Literature Study on the Compression Behaviour of Cold Formed Corrugated Steel Sections

Deenadhayalan.S[1] Iyappan.G.R[2] S.Suresh babu[3]
[1]P.G Student [2,3]Assistant Professor
[1,2,3]Valliammai Engineering College, Potheri-02, India

Abstract— With ever-advancing technology, cold-formed members are being fabricated with higher yield stress materials. With the use of higher-strength steels comes a reduction in thickness, which leads to the development of highly stiffened sections with more folds and stiffener noted that there would be a strong interest for the application of cold-formed framing systems in residential and low-rise buildings. Cold-formed steel sections are usually formed in channel sections, Z-sections, hat sections, angle sections and other sections due to the manufacture process, and these sections are categorized as open sections. These sections can be also formed by connecting two or more sections together, for examples, an I-section formed by connecting two channel sections back-to-back, and a box section formed by connecting two channel sections in the flanges. These sections may fail by local and/or distortional buckling due to their plate width-to-thickness ratio. However, cold-formed steel sections can be strengthened by forming edge and web stiffeners in the sections as well as using I-shaped sections. Therefore, the focus of this study is to investigate the cold-formed steel I-shaped open sections with edge and web stiffeners.

Key words: Cold-Formed Steel, Buckling Mode, Column, Edge Stiffener, Open Section, Web Stiffener, Ultimate Strength

I. INTRODUCTION

All over the world, applications of thin-walled sections have been a growing demand in all the engineering industry due to their low self-weight, high performance of structural systems with uniform quality, simple fabrication process and cost-effective in both transport/erection. Cold-formed steel sections can be used effectively as a structural element in cases where hot-rolled sections or others are not efficient. Thin sheet steel products are extensively used in building industry, and range from purlins to roof sheeting and floor decking. Generally these are available for use as basic building elements for assembly at site or as prefabricated frames or panels. These thin steel sections are cold-formed, i.e. their manufacturing process involves forming steel sections in a cold state (i.e. without application of heat) from steel sheets of uniform thickness. These are given the generic title Cold Formed Steel Sections. Sometimes they are also called Light Gauge Steel Sections or Cold Rolled Steel Sections. The thickness of steel sheet used in cold formed construction is usually 1 to 3 mm. Much thicker material up to 8 mm can be formed if pre-galvanised material is not required for the particular application. The method of manufacturing is important as it differentiates these products from hot rolled steel sections. Normally, the yield strength of steel sheets used in cold-formed sections is at least 280 N/mm2, although there is a trend to use steels of higher strengths, and sometimes as low as 230 N/mm.

Manufacturers of cold formed steel sections purchase steel coils of 1.0 to 1.25 m width, slit them longitudinally to the correct width appropriate to the section required and then feed them into a series of roll forms. These rolls, containing male and female dies, are arranged in pairs, moving in opposite direction so that as the sheet is fed through them its shape is gradually altered to the required profile. The number of pairs of rolls (called stages) depends on the complexity of the cross sectional shape and varies from 5 to 15. At the end of the rolling stage a flying shearing machine cuts the member into the desired lengths. An alternative method of forming is by press - braking which is limited to short lengths of around 6 m and for relatively simple shapes. In this process short lengths of strip are pressed between a male and a female die to fabricate one fold at a time and obtain the final required shape of the section. Cold rolling is used when large volume of long products is required and press breaking is used when small volumes of short length products are produced.

II. LITERATURES

A. Derrick C. Y. Yap Et Al, "Experimental Study of Complex High-Strength Cold-Formed Cross-Shaped Steel Section" Volume 134 Number 8 August 1, 2008

This paper describes the design and experimental investigation of a series of compressive tests on a stiffened cross-shaped section fabricated from cold-formed high-strength steel of 0.42 mm thickness and nominal yield stress of 550 MPa. The complex shape has been chosen so that it has a local buckling mode, two distinct distortional buckling modes, and a flexural-torsional mode. The first distortional buckling mode has a shorter buckle half wavelength and hence is classified as a short half-wavelength distortional buckling mode, while the other distortional mode has a much longer buckle half-wavelength and is classified as a long half-wavelength distortional buckling mode. The compression tests were carried out in a 300 kN capacity SINTEC testing machine over a range of lengths with fixed-ended conditions. The varying lengths were chosen so as to observe the buckling modes and the possibility of interaction between them. The experimental results are then compared with design methods in the existing design standards. The methods include the direct strength method (DSM) recently incorporated in the North American specification and the Australian Cold-Formed Steel Structures Standard AS/NZS 4600. When compared to the existing methods, the test results indicate that at intermediate and longer specimen lengths, the interaction of local and distortional buckling modes has a significant effect on the strength of the section. This paper presents the procedures taken to design the complex shape and the experiments carried out to obtain the geometric imperfections and material properties of the specimens and

the test results. New design methods are proposed for the local buckling DSM curve as well as for the distortional buckling strength curves so as to account for the effects of interaction of local and distortional buckling modes.

B. Milan Veljkovic, Bernt Johansson "Thin-walled steel columns with partially closed cross-section:Tests and computer simulations" Journal of Constructional Steel Research 18 January 2008

Cold formed sections can be optimized for different purposes and they are fairly inexpensive to produce in small series. They have an inherent weakness in their small torsional stiffness, which is unfavourable for columns. One solution presented here is to make a closed section by adding a thin cover plate connected discretely with self-tapping screws. It is here called a partially closed cross-section because it is not continuously and rigidly connected. The aim of this paper is to evaluate the efficiency of this solution by comparing the behaviour of partially closed and open cross-section. Four columns were tested within the project, two of them with centric axial load and two with eccentricities. Numerical analysis was performed using ABAQUS for establishing the influence of the cover plate on the critical load and the resistance. A good agreement between non-linear FEM and experiments were found. After this verification of the FE model a parametric study was carried out. Results of experiments and numerical analysis were compared with the predicted resistance by Eurocode 3, Part 1–3, and the Direct Strength Method. Both design methods give good predictions of the resistance.

C. Jia-Hui Zhang, Ben Young "Compression tests of cold-formed steel I-shaped open sections with edge and web stiffeners" 15 November 2011

A series of column tests on cold-formed steel I-shaped open sections with edge and web stiffeners has been conducted. The test specimens were firstly brake-pressed from high strength zinc-coated steel sheets and then two of the same members were connected back-to-back by self-tapping screws to form an I-shaped section with edge and web stiffeners. The members had the nominal thicknesses of 0.48, 1.0 and 1.2 mm. The column length of the test specimens varied from 300 to 3200 mm with an increment of approximately 600 mm. The column specimens were compressed between fixed ends. Tensile coupon tests were also conducted to obtain the material properties at both flat and corner portions of the sections. Initial local and overall geometric imperfections were measured. The columns were failed by local, distortional, flexural buckling and the interaction of these buckling modes. The failure modes and ultimate strengths of the column specimens were presented. The direct strength method in the North American Specification and the Australian/New Zealand Standard was used to calculate the design strengths of the I-shaped open section columns. The appropriateness of the direct strength method for I-shaped open sections with edge and web stiffeners was evaluated. In addition, the reliability of the direct strength method for the I-shaped open sections was evaluated using reliability analysis. It is shown that the direct strength method can be used for cold-formed steel I-shaped open sections with edge and web stiffeners.

D. Nuno Silvestre, Dinar Camotim Et Al "Post-buckling behavior and direct strength design of lipped channel columns experiencing local/distortional interaction"13 january 2012

This paper reports an investigation aimed at developing a Direct Strength Method (DSM) approach to estimate the ultimate strength of lipped channel columns affected by local/distortional buckling mode interaction. Following a brief presentation of a few relevant aspects concerning the shell finite element analysis of the geometrically and materially non-linear behaviour of thin-walled members, one illustrates the methodology adopted to obtain a lipped channel column ultimate load "data bank" intended to be used in the development and assessment of a DSM design approach. Next, the current DSM expressions to predict the load-carrying capacity of columns failing in local and distortional modes are briefly reviewed, devoting special attention to an approach that takes into account the above mode interaction. Then, the results of a parametric study, carried out by means of the code ABAQUS, are presented and discussed this study involves the evaluation of the "exact" ultimate loads of276lippedchannel columns with various geometries and two boundary conditions (pinned and fixed end supports), all exhibiting local/distortional interaction. Finally, these ultimate strength data are compared with the estimates provided by the available DSM expressions and, on the basis of this comparison, one identifies several features that a DSM approach successfully accounting for local/distortional interaction must incorporate.

E. M. Anbarasu K. Kanagarasu Et Al "Investigation on the behavior and strength of cold-formed steel web stiffened built-up battened columns" 31 October 2014

Cold-formed steel built-up sections are commonly used as compression elements to carry larger loads and over longer spans when a single individual section is insufficient. This paper reports a numerical study of the cold-formed steel built-up web stiffened lipped channel sections under axial compression. The built-up sections are formed by two identical lipped channels placed back to back with batten plates and are connected by self-driving screw. The Finite element model is developed by ABAQUS software and the model is validated with the results available in the literature. Three types of web stiffened lipped channel cross section have been chosen for the study, based on the AISI-S100:2007 Geometric limitations. The parametric study is extended by the validated model for various slenderness ratios. The column strength predicted by the finite element analysis is compared with the design column strengths predicted by direct strength method (DSM). Based on this study a recommendation is proposed to DSM.

F. P. Manikandan N. Arun "Behavior of Partially Closed Stiffened Cold-Formed Steel Compression Member"10 December 2015

Usually, thin-walled open column sections have an intrinsic weakness in their low torsional strength, which is unpleasant for resistance of an open section. The distortion behaviour of cold-formed steel open section has a significant role in structural steel design. Hence, initiativeness is made for converting partially closed section by adding simple spacer

plates connected with self-tapping screws. The intend of this work is tested to estimate the competence of this solution by comparing the strength and performance of partially closed and open stiffened complex channel section under axial compression. The buckling characteristics of the section are computed using the linear elastic buckling analysis program CUFSM. The resistance and behaviour of the intermediate columns are examined in detail using finite element analysis software ANSYS. A good conformity between finite element analysis and experiments is found. The nominal design capacities are evaluated using the necessities of the direct strength method, North American iron and steel specification and Indian standard and are compared with those from test and finite element analysis. After this verification of the numerical model, a crucial parametric study is carried out to inspect the effect of vitiations on thickness, depth, spacing and slenderness of spacer plates. The particulars of this study and results are offered in this research article.

G. Jia-Hui Zhang, Ben Young "Numerical investigation and design of cold-formed steel built-up open section columns with longitudinal stiffeners" 17 December 2014

A built-up I-section with longitudinal stiffeners is expected to have better performance to resist against local and distortional buckling compared to conventional built-up I-section by simply connecting two plain channels back-to-back. This paper presents a non-linear finite element analysis to investigate the behaviour of cold-formed steel built-up open section columns with edge and web stiffeners. A finite element model was firstly developed and verified against tests of cold-formed steel built-up compression members, in which the initial geometric imperfections and material properties of the test specimens were included. Secondly, the verified finite element model was used for an extensive parametric study of fixed-ended cold-formed steel built-up open section columns. The parametric study was designed to investigate the effect of edge and web stiffeners in the built-up open sections. The finite element results together with the test results were compared with the design predictions calculated from the current design rules in the North American Specification and the Australian/New Zealand Standard. Furthermore, design rules of the current direct strength method were modified. It is shown that the design strengths predicted by the modified direct strength method are generally in good agreement with the ultimate loads of the built-up open section columns. In addition, the current design rules and the modified direct strength method were evaluated by reliability analysis.

H. Mohamed Dabaon, Ehab Ellobody Et Al "Nonlinear behaviour of built-up cold-formed steel section battene columns" 12 March 2015

This paper discusses nonlinear behaviour and design of built-up cold-formed steel section battened columns. The built-up columns were pin-ended and consisted of two cold-formed steel channels placed back-to-back and were connected using batten plates. Nonlinear 3-Dfinite element models were developed to simulate the structural performance of the axially loaded columns. The nonlinear material properties of flat and corner portions of the channels, initial geometric imperfections, actual geometries and boundary conditions were carefully considered in the models. The finite element models were verified against tests, recently conducted and reported by the authors, on the same form of construction. The column strengths, failure modes, deformed shapes at failure, load-lateral displacement and load-axial strain relationships were predicted from the finite element analyses and compared well against the test results. In addition, the validated finite element models were used to perform an extensive parametric study investigating different parameters affecting the behaviour of the columns comprising different slenderness, column lengths, cross-section geometries, steel strengths, spacing between channels and different batten plates spacing. Furthermore, the column strengths predicted in the parametric study were compared with design strengths calculated using the North American Specification, Australian/New Zealand Standard and European Code for cold-formed steel columns.

I. Ben Young, Ju Chen "Column tests of cold-formed steel non-symmetric lipped angle" 18 January 2008

The geometry of angle sections is simple, but the behaviour and design calculations of angle sections can be quite complicated. Furthermore, lipped angle sections with unequal flange widths form a non-symmetric section and the behaviour of the section is even more complicated than a singly-symmetric angle section with equal flange widths. A test program on cold-formed steel non-symmetric lipped angle columns is presented. The non-symmetric angle sections were brake-pressed from high strength structural steel sheets having nominal yield stresses of 450 and 550 MPa with plate thicknesses of 1.0, 1.5 and 1.9 mm. The material properties of the column specimens were obtained by tensile coupon tests. The behaviour and strengths of cold-formed steel non-symmetric lipped angle columns were investigated. The test strengths are compared with the design strengths calculated using the North American Specification for the design of cold-formed steel structural members. In addition, the current design rules in the North American Specification for cold-formed steel non-symmetric lipped angle columns are assessed using reliability analysis. It is shown that the design strengths are generally quite conservative.

J. D. Cava, D. Camotim Et Al "Numerical investigation and direct strength design of cold-formed steel lipped channel columns experiencing local–distortional–global interaction" 25 March 2016

This paper reports the results of a numerical investigation concerning the relevance and Direct Strength Method (DSM) prediction of the ultimate strength erosion caused by local-distortional-global (LDG) interaction in cold-formed steel fixed-ended lipped channel columns. The geometries of the columns analysed (cross-section dimensions and lengths) were carefully selected to ensure that the three competing critical buckling loads are not more than 20% apart, thus guaranteeing a fairly high level of LDG coupling, and ordered in all the various possible sequences. In order to cover a wide slenderness range, several yield stresses are considered, falling below, in-between and above the lowest and highest critical buckling stresses. After providing a brief description of the column selection procedure, which is based on buckling analyses performed with Generalised Beam Theory (GBT), the methodology adopted to identify the most detrimental initial geometrical imperfection shape

(in the sense it minimises the column strength) is addressed– it employs Koiter's asymptotic method along with a Monte Carlo simulation. Then, columns containing those initial geometrical imperfections are compressed up to failure, by means of ABAQUS shell finite element analyses (SFEA), making it possible to acquire in-depth knowledge on the behaviour of lipped channel columns undergoing LDG interaction and gather considerable failure load data. Finally, the last part of the paper is devoted to the DSM prediction of those failure loads and uses the obtained "data bank" to assess whether the available design approaches are able to handle adequately the ultimate strength erosion caused by the triple interaction phenomenon under investigation if this is not the case, new design curves must be developed.

K. Aizhu Zhu , Hongping Zhu Et Al "Experimental study and analysis of inner-stiffened cold-formed SHS steel stub columns"

A series of axial compression tests was conducted to investigate the compressive behaviour of cold-formed steel stub columns with relatively thick walls. Four different inner-stiffener arrangements were considered. Tensile coupons were cut from different parts of the square hollow section (SHS) sections to obtain a full picture of the enhanced material properties due to the cold-forming process. A finite element model was also developed and employed to provide a numerical perspective of the behaviour of the SHS columns. The applicability of two code-specified methods for the calculation of the strength of thin-walled cold-formed SHS columns for the present thick-walled cases is examined. The comparison shows that the AISI (and similarly AS/NZS) method tends to overestimate the sectional strength for the unstiffened and partially stiffened 6-mm thick columns, but predicts generally well (with slight underestimate) in the cases of well-stiffened 6-mm columns and all the 10-mm thick columns. The GB method, on the other hand, appears to predict well for all cases where the stiffening effect was less significant, but underestimates the sectional strength in the well-stiffened cases.

III. Conclusion

Based on the literature study, the following conclusions have been arrived.

1) cold-formed column steel sections can be strengthened by forming edge and web stiffeners.
2) A built-up I-section with longitudinal stiffeners is expected to have better performance to resist against local and distortional buckling compared to conventional built-up I-section by simply connecting two plain channels back-to-back.
3) Due to corrugated Cold formed profiles as columns to improve the torsional stiffness.
4) A built-up section can span more distance, present a higher load carrying capacity and higher torsional stiffness.
5) built-up members are symmetric, eliminating eccentricities between shear and gravity centers, leading to higher member stability.
6) The local buckling is completely eliminated due to the provision of intermediate stiffener in the web.

References

[1] Mulligan GP, Pek¨ oz T. Locally buckled thin-walled columns. Journal of Structural Engineering—ASCE 1984;110(11):2635–54
[2] Kwon YB, Hancock GJ. Tests of cold-formed channels with local and distortional buckling. Journal of Structural Engineering—ASCE 1992;117(7):1786–803
[3] IS: 801 – 1975, "Code of practice for use of cold-formed light gauge steel structural member in general building construction".
[4] Sukumar S, Parameswaran P, Jayagopal LS (2006) Local-distortional-,and Euler buckling of thin walled built-up open cross-sections under compression. J Struct Eng—Madras32(6):447–454
[5] B. Young, J. Chen, Column tests of cold-formed steel non-symmetric lipped angle sections, J. Constr. Steel Res. 64 (2008) 808–815.
[6] El Aghoury MA, Salem AH, Hanna MT, Amoush EA (2010) Experimental investigation for the behaviour of battened beam-columns composed of four equal slender angles. Thin-Walled Struct 48(9):669–683
[7] V.B. Nguyen, C. Wang, D.J. Mynors, M.A. English, M.A. Castellucci, Compression tests of cold-formed plain and dimpled steel columns, J. Constr. Steel Res. 69 (1) (2012) 20–29.
[8] I. Georgieva, L. Schueremans, L. Pyl, L. Vandewalle, Innovative cross-section shapes for built-up CFS columns. Experimental investigation. in: Proceedings of the 21st International Specialty Conference on Cold-Formed Steel Struc-tures, Missouri, USA, October 2012.
[9] N. Silvestre, P.B. Dinis, D. Camotim, Developments on the design of cold-formed steel angles, J. Struct. Eng. 139 (2013) 680–694.
[10] Li Yuanqui, Li Yinglei, S. Wang, Z. Shen, Ultimate load-carrying capacity of cold-formed thin-walled columns with built-up box and I section under axial compression, Thin-Walled Struct. 79 (2014) 202–217.

