

Web Crippling Behaviour of Cold-Formed C-Section with and Without FRP Wrapping

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Abstract — Cold-Form sections are widely employed in steel construction because of their lighter and more economical than traditional Hot-Rolled members. The easy availability and accessible cost of high strength low-alloy steels, weathering steels and Zinc-coated steels have led to members with high/thickness (h/t) ratios, rendering them even more susceptible to local buckling and to another buckling mode called distortional and global. Many studies are going on in local buckling, web crippling etc.

In this thesis it is proposed to study the web crippling behaviour of Cold-Form section subjected to various loading conditions like End One-Flange (EOF) loading, End Two-Flange (ETF) loading, Interior Two-Flange (ITF) loading. More over without increasing the thickness of the element it is proposed to use the FRP on web, to reduce the web crippling of Cold-Form sections.

Keyword: Cold-Formed Steel Section, Web Crippling, EOF, ETF, ITF.

I. INTRODUCTION

Cold Formed Steel Structural members are cold formed in rolls or press brakes from flat steel. Under mass production they are framed most economically by cold rolling, while smaller quantities of special shapes are most economically produced on press brakes. Members are connected by spot, fillet, plug, or spot welds, by screw, bolts, cold rivets, or any other special devices. Cold formed steel sections are increasingly used these days in structural applications due to their inherent high strength to weight ratio.

Cold-formed steel members are widely employed in steel construction because they are lighter and more economical than traditional hot-rolled ones. Nowadays the easy availability and accessible cost of high-strength low-alloy steels, weathering steels, and zinc-coated steels have led to members with high/thickness ratios, rendering them even more susceptible to local buckling and to

another buckling mode called distortional, C sections, Z sections, hat, rack, etc. Hence, current versions of technical codes for cold-formed steel design have warned about the importance of this phenomenon, outlining procedures to evaluate member strength based on distortional buckling.

It is desired that load carrying members should also provide useful surface like floor panels and roof decks mostly installed without any wall panels. In addition to their use in building construction, cold formed steel structural elements are widely used in automobile industry, ship building, rail transport, the aircraft industry engineering, agricultural and industrial equipments, chemical, mining, nuclear and space industries, the loads applied to angular beams usually out of the principal planes that cause simultaneous bending about both axes. It is most widely used all over the world, because of more advantages than the hot rolled steel section and replace hot rolled steel for its more economical design as well as easy to construct the structures.

1.1 OBJECTIVE

- To investigate the behavior of cold formed C section for web crippling with and without FRP (Fiber Reinforced Plastic)
- To obtain experimental data of section and member capacities of the cold formed C - section with and without FRP subjected to concentrated load for web crippling.
- To study the possible modes of ultimate failure of the web members of C section under static loading for following four loading case:
- EOF -(End One-Flange Loading)
- IOF-(Interior One-Flange Loading)
- ETF-(End Two-Flange Loading)
- ITF-(Interior Two-Flange Loading)

To compare the results obtained from experimental with theoretical calculation as per IS Code and North American Cold-Formed Steel Specification.

1.2 SCOPE

It is proposed to study the web crippling of cold-formed for C Sections (Channel Sections) with and without FRP wrapping. The channel specimens were tested using the four loading conditions according to Australian/New Zealand Standard (AS/NZS 4600) and the American Iron and Steel Institute Specification (AISI). There are some place in which welding is not permitted to increase the capacity of the existing beam. Hence it is decided to assess the strength of cold form section with zero welding technology, i.e., by pasting FRP laminates in web portion of cold form channel section to prevent the web crippling. In this thesis it is proposed to study the web crippling of cold form C Section with and without FRP wrapping. The ultimate strength of without FRP wrapping and with FRP wrapping in web portion of specimens are compared with each other.

II LITERATURE REVIEW

2.1 LITERATURE SURVEY

Several studies have been carried out to produce behavior of cold-formed section web crippling. Some of the reports have been presented in this chapter which is used as guidance for this thesis.

Hetrakul and Yu 1978, Prabakaran 1993, There are six key parameters that influence the web crippling strength of cold-formed steel members. These key parameters are the following: Thickness of the web, t ; Yield strength of the web, F_y ; Web slenderness ratio, h/t ; Inside bend radius to thickness ratio, R/t ; Length of bearing to thickness ratio, N/t ; and Web inclination, θ . In addition to these key parameters, an additional parameter that must be considered in a test program is the fastening of the flanges. Earlier web crippling tests were performed with the test specimens not being attached to their supporting flange elements. Recent studies have shown that the presence of a flange attachment can have a significant influence on the web crippling strength. In order to include all of these parameters in the test program, a number of different tests must be carried out to adequately cover the range of these parameters and the loading cases.

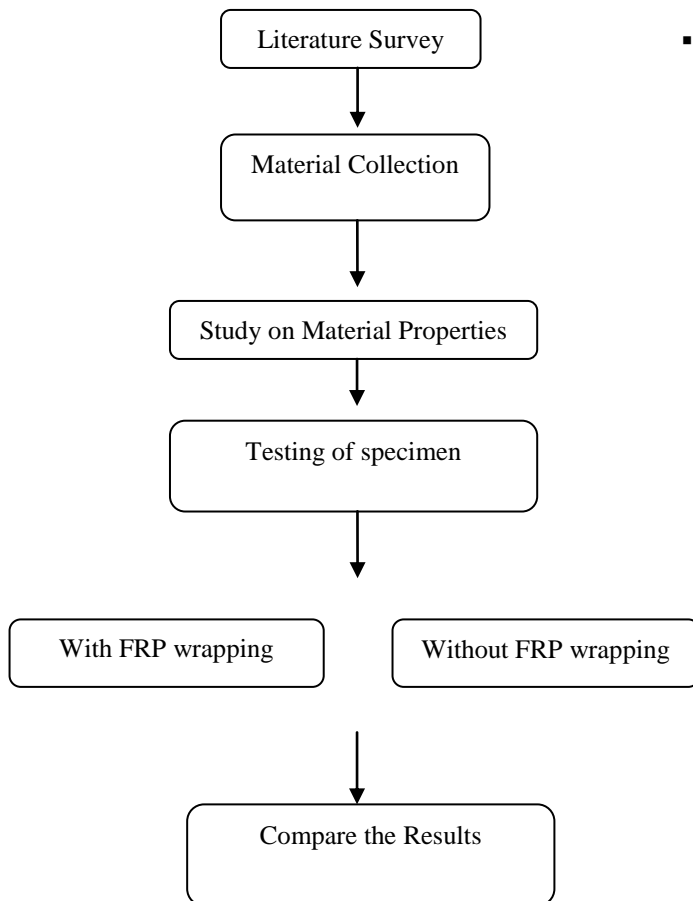
Rhodes and Nash (1998), the computation of web crippling strength obtained using empirical method is relatively rapid and safe within their range of application, which does not imply that empirical methods are without drawbacks. The equations, derived through empirical methods, are only applicable for a specific range, and it may be difficult to ascertain the underlying engineering principles in parts of the complex equations. Therefore, there is a need to determine the appropriateness of the current design rules on the various types of steel members and to propose design equation that are not purely empirical in nature but a combination of both theoretical and empirical base.

Ben Young and Gregorg J.Hancock (Oct 2001) a test program on cold-formed unlipped channels subjected to web crippling has been studied. Channel specimens having a nominal yield stress of 450 MPa with different plate slendernesses of the web are tested. Web slenderness values ranging from 15.3 to 45 have been investigated. The tests were conducted under the four loading conditions (End-One-Flange, Interior-One-Flange, End-Two-Flange, and Interior-Two-Flange) specified in the Australian /New Zealand and American specification for cold-formed steel structure. The test strengths are compared with the design strengths obtained using the specifications. It is demonstrated that the design strengths predicted by the specifications are generally unconservative for unlipped channels. Test strengths as low as 43% of the design strengths were obtained. Hence, new web crippling design equations for unlipped channels proposed. The proposed design equations are derived based on a simple plastic mechanism model, and the web crippling strength is obtained by dispersing the bearing load through the web. It is shown that the web crippling strengths predicted by the proposed design equations are generally conservative for unlipped channels with web slenderness values of less than or equal to 45. It is concluded that the proposed design equations for unlipped channels having stocky webs are reliable.

Ben Young and Gregorg J.Hancock (March 2002), An experimental investigation of cold-formed channels subjected to combined bending and web crippling is described in this paper. A series of tests was performed on unlipped channels rolled from high strength structural steel sheets having nominal plate thickness up to 6 mm, and a maximum web slenderness value of 45. This value is considerably

lower than the intended web slenderness values used in the Australian/New Zealand Standard (AS/NZS 1996) and the American Iron and Steel Institute (AISI 1996) specification for cold-formed steel structures. Therefore, the appropriateness of the combined bending and web crippling design rules for members with comparatively stocky webs is investigated in this paper. The specimens were tested at various lengths using the Interior-One-Flange loading condition specified in the AS/NZS (1996) and the AISI (1996) specification, and the test strengths are compared with the design strengths obtained from these specifications. Generally, it is shown that the specifications conservatively predicted the strengths of unflipped channels having stocky webs subjected to combined bending and web crippling.

III. METHODOLOGY AND MATERIALS



3.1 Tension Test on Steel Sheet:

IS 1608 – 2005 (Part – I) prescribes the method of conducting tensile test on steel sheet strip less than 3mm and not less than 0.5mm thick.

3.2 Test Specimen:

- The test piece has a width 'b' of 20mm and gauge length 'lo' of 80mm. However, if the nominal thickness 'a' is not greater than 2mm, the test piece may have a width of 12.5mm and a gauge length 'lo' of 50mm.
- The test piece generally has enlarged ends in which case there is a transition radius of not less than 20mm between the griped ends and the parallel lengths. The Width of the enlarged ends is not less than 20mm and not more than 40mm. alternatively; The test piece may consist of a strip with parallel sides.
- The ends of the test piece metal held in suitable grips in the testing machine in such a way that the centre line of pull coincides with the longitudinal axis of the test piece.
- The parallel length is kept between "Lo + b/2 & Lo + 2b".

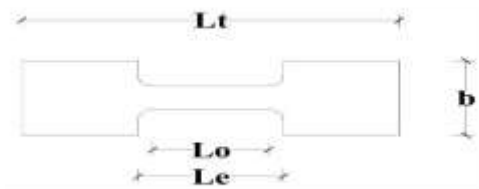


Fig 3.2.0 Tension test on Steel Sheet

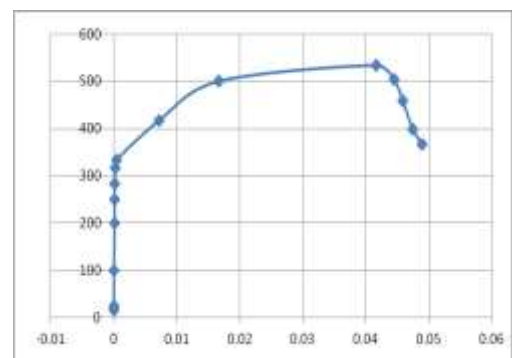
Where,

Lo = Original Gauge length

Le = Parallel length

Lt = Total length

b = Width of the test piece



3.3 STRESS VALUES:

From the plotted graphs ultimate stress of the specimen is 510N/mm²

From the plotted graphs yield stress of the specimen is 350N/mm²

IV. EXPERIMENTAL INVESTIGATION

4.1 Length of the Specimen:

The specimen length (L) was determined according to AS/NZS 4600 and the AISI specification. Generally, the clear distance between opposed loads was set to be 1.5 times the overall depth of the web, rather than 1.5 times the depth of the flat portion of the web, the latter being the minimum specified in the specification.

The minimum specimen lengths may be taken as follows:

EOF Loading: $L_{min} = 3h + \text{bearing plate lengths}$

ETF Loading: $L_{min} = 3h$

ITF Loading: $L_{min} = 3h$

Where h = Depth of the flat portion of the web measured along the plane of the web.

4.2 Bearing Plates:

The load or reaction forces were applied by means of bearing plates. The bearing plates were fabricated using high yield stress. All bearing plates were machined to specified dimensions, and the thickness was 50mm for all bearing plates. The bearing plates are designed to act across, the full flange widths of the channels, excluding the rounded corner. The length of bearing (N) was chosen to be the full and half flange widths of the channels. The flanges of the specimens were not restrained by the bearing plates.

4.3 Specimen Labeling:

The specimens to be labeled in such a way that loading type, without FRP wrapping and with FRP wrapping would be identified from the table. In this thesis the test specimens are designated as shown in table – 5.3

Table 4.3- Specimen Designation:

Sl.No	Without FRP in Web	With FRP in Web
1	EOF ₁ , EOF ₂	EOF _{1F} , EOF _{2F}
2	ETF ₁ , ETF ₂ , ETF ₃	ETF _{1F} , ETF _{2F} , ETF _{3F}
3	ITF ₁ , ITF ₂ , ITF ₃	ITF _{1F} , ITF _{2F} , ITF _{3F}

The first three letters indicate that the loading conditions End-One-Flange (EOF) or Interior-Two-Flange (ITF)

4.4 Loading Condition:

In these experimental investigations, the web crippling tests are to be carried out under the following four loading conditions according to AS/NZS 4600 and the AISI Specification for beams having single unreinforced webs. The loading conditions are

- EOF -(End One-Flange Loading)
- ETF-(End Two-Flange Loading)
- ITF-(Interior Two-Flange Loading)

All loading conditions are illustrated in Fig. 4.4 In Fig. 4.4(a) and 4.4(b) the distances between bearing plates were kept to no less than 1.5 times the web depth in order to avoid the two-flange action.

Table.4.4. Comparison of Experimental load and Theoretical Load

Sl. No	Specimen	Experimental Web Crippling Load (P _e) in kN Without FRP	Theoretical Web crippling Load as per NAS (P _t) in kN
1	ETF	23.43	21.01
2	ITF	31.33	30.62
3	EOF	27.70	23.70

Fig 4.4 (a) End one-flange (EOF)

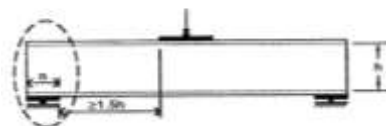


Fig 4.4(b): End Two-Flange (ETF)

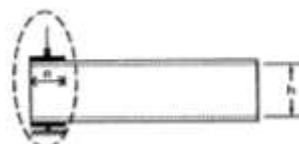
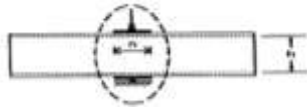


Fig 4.4 (c): Interior two-flange (ITF)



V. RESULTS AND DISCUSSIONS

5.1 General

The load carrying capacities of specimens, estimated by using numerical analysis and North American Specification design (NAS-2001) are compared with the experimental failure load. Discussions were carried out with respect to the load carrying capacities, displacement and the failure mode occurred.

5.2 Discussion

Specimen having stiffened flange, failure of flange didn't take place in the following loading condition, End two flange loading, Interior two flange loading, and End one flange loading. Experimental web crippling load without FRP and theoretical web crippling load as per North American Specification design (NAS-2001) are tabulated below.

From the above result experimental web crippling load is lesser than theoretical web crippling load as per North American Specification design (NAS-2001).

Table.5.2. Comparison of load with FRP and without FRP

Sl. No	Specimen	With FRP		Without FRP	
		Average Web Crippling Load (kN)	Average Displacement (mm)	Average Web Crippling Load (kN)	Average Displacement (mm)
1	ETF	31.33	6.23	23.43	5.68
2	ITF	37.86	10.82	31.33	6.90
3	EOF*	33.25	-	27.70	-

EOF*- Tested in old UTM machine .

Form the above result specimen laminated with FRP (glass fibre unidirectional using epoxy resin) in either side of the web is carries more web crippling strength compare to specimen without FRP. The displacement during loading is lightly more than without FRP specimen at ultimate load.

Table.5.2. Comparison of Displacement obtained

S.No	Specimen	Experimental Displacement in (mm)	FEM analysis (Ansys) Displacement in (mm)
1	ETF	5.94	5.444

On comparing the displacement obtained from the Finite element analysis, and the experimental analysis, it was found the displacement of the specimens is lightly more in the experimental results.

VI. SUMMARY AND CONCLUSION

In this project the web crippling strength of cold-form c section are analysis experimentally, theoretically and using FEM software (Ansys). The channel specimens were tested for the following loading case ETF, ITF and EOL, according to Australian/New Zealand Standard (AS/NZS 4600) and the American Iron and Steel Institute Specification (AISI) with and without FRP. The glass fibre 1200gsm is laminated in unidirectional path on either side of the web by using epoxy resin.

The specimens are tested in computerised UTM and the results are predicated. The stress Vs strain, load Vs displacement, Load Vs time, displacement Vs Time are plotted and the result are compared.

From the above result it was found that the peak loads for the Cold-Formed C section without FRP for the following loading case:

- i) End two flange loading condition = 23.43 kN.
- ii) Interior Two-Flange Loading = 31.33kN
- iii) End one flange loading condition=27.70 kN.

Peak loads for the Cold-Formed C section with FRP laminated to either side of the web for the following loading case:

- i) End two flange loading condition = 31.33 kN.
- ii) Interior Two-Flange Loading = 37.86 kN
- iii) End one flange loading condition = 33.25 kN.

It is found that the web crippling strength for the cold form C- section is increased if by 25.%,

17%, 17% for ETF, ITF, EOF loading condition respectively, with FRP section.

The displacement for the cold-form C-section is also increased by 8.8%, 36% for ETF, ITF, loading condition respectively, with FRP section.

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