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Analytical and Numerical Investigation of Cold Formed Steel Beam and Optimization of Parameter by DOE and SAA

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***Abstract*: The current research work is based on the analysis of cold formed steel channel beam under the static loading condition. Cold-framed steel structure components have generally been utilized as auxiliary load conveying individuals in a wide scope of uses as rooftop purlins, divider girts, stud dividers and cladding. An analytical method has applied to find out the most suitable and appropriate size of channel section and also finding the sustainable loading condition. Todays the analytical and experimental method is not suitable for new design and analysis to find out the behavior and performance of assembly due to its time, money and effort. It is complicated to investigate the behavior of beam under the certain boundary condition. A virtual environment of simulation of such model is available which is called FEA. Modelling and assembly of the beam is done by using the CATIA software and then whole assembly was simulated with given boundary condition in static structure workbench. The outcome result of simulation shows vary good agreement with analytical method. Once the validation is done, the design of experiment process has applied to find out the feasible combination of web and flange under the same boundary condition then we move on the optimization technique by using SAA algorithm to find out the most optimum configuration of web and flange.**

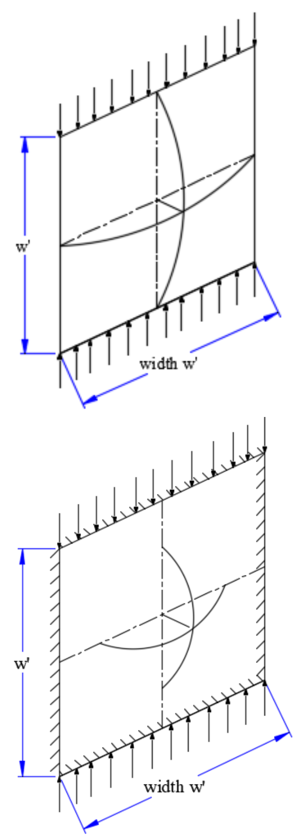
***Keywords*: Steel beam.**

1. Introduction

Light gauge steel formed by steel sheet or strip of cold formed steel, it divided into three different categories as framing member, wall and floor panel and wall cladding and roof deck. The light gauge member can be either press or rolls by cold formed from flat steel mainly not thicker than 12.5 mm. Generally cold forming process preferred for cold rolling and for small quantity of special shapes are most economically produced on press brakes. Today's light gauge member in India manufactured by both press brake system and by cold rolling system. The cold formed steel member generally connected by spot, fillet, plug or slot weld, by screws, bolts, cold rivet, or by special fasteners. The cold forming process consist of large verity of section of steel gauge due to its automatic welding permit between the section profiles. During the design of steel section, the main aim is to develop a unique shape which is economic with sufficient strength weight ratio with versatility, ease of large production, easily assembled with different member or to non-structure collateral materials of both of them.

A. Local Buckling of Thin Element

The ratio of width to thickness for light gauge member is quite larger and hence failure of plate element is invariably by buckling. In contrast to this in hot roller section the buckling of the plate element was neglected because limits were put on the width thickness ratio of the plate element so that they fail by yielding and not by buckling. For light gauge plate element, the buckling occurs at low stress resulting due to compression or bending or shear or bending.



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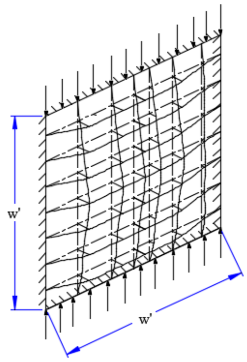

Fig. 1. Local and post buckling strength of plate

B. Post Buckling Strength

A hot rolled section column buckles, it has no post buckling strength and hence the allowable stress is taken as critical stress divided by a factor of safety. However, in the thin stiffened wide plate element the ultimate strength is many times greater than the critical stress, because of its post buckling strength. However, in narrow thick plate failure load is found to be nearly the same as visualised by a model shown in figure below. Consisting of a grid of longitudinal and transverse bars along the actual material of the plate is through to be concentrated.

C. Problem Identification

The cold formed steel channels failed due to effect of combined bending and web crippling occur when there is highly concentrated interior force on it. The cold formed channel without liped or stiffeners under such loading condition may reduce the ultimate web cripping strength of the channels. Cold rolling of the cold formed sheet makes the final shape of a structural member. The element with large flat width ratio uneconomical because they have only very small effective widths. For w/t= 100, less than 50% of the width is effective. For still large w/t ratio, effective width will be still smaller. Here the design of channel width and w/t ratio is one of the crucial parameter and it need proper attention.

The basic objective of the research work is to find out the load carrying capacity by analytical method of two cold formed steel channel assembly and Justify the analytical result by using Numerical method.

2. Methodology

A. Analytical Method

For the analytical analysis and to find out the load carrying capacity of cold formed channel section with lipped edge, we have taken Two channel 200x80 with bent lips are connected with webs to act as beam given below. The thickness of the plate is 2.5 mm and the depth of lip is 25 mm. Also we determine the deflection at the allowable load.

The steel has a yield point of 235 N/mm^2. Take E = 2x105 N/mm^2.

1) Computation of effective width

The section is symmetric about x-x axis hence the stiffened compression flange will govern the design. The effective width of compression flange will be found on the basis of design stress,

$f_b = 0.6*f_y = 0.6x235 = 141$ N/mm^2
Thus $f = f_b = 141$ N/mm^2

For load determination effective width is given by equation,

$$\frac{b}{t} = \frac{658}{\sqrt{f}}\left[1 - \frac{145}{\left(\frac{w}{t}\right)*\sqrt{f}}\right] = \frac{658}{\sqrt{141}}\left[1 - \frac{145}{\left(\frac{45}{2.5}\right)*\sqrt{141}}\right] = 28.98$$

$b = 28.98 * 2.5 = 72.4\ mm > 64$
$b = w = 64\ mm$

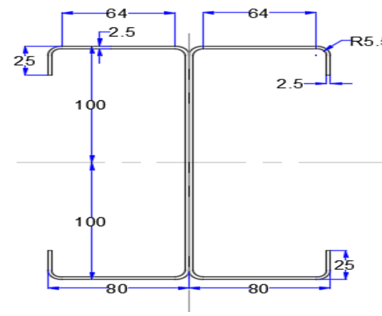

Fig. 2. Cold formed steel section profile

Determination of moment of inertia and section modulus:

I and Z will be determined by taking b = w = 64 mm

$I_{xx} = 4(64+16) * 2.5*(100-1.25)^2 + \frac{1}{12} * 5 *(195)^3 + 4*2.5*22.5*(100-25-11.25)^2$

= 12564570 mm^4,
$Z = \frac{12564570}{100} = 125.65X10^3$ mm^3

Determination of safe load:

$M = f*Z = 141x125.65x10^3 = 17.72$ Kn-m

Let w be the load in kN/m

$\frac{w(4)^2}{8} = 17.72$ kN/m = 8.85

2) Check for web shear

Max. Shear force $= \frac{8.858*4}{2} = 17.716$ kN

Max. Average shear force $\frac{17.716*1000}{2*2.5*195} = 18.17$ N/mm^2

Now $\frac{h}{t} = \frac{195}{2.5} = 78, \frac{1425}{\sqrt{fy}} = \frac{1425}{\sqrt{235}} = 92.96$

For h/t not greater then $1425\sqrt{f_y}$ then $f_y = \frac{396\sqrt{fy}}{\frac{h}{t}}$ with a max of 0.40 f_y

Hence the above equation is applicable here

$f_y = \frac{396\sqrt{f_y}}{\frac{h}{t}} = f_y = \frac{396\sqrt{235}}{78} = 77.83\ N/mm^2 \leq 0.4x236$
$= 94.4\ N/mm^2$

Thus $f_v = 77.83\ N/mm^2$, which is much greater than the max. Average shear stress of $18.17\ N/mm^2$, the beam is therefore safe in shear.

3) Check for bending compression in web

$f_{bw'} = 141 * \frac{100-2.5}{100} = 137.48\ N/mm^2 = \frac{3525000}{(\frac{h}{t})^2} = \frac{3525000}{78^2}$
$= 579.4 > 137.48$ hence safe

4) Determination of deflection

For determination of deflection one may use effective section at max. B.M., however effective width for deflection determination is different from the one found for load termination.

$\frac{b}{t} = \frac{842}{\sqrt{141}}[1 - \frac{186}{\frac{64}{2.5} * \sqrt{141}}] = 27.65$

$b = 27.65 * 2.5 = 69.1 > 64$ mm

$I = 12564570\ mm^4$

$\delta = \frac{5}{384} * \frac{(wL)L^3}{EI} = \frac{5}{384} * \frac{(8.858*10^3*4*(4000)^3}{2*10^5*12564570} = 11.7$ mm

On the basis of analytical calculation, it is found that the cold formed steel channel 200x80x25 lipped section is safe and show vary good response under the loading condition and the generated amount of bending stress 137.48 N/mm^2 and deflection 11.7 mm is under safe limit.

B. FEA Method

Geometric Modelling: The finite element analysis is one of the key tools to simulate the problem in virtual environment to find out the nature of the job under the actual working condition. The geometric model of the CFS is prepared in modelling workbench of CATIA and then assembled in product platform to achieve the required position of both beam.

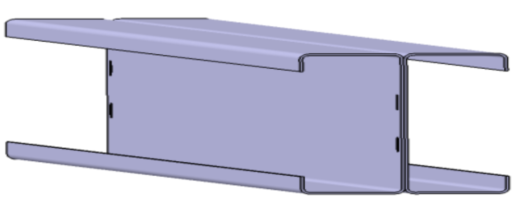

Fig. 3. 3D model of CFS beam

Meshing and boundary condition: After successfully development of 3Dmodel and assembly we move into the static structure workbench to simulate the beam with the help of required boundary condition.

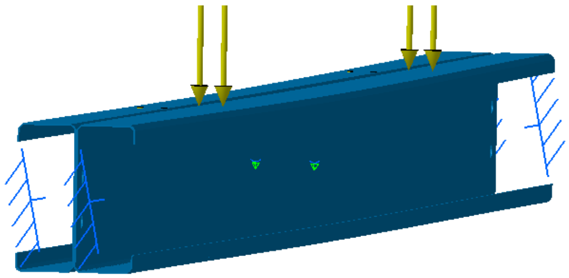

Fig. 4. Boundary condition of CFS beam

3. Results and Discussion

The output of simulation is shown by CATIA in the form of graphical representation with the help of different colour of band. It shows different value for different loading condition and it also provide flexibility to change it according to the requirement. The stress value of beam assembly are calculated with the help of simulation workbench to clearly understand the behaviour of beam assembly under the action of point load.it shown below.

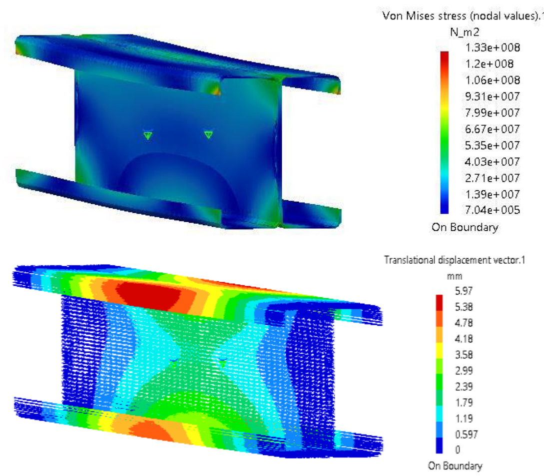

Fig. 5. Stress and deflection distribution in CFS Beam

In order to validate the result of analytical method we apply finite element analysis on the cold form steel channel with the same parameter and boundary condition and compared the output result of both approaches in the form of stress and deflection of the beam which is shown in the table below.

Table 1
Comparison of analytical and FEA method

Method	Stress MPa	Deflection Mm
FEA	133	5.97
Analytical	137	11

A. Response of stress and deflection to variations in web and flange by DOE

After applying FEA, Design of experiments is performed for the same model where web and flange were varied in a specific range that is web height between 180 mm to 220 mm & flange between 70 mm to 90 mm. It took approximately 200 minutes to compute the results based on 25 combinations of web and flange.

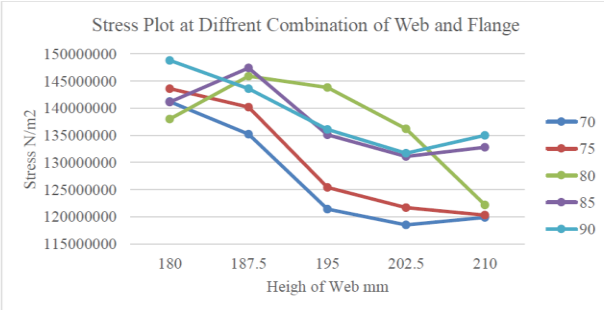

Fig. 6. Stress distribution under different combination of web and flange

B. *Optimization by SAA*

The optimization with SAA has been performed to find out the optimum combination of web and flange with the given boundary condition. With reference to the Table 4.4 it is to be found that iteration 32nd shown the minimum stress value with the web 203.6 mm and flange 70.7mm. The magnitude of stress for web is continuously going down from iteration number 1 to 10 then it's going up and down till iteration No. 11 to 29 but the average values is almost same.

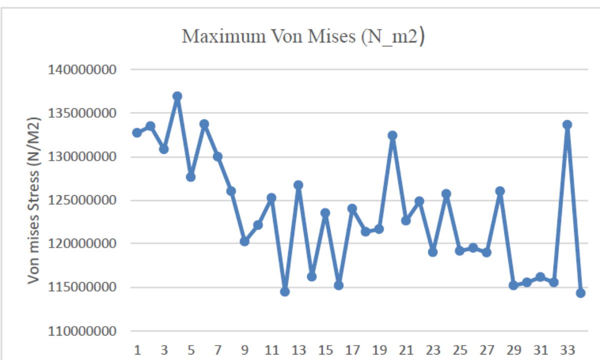

Fig. 7. Variation of Stress as per the iterations via SAA

4. Conclusion

The main aim of the project was to substantially reduce the stress concentration will in-turn help in reducing the overall life of member with cost effective way. This was done with the help of a CAE & CAD software in the form of CATIA where we had analysed the existing steel structure. The structure was analysed in the static structural workbench in CATIA.

We have selected an analytical problem for analysis and alternate solution of existing problem of column and beam connection. The analytical problem guides us to select the parameter of beam under the satisfactory condition. But it was analysis that the FEA result slightly different with analytical solution, due to high stress concentration was found in the web face of the structure. This problem can resolve by changing the size of web in CFS member.

On the basis of results furnished above it is very clear that DOE and Optimization technique emerges to be the most feasible and safe option. It showed a considerable reduction in stress i.e. 114 MPa and the corresponding percentage reduction in mass computed was 14 %.the amount of weight is also reduced around 3% as compare to the previous design of CFS.

References

[1] Jun Ye, "Experimental investigation of local-flexural interactive buckling of cold formed steel channel columns," 2018.

[2] Mohd Syahrul Hisyam Mohd Sani et al, "Experimental Analysis of Cold-Formed Steel C-Sections with the Notch Subjected to Axial Compression". KSCE Journal of Civil Engineering (2020) 24(4):1228-1239.

[3] Aamer Nazir & Jeng-Ywan Jeng, "Buckling behaviour of additively manufactured cellular columns: Experimental and simulation validation", 2019.

[4] Žilvinas Bučmys et al, "analytical and experimental investigation of cold-formed steel beam-to-column bolted gusset-plate joints", Journal of civil engineering and management.

[5] Asraf Uzzaman et al, "Experimental and analytical studies of cold-formed steel sections with edge-stiffened circular holes subjected to web crippling", Wei-Wen Yu International Specialty Conference on Cold-Formed Steel Structures St. Louis, Missouri, U.S.A., November 7 & 8, 2018.

[6] V. Chandrikka et al, "Analytical and Experimental Investigation of Cold Formed Steel Sections under Bending". International Journal of Scientific Engineering and Science Volume 3, Issue 4, pp. 5-10, 2019.

[7] J. Vijayakumar & J. Pavithra, "Experimental and Analytical Study on Strengthening of Deformed Cold-Formed Steel Lipped Channel Section". International Journal of Engineering Research & Technology.

[8] Alex J & Iyappan. G. R, "Experimental Study on Flexural Behaviour of Cold Formed Steel Section", International Journal of Science Technology & Engineering, Volume 2, Issue 10, April 2016.

[9] Muhammad Firdaus, et al, "Experimental Study of Slip-in Haunched Gusset Plate Connection for Double Lipped Cold-Formed Steel Section". International journal of scientific & technology research volume 8, issue 12, December 2019.

[10] Paul Makesh A & Arivalagan S, "Experimental and analytical study on behaviour of cold formed steel using angle section under tension members". International Journal of Engineering Technologies and Management Research, vol. 5, no. 1, January 2018.

[11] M. Prakash et al, "Analytical and experimental study on web-crippling behaviour of cold formed C-section with and without FRP wrapping." Asian Journal of Civil Engineering, 2018.

[12] Wei-Xin Ren et al, "Analysis and design of cold-formed steel channels subjected to combined bending and web crippling." 2006 Elsevier Ltd. Thin-Walled Structures 44 (2006) 314–320.

[13] Cristiane Cruxen Daemon d´Oliveira Bastos, "Experimental analysis of built-up cold-formed steel lipped channel stub column." REM, Int. Eng. J., Ouro Preto, 72(4), 571-579, Oct. Dec.

[14] Asraf Uzzaman et al, "Experimental and Analytical Studies of Cold-Formed Steel Sections with Web Openings Subjected to Web Crippling" The 6th International Conference on Coupled Instabilities in Metal Structures, 2016.