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Study on Buckling Behavior of Cold Formed Steel Beam – Channel Section

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ABSTRACT -This paper present the literature review regarding to buckling behaviour of different cold formed steel sections used as a beam. Cold formed steel members are used as a secondary structural element in building construction. Recently the application of cold formed steel has increased in buildings for its inherent features like higher weight to strength ratio, adaptability, non- combustibility, and easier production process. But cold formed steel beam can also cause local buckling at stresses below the yield point because it is usually thin in relation to its width. In this paper the influence of stiffeners, various sections, aspect ratio and their failure modes were studied.

Key Words: Cold Formed Steel, Buckling, Beam, Channel Section, Nonlinear.

I. INTRODUCTION

Steel as a structural material has become the perfect choice in the construction sector for its innumerable advantages over other building materials. Steel used in the construction mainly categorized into two families as hot rolled shapes member and plates and other is cold form steel (CFS). Although first one is the most familiar, various benefits of cold formed steel are growing interest in both the research and construction sectors especially in Industrialized Countries, like USA, Canada, Australia and some European Countries. In the construction of low-rise residential building, transmission towers and commercial building cold-formed steel is being used as a structural element. It is also being used in the construction of bridge, storage and drainage facilities, bins etc. Generally in cold formed steel structure, the plates and bars having the thickness of 25.4 mm can be converted into cold formed steel element. In spite of having advantages like economic production, easy transportation, low labour costs, higher strength-to-weight ratio. Cold Formed Steel sections involves complex behaviour and problems like more slenderness and local, distortional and coupled instability phenomena. To reach deep inside these properties and find appropriate modifications in models, specifications, and code, researchers did many important studies regarding the complexity of cold form steel. Due to good structural performance and economy, it is also a good choice for engineers, contractors, and owners.

1.1 Cold Formed Steel

Cold-formed steel (CFS) members are made from structural quality sheet steel that are formed into C-sections and other shapes by roll forming the steel through a series of dies. No heat is required to form the shapes (unlike hot-rolled steel), hence that named as cold-formed steel. A variety of steel thicknesses are available to meet a wide range of structural and non-structural applications.

1.2 Manufacturing Process

The CFS sections are cold-formed from carbon or low alloy sheet, strip, plate or flat bars in cold-rolling machines or by press brake or bending brake operations. Their manufacturing process involves forming steel sections in a cold state i.e. without application of heat, from steel sheets of uniform thickness. There are three methods to form any shape of CFS:

- Cold-roll forming
- Press brake operation
- Bending brake operation

1.3 SHAPES

The shapes of cold-formed sections used in industrial applications are necessarily shaped to meet the specific requirement of the loading conditions and the utility. Most common sections in building applications are C & Z sections with wide variation in their original forms to enhance the efficiency of these sections with use of lips and stiffeners.

Table -1: Manufactures in India

Name of the Company	Products
Tata Steel, India	Cold Rolled Strips, Sheets, Closed Structures, C, Z.
MohtaColdsec, Mumbai	Z purlins
Tiger Steel Engg. Pvt. Ltd., Baroda	Z purlins with Inclined Lips, Side Girts
Navratan Pipe & Profile Limited, Delhi	Z purlins, Decks, Channel sections with and without lips
TI Metal Sections, Chennai	Z purlins (as per IS 811 1987)
Frontline enterprises, AP India	U, C, Z sections

1.4Applications of CFS

1. Framing
2. Composite section
3. Lateral load resisting system
4. Secondary load bearing members
5. Storage racks

II. LITERATURE SURVEY

Francisco J. Meza et al (2020) experimented on the comprehensive experimental program on cold formed steel built-up beams with two different cross-sectional geometries. The work aimed to experimentally investigate the interaction between the individual components under increasingloading and to quantify the effect of the connector spacing on the cross-sectional moment capacity and the behaviour of the beams. In total,12 specimens were tested in a four-point bending configuration, with lateral restraints provided at the loading points in order to avoid globalinstabilities. The built-up specimens were composed of three or four plain channels with nominal thicknesses of 1.2 and 1.5 mm, which werejoined together using M6 bolts. Each built-up geometry was tested with three different connector spacing's. The specimens were designed tofail by local buckling of their components. Additionally, strut buckling of the channel comprising the flange in between connector pointswas observed. Between the local buckling patterns of the components, with the interaction being affected by theconnector spacing and the type of geometry. However, the connector spacing showed a less significant effect on the ultimate capacity when failure was governed by local instabilities of the components.

M. Anbarasu (2019) experimented on thestructural behaviour of cold-formed steel (CFS) closed Built-up beams composed of twosigma sections primarily fail due to local buckling under four-point bending about the major axis. It is aimed toestablish accurate finite element models for CFS built-up I-beam subjected to a transverse load. The numericalmodel was developed by using Finite Element (FE) software ABAQUS 6.13. The numerical model is validated by means ofcomparison with the experimental results published in the literature in terms of moment capacities, momentversus deflection curve and failure mode of specimens. For different cross-section geometries and differentthickness of the built-up closed beam, the numerical parametric study has been carried out by using the verifiedFE model, and the obtained flexural resistances were compared with those predicted by using current DSM andDSM proposed for built-up beams. The moment capacity decreases with increase in compression flange width tothickness ratio. In general, the moment of resistance of the section increases with decreasing the aspect ratio.There is no significant effect in flexural strength of the built-up closed beams due to the change in depth of webstiffener.

Hong-Xia Wan et al (2016) experimented on thebuckling behaviour and design of cold- formed steel beams subject to combined bending and torsional actions. A finite element model considering the effects of initial geometrical imperfections and residual stresses was developed to simulate the combined bending and torsion of cold-formed steel beams. The finite element model was used to conduct analysis on cold-formed lipped channel sections, Z sections and hollow flange channel sections. Elastic buckling analysis was first conducted to study their buckling modes and buckling loads. Nonlinear analysis including the effects of large deformation and material yielding was conducted to obtain their ultimate buckling strength. The interaction between the ultimate bending and torsional moment capacities was studied and appropriate design rules were suggested. ANSYS Version 13.0 was used to create finite element models and to conduct analyses. Elastic buckling behaviour and failure characteristics of C sections, Z sections and LSBs under negative and positive eccentricity loading cases were revealed. For C sections, negative eccentricity loading is more disadvantageous, due to the effects of flange-lip distortion. For Z sections, positive eccentricity loading is more disadvantageous, due to the effects of web buckling. In some range, negative eccentricity can help to improve the capacity of Z section, however, greater negative eccentricity can lead to flange-lip distortion and thus strength dropping.

Pooja S. Ajay et al (2014) Investigated on the flexural behaviour of cold form steel I beam with diagonal stiffeners. Here a total of six specimens were tested in which two specimens were without stiffeners, two specimens with stiffeners and two specimens with stiffeners and in-filled concrete. The span of the beam was 2000 mm and the cross sections of the I-beams were 150 mm x 100 mm x 2mm. The yield strength of steel used was 380 Mpa and the web was encased with M 30 grade. Intermittent welds of 4 mm were used and a pair of stiffeners was provided at both the load points to minimize the local effect due to concentrated loads. All the specimens were tested for flexural strength under two point loading. The results were compared and analysed. The ultimate load of normal I section was 17 KN and the ultimate deflection was 6.5 mm. The ultimate load of diagonally stiffened beam was 30.8 KN and ultimate deflection was 9.5 mm. The ultimate load of encased diagonally stiffened beam was 92.6 KN and ultimate deflection of 24.9 mm. The majority of cracks were formed between the zones of two point loading and also some cracking was also observed near the supports end. The ultimate load carrying capacity of the beam with stiffeners was 40-45% higher than the beam without stiffeners. The ultimate load carrying capacity of the beam with stiffeners and in-filled concrete was 80-85% higher than the beam without stiffeners.

Ahmad Ali Ghosn (2002) Experimented on the stiffened Z-section beam purlins were tested to evaluate the deflection behaviour of lap joints under combined bending and shear. The tested beams had a span length of 243.84 cm (8 ft), nominal web depths of 20.32 cm (8 in.) and 24.13 cm (9.5 in.), and a metal thickness ranging from 1.542 mm (0.060 in.) to 2.565 mm (0.101 in.). The corresponding web depth-to-thickness ratio (h/t) ranged from 79 to 131. The experimental program included testing a single section beam of each Z section and lapped beams with lap-to-span ratio ranging from 0.25 to 1.0. The test results indicated that the lapping process enhanced the ultimate load capacity and stiffness of the beams. This enhancement was more pronounced for beams with lap-to-span ratios less than or equal to 0.5. For higher ratios, little or no change in the results was noted. The failure mechanism was governed by bending stresses and was caused by buckling of the compression flanges at stress levels close to the yield stress of the parent steel. A relative stiffness behaviour approach was used to analyse the results. This approach compares the deflection behaviour of lapped beams with that of a single section beam having the same span length and the same Z section. Based on this analysis, semi empirical equations were obtained to predict the deflection of lapped beams. Theoretical deflection equations were also derived and the results based on these equations were compared with the experimental results. It was concluded based on this comparison that the proposed correlation was adequate for predicting the deflection in the lap joint zone of nested Z beams.

YaredShifferaw et al (2012) Investigated to provide and verify a general design method for prediction of inelastic bending capacity in cold-formed steel members potentially subject to local, distortional, and/or lateral-torsional buckling modes. An extensive experimental database of tested cold-formed steel beams is collected and indicates that inelastic reserve in the bending capacity of thin-walled cold formed steel members is more common than typically assumed. Elementary mechanics for inelastic reserve are reviewed and simplified expressions provided for connecting the strain demand to the inelastic bending capacity in the range between the yield moment and the fully plastic moment. The strain capacity that can be sustained in inelastic local and inelastic distortional buckling is investigated through existing experiments coupled with nonlinear finite-element (FE) analysis. The nonlinear FE models provide a comprehensive means to investigate the relationship between cross-section slenderness, normalized strain capacity, and the resulting bending strength. A design approach for inelastic lateral-torsional buckling 1s provided on the basis of the hot-rolled steel AISC Specification. The resulting relationships for inelastic local, distortional, and lateral-torsional buckling are provided in a Direct Strength Method format for potential adoption in the cold-formed steel American Iron and Steel Institute (AISI) Specification. The provided design method is assessed against available data and shown to be a reliable predictor of inelastic bending capacity in cold-formed steel members. For analysis

ABAQUS 6.7.1 was used and that focuses solely on distortional buckling limit states in typical C and Z cold-formed steel sections. The developed FE model is used to perform parametric studies to establish the relationship between distortional cross-section slenderness and the strain that may be sustained in inelastic distortional buckling.

P. Keerthan et al (2012) Experimented on the shear behaviour of LCBs with web openings. Due to limited research has been undertaken on the shear behaviour and strength of LCBs with web openings, Hence a numerical study was undertaken to investigate the shear behaviour and strength of LCBs with web openings. Finite element models of simply supported LCBs with aspect ratios of 1.0 and 1.5 were considered under a mid-span load. They were then validated by comparing their results with test results and used in a detailed parametric study. Experimental and numerical results showed that the current design rules in cold-formed steel structures design codes are very conservative for the shear design of LCBs with web openings. Improved design equations were therefore proposed for the shear strength of LCBs with web openings. This paper presents the details of this numerical study of LCBs with web openings, and the results.

PoologanathanKeerthan et al (2011) : A detailed experimental study involving 36 shear tests using a three-point loading arrangement was conducted first to investigate the shear behaviour and strength of LSB sections. To achieve the primarily shear condition, relatively short spans of LSBs were selected with aspect ratios of 1.0 and 1.5. All three types of shear failure (shear yielding, inelastic, and elastic shear buckling) were investigated in this study, and suitable shear design rules were developed for LSBs on the basis of the results from both finite-element and experimental studies. This paper presents the details of finite-element models developed to simulate the nonlinear shear behaviour of LSBs, including their buckling characteristics and ultimate shear strengths.

III. CONCLUSION

From the literature survey, the results are concluded as,

- The load carrying capacity of the cold formed steel beams can be improved by providing diagonal stiffeners.
- The flexural strength of built-up cold formed sections is more than the single cold formed steel sections.
- The ultimate capacity of the CFS build-up beams can be increased by reducing the connector spacing.

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