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Numerical Modelling and Design of Lipped Channel Beam Subjected to Web Crippling

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ABSTRACT

Cold formed steel members are these days been utilised in the fabrication of thin walled members the usage of a roll-forming method to provide purlins, ground joists, and other structural bearers. Such members are regularly subjected to transversely focused loads which may additionally a critical web crippling failure. Web crippling is a not unusual mode of failure in web elements of thin walled beams under focused loads or reactions. Lipped channel beams (LCB'S) are usually used as floor joists and bearers in the production enterprise. This paper describes a numerical modeling based research study undertaken to study the web crippling of lipped channel beam under the End One Flange (EOF) loading and Interior One Flange (IOF) loading. Finite element models had been advanced by using ANSYS software program to recognize the web crippling behavior of lipped channel beams is proven using the data available in the literature. Numerical research is executed in an effort to provide stiffeners in lipped channel beam inspect greater about the web crippling behavior of lipped channel beam. The results indicate that the numerical model can be similarly progressed web crippling capacity by incorporating stiffeners in lipped channel beam.

Keywords: Lipped channel beams (LCB'S), End One Flange (EOF), Interior One Flange (IOF).

1 Introduction

Thin sheet steel products are appreciably used in building industry, and range from purlins to roof sheeting and floor decking. Normally those are available to be used as simple constructing factors for assembly at site or as prefabricated frames or panels. These thin steel sections are cold-formed, i.e. their manufacturing system involves forming steel sections in a cold state (i.e. without application of heat) from steel sheets of uniform thickness. These are given the universal identify cold formed steel Sections. On some occasion they are additionally called mild Gauge metallic Sections or cold Rolled steel Sections. The thickness of steel sheet used in cold formed production is normally 1 to 3 mm. A great deal thicker material up to 8 mm may be shaped if pre-galvanized material is not required for the specific utility. The method of manufacturing is vital as it differentiates those products from hot rolled metallic sections. Now a day's cold-formed steel member are in present in modern construction enterprise due to their inherent more advantageous characteristics over conventional thicker hot-rolled sections. Cold formed steel members are typically thin-walled

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contributors with large width-to-thickness ratios. Cold-formed steel sections are made of metallic plates, sheets or strip material. The manufacturing procedure involves forming the material via both press braking and cold roll forming thin steel sheets to attain the favored form. Press braking is regularly used in the manufacturing of small quantity of easy shapes even as cold roll-forming is popularly applied for the mass production of cold-formed structural members. Due to the fact cold-formed metallic members are produced at room temperature, the material becomes harder and stronger. The strength of the steel is extended through strain hardening by approximately 20 to 50% depending on the fabrication technique used and the steel thickness. The shapes of cold formed sections utilized in commercial applications are necessarily shaped to meet the unique requirement of the loading situation and the application. Most common sections in building applications are C & Z sections with huge variation of their unique forms to enhance the efficiency of these sections with use of lips and stiffeners The roll-forming process consists feeding a continuous metal strip through a series of opposing rolls to deform the metallic plastically to form the preferred shapes. Normally, a simple section may be produced the usage of a few pairs of rolls but a complex section may additionally require many units of rolls to reach the final shape. This approach is usually used to produce cold-formed steel sections where a large quantity of a given section is needed. However, a widespread limitation of this method is the time taken to alternate rolls for different size sections. Consequently, adjustable rolls are frequently used which permit a rapid alternate to a different section width or depth. From a structural point of view, roll-forming may also produce a kind set of residual stresses in the segment and for this reason the section strength can be exceptional in case where in buckling and yielding interact. The gadget used in the press brake operation basically includes a moving top beam and a stationary bottom bed that produce one complete fold at a time along the full length of the section. This technique is commonly used for low quantity manufacturing where a variety of shapes are required and the roll-forming tooling prices cannot be justified. However, this method has a limitation that it is difficult to provide non-stop lengths exceeding about five meters

2 Literature Review

M. Macdonald (2008) conducted to review web crippling behaviour of cold-formed thin-walled steel lipped channel beams subjected to End-One-Flange (EOF) and End-Two-Flange (ETF) loading conditions as defined by the American Iron and Steel Institute (AISI). An experimental program was designed to get the load-deformation characteristics of beam members with varying cross-sectional and loading parameters under the 2 web crippling loading conditions. Nonlinear finite element models were developed to simulate web crippling failure of the 2 loading conditions considered within the experimental program. The comparison of experimental and finite element results revealed that the nonlinear finite element models were capable of closely simulating the online crippling failure behaviour

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observed within the experiments. Web crippling strength predicted from the AISI Specification was also compared with the experimental results and therefore the comparisons indicated considerable underestimations for the range of specimens under EOF and ETF loading conditions.

Gintaras Sakalys (2017) investigates an efficiency of application of vertical stiffeners within the web of cold-formed C-section beams under local concentrated loading. The stiffeners would be cold formed – an I-section cut is formed on the web and therefore the cut edges are folded into the inner side of the profile. A lipped channel beam with a length of 1 m was selected to research the efficiency of vertical web stiffeners. As a validation of rational stiffener parameters requires an in depth 7 experimental program that's time-consuming and prohibitively expensive, thus, the numerical modelling using finite element method (FEM) was adopted. The numerical modeling was performed consistent with the standardized methodology of American Iron and Steel Institute (AISI) with the increasing height of the stiffeners, the very best efficiency is achieved under the ETF loading. This is often explained by the very fact that under such a condition the unstiffened web of the beam buckles through its entire height at relatively low loading intensity. Under the EOF loading the efficiency also increases with the increasing height of the stiffener, though the increment isn't so high. This is often due to fact that the buckling of the unstiffened web takes place not over its entire height but at bottom part only. The critical slenderness of stiffeners are going to be determined like the failure of the online without buckling of the stiffener.

Soundharyaet all (2017) conducted the theoretical, experimental and therefore the numerical investigation of back to back lipped channel section with circular web holes subjected to web crippling strength. The tests are conducted on concentrated loading condition and finite element models were used for the needs of parametric study on effect of various size and position of web holes. The study concluded that the ratio of a/h and h/t are the first parametric relationships influencing the web crippling behavior of the rear to back lipped channel section with the web holes.

Lavan Sundararajah et.al (2017) described an experimental study of high strength cold-formed steel lipped channel beams (LCB) unfastened to supports under EOF and IOF load cases conducted using the AISI standard web crippling test method. This study consisted of 36 web crippling tests using high strength LCBs with minimum yield strengths Comparisons with experimental web crippling capacities showed that AS/NZS 4600 and AISI S100 design rule predictions are unconservative, whereas Euro code 3 Part 1-3 design predictions are overly conservative for LCBs under EOF load case. For IOF load case, AS/NZS 4600 and AISI S100 predictions agree reasonably well with experimental capacities, whereas Euro code predictions are very conservative. A review of recent web crippling test results also showed that the predictions of the prevailing web crippling design equations for cold formed steel channel sections are inconsistent. Therefore, the web crippling coefficients of AS/NZS 4600 and AISIS100 design equations were modified based on the results from the experimental study conducted using the AISI S909 standard web crippling test method.

B. Janarthanan(2019) discussed the web crippling studies of lipped and unlipped channel sections with unfastened to supports, SupaCee sections unfastened to supports and unlipped channel sections 8 fastened to supports and their important outcomes. These studies were based on supported both experimental and finite element studies. Finite element models were then developed, analysed using quasistatic analysis and validated using experimental results. The proposed coefficients to AS/NZS 4600 and AISI S100 design equation were then revised using the parametric study results. A material yield strength factor was proposed and included within the current web crippling design equation with suitable coefficients for lipped channel sections with unfastened supports and unlipped channel sections with fastened supports. Direct Strength Method (DSM) based equations were also proposed for lipped and unlipped channel and Supa Cee sections for all four load cases. The findings from the studies reported during this paper are often included within the future versions of cold-formed steel design standards.

Lavan Sundararajah et.al (2019) studied cold formed lipped channel beam sections subjected to one-flange web crippling loads (EOF and IOF load cases). Finite-element models capable of simulating the web crippling behavior were first developed and their accuracy was investigated by comparing their results with those from web crippling tests undertaken using the AISI S909 standard test method. The developed web crippling finite element models are ready to predict the experimental web crippling capacities, failure modes and load-deflection plots of LCBs under EOF and IOF load cases. New web crippling design equations were proposed within the sort of modified web crippling coefficients for the three important parameters of inside bent radius, bearing length, and web slenderness ratio. a replacement parameter was also included to permit the utilization of the proposed web crippling equations for LCBs made from both low- and high-strength steels. The proposed web crippling equations during this paper are often considered for inclusion in future versions of AISI S100 and AS/NZS 4600

Asraf Uzzaman et.al (2020) presents a mix of tests and finite element analysis, to research the effect of edge stiffened circular web holes on web crippling strength of CFS lipped channel sections under ITF loading condition. For comparison, channel sections without holes and with unstiffened holes also are considered. A non-linear finite element (FE) model is described, and thus the results were compared against the test results, which showed an honest agreement in terms of both the web crippling strength and failure modes. The results indicate that the stiffened web holes can significantly improve the online crippling strength of CFS channel sections. From the results of the parametric 9 study, design recommendations within the type of web crippling strength reduction factors are proposed, that are conservative to both the experimental and FE results.

Husam Alsanatet.al (2020) the study was conducted to research the mechanism of web crippling for roll-formed aluminium lipped channel (ALC) sections with flanges attached to

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supports (fastened) under two-flange loading conditions.. The acquired web crippling data were then used to investigate the influence of the flange restraints on the web crippling mechanism of the ALC sections. Furthermore, a thorough assessment of the consistency and reliability of the currently available design rules utilized in practice was administered. The predictions of the web crippling design guidelines given within the Australian, American and European specifications were found to be unsafe and unreliable, whereas a good agreement was obtained between the predictions of our recently proposed design guidelines and purchased web crippling results. Further an appropriate Direct Strength Method (DSM)-based design approach was developed during this study with associated equations to predict the elastic bucking and plastic loads of fastened ALC sections under two-flange loading conditions.

Anwar Badawyet. Al (2020) developing a replacement simple but rational analytical model to predict web crippling strength of cold formed steel Z beams. Results of the developed analytical model were verified experimentally and numerically utilizing the finite element non-linear analysis. Web crippling strengths obtained by the proposed analytical model, tests and numerical analysis were compared to the corresponding strength calculated by the equations of AISI-2016 and Eurocode. Both codes adopt empirical equations for estimating the web crippling resistance. The design codes included during this study aren't conservative for estimating the web crippling nominal strengths compared to both finite element and experimental results finite element and experimental results.

3 Experimental Methodology and Investigation

ANSYSisanAmericancomputeraidedengineeringsoftwaredeveloperheadquarteredinUnitedStates.ANSYSpublishesengineeringanalysissoftwareacrossaarrayofdisciplinestheyarefiniteelementanalysis,structuralanalysis,computationalfluiddynamics,explicitandimplicitmethods,and heat transfer. ANSYS Mechanical is a well-known finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This type of computer simulation gives finite elements to model behavior, and supports material models and equation solvers for a wide variety of mechanical and structural design issues. ANSYS computer simulation tool used for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions. ANSYS also has a module called Explicit Solver using Autodyn which is easier to use compared to the Autodyn solver and has all the capabilities of Autodyn solver. Several modules are provided within the ANSYS Workbench environment making the software capable of handling a wide range of problems including finite element analysis, static structural analysis, implicit as well as explicit dynamic analysis, thermodynamic analysis etc. The analysis work for this is done using the ANSYS Work bench 18.0 software in the static structural solver.

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3.1 Model Descriptions

For the validation purpose the journal entitled "Numerical Modelling and Design of Lipped Channel Beams Subjected to Web Crippling under One flange Load cases" published in 2019 by Lavan Sundararajah et.al .The journal discusses the numerical study on the web crippling of lipped channel sections and comparing the results. The load and deformation of section under one flange load condition found numerically with the help of ABAQUS software. In this chapter, we discuss the web crippling capacity of lipped channel section numerically with the help of ANSYS WORKBENCHWEBCRIPPLING-AS/NZS4600. AS/NZS 4600 provides the design policies for the bearing potential of commonly used cold formed steel sections. These sections encompass cold formed steel beams with and without holes within the web for maximum of the typical sections including again to returned channel sections, single web channels (lipped and unlipped channels), unmarried net Z-sections, unmarried hat sections and multi-net deck sections. The bearing ability equation for focused load or reaction for one stable web connecting top and bottom flanges is as follows,

$2R = Ctf \sin\theta \, (1-Cbwy)$

in which,

$(\sqrt{r} / triw)\ (1 + C \sqrt{\ell} / t\ell\ bw)\ (1 - C \sqrt{d/})\ 1\ w$

d=203.8mm

C = usual coefficient=4

Θ = attitude among the plane of the web and the plane of the plane of the bearing surface=900

Cr= Coefficient of inside bent radius to web thickness (ri/tw) =0.14

Cℓ = Coefficient of bearing length to thickness (ℓb/tw) = 0.3516

ℓb = actual bearing duration. For the case of equal and opposite focused masses=100mm

Cw = Coefficient of web slenderness (d1/tw) = 0.02

d1 = intensity of the flat portion of the web measured alongside the plane of the web

d =d-2(t1+r) = 203.8-2(2.41+5) =188.8mm

ri = inside bent radius=5mm

tw = thickness of web=2.4mm

fy = Yield strength=526Mpa

$2R$ = 4 x 2.41 x 526 x 1(1-0.14√5/2.41) (1+0.35 √100/2.41) (1-0.02 √188.8/2.41)=26092.67N=26.09KN

3.2 Web Crippling Of Lipped Channel Section with Stiffnersi of Load Condition

The web crippling capacity of lipped channel section under interior one flange loading is find out numerically. Here we have done the validation for lipped channel section having 1000mm length. The dimensions and material properties are shown in table 5.3 and table 5.4 respectively. The model is developed and analyzed using ANSYS workbench software.

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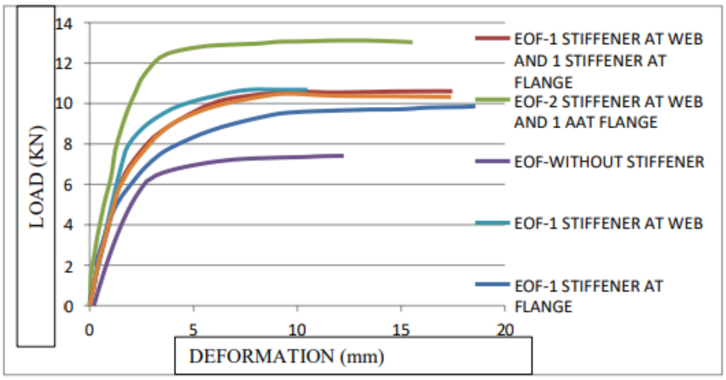
Nonlinear analysis is performed. The three dimensional shell elements S4R were used to model lipped channel section. The lipped channel sections with 5mm mesh size and 100mm bearing length. The web side plate is used in IOF load condition. The length and thickness of web side plate is 100 and 5mm. The density of steel is 7850Kg/m3 and poison's ratio is 0.3. The loading plate assigned by displacement control method. The loading plate was move in vertical direction with a limit of 20mm.The translation along both lateral and longitudinal axes and twist rotation of loading plate were restrained. The simply supported condition was simulated at the support plates by using pin and roller boundary conditions in the support bearing plates. In pin support the translation along all three directions and rotation about the longitudinal axes were restrained. In roller support translation along lateral and vertical axes and rotation about the longitudinal axis restrained.

4 Result and Discussion

In EOF load condition there are six models analysed for web crippling with and without web stiffeners. The web crippling capacity increases with number of stiffeners in web and flange. The table 5.5 shows the web crippling capacity of all models under EOF load condition. The web crippling capacity without stiffener by AS/NZS4600 is 7.04KN and the web crippling capacity by numerical analysis is 7.41 KN. The web crippling capacity of lipped channel section with stiffener at flange 38 gives less web crippling capacity compared to lipped channel section with stiffener is provided at web and flange. The web crippling capacity increases with number of stiffeners increased in web and the maximum value of web crippling capacity is given by two stiffeners in web and one stiffener in flange. The fig shows the load-deformation graph of all models under EOF load condition



5 Conclusion

The paper presents analytical studies on the web crippling capacity of lipped channel beam under one flange loading. The analytical investigations of sections are carried out using finite element software of ANSYS workbench. The stiffeners in v shape are provided at web and flange for the improvement in web crippling capacity. There are 6 models were considered

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under EOF and IOF load condition. The following conclusions were summarized: Nonlinear analysis of web crippling of lipped channel section with and without stiffeners under IOF and EOF load is conducted. Lipped channel section without and with stiffeners at web and flange with six models were considered. The result of finite element analysis influence of the stiffeners in v shape under EOF and IOF load condition. As the stiffeners in web increases the web crippling capacity increases. As the stiffener is provided only at flange, the web crippling value may be decrease compared to stiffener is provided at web. The web crippling capacity of lipped channel section under IOF and EOF increases with stiffeners. Combination of stiffener at web and flange can be provided in lipped channel section increases the web crippling capacity. Load carrying capacity of lipped channel section increases with stiffener in v shape. The lipped channel sections are light weight, makes it ease and more economical to mass production, transports and installation

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