it can help them provide improved function and greater aesthetic appearance for many applications at low cost.

Semi analytical complex finite strip method using bubble functions to study the local, distortional and global buckling of stiffened as well as unstiffened cold formed steel I- sections under compression and bending loading conditions and also a comparison between stiffened and unstiffened cold-formed I-sections is made for different buckling modes (Reza et al. 2010). The accuracy of bubble finite strip method in predicting the buckling stresses of mono symmetric cold-formed I-section beams in comparison with Generalized Beam Theory (GBT method) will be established. The behavior of base connections, fabricated from cold-formed channels and hot-rolled angle cleats is described (Dundu et al.2012). Angle cleat base connections can be a viable alternative to welded base connections, especially for cold-formed portal frames spanning from 5 to 16 m. The base connections are subjected to four loading configurations and these are dependent on the eccentricity of the load. In base connections where cold-formed angle cleats were used, failure of the bases was largely caused by premature deformation of the angle cleats. Base connections with hot-rolled angle cleats were so stiff that failure occurred in the column channels instead of the angle cleats. Observed modes of failure include premature deformation of the angle cleats, distortional and local buckling of the channel section and bearing distortion in the bolts. Premature deformation of the angle cleats was experienced in all tests where cold-formed angle cleats were used, whilst distortional buckling, local buckling and bearing failure were experienced in connections with hot-rolled angle cleats.

In full-scale site fire test, the building collapsed asymmetrically at a temperature of 714°C. A non-linear elasto -plastic finite-element shell model is described and is validated against the results of the full-scale test. The practical relevance of this research will be to form the basis of a performance- based design method for single-storey cold-formed steel portal frames in fire boundary conditions. As the collapse temperature predicted using the FE shell model is conservative compared with that recorded for the fire test, in the absence of further test results, the shell model can be used to assist with the design of such frames in fire boundary conditions (Ross et al. 2014). The collapse temperature for the full building arrangement model was 704°C, which is closer to the experimental results of 714°C than the single portal model, which collapsed at 682°C. The slight increase in failure temperature over the single portal model can be explained by the beneficial effect of secondary structural elements and stiffness from the gable end. Modelling of pitched roof cold-formed steel portal frames with slender cross-sections explained and two types of finite element models are introduced: a shell finite element model and a modified beam finite element model (Zhang et al.2015). In modelling the apex and eave joints, the semi-rigid behavior was considered by inserting rotational spring elements at the centre of the joints. In both experiments and shell element analyses, local buckling deformations occurred over the full length of the frame, whereas distortional buckling deformations only occurred in the top half of the column members which were predominantly subject to bending.

A general cold-formed steel portal framing system is proposed that uses simple bolted moment connections, formed through brackets, for the joints (Lim et al.2016). Such brackets are easy to manufacture and the joints easy to assemble on site. The joints, however, are semi-rigid and the importance of this for the design of the frame is explored through a combination of numerical analysis and full-scale testing. The column and rafter members of the portal frame and composed of back to back channel sections. The performance of the proposed portal frame has been compared to that of an equivalent rigid jointed frame. The advantage of a horizontal frame test is that only one frame is required. In a vertical frame test, gable frames on both sides of the test frame would also be necessary in order to support the purlins required for lateral bracing. An experimental program was carried out on a series of portal frame systems composed of back-to-back lipped channels for the columns, rafters and knee braces (Blum et al. 2019). The system consisted of three frames connected in parallel with purlins to simulate a free standing structure, with a span of 14m, column height of 5.3m, and apex height of 7 m. Displacements were measured at multiple locations on the frame including at the main connections and along the height of the column to determine overall column behaviour. Load displacement curves were plotted to show frame behaviour.

Seismic performance of a single storey moment resisting col dformed steel (CFS) portal frame through cyclic testing is investigated and six monotonic and six cyclic tests were performed on three different section sizes of CFS (Daniel et al.2019). Initial failure was localized at the top of the column sections in the form of local buckling at the web-to-flange junction under compressive stresses. The buckling or tearing failure in the columns would result in a reduced axial load carrying capacity. Design approaches for cold-formed steel single C-section portal frames based on the Direct Strength Method and the Direct Design Method is explained (Hao et al. 2019). For the Direct Strength Method, two approaches are presented, one that determines the design capacity of portal frames ignoring the effect of bimoment, as in current practice, and one that considers the effect of bimoment. The Direct Design Method determines the frame strength directly using geometric and material nonlinear analysis, also referred to as Advanced Analysis.

MODELLING AND ANALYSIS

Software study: ANSYS is versatile finite element analysis software with many features aiding the modelling and analysis of a complex structure like portal frame. ANSYS Mechanical software is a FEA tool for structural analysis including linear, non-linear and dynamic studies. The software used for modelling is PTC Creo software and analysis was ANSYS R16.0. ANSYS was selected since the software is capable of solving complex structural engineering problems more effectively and complex models can be completed using this.

Validation details: The journal paper taken for the validation was Numerical modelling of cold formed steel single C-section portal frames, Journal of constructional steel research, 158,143-155” (Rinchen et al. 2019). For the purpose of research, C-Section (C30024) portal frame was modelled in ANSYS software using link 180 element. Their parameters are as follow: a) Dimensions are for portal frame length=13600mm, H= 5435mm b) For test frame column and rafters t = 2.4 mm, D=300mm, B=96mm, L= 27.5mm. c) For end frame columns t=1.9mm, D= 203mm, B=76mm, L= 19mm. d) Connection details at Base are M16 and M20 bolt, at Eaves are M8 and M16 bolt and at apex are M16 and M8 bolt. e) Material of steel – Steel 550. f) Dead Loads were calculated as follows, Weight of CGI sheet= 0.05 kPa, Self-weight of purlin= 2.89 kg/m, Self-weight of rafter = 10.09 kg/total dead load = 5.1 kN, Total live load = 12.6kN unload combination = 1.2D+1.5L, Total nominal load = 25.1 kN.

Results of Validation: The results of the deformation for each of frames are shown in table 1, and he deformation of frame 1, 2 and 3 without stiffeners are given in figure 1.

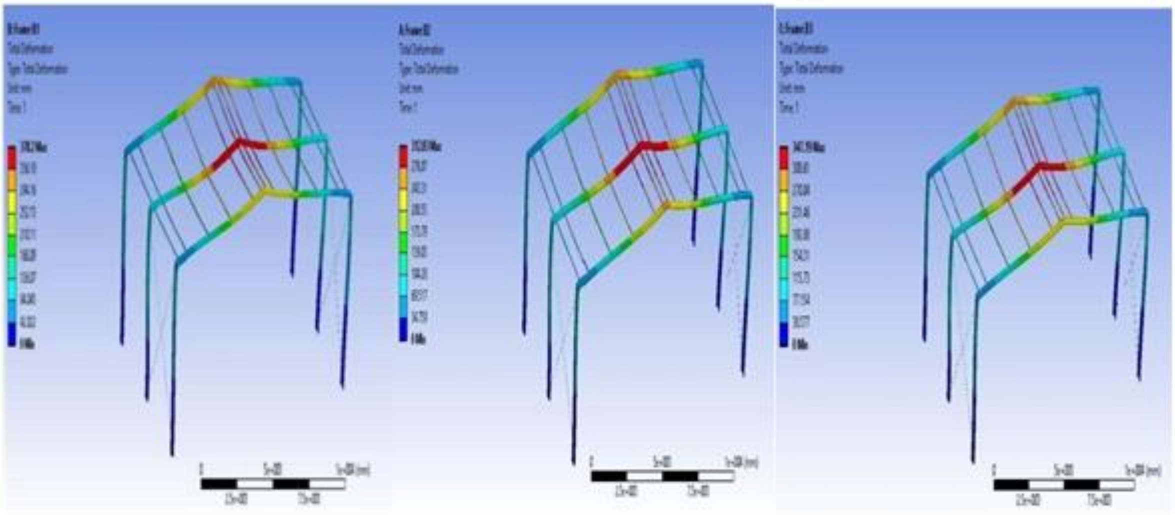

Figure 1: Deformation of frame 1, 2 and 3

Table 1 Deformation results of portal frame

Specimen	Deformation(mm)		% Error
	Actual	Obtained	
1	381	378.2	0.73
2	320	312.83	2.24
3	360	347.19	3.55

Results and Discussion

Analysis was carried out for the cold formed steel angle section portal frames using ANSYS APDL. The deformation of three frames were studied. Angle section with flange 100 mm, web 100 mm and thickness 3.15 mm is used. The deformation of frames 1,2 and 3 are given in figure 2.

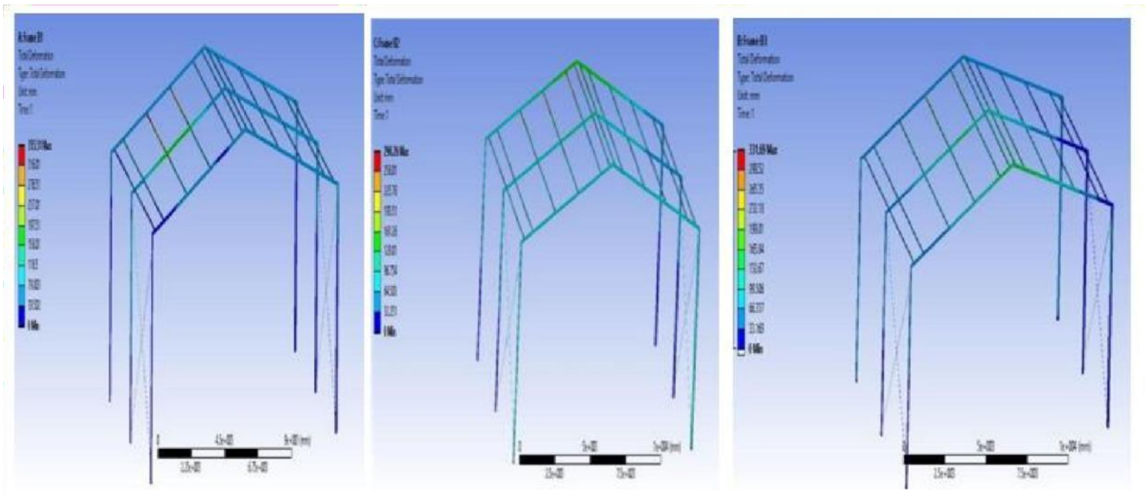

Figure 2: Deformation of frame 1, 2 and 3

The results of the performed deformation for each angle section portal frames are shown in table 2.

Table 2: Deformation results of frame 1, 2 and 3

Model	Deformation(mm)
Frame B1	355.51
Frame B2	290.26
Frame B3	331.69

As conclusion, CFS portal frames are susceptible to sectional instabilities and are likely to undergo large deformations, it is crucial to capture such instabilities and related deformations in the numerical analysis. Finite element analysis was done on CFS portal frames with Angle section. The following were concluded from this study;

- The Angle section shows less deformation compared to that C-section.
- Considering the peak values, the deformation of Frame B1 is reduced by 6.7% and similarly for Frame B2 it is reduced by 9.29% and for Frame B3 deformation is reduced by 7.86%.
- Angle section CFS portal frames are found to be efficient compared to C-section CFS portal frames.

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Received: 15th February 2021; Accepted: 21th April 2021; First distributed: 21th March 2021