International Journal on Recent Researches in Science, Engineering & Technology (IJRRSET)
A Journal Established in early 2000 as National journal and upgraded to International journal in 2013 and is in existence for the last 10 years. It is run by Retired Professors from NIT, Trichy. Journal Indexed in JIR, DIIF and SJIF.
Research Paper
Available online at: www.jrrset.com

ISSN (Print) : 2347-6729
ISSN (Online) : 2348-3105
Volume 5, Issue 12
December 2018.
JIR IF : 2.54
SJIF IF : 4.334
Cosmos: 5.395

Received on: 02.12.2017 Published on: 28.12.2018 Pages : 65-75

COMPREHENSIVE STUDY OF THE STRENGTH AND BEHAVIOUR OF COLD FORMED STEEL SECTIONS UNDER BENDING

Kuttimarks MS[1], Puneet Verma[2]
[1]Research Scholar, [2]Professor
Department of Civil Engineering
Maharishi University of Information Technology
Uttar Pradesh, India

ABSTRACT

In developed countries, cold-formed steel parts are commonly used in building construction either as a main structural element, such as beams , columns, frames, etc., or as a secondary structural element, such as roof puslins, although in India it is at a formative stage. We are looking for costly applications of secondary civil engineering in the automotive , aerospace, and various structural elements. The key advantage of the cold-formed steel sections is their high strength weight ratio, light weight and ease of manufacturing and construction compared to hot-rolled pieces, cold-formed steel components are less expensive to manufacture and provide more flexibility in creating the desired shape. Wide-ranging work is undertaken across different parts of the globe to improve the performance, strength and actions of cold-shaped steel pieces. The material and sectional properties govern the strength and motion of the members of cold formed steel. The flexural strength of the web in bending of a cold shaped steel portion is usually strengthened by the presence of intermediate stiffeners and stiffer components. A stiffened part supports the compression flange at the flange / web junction and edge stiffener at the flanges. A series of flexural tests focussing on the cold-formed steel built-up I segment under the state of pure bending were documented in this research. The study comprises both experimental and analytical (ANSYS) tests. Experimental tests validate current models of finite elements. After validation a number of important parameters were tested to test their effects on the strength and behavior of the bending beams. The findings obtained from the experiments and the finite-element study are compared with the design strength predicted from the North American Iron and Steel Institute requirements for cold-formed steel structures (AISI: S100-2007). Finally, the suitability of the current design methods (AISI) and an acceptable design recommendation are given for built-up sections of cold shaped steel.

Keywords: roof puslins, stiffened elements, ANSYS

2. REVIEW OF LITERATURE

Bending over the last 15 years is subject to a review of the work pertaining to the flexural behavior of cold-formed steel pieces. This also includes science, analytical, and theoretical literature. Beshara & Lawson (2002) examined the actions of built-up box sections in cold shaped steel under bending by varying the location of the screw attachment. The test findings were compatible with the specifications of the North American Iron and Steel Institute (AISI), for cold-formed steel structures. It has been shown that the required output strength for built-up box parts was usually unconservative, based on the AISI design specifications. Based on test results from the test series, they indicated that the nominal moment capacity of the built-up box parts should be considered equal to 75 percent of the total nominal moment capacity of their components. Pan & Yu (2002) performed an experimental investigation on cold-formed hybrid beams consisting of higher-resistance steel flanges connected to webs of low-resistance steel subject to dynamic loads. 72 Specimens were tested at various rates of pressure. The concentrations of strain have been shown to have a major effect on beam strength and behaviour. A detailed method of design to calculate the strength of hybrid beams in the members was also developed.

Yu & Schafer (2003) reported on a series of new flexural tests focusing on the role of web slenderness in cold-formed steel C, Z segment flexural members in local buckling failures. Studies of the traction were carried out to examine the mechanical properties of the segment. CUFSUM was used to measure the effect of section geometry at the moment of elastic buckling, using the Finite Strip process. Compared with the various design criteria, the flexural strength obtained from test methods and finite stripes. It has been shown that the strengths predicted by the AISI Specifications and Canadian Standards for cold-formed steel structures were usually unconservative for unslender specimens, whereas the strength predicted by the Direct Strength Methods was conservative for both slender and unslender specimens. Serrette (2004) has investigated the flexural performance of CFS built-up box beams under eccentric and edge loading. They tried three different types of box beams, and all these beams failed by twisting. The eccentric loading and load transfer mechanism were found to cause twisting in the box beam from the directly loaded joist member to the adjacent joist member. It was shown that the edge loaded box beam would resist 85-90 percent of its fully braced flexural ability measured.

Setiyawan, P(2012), performed an experimental study with complex edge stiffeners (consisting of simple and return lip) subject to major axis bending on the strength and action of cold-formed steel Z-beams. Thirty beam experiments with three different cross sectional geometry and different flange slenderness were tested over a range of beam lengths. Extensive tests were carried out to determine the material properties and geometrical imperfection of the specimens. All the specimens failed in shear contact and bending loss. A nonlinear finite-element model was developed and tested on the experimental results. The model introduced imperfection in geometry and nonlinearity in materials. Based on the structural strength required by the use of AISI Criteria, Australian / New Zealand Standards, direct strength method for cold-formed steel structures, total bending strength from experiments and finite element analysis. The total strength of the design calculated from the three criteria has been demonstrated to be generally conservative for the specimens tested. Schafer et al (1998) created a new design technique for measuring the effective width of stiffened product with multiple longitudinal intermediate stiffeners. Comparisons of the design approach to the results of the latest experimental and finite-element analysis have also been made. Finally, it was shown that the design technique could be used with a high degree of confidence to predict the strength of stiffened cold-formed steel parts with multiple longitudinal intermediate stiffeners in the compression flange.

Pi et al (1998) used finite-element analysis to present a quantitative study on the strength and behavior of cold-formed lipped canal beams. A nonlinear finite-element model was developed, the finite-element model included residual stress, nonlinearity of the material and cold forming work effect. The finite element model developed was used for the parametric study that investigated the effect on the strength and flexural behavior of the cold-formed lipped channel sections of web distortion, initial crookedness and twist, moment distribution, and load height. Relevant design amendments were also implemented in the form of changes to existing Australian bending specifications for hot rolled and cold formed steel structures. This has also been shown that the required design strength is usually conservative based on Australian hot-rolled specifications, whereas Australian / New Zealand specifications for cold formed steel structures yield unconservative results for cold formed steel lipped channel beams. Schafer et al (2006) developed a finite element model with complex edge stiffeners that are subjected to pure bending for the flexural actions of the cold-formed steel channel section. Present experimental results confirm the accuracy of the proposed model of finite elements. The model brought in geometric imperfection, residual stress and nonlinearity of material. It was observed from this study that the complex edge stiffener given in the flange element increases the bending strength, improves their overall behavior and decreases local buckling of the flange elements. The results were compared with the force required in the AISI Specifications and Direct Strength System for the cold-formed steel structures. It was also shown that the design strength expected was typically unconservative based on the North American Iron and Steel Institute model, although conservative for the cold shaped steel channel segment with complex edge stiffeners in the Direct Strength Process.

3. PROBLEM STATEMENT

Studies on built-up cold-shaped steel beams are inadequate for various build loads. As flexural members are used built sections consisting of section C back to back or nested sections C forming a portion of the frame. Depending on the span to depth ratio and the lateral support length of the members, cross sections, shapes, and proportions of each of these buckling modes can be significant. Therefore it is beneficial to find alternative new forms of cross sections of shaped cold beams. For this analysis, two series of tests were performed with the cold formed steel built-up section closed with intermediate web stiffener, unstiffened and stiffened cold formed steel built-up open section with or without edge stiffener. They analyze their impacts on the flexural intensity and actions of the participants.

4. OBJECTIVE AND SCOPE

OBJECTIVE

The object of this research is to investigate the conduct and strength under flexure of the built-up section of cold formed steel. The goal of this research is to estimate the flexural strength and to investigate the behavior of cold-formed steel built-up open parts of the same cross-sectional area of different cross-sectional profile.

SCOPE

1. For studying the flexural strength and behavior of cold-shaped steel built-up parts under clearly supported end conditions.

2. The effect of geometric cross-section change, flat width-to - thickness ratio, depth-to-thickness ratio, span-to - depth ratio of the load carrying capacity and its behavior is investigated.
3. Using finite-element analysis program ANSYS to build a model of nonlinear finite-elements and check results against experimental effects.
4. Using proven finite element model, perform a parametric analysis to investigate the set of influential parameters influencing the members' flexural strength and behavior.
5. Comparing the flexural strength obtained from the experimental and numerical analysis with the theoretical measurements according to the AISI specification for cold formed steel structures.
3. To create a design equation for evaluating the flexural strength of the built-up open section with or without unstiffened and durable cold-formed steel edge stiffeners.

5. METHOD AND ITS DESCRIPTION

This chapter explains the experimental and numerical research into the flexural strength and actions of under bending the built-up portion of cold formed steel. The key research goals are:

Using finite element analysis software ANSYS 12 to analyze the flexural strength and action under experimental bending of the cold-formed steel built-up section, and their results are contrasted with the numerical analysis.

To test and compare the results obtained from experiments and the analysis of finite elements with the strength calculated according to AISI criteria for the cold-formed steel structures.

To propose a design equation for determining the flexural strength of the built-up open sections of unstiffened and steep cold shaped steel with or without edge stiffeners undergoing mixed local and distortional, flexural bending and lateral torsional buckling modes.

TEST SECTION

The experimental program includes the manufacture of two series of built-up cold-formed steel section made from cold rolled steel sheets which are available locally. It is composed of

- Cold-formed, stainless steel section closed
- Built-up open segment of cold molded steel

SELECTION OF SECTION

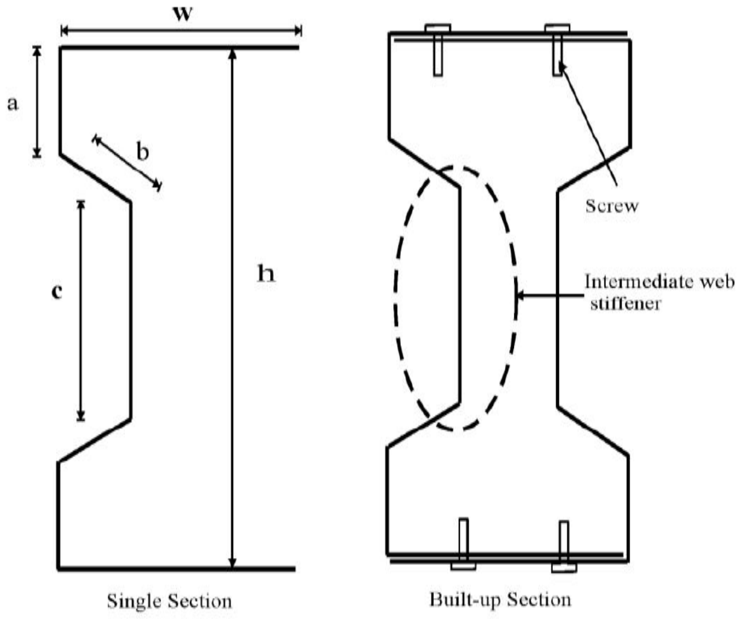
The cross-sectional measurements are set to reduce the risk of local buckling for cold-formed steel structures based on the AISI standard and to fit the practical range of channel section beams currently in use in the industry. Though AISI Requirements for cold-formed steel structures (AISI: S100-2007) do not set limits for D / b ratios, Kankanamge & Mahendran (2012) provided guidelines for selecting the D / b ratios of cold-formed steel beams within the range 2 to 3.3.
The length of the segment is chosen within the range where the flexural bending takes place during the elastic buckling. All the bits are 2300 mm long and made from a 2 mm thick board. Geometries and dimensions of the section are chosen so as to satisfy all types of buckling modes. To prevent local buckling, the maximum size of the stiffened element at the flange/web junction, edge stiffener size, and intermediate web stiffener is limited to 15 mm (Kankanamge & Mahendran 2012). Table 3.1 describes the geometries and descriptions in portion.

Table 3.1 Specimen particulars

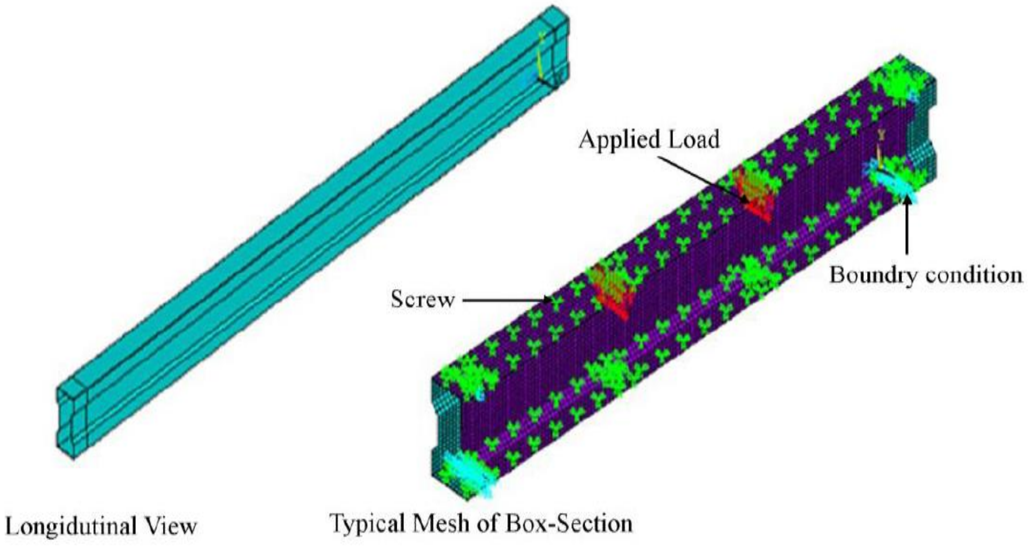
S.No	Section Geometries	Series	No. of Specimens Tested
A) COLD-FORMED STEEL BUILT-UP CLOSED SECTION			
1	Built-up box section with intermediate web stiffener	B	9
B) COLD-FORMED STEEL BUILT-UP OPEN SECTION			
1	Simple built-up beam	USB	3
2	Stiffened built-up beam	SB	3
3	Stiffened built-up beam with inclined edge stiffener	SB-I	2
4	Stiffened built-up beam with upright edge stiffener	SB-U	4
5	Unstiffened built-up beam with complex edge stiffener	USB-C	4

Cold-Formed Steel Built-up Closed Section

The built-up closed sections with intermediate network stiffeners (neine specimens) are chosen for testing, as shown in Figure 3.1a. Cold-formed stainless steel built-up closed I-shaped section consists of two identical C-channel sections using self-tapping screws with toe-toe mounted intermediate network stiffeners.



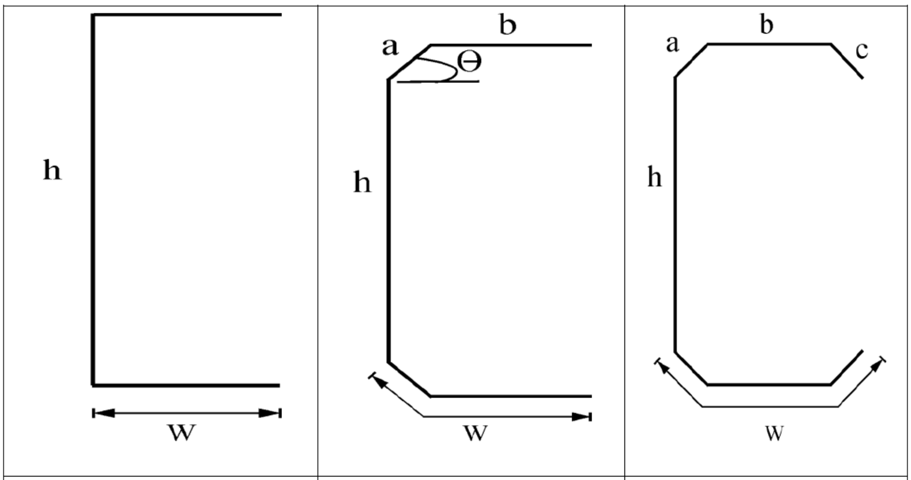
(a) Section Geometries



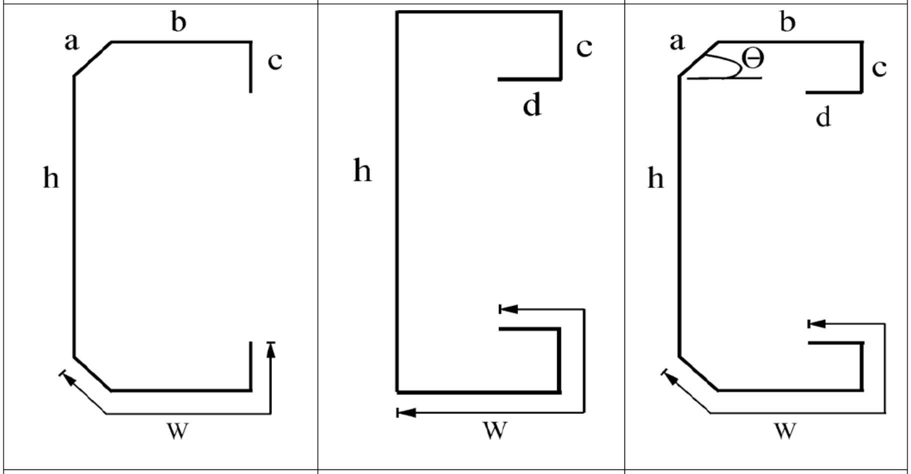
(b) Finite Element Model

Fig.3.1 Details of specimen-cold-formed steel built-up closed section

The primary (USB) is a simple built-up beam (Figure 3a), second (SB) a stiffened built-up beam (Figure 3b), third (SB-I) a stepped built-up beam with inclined edge stiffener (Figure 3c), fourth (SB-U) a stiffened built-up beam with upright edge stiffener (Figure 3d), fifth (USB-C) a stiffened built-up beam with complex edge stiffener (Figure 3e), sixth (SB-C) is a stiffened built-up beam.

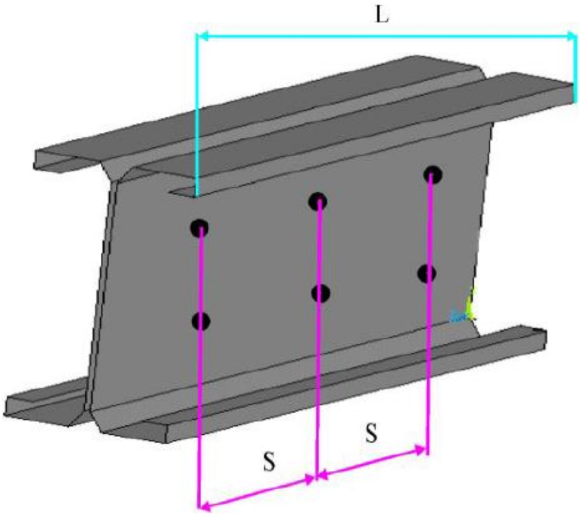


(a) USB (b) SB (c) SB - I

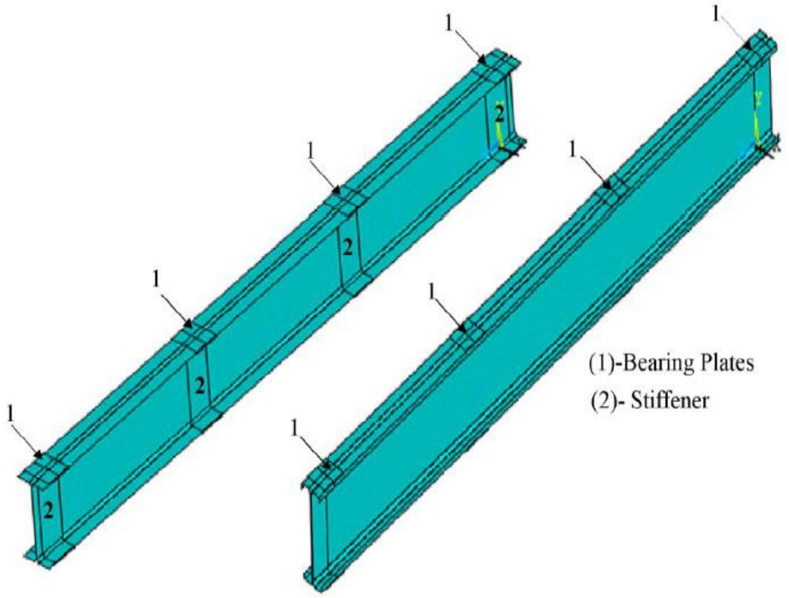


(d) SB - U (e) USB - C (f) SB - C

Figure 3.3 Section geometries- cold-formed steel built-up open section



a) Longitudinal View



b) Specimen without Edge Stiffner c)Specimen with Edge Stiffner

Figure 3.4 Details of specimen-cold-formed steel built-up open section

The built-up members are composed of two cold-formed sections with or without stiffened channel profile back to back, which form an I-section beam with or without edge stiffeners by using bolted ties with a spacing (S) of 150 mm (Figure 3.4a) and to avoid bearing failure, bearing plates are given at the supports and loading points as shown in Figure 3.4(b) and Figure 3.4(c).

6. RESULTS AND DISCUSSIONS

On the various research sets, experimental results are analysed. Results from the experiments and finite element analysis (ANSYS) are compared with the power of the measured device using AISI parameters for cold shaped steel structures

LOAD - DEFLECTION CURVES

For both tests the load vs deflection curves were plotted to evaluate the beam's flexural strength. The flexural force is determined by the load deflection curves log shift at the slope. The same methodology will be used for both experiments and the results will be tabled in Table 4.1 to Table 4.5. For example, in Figure 4.1 to Figure 4.3, for the cold-formed steel built-up closed section and Figure 4.10 to Figure 4.15, for the cold-formed steel built-up open section, the load deflection curve for some of the specimen is shown. As shown in Figure 4.1 through Figure 4.3 for cold-formed steel built-up closed section and Figure 4.10 through Figure 4.15 for cold-formed steel built-up open section, the load-deflective curves obtained from the finite element analysis are in good agreement with the test results. This produces similar outcomes on all other specimens. Regional buckling, flexural bending, lateral torsional buckling, network buckling and interaction between these buckling modes are observed in the experiments and are numerically tested using the finite element model (ANSYS), as illustrated in Table 4.1. The modes of failure obtained through the experiments are in strong accordance with the results of the finite element analysis (ANSYS), as shown In Figure 4.4 to 4.7.

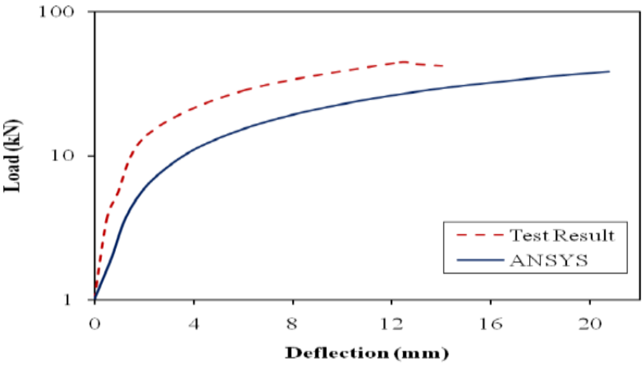


Figure 4.1 Load deflection curve for specimen-B3

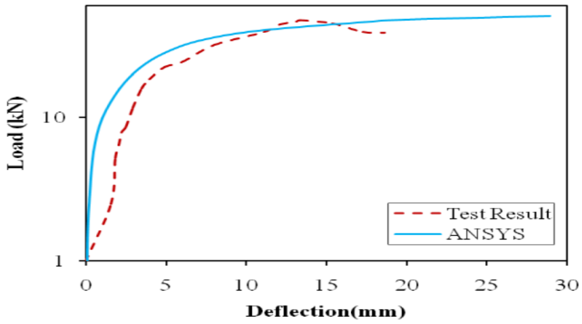


Figure 4.3 Load-deflection curve for specimen -B9

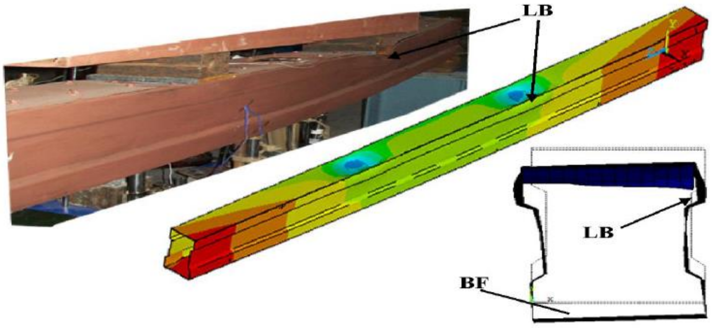


Figure 4. 4 Flexural bending of specimen-B3

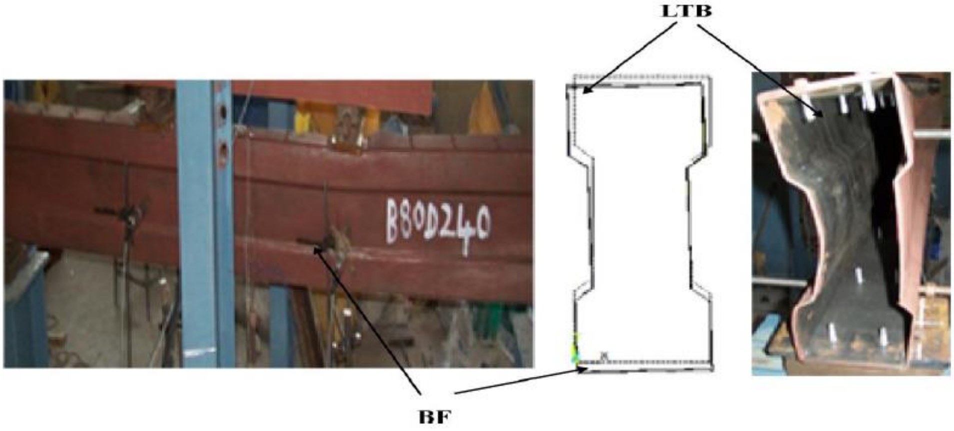


Figure 4.5 Flexural bending + Lateral torsional buckling of specimen-B4

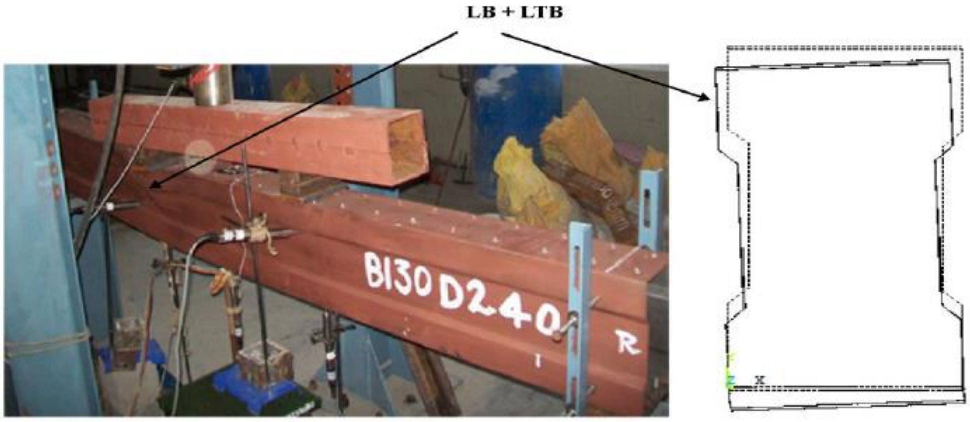


Figure 4.6 Lateral torsional buckling of specimen-B6

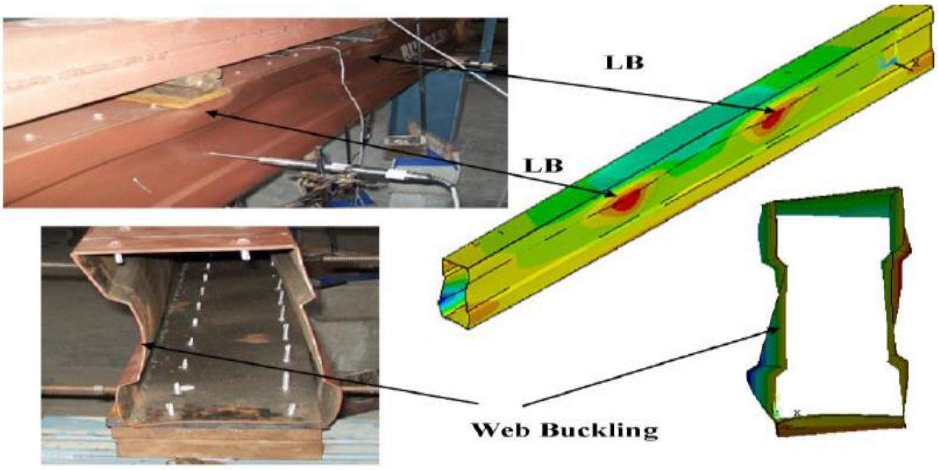


Figure 4.7 Web buckling of specimen-B9

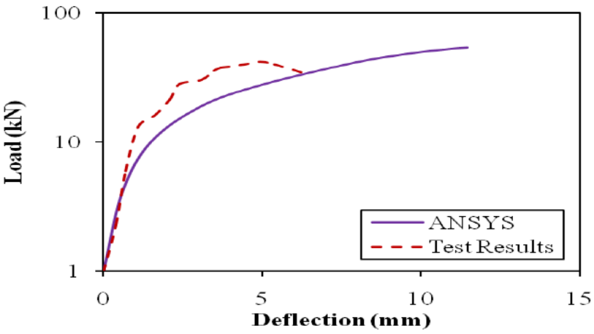


Figure 4.10 Load-deflection curve for specimen-USB-2

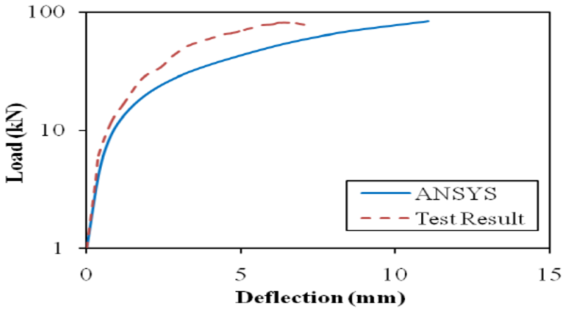


Figure 4.11 Load-deflection curve for specimen -SB-2

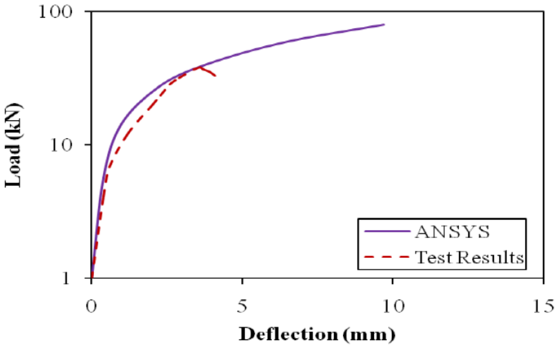


Figure 4.12 Load-deflection curve for specimen -SB-U3

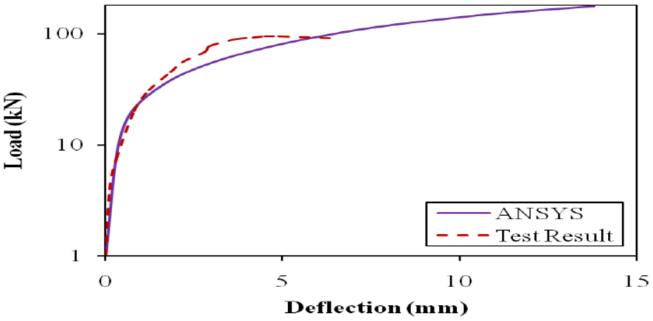


Figure 4.13 Load-deflection curve for specimen -SB-C4

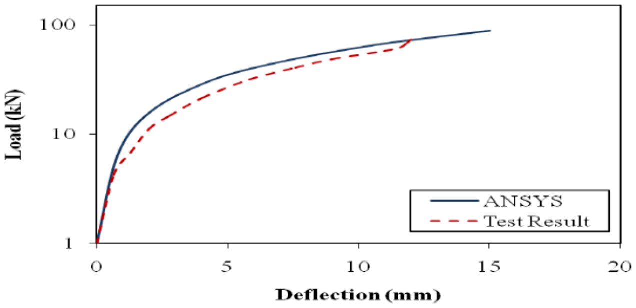


Figure 4.14 Load-deflection curve for specimen -SB-C5

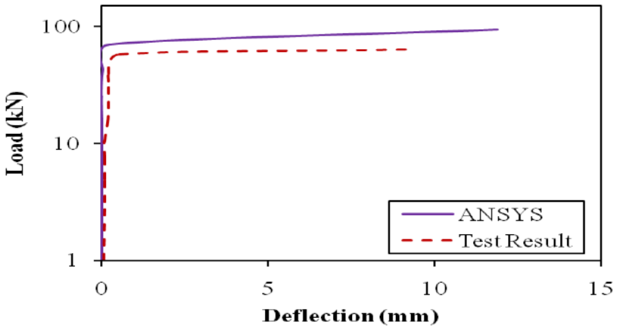


Figure 4.15 Load-deflection curve for specimen -USB-C3

B1, B2 and B3 specimens (Figure 4.4) fail because of flexural bending and their flexural strength is 31 per cent, 34 per cent and 20 per cent yield strength respectively. Specimens B4 (Figure 4.5) and B5 fail due to buckling of the lateral torsion, while specimen B6 fails due to local buckling. The flexural strength for B4 is 31 percent yield strength, 32 percent yield strength for B5 and 20 percent yield strength for B6. Likewise, web buckling fails on B7, B8, and B9 specimens (Figure 4.7), and flexural strength is yield strength of 22%, 24%, and 21 % , respectively.

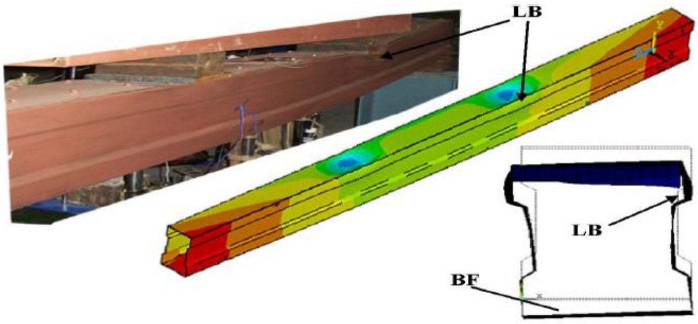


Figure 4.4 Flexural bending of specimen-B3

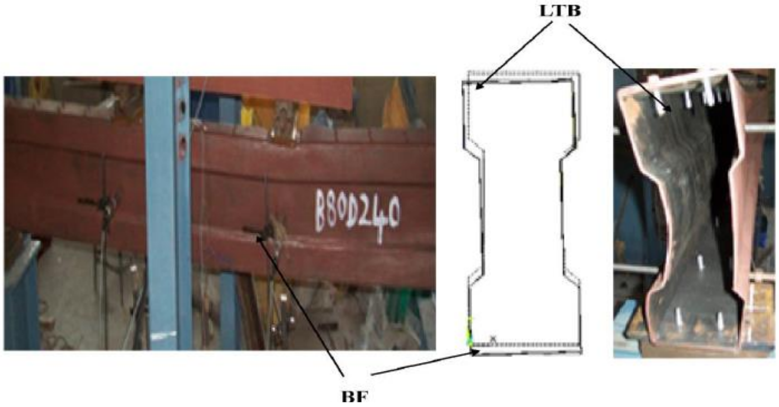


Figure 4.5 Flexural bending + Lateral torsional buckling of specimen-B4

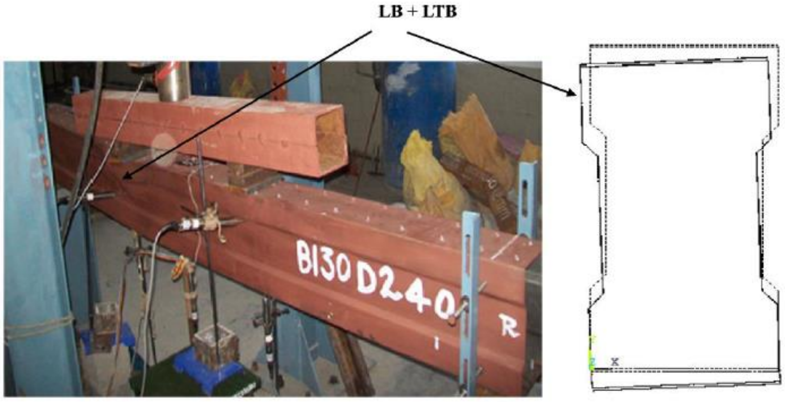


Figure 4.6 Lateral torsional buckling of specimen-B6

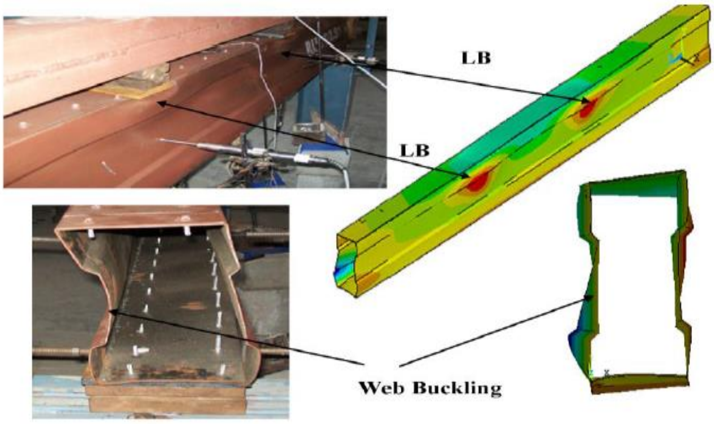


Figure 4.7 Web buckling of specimen-B9

REFERENCES

Beshara, B., & Lawson, T. J. (2002). Built-up girder screw connection variation flexural tests. Dietrich Design Group Internal Report.

Pan, C. L., & Yu, W. W. (2002). Bending strength of hybrid cold-formed steel beams. Thin-walled structures, 40(5), 399-414.

Yu, C., & Schafer, B. W. (2003). Local buckling tests on cold-formed steel beams. Journal of Structural Engineering, 129(12), 1596-1606.

Serrette, R. L. (2004). Performance of edge-loaded cold-formed steel built-up box beams. Practice Periodical on Structural Design and Construction, 9(3), 170-174.

Setiyawan, P. (2012). *Plastic Behaviour of Strengthened Cold-formed Steel Section* (Doctoral dissertation, Universiti Teknologi Malaysia).

Schäfer, T., & Shuryak, E. V. (1998). Instantons in QCD. Reviews of Modern Physics, 70(2), 323.

Ruderman, N., Chisholm, D., Pi-Sunyer, X., & Schneider, S. (1998). The metabolically obese, normal-weight individual revisited. Diabetes, 47(5), 699-713.

Nghiem, L. D., & Schäfer, A. I. (2006). Fouling autopsy of hollow-fibre MF membranes in wastewater reclamation. Desalination, 188(1-3), 113-121.

Kankanamge, N. D., & Mahendran, M. (2012). Behaviour and design of cold-formed steel beams subject to lateral–torsional buckling. Thin-walled structures, 51, 25-38.