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Review of Cold-formed Built-up compression members

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Abstract: The purpose of this paper is to understand the strength and behaviour of cold-formed steel built-up section under compression. Combination of two individual sections connected by various fastening sections were called built-up sections. The review of experimental, numerical and theoretical investigations on built-up sections were presented. Comparison were made for design strength calculation for various code books. The recommendation of authors for designing the built-up sections were presented.

KEYWORDS: Cold-formed steel, built-up section, column, experimental investigation, numerical analysis.

1. INTRODUCTION

In industrial growth of construction, the utilization of cold-formed steel were becoming more applicable. Back-to-back built-up cold-formed steel channel sections were widely utilized as compression members in structures. (Tina Chui Huon Ting, Krishanu Ro 2017). The local buckling resistance of built-up members does not get improved by the overlapping of flanges. Anyway, it does enhance the distortional buckling resistance to some extent. (M. Adil Dar et al (2018).

Cold-formed steel (CFS) structures were widely utilized compared to hot-rolled steel structures and there were research on more structurally efficient cross-sectional shapes. It was found that for column members in cold-formed steel structures face-to-face built-up cold-formed steel channel sections were becoming increasingly popular. Usually the hot-rolled sections always fail as a result of global buckling, but the cold-formed sections may fail in distortional or local buckling (Biggs 2008).

2. REVIEW OF BUILT-UP SECTION

Krisda Piyawat and Chris Ramseyer (2013) carried out investigation on the development of an Axial Load Capacity Equation for Doubly Symmetric Built-Up Cold-Formed Sections. In this paper 360 different configurations were carried and the numerical result were compared with the specifications from American Iron and Steel Institute. Out-of-straightness and out-of-flatness, were thoroughly investigated and the axial load capacities and failure modes were analysed. A regression analysis of a three-dimensional surface fitting and calibration with the experimental data were carried out. It was found that 2007 AISI specifications were overly conservative for double symmetric built-up sections after analysing it with numerical analysis. A simple and reliable axial load capacity equation was then developed. By ensuring safety and efficiency, as well as numerically simulated and experimentally measured capacities an equation is proposed which was in good agreement. A distortional buckling mode occurs for a short member and 0.88 was the average of the experimental to numerical strength ratios.

Mohamed Dabaon, Ehab Ellobody (2014) carried out investigation on nonlinear behaviour and design of built-up cold-formed steel section battened columns. The built-up columns were designed with pin-ended boundary conditions and consisted of two cold-formed steel channels placed back-to-back and were connected using batten plates. The nonlinear material properties of flat and corner portions of the channels, initial geometric imperfections, actual geometries as well as the boundary conditions were carefully considered in the models.

Fig-1: Test setup for the built-up cold-formed steel section battened column.

The specifications were unconservative for the built-up cold-formed steel section battened columns failing mainly by local buckling, whereas it was found that the specifications were conservative for the built-up columns failing mainly by elastic flexural buckling.

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David C. Fratamico et al (2017) presented experimental investigation on the global buckling and collapse of built-up cold-formed steel columns 16 different CFS lipped channel sizes connected at the web using a pair of self-drilling screw fasteners for a column length of 6ft (1.83 m). It was observed that a concentric compression, displacement-controlled monotonic tests on 32 specimens were carried out at key locations. Prevalent mode of failure was local-global interaction. It was observed that the stud-to-track end condition was determined to be semi-rigid, but generally closer to a fixed condition. Southwell approach was utilized for end rigidities. There was a proposal and validation of test data on rational design approaches extending the application of the Direct Strength Method (DSM) and employing current state-of-the-art numerical modeling techniques. There was a study undergone for the development of definitive design recommendations that help reduce the complexity of fastener designs and incorporates the DSM framework when predicting built-up member strength. Work was undergone for bare, unbraced, and unperforated back-to-back lipped channel sections and were tested using realistic end conditions by installing each stud in track to study the buckling behavior and strength of multiple cross section sizes and varying web fastener layouts. When more isolated global (flexural) buckling occurs composite action was developed through the web screws

Krishanu Roy and Tina Chui Huon Ting (2018) conducted investigation on nonlinear behaviour of back-to-back gapped built-up cold-formed steel channel sections under compression. In this literature, nondimensional slenderness ranges from 1.08 to 1.16. The experimental results were compared with the numerical non-linear finite element model and it was found to be in good agreement with the experimental analysis. After analysing 84 models it was observed that design of section using American Iron and Steel Institute (AISI) and Australian and New zealand Standards were conservative by 53%. It was concluded that slight modification in non-dimensional slenderness resulted in a gap, and there was a conservation of 5% in the design standards with respect to the experimental and finite element results.

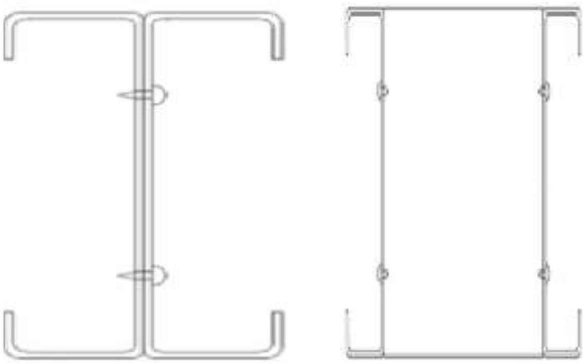

Fig-2: Back-to-back built-up cold-formed steel channel columns without and with the gap in between.

To overcome this problem nonlinear finite-element analyses were conducted on a total of 360 cases with 18 built-up configurations and compared with the AISI specification and previous experimental data. For further validation it was found that the more pure compression tests on other practical, built-up configurations were needed for the proposed equation.

Tina Chui Huon Ting et al (2017) carried out investigation on the effect of screw spacing on behavior of axially loaded back-to-back cold-formed steel built-up channel sections. By referring the Australian and New Zealand Standards for built-up sections a modified slenderness approach was carried out. For the 300, 500, 1000, and 2000 mm section lengths, the maximum imperfections of the test specimens were 0.2, 0.2,0.4, and 0.6 mm. Nearly 30 experimental tests were conducted for stub to slender columns. Using ABAQUS 6.14-2 (ABAQUS, 2014) a non-linear elasto-plastic finite element model and the center line dimensions were utilized for the cross section design.

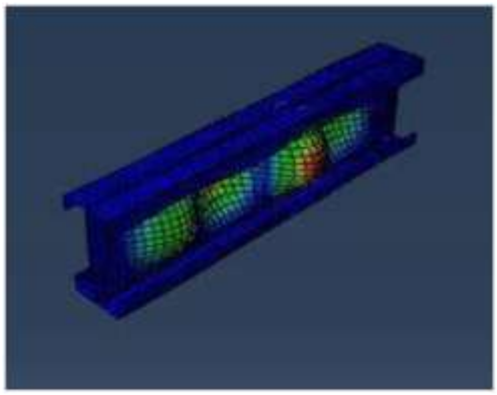

Fig-3: Initial imperfection contour for (BU75-S50-L300-1)

Nearly 144 models were utilized by varying the parametric study and it was found that around 10% stub columns were unconservative while generally they were conservative for varying the slenderness approach.

Krishanu Roy, Tina Chui Huon Ting and Hieng Ho Lau (2018) were conducting investigation on Nonlinear behavior of axially loaded back-to-back built-up cold-formed steel un-lipped channel sections. Cold-formed steel built-up un-lipped channel sections were used as trusses, wall frames and portal frames. In built up columns, intermediate fasteners resist the buckling of individual channel sections. The authors specially investigated the effect of screw spacing on axial strength of such columns. Analysing of 95 specimen by finite element, ranging from stub to slender columns were done. For parametric study the verified finite element model were utilized for the investigation on axial strength with the effect of screw spacing. Presentation on 15% over conservation, were felt on New Zealand and Australian standards and it failed by overall buckling. Then 8% unconservation for built-up columns using the same specification were found to be failed by local buckling.

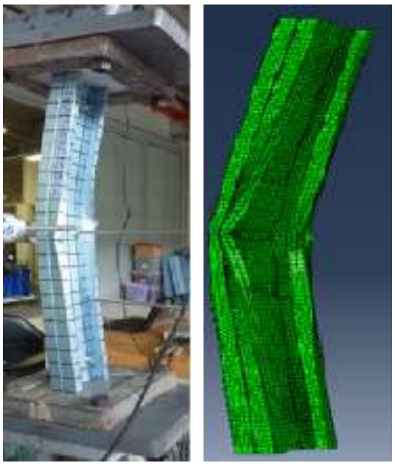

Fig-4: Comparison of experimental and numerical analysis of Short column (BU75-S100-L500)

There was an increase in axial strength by 31% when built-up lipped channel sections were utilized than the built-up un-lipped built-up sections.

Krishanu Roy et al (2018) conducted experimental and numerical investigation into the behaviour of face-to-face built-up cold-formed steel channel sections under compression. Presentation on the results of 36 experimental tests were conducted on face-to face built-up cold-formed steel channel-sections by covering a wide range of slenderness from stub to slender columns. The experimental results and the nonlinear finite element model were found to be in good agreement with each other.

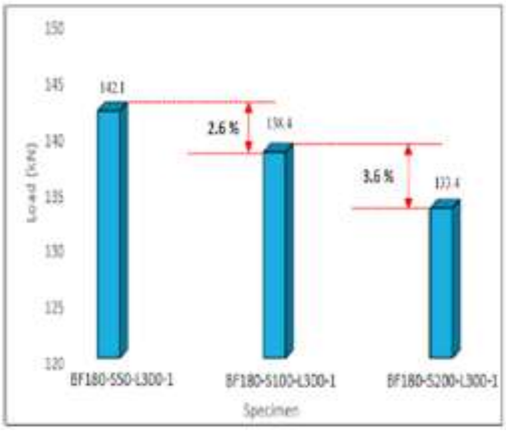

Fig-5: Effect of screw spacing on axial strength of face-to-face built-up cold-formed steel channel sections. (a) Stub columns (Length = 300 mm)

Modelling of intermediate fasteners, initial imperfections and material non-linearity were done using the finite element model. Comparison was made between both finite element and experimental results against the design strengths calculated in accordance with the American Iron and Steel Institute (AISI), Australian and New Zealand Standards (AS/NZS) and Eurocode (EN 1993-1-3). Comprising of 90 models finite element model was utilized for the purpose of the parametric study.

Krishanu Roy et al (2018) carried out investigation on the Effect of thickness on the behaviour of axially loaded back-to-back cold-formed steel built-up channel sections both experimental and numerical investigation. For preventing the channel-sections from buckling independently, intermediate fasteners were required at discrete points along the length. The use of modified slenderness by taking into account the spacing of the fasteners with the guidance of the AISI &AS/NZS for such back-to-back built-up cold-formed steel channel sections. To understand the effect of column thickness and slenderness's on axial capacity only limited research had been done on back-to-back built-up cold-formed steel columns. The results of 60 experimental tests were presented. By varying thickness, length and cross section of columns, detailed observations on different failure modes and column strengths were made. By including the material non-linearity, geometric imperfections and explicit modelling of web fasteners a non-linear finite element model was developed. For 204 models comprehensive parametric study was carried out on wide range of thickness and slenderness, by considering the back-to-back built-up columns. For local buckling of stub and short columns AISI& AS/NZS standards were unconservative while for overall buckling of intermediate and slender column it was conservative.

M. Adil Dar et al (2018) carried out investigation on Behaviour of laced built-up cold-formed steel columns, both Experimental investigation and numerical validation. Steps were taken to study the performance of monotonically increasing axial compression loading in the evaluation of built-up cold-formed steel (CFS) columns. Four CFS angle sections connected by single lacing systems were used for the fabrication of five test specimens of built-up columns. In the test specimens height of columns, width-to-thickness ratios and slenderness ratios of chord and lacing elements were the varied parametes. The main parameters evaluated were column strengths, axial load vs. displacement response, mode of failure, and deformed configurations. Using a finite element software ABAQUS the numerical analysis were carried out.

Fig-7: Various modes of failures observed.

In built-up laced CFS columns, test results were used to develop the column strength curves. Using the North American Standards and European Standards for CFS sections the results of this study were compared with the design strength.

M.Ranjith and G. Aruna (2018) carried out investigation related to study on behavior of cold formed built-up compression member. The behaviour and design of cold formed steel built-up closed sections with intermediate stiffeners on both legs of the angle sections were predicted. The connections of two sections were made using self-tapping screws which was made at 20 mm distance from both ends and the connections were made at 100mm equal interval zigzag throughout the length of column.

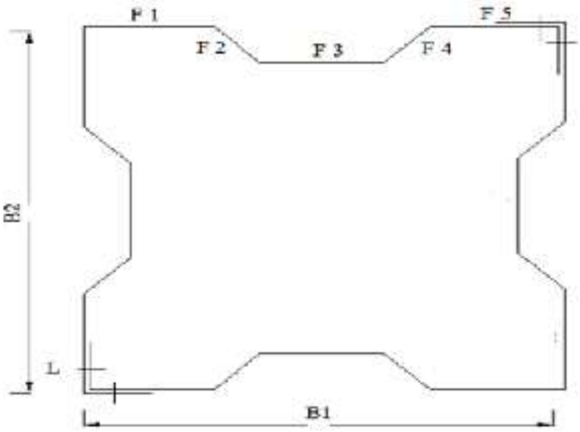

Fig-6: Cross sectional dimensions of the specimen.

The ultimate load prediction by theoretical analysis as well as for every specimen length and the model calculation of nominal axial strength of column was also described. Using self-tapping screws to form a built up closed box sections then two of the L-sections were connected at their lip to flange. The D/t ratio was directly proportional to the ultimate load carrying capacity of the specimens and it was found to be increased. Distortional buckling occurs with larger area initially whereas distortional buckling was the dominant failure for intermediate columns.

3. CONCLUSIONS

The load-lateral displacement, load-axial strain relationships as well as the column strengths, failure modes, deformed shapes at failure were predicted numerically and compared it with measured experimental values. For the built-up cold-formed steel sectioned battened columns it had been shown that the specifications were unconservative which was failing mainly by local buckling, and the specification were conservative for the built-up columns when they were failing mainly by elastic flexural buckling. It was observed that there was 53% more strength than the design standards when non-dimensional slenderness (λc) was used to calculate design capacity. There was unconservation for stub columns, when the AISI and AS/NZ standards were utilized.

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