STUDY ON COLD-FORMED STEEL HOLLOW SECTION COLUMNS

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Abstract - *Steel hollow members have long been used by architects and engineers because of their various advantages over open sections such as high torsional rigidity, low drag coefficient, reduced protection requirement, usable internal space, inherent aesthetic appearance etc. Because of their high torsional rigidity, steel tubular members are particularly suitable to be used as efficient torsional members. The aim of this paper is to understand the strength and behavior of cold-formed steel hollow sections. Using various code books comparison were made for design strength calculation. The review of experimental, numerical, theoretical investigations on hollow sections were presented.*

***Key Words*: *Cold-formed steel, hollow section, column, experimental investigation, numerical analysis*.**

1. INTRODUCTION

Structural hollow sections are widely used in a range of engineering applications, offering structural efficiency, aesthetic solutions and the possibility of being concrete-filled to achieve greater load-carrying capacity. Hollow sections are used in construction industries are manufactured commonly either by hot-rolling or cold-forming. Cold-formed steel sections are widely used as primary load bearing structural components. Typical steel sections, such as the I-section, channel section, circular hollow section (CHS), square hollow section (SHS), rectangular hollow section (RHS), and so on are used in various structures. However, the industry continually develops new sections with requirements for both efficiency and aesthetics.

2. REVIEW OF HOLLOW SECTIONS

Chen and Young (2019) investigated the structural performance of cold-formed steel elliptical hollow section pin-ended columns buckled about the minor axis. In this twenty-two column tests were conducted between pinned ends with the specimen lengths varying from 200mm to 1500mm. The results obtained from test program were employed in validation of finite element (FE) model. An extensive parametric study comprising 280 finite element analyses was performed based on the verified model. Experimental and numerical results were compared with predicted strengths by equivalent diameter method, equivalent rectangular hollow section (RHS) as well as with the Direct Strength Method (DSM). Modification on DSM is proposed. Result shows that the Direct Strength Method offers the most accurate and the least scattered design strength.

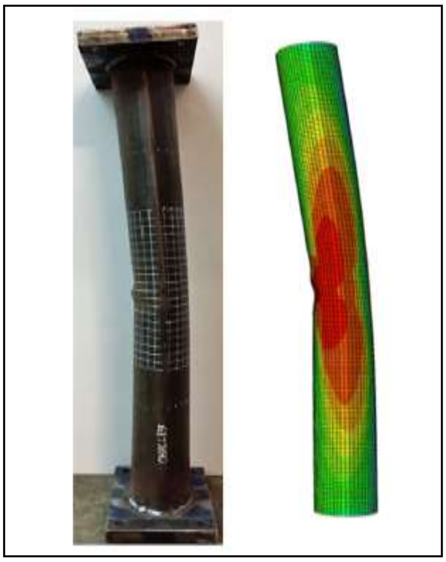

Fig:1 Comparison between experimental and numerical failure modes for EHS column specimen 140x80x3-CL850.

Roy et al. (2019) performed experimental and numerical investigation on the behaviour of face-to-face built-up cold-formed steel channel sections under compression. The length of the specimen covering a wide range of slenderness from stub to slender columns. Both finite element and experimental results were compared 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). It is observed that the design in accordance with the AISI & AS/NZS and Eurocode is generally conservative by around 15%, however, AISI & AS/NZS and Eurocode can be un-conservative by 8% on average for face-to-face built-up columns failed through local buckling.

Man-Tai Chen, Ben Young (2019) presented the investigation on material properties and structural behavior of cold-formed steel elliptical hollow section stub columns. Material properties and initial local imperfections for each cross-section series were measured and the stub column tests were conducted between fixed ends. A finite element model was developed and verified against test results, with which an extensive parametric study also carried out. The strength obtained from experimental and numerical investigations were compared with design strengths predicted by equivalent diameter method and equivalent rectangular hollow section approach, as well as the Direct Strength Method and the Continuous Strength Method. The comparisons generally shows that equivalent diameter method, equivalent rectangular hollow section approach and existing traditional design rules with equivalent diameter provide very conservative whereas predictions by existing Continuous Strength Method are less scattered and are generally in good agreement with experimental and numerical results. The strength predicted by Direct Strength Method also conservative.

Chen and Young (2018) conducted the test on 19 columns under pinned end conditions. The length of test specimens designed to vary from 200 mm to 1500mm. A non-linear

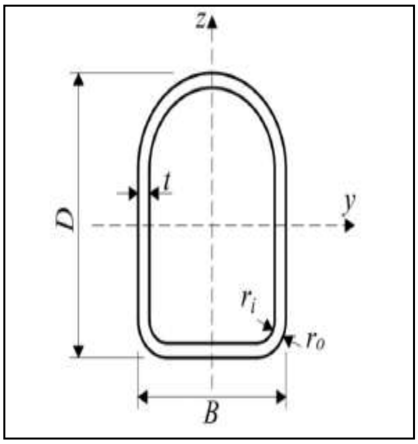

Fig:2 Cross-section geometry of SOHS.

finite element (FE) model was developed and validated against test results. An extensive parametric study comprising 200 column specimens were performed based on the validated FE procedure. The comparison results show that existing Direct Strength Method generally provides conservative predictions, but predictions are scattered for slender sections. The modified Direct Strength method is suitable for cold-formed steel semi-oval hollow section columns (SOHS), especially for short column members and columns with slender sections.

Jia-Hui Zhang, Ben Young (2018) conducted numerical investigation and design of cold-formed steel built-up closed section columns with web stiffeners under fixed-ended conditions. The geometric imperfections and nonlinear material properties were considered in the finite element analysis. Totally 252 specimens were analyzed in the parametric study. The results obtained from the FEA shows that sections with deeper inward web stiffeners and moderate outward web stiffeners performed better than other sections. It also shown that the modified direct strength method is generally conservative and reliable.

Poomari and Manu (2018) performed experimental investigation on the effect of axial loading on light gauge steel fluted column. The test was conducted on hollow circular

Fig:3 Experimental setup for the trapezoidal fluted column.

fluted columns with modification in the number of flutes (trapezoidal shape). Different sections like four, five and six numbers of trapezoidal fluted column sections was studied by finite element analysis software. The trapezoidal fluted column with 6 flutes have more load bearing capacity with lesser value in axial deformation when compared to the hollow circular column without trapezoidal flutes.

Aizhu Zhu , Yong Lu (2016) conducted experimental study and analysis of inner-stiffened cold-formed SHS steel stub columns. Four different inner-stiffener arrangements were

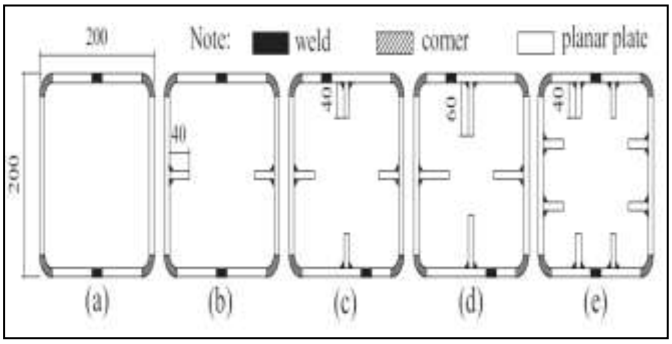

Fig:4 Cross-section geometry of Unstiffened and Stiffened sections

considered. A finite element model was developed and employed to provide a numerical perspective of the behavior of the SHS column. Two codified methods for the calculation of the strength of cold-formed thin-walled sections, namely the AISI and GB methods were examined and discussed by comparing the predictions with the corresponding experimental results.

Morgan and vongani (2014) carried out investigation on cold-formed circular hollow sections under axial compression. Two series of experiments with pinned-ended conditions were carried out. A total of 30 columns were tested in that 20 columns in Series 1 and 10 columns in Series 2. The outside diameter-to-thickness ratio (d/t) and the slenderness ratio (KL/r) ranged from 29.7 to 46.4 and 20.8 to 82.2 for Series 1 and from 55.0 to 62.9 and 10.7 to

34.9 for Series 2. In general, Series 1 columns failed by overall flexural buckling and Series 2 columns failed by local

Fig-5: Local ring type and flexural buckling of circular column.

ring-type buckling. The test strengths of the columns were compared with the strengths predicted by the South African and the European design standards.

Zhu and Young (2011) performed investigation on cold-formed steel oval hollow sections (OHS) under Axial

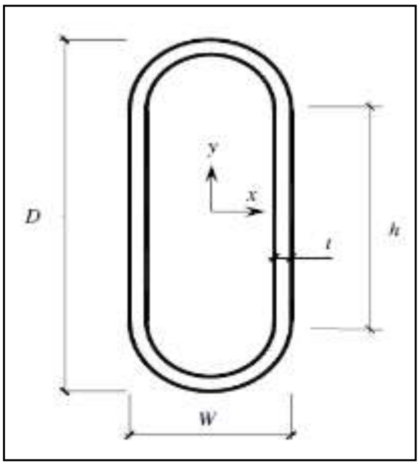

Fig-6: Cross-section geometry of OHS

Compression. The total of 28 column specimens were separated into four series of different cross-sectional dimensions under fixed ended condition. The test strengths were compared with the design strengths using North American (AISI), Australia/New Zealand (AS/NZS) and European specifications for cold-formed steel structures. It can be seen that the design strengths predicted by AISI and AS/NZS specifications are identical and generally conservative, and the predictions by European code design strengths are more conservative.

Yuanqi et al. (2010) studied the load-carrying capacity of cold-formed thin-walled steel columns with built-up box section. A series of tests including 21 axially-compressed columns and 19 eccentrically-compressed columns subjected to bending moments about weak axis as well as strong axis were carried out. The test specimens were built up by two channel sections with two intermediate stiffeners in the web, and they connect at their flanges using self-drilling screws. From the results it is observed that the ultimate load-carrying capacity of built-up section is 10 to 20 percent higher than sum of the ultimate load-carrying capacity of each lipped channel section columns.

Whittle and Ramseyer (2009) investigated buckling capacities of axially loaded cold-formed built-up C-Channels. The compression test of around 150 specimens were experimentally determined and compared to theoretical buckling capacities based on the modified and unmodified slenderness ratio. Built-up member design is addressed in the American Iron and Steel Institute (AISI). It was observed that use of modified slenderness ratio was conservative for longer built-up members and thicker built-up sections. Capacities based on unmodified slenderness ratio and fastener and spacing provisions were consistently conservative. The axial capacities determined using the unmodified slenderness ratio are on average 12% less conservative than modified slenderness ratio for all built-up members.

3. CONCLUSION

From the study, it was observed that most of the researchers investigated about the strength and behavior of cold-formed steel hollow columns under compression. The column strengths, failure modes, deformed shapes at failure, load lateral displacement and load-axial strain relationships were predicted from the finite element analysis were compared with the test results. It is shown that the finite element results correlated well with the test results. Use of Direct Strength Method (DSM) offers most accurate and least scattered design strength. It can be seen that the design strengths predicted by AISI and AS/NZS specifications are identical and generally conservative, and the predictions by European code design strengths are more conservative.

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