A Review of Cold-Formed Steel Built-Up Open Columns

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***Abstract* - This review paper is prepared by studying previously published research papers on Cold Formed Steel. Selected papers covering area of study like sections, its manufacturing processes, advantages-disadvantages, various buckling modes along with analysis done by different methods and software viz. ABAQOUS, THINWALL, CUFSM etc.**

***Index Terms* - Cold Formed Steel, ABAQOUS, THINWALL, CUFSM.**

1.INTRODUCTION

2.1 GENERAL:

Cold-formed steel products are found in all aspects of modern life in the home, the shop, the factory, the office, the car, the petrol station, the restaurant and indeed in almost any imaginable location. The use of these products is many and varied. A multiplicity of widely different products with a tremendous diversity of shapes, sizes and applications are produced in steel using the cold forming process. Cold-formed steel (CFS) is the common term for steel products shaped by coldworking processes carried out near room temperature, such as rolling, pressing, stamping, bending etc. CFS sections are light-weight structural members that are made by forming flat plane sheets or panels of sheet at ambient temperature into different shapes which will support more than the flat sheets themselves and be used to convince structural and functional requirements. The produced shapes are thin-walled and the formed CFS members offer one of the highest load capacities to-weight ratio among the various structural component. Therefore, the CFS, members also called ‘light gauge steel members. Cold-formed steel products such as sections have been commonly used in the metal building construction industry for more than 40 years. The popularity of these products has dramatically increased in recent years due to their wide range of application, economy, ease of fabrication and high strength to weight ratios. In market various shapes of these products are available C-sections are predominantly used in light load and medium span situations such as roof systems. Their manufacturing process involves forming steel sections in a cold state (i.e. without application of heat) from steel sheets of uniform thickness.2The market share of cold-formed structural steel work continues to increase in the developed world. The reasons for this include the improving technology of manufacture and corrosion protection which leads in turn to increase competitiveness of resulting products as well as new applications. Recent studied have shown that the coating loss for galvanized steel members is sufficiently slow and indeed slows down to effectively zero, then a design life in excess of 60 years can be guaranteed.

2.LITERATURE REVIEW

2.1 REVIEW OF LITERATURES:

1. Axial strength of back-to-back cold-formed steel channels with edge-stiffened
holes, unstiffened holes and plain webs- Boshan Chen, Krishanu Roy, Asraf Uzzaman, Gary Raftery, James B.P. Lim;2020

Discussion: This paper presents an experimental investigation on back-to-back
channels with edge-stiffened holes so to understand the effects of composite actions between the back-to-back channels on the axial strength of such channels. This paper presents a total of 162 new results comprising 27 axial compression tests and 135 finite element analysis (FEA) results on the axial strength of back-to-back channels with edge stiffened holes, un-stiffened holes and plain webs. Prior to compression tests, initial geometric imperfections were measured using a laser scanner. Tensile coupon tests were also conducted to determine the material properties of both the flat and corner portions of the channels. The test results show that for the case of back-to-back channels with edge-stiffened holes, the axial strength increased by 6.6% on average, compared to a back-to-back plain

channel. For comparison, the same section with un-stiffened holes had a 12.4% reduction on average in axial strength, compared to a back-to-back plain channel. A nonlinear elasto-plastic finite element (FE) model was then developed, and the results showed good agreement with the test results. The validated FE model was used to conduct a parametric study involving 135 FE models to investigate the effects of column slenderness, diameter of hole, screw spacing, stiffener lengths and stiffener fillet radius on the axial strength of such channels. Finally, the tests and parametric study results were compared against the design strengths calculated in accordance with the American Iron and Steel Institute (AISI) (2016) and Australian and New Zealand Standards (AS/NZS) (2018) for back-to-back plain channels and against the design equations of Moen 10 and Schafer (2011) for back-to-back channels with un-stiffened holes. It was found that the AISI (2016) and AS/NZS (2018) are only 3% conservative to the test results. The Moen and Schafer equations (2008, 2009, 2011) are conservative by 21% on average for back-to-back channels with un-stiffened holes.

2. Finite element analysis and design of cold-formed steel built-up closed section columns with web stiffeners- Jia-Hui Zhang, Ben Young;2018

Discussion: This paper presents a numerical investigation and design of cold formed steel built-up closed section columns with web stiffeners. A finite element model (FEM), considering the initial geometric imperfections and nonlinear material properties, was developed to simulate the structural behaviour of fixed ended built-up closed section compression members. The comparison between then numerical results and the available test results show that this FEM can provide good predictions for both the ultimate strength and the failure modes of the test specimens. The verified FEM was used to conduct an extensive parametric study for the investigation on the structural behaviour of cold-formed
steel built-up closed sections with web stiffeners. The parametric study was designed to investigate the effect of web stiffeners as well as to evaluate the current design method. The column strengths obtained from the finite element analysis and the test results were compared with the design strengths calculated using the direct strength method in the North American Specification and the Australian/New Zealand Standard for cold-formed steel structures. Design curves modified from the current direct strength method are proposed for flexural, local and distortional buckling. The reliability analysis was used to assess the current design rules and the modified design curves. It is shown that the modified direct strength method is generally conservative and reliable for the design of cold formed steel built-up closed section compression members.

3. Behavior and design of perforated steel storage rack columns under axial
compression- Bassel El Kadi, G. Kiymaz;201411

Discussion: The present study is focused on the behavior and design of perforated steel storage rack columns under axial compression. These columns may exhibit different types of behavior and levels of strength owing to their peculiar features including their complex cross-section forms and perforations along the member. In the present codes of practice, the design of these columns is carried out using analytical formulas which are supported by experimental tests described in the relevant code document. Recently proposed analytical approaches are used to estimate the load carrying capacity of axially compressed steel storage rack columns. Experimental and numerical studies were carried out to verify the proposed approaches. The experimental study includes compression tests done on 8 members of different lengths, but of the same cross-section. A comparison between the analytical and the experimental results is presented to identify the accuracy of the recently proposed analytical approaches. The proposed approach includes modifications in the Direct Strength Method to include the effects of perforations (the so-called reduced thickness approach). CUFSM and CUTWP software programs are used to calculate the elastic buckling parameters of the studied members. Results from experimental and analytical studies compared very well. This indicates the validity of the recently proposed approaches for predicting the ultimate strength of steel storage rack columns.

4.Experimental investigation on performance of perforated cold-formed steel
tubular stub columns- Tekcham Gishan Singh, Konjengbam Darunkumar
Singh;2018

Discussion: This paper describes an experimental study to estimate the stub columns capacity of cold–formed square (SHS) and rectangular hollow sections (RHS) containing two opposite central circular perforations at column mid–-height. The stub columns were extracted from commercially available TataStructura–YSt 310 tubular sections, with minimum yield strength of 310 MPa,12 conforming to Indian Standard 4923. the influence of two opposite central circular perforations on the structural performance of tubular steel stub columns under concentric loading was investigated for perforation size to flat width ratios up to 0.9. The local geometric imperfections, load–end shortening curves, strain distributions at mid height of column and typical failure modes observed from the present test programme are documented in this paper. Further, the ultimate column capacities recorded from the test programme are compared with codified design predictions as well as design equations proposed by various researchers. Based on the comparison, it is observed that the predictions made by most of the currently available design equations are conservative and reliable but generally scattered for design of cold–formed tubular structural steel stub columns having central circular perforations.

5.Design of Perforated cold-formed steel tubular stub columns-DSM ApproachTekcham Gishan Singh, Konjengbam Darunkumar Singh

Discussion: This paper presents a preliminary attempt on the design of cold formed steel tubular stub columns, having two opposite central circular perforations at column mid-height. The work is an extension to a previous experimental study on the structural performance of perforated cold- formed steel stub columns reported by the authors. Initially, finite element (FE) models were developed and validated against the previous test results. Upon validation, FE models were then developed to generate ultimate column capacities wide range of cross-sections and perforation size to flat wide ratio up to 0.5.A total of 134 stub column capacities comprising of 15 test and 119 FE analyses results were employed to assess the suitability of the existing Direct Strength Method (DSM) design prediction detailed in American Standard. Based on the analysis, it was found that the current DSM design equation provides overly conservative and scattered predictions. Hence, a new set of modified DSM equation was proposed, considering the effect of perforation size and cross-section slenderness. The13 newly proposed modified DSM approach is found to provide accurate and conservative predictions.

6. Ultimate capacity of battened columns composed of four equal slender angles M.A. El Aghoury, A.H. Salem, M.T. Hanna, E.A. Amoush;2013

Discussion: Cold-formed steel structural members play a great role in modern steel structures due to their high strength and light weight. The behavior and strength of battened column members composed of slender angle sections are mainly governed by local buckling of angle legs or torsional buckling of the angle between batten plates. Moreover, local buckling depends on the interaction between the width–thickness ratio of angle leg, overall slenderness ratio of angle between batten plates and overall slenderness of column. Theoretical study has been carried out by a nonlinear material and geometrical finite element model. Numerous cases of slender battened column sections having different width– thickness angle leg ratios, overall slenderness ratios between batten plates and overall slenderness ratios are chosen in this study. Complete ultimate strength curves are drawn and different failure modes are studied by taking different member lengths, which produce local or torsional buckling of single angles between batten plates or overall buckling of the member. Empirical equations for the effect of shear deformation factor and the ultimate axial load capacities of members formed of battened slender angle sections are proposed. Strengths of axially loaded battened members predicted using finite element as well as the proposed empirical equations is compared with the design strengths obtained using North American and European codes. It is concluded that the design strengths predicted by North American and European codes are generally conservative, and these design rules have been shown to be reliable using reliability analysis.14

7. Experimental investigation and a novel direct strength method for cold-formed built-up I- section columns- Yan Lu, Tianhua Zhou, Wenchao Li, Hanheng Wu;2016

Discussion: This paper aims at investigating the structural response and predicting the ultimate strength of the cold-formed built-up I-section columns affected by local, distortional, global and in particular by the local-distortional (LD) interactive and local-distortional-global (LDG) interactive buckling modes. For this purpose, a total of 18 single C-section columns and 18 built-up I section columns were tested under uniaxial compression load, respectively. The cross-sectional dimension, the thickness and the length of the tested members were varied in the test so as to cover a wide range of local, distortional and overall slenderness. It was shown in the test that noticeable LD interaction was observed for a built-up column with short length as well as LDG interaction for a built-up column with intermediate length. Due to the clear evidence obtained in the test that LD and LDG interactions cause substantial ultimate strength erosion in cold formed built-up I-section column, a novel direct strength-based method was proposed in this paper to quantify such an erosion effect. The validity of the proposed method was then verified by comparing the results obtained from the proposed method with the test results in this paper as well as several other test results in the literature. The comparison results proved that the proposed method can be used successfully in estimating the ultimate strength of cold-formed built up I-section column affected by pure buckling mode as well as interactive buckling mode.

8. Description of stress-strain curves for cold-formed steels- Leroy Gardner,
Xiang Yun;2018

Discussion: Cold-formed steels are generally characterized by a rounded stress-strain response with no sharply defined yield point. It is shown herein that this material behaviour can be accurately described by a two-stage Ramberg-Osgood15 model provided that the values of the key input parameters can be established. The focus of the present paper is to develop predictive expressions for these key parameters to enable the full engineering stress-strain response of cold-formed steels to be represented. The predictive expressions are based on the analysis of a comprehensive set of material stress-strain data collected from the literature. In total, more than 700 experimentally derived stress-strain curves on cold-formed steel material have been collected from around the world, covering a range of steel grades, thicknesses and cross-section types. The strength enhancement in the corner regions of cold-formed sections has also been analysed and the applicability of existing predictive models has been evaluated. Finally, standardized values of strain-hardening exponents used in the Ramberg-Osgood model have been recommended for both flat and corner material in cold-formed steel sections. The proposed stress-strain curves are suit- able for use in advanced numerical simulations and parametric studies on cold-formed steel elements.

9. Effect of access openings on the buckling performance of square hollow
section module stub columns- Tekcham Gishan Singh, Tak-Ming Chan;2020

Discussion: This paper presents a systematic finite element (FE) based parametric study to quantify the buckling capacity of perforated cold-formed and hot-rolled steel module column. The effects of various key geometric parameters such as eccentricity (location of perforation/column length), shapes (viz. circular, square and hexagonal), sizes (width/diameter) and height (depth) of perforation; and cross-sectional thickness, on the buckling performance of cold-formed and hot-rolled steel stub columns, have been investigated. Based on the analysis, the reduction in column capacity is found to be maximum when the perforation is located at column mid-height, as anticipated. The perforation shapes under consideration have been found to have marginal impact on the buckling capacity of the module stub columns, although the reduction in column capacity is seen to be in the order – square > hexa- gon > circular perforated columns (having same16 perforation size). The critical buckling capacity of perforated module column is observed to be linearly decreasing as the perforation size ratio (perforation size/flat element width) increases. However, for the same width of perforation, increasing the perforation height up to 2.5 times the perforation width, the change in column capacity is found to be negligible. Furthermore, the applicability of existing design for perforated columns has been assessed and found that, although most of the design equations generate conservative and reliable predictions both for cold-formed and hot-rolled steel, the design formulae which are based on effective width method are found to be more accurate as compared to those which are based on total area method.

10. Structural performance of YSt–310 cold–formed tubular steel stub columnsTekcham Gishan Singh, Konjengbam Darunkumar Singh;2017

Discussion: This paper describes experimental and numerical investigations conducted to characterize the basic material properties and design of YSt–310 cold–formed structural steel sections at Indian Institute of Technology, Guwahati. Square (SHS) and rectangular (RHS) hollow sections with minimum yield strength of 310 MPa manufactured by Tata Steel India, were considered in the study. Initially, results from elemental analysis via optical emission spectrometer (OES) investigation and metallographic examination using optical microscope are presented. Key stress–strain parameters viz., Young's modulus, proof stress, ultimate strength, percentage elongation, strain hardening exponent etc. were generated based on flat, corner and weld coupon tests data. Extent of corner strength enhancement due to cold – forming determined using Vickers's microhardness test are reported. Additionally, cross – section capacity of the stub columns was also investigated experimentally and numerically. The column capacities generated from test and finite element study are compared with the existing design code – EN 1993–1–1 (EN 1993-1-1, 2005) [1] and design rules – continuous strength method (CSM) (Zhao et al., 2017) [2] and direct strength17 method (DSM) (North American Specification for the Design of Cold-Formed Steel Structural Members, 2016; Arrayago et al., 2017) [3,4]. Based on the comparison, modifications on the existing design code and rules are suggested to provide a more accurate and reliable compressive design predictions.

3.CONCLUSION

After studying the above research papers, we can conclude that

- There are several methods of design for Cold formed Steel e.g. Allowable Stress Design (ASD), Load and Resistance Factor-Design (LRFD), Working Stress Method (WSM) and Limit Stress Method (LSM). LSM gives better results.
- There are several applications are being used for analysis of the steel sections viz. ABAQUS, THINWALL, CUFSM etc.
- Cold Formed Steel Sections should be strengthened against buckling so that preventive measures in the field of buckling can lead its more use in the construction.

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