International Journal of Civil Engineering and Infrastructure
Vol. 2, No. 2, October 2022

NUMERICAL STUDY ON BEHAVIOUR OF COLD-FORMED STEEL UNLIPPED CHANNEL SUBJECT TO AXIAL COMPRESSION

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Received May 10, 2022 | Accepted July 18, 2022

ABSTRACT

Innovation in obtaining construction materials that are efficient and applicable to various conditions is a challenge for researchers. Cold-formed steel is a material breakthrough in construction that has advantages over hot-rolled steel. Many studies have been carried out on Cold-formedsteel subjected to various loadings to examine the behavior and capacities of the sections. This study aims to investigate the behavior and section capacity of cold-formed steel unlipped channels due to axial compression loads. This research begins with conducting a literature study, then carrying out numerical analysis using the finite element method in ABAQUS, numerical test, and calculation of section capacity based on existing research in the literature. The calculation of section capacity is carried out based on SNI 7971-2013 or AS/NZS 4600:2005. The results of the numerical analysis can be seen from the behavior and capacities of the sections of the unlipped channel, the section capacity from the numerical test will be compared with the section capacity obtained from the calculation based on SNI 7971-2013 or AS/NZS 4600.

Keywords: *Cold-Formed Steel, Unlipped Channel, Axial Compression Load, Finite Elemen method*

1. INTRODUCTION

One of the construction materials used in buildings is steel, in steel construction, there are two types of structural steel elements used, namely hot-rolled steel which is made at high temperatures, and cold-formed steel which is formed at high temperatures. Cold-formed, cold-rolled steel cross-sections are prepared from cold-rolled steel sheets by bending or pressing. Cold-formed steel is an alternative to hot rolled steel which has been previously used and is commonly used in building construction, the use of cold-formed steel as a construction material was originally used in automotive, electronics, and household appliances. [1].

Rolled steel has several weaknesses including the ratio of strength to dimensions which is not as big as Cold-formed steel, to overcome this the researchers propose several efficient sections to overcome the weaknesses of hot rolled steel. The use of cold-formed steel in construction is because cold-formed steel has several advantages including high strength and height, quick and easy installation, producing more accurate shapes, and ease of fabrication. There are several cross-sectional shapes of cold-formed steel depending on which C and Z shapes are commonly used, unlipped channel is one of the cross sections that is widely used because it can be applied in several locations, such as purlins, beams, and columns [2].

Special problems such as local buckling, distortion buckling, the effect of cold working, regarding joints, and fatigue are things that must be considered, this problem is due to the shape of the cross-section of Cold-formed steel which is thinner and slimmer than hot rolled steel. Research on cold-formed steel using cross-section unlipped channels has been done by several researchers [3]-[11]. Peiris & Mahendran [12] Tested the cross-section of the lipped channel steel due to axial compressive loads, the behavior of elements subjected to compressive axial loads was investigated by performing numerical tests using the finite element method, experimental tests, and calculation of cross-section capacities using AS/NZS 4600 [13], results of all methods get close results.

Further research on unlipped channel steel elements against compressive axial loads using the finite element method and capacity calculations based on SNI 7971-2013 [14] has not been available in the literature. In this study, a numerical test will be carried out using the finite element method with the help of ABAQUS software, and the calculation of the cross-sectional capacity using SNI 7971-2013, the results of the numerical test using the finite element method will be compared with the results of calculating the cross-sectional capacity based on SNI 7971-2013. This study aims to look at the behavior of the cross-section of Cold-formed steel unlipped channel due to loading, to see the buckling effect and the capacity of the section.

2. FINITE ELEMENT MODELLING

One way to get optimal results in analyzing a complicated element is by using numerical methods, numerical methods are used where analytical solutions cannot get good results, one of the commonly used numerical methods is the finite element method. This method uses a discretization technique on elements by dividing a continuous structure into a set of small pieces called finite elements, which are interconnected only at the nodes. Bending analysis using the elemental method gives good results [15].

Tests in observing the cross-sectional behavior of Cold-formedsteel involve a lot of tests using the finite element method in addition to experimental tests in the laboratory. In this study, a numerical test will be carried out using the finite element method using ABAQUS 6.14 software. ABAQUS can provide a visualization of the cross-sectional response of cold-rolled steel due to a given load, besides that ABAQUS can also provide capacity values of cold-rolled steel sections.

Material and Section of Geometry

The cold-formed steel sections used in this study are 6 unlipped channels made of G450 grade steel. The steel cross-section is the type that has been widely tested in several studies and has several interesting variables, which have an overall depth in the range of 100 to 300 mm and have three types of thickness. Nominal dimensions can be seen in table1.

Table 1. Nominal dimensions of unlipped channel sections..

Section	*d (mm)*	*b_f (mm)*	*t (mm)*	*r_i (mm)*
300 x 90 x 6	300	90	6	8
250 × 90 × 6	250	90	6	8
200 × 75 × 5	200	75	4.7	4.5
150 × 75 × 5	150	75	4.7	4
125 × 64 × 4	125	64	3.8	4
100 × 50 × 4	100	50	3.8	4

Element Type and Mesh Size

Research on Cold-formed steel elements using ABAQUS showed that the S4R shell elements showed good results, so in this study, the unlipped channel steel elements were modeled as S4R shell elements. The finite element method will break the elements into small parts which are called meshes, the mesh greatly determines the results of the analysis, in theory using a fine mesh should get good results, but has the disadvantage that it will require high computation time. In this paper, we will use a mesh size of 4 mm x 4 mm which has been proven to give good results from research in the literature.

Boundary Conditions and Loadings

Unlipped channel steel elements are modeled as having 6 DOFs for each node, the elements are modeled to be restrained at each end by rotation in the z direction, and translation in the x, y, and z directions, except at the loading location where the z-direction translation is removed. The application of boundary conditions is bound together at one reference point using the MPC (multi-point constraint). In this study, the behavior and strength of the unlipped channel cold-formed steel section will be subjected to an axial compressive load concentric at the center point which is modeled at the reference point.

Analysis Method

The analysis begins by performing a linear perturbation analysis to obtain the buckling load and shape mode. The value of the analysis results will be used to determine the initial geometric imperfection which will be used to carry out the next analysis, namely non-linear analysis, this second stage of analysis uses the modified riks method.

Cold-formed steel elements go through many processes starting from forming to construction, as a result of which these elements have geometric imperfections. Geometrical imperfections can use the values in SNI 7971 2013 or AS/NZS 4600, and the values recommended by researchers. In this study, buckling gemotrical imperfection was used which was 0.25t, where this value was following the recommendations of Schafer and Pekoz [1] who suggested that the imperfection value for Cold-formedsteel was in the range of 0.14t to 0.66t, where t is the thickness of the cross-section. The imperfection value for overall buckling or global buckling is L/1000.

3. EFFECTIVE WIDTH METHOD

Calculation of the cross-sectional capacity of Cold-formedsteel unlipped channel according to SNI 7971-2013 will be explained briefly. SNI 7971-2013 which refers to AS/NZS 4600 is used to determine the compressive capacity of Cold-formedsteel sections due to the applied force, the design axial compressive force (N*) must meet the following

$$N^* \leq \phi_c N_s \quad (1)$$

$$N^* \leq \phi_c N_c \quad (2)$$

Where N_s is the nominal cross-sectional capacity of the member in compression

$$N_s = A_e f_y \quad (3)$$

The notation N_c is the nominal structural member of the structural member in compression

$$N_c = A_e f_n \quad (4)$$

Where f_n is the critical stress

$$f_n = (0,658^{\lambda_c^2}) f_y, \text{when} \quad f_n \le 1,5 \quad (5)$$

$$f_n = (0,877 / \lambda_c^2) f_y, \text{when} \quad f_n > 1,5 \quad (6)$$

where Nondimensional Slenderness is

$$\lambda_c = \sqrt{\frac{f_y}{f_{oc}}} \quad (7)$$

The effective width can be calculated by the following equation

$$b_e = b, \text{ ketika } \lambda \le 0,673 \quad (8)$$

$$b_e = \rho b, \text{ ketika } \lambda > 0,673 \quad (9)$$

The notation b is the flat width of the element, and the slenderness is

$$\lambda = \sqrt{\frac{f^*}{f_{cr}}} \quad (10)$$

Where f^* is the flat width of the element, and slenderness is the design stress in the compression element based on the effective design width and f_{cr} the elastic buckling stress of the plate

$$\frac{f^*}{f_{cr}} = \frac{k\pi^2 E}{12\left(1-\nu^2\right)}\left(\frac{t}{b}\right)^2 \quad (11)$$

coefficient of plate buckling, k=4 for both sides supported elements, effective width factor

$$\rho = \frac{\left(1 - \frac{0,22}{\lambda}\right)}{\lambda} \le 1 \quad (12)$$

4. RESULT ANALYSIS

Numerical analysis using the finite element method in ABAQUS is carried out by analyzing the shell elements subjected to axial compressive loads, the ultimate load capacity that can be withheld by the unlipped steel cross-section compared to the estimated load capacity based on SNI 7971 2013 or AS/NZS 4600.

Table 2. Comparison of finite element analysis (FEA) and the code

Section	***Length (mm)***	***P_{FEA} (kN)***	***$P_{AS/NZS}$ (kN)***	***$P_{AS/NZS}$ /P_{FEA}***
300 x 90 x 6	1500	762.55	608.78	0.80
250 × 90 × 6	1500	699.87	580.33	0.83
200 × 75 × 5	1500	396.94	377.68	0.95
150 × 75 × 5	1500	354.61	344.17	0.97
125 × 64 × 4	1500	313.48	349.77	1.12
100 × 50 × 4	1500	162.07	171.32	1.06
Mean				0.96
SD				0.125

From the results of the numerical analysis in Table 1, the ultimate load capacity that can be withstood by the Cold-formed steel unlipped channel section obtained from the element method modeling has a good correlation with the ultimate load obtained from the approach using SNI 7971 2013 or AS/NZS 4600. The difference in ultimate load obtained from the two methods is 2.94% - 20/17%.

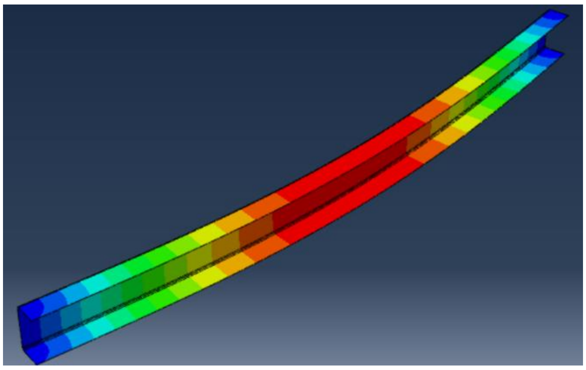

Figure 1. Buckling shape of the first eigenmode of 100 x 50x 4 section.

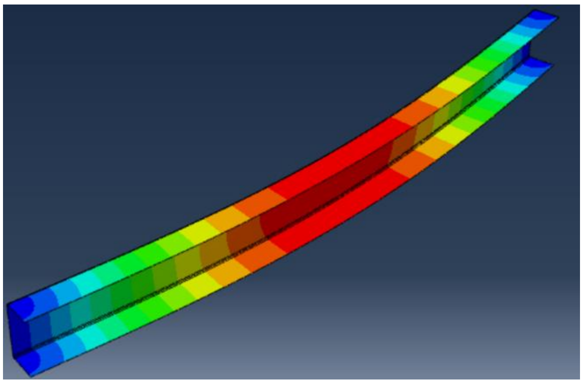

Figure 2. Buckling shape of the first eigenmode of 125 x 64 x 4 section.

Figures 1 and 2 show that elements with a height *d* of 100 – 125 tend to have a global buckling mode, this is due to the large ratio of length to height *d*.

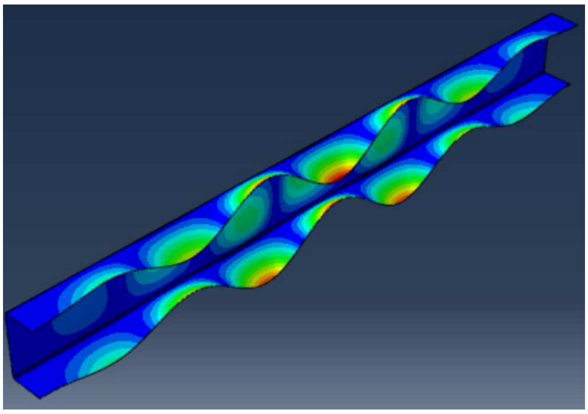

Figure 3. Buckling shape of the first eigenmode of 150 x 75 x 5 section.

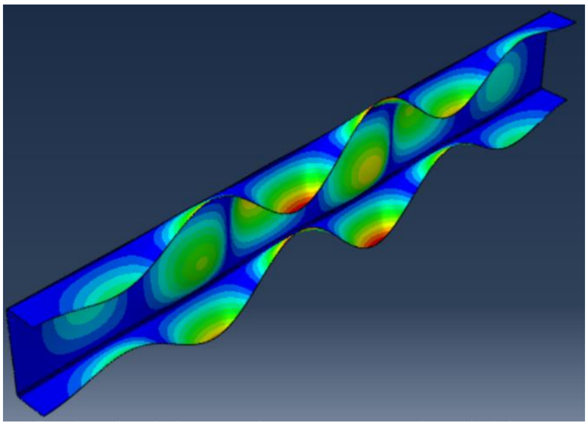

Figure 4. Buckling shape of the first eigenmode of 200 x 75 x 5 section.

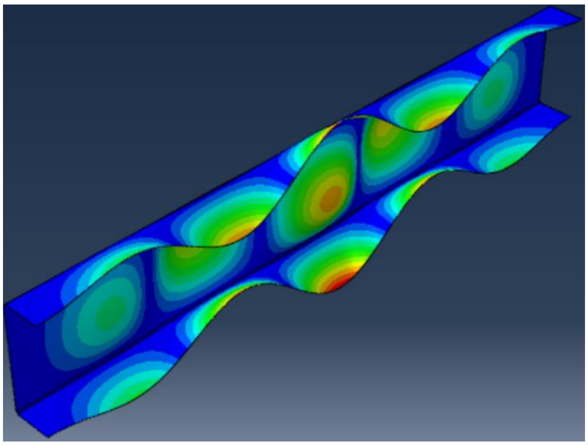

Figure 5. Buckling shape of the first eigenmode of 250 x 90 x 6 section.

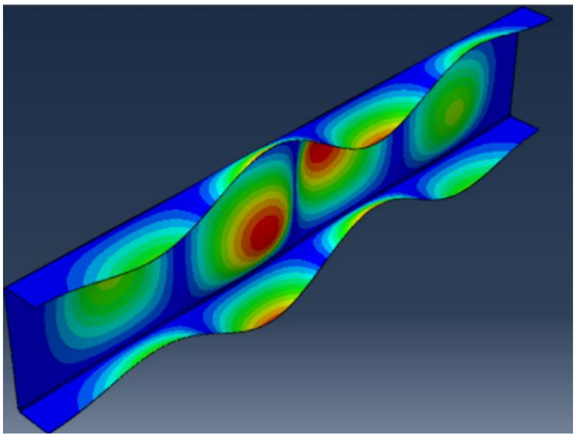

Figure 6. Buckling shape of the first eigenmode of 300 x 90 x 6 section.

In Figure 3-6, it can be seen that for elements that have large dimensions, namely with a cross section of 150 x 75 x 5 to 300 x 90 x 6, the buckling mode that occurs tends to be local buckling, the length to height ratio of

1500 mm does not cause the element to experience global bucking.

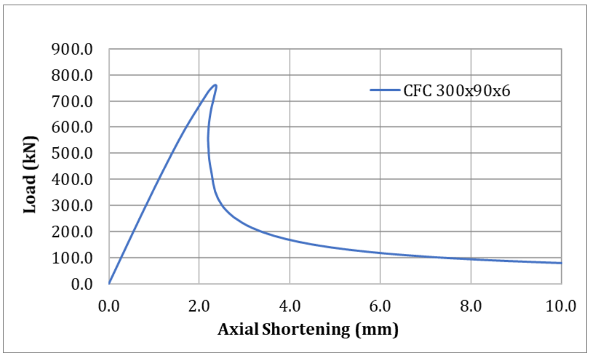

Figure 7. Axial shortening behavior of 300 x 90 x 6 section.

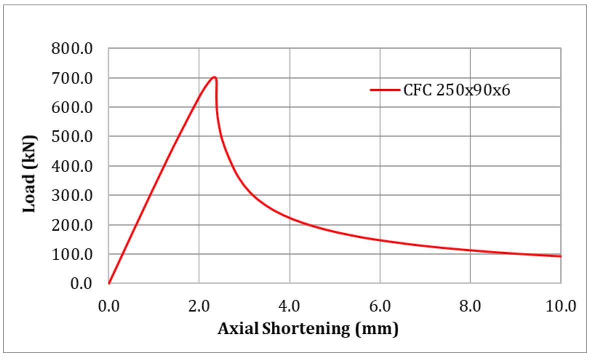

Figure 8. Axial shortening behavior of 250 x 90 x 6 section.

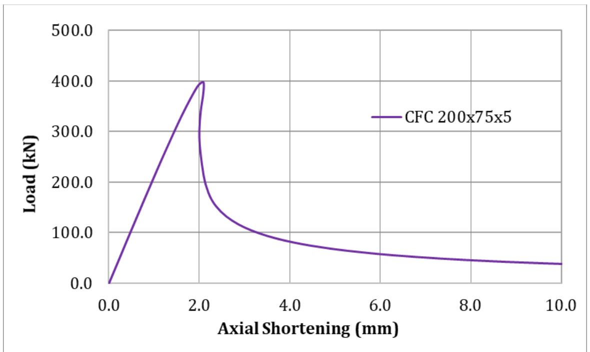

Figure 9. Axial shortening behavior of 200 x 75 x 5 section.

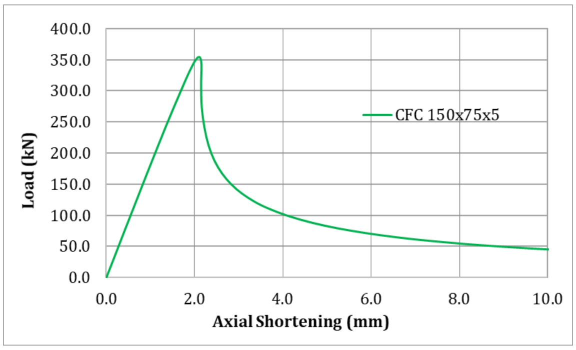

Figure 10. Axial shortening behavior of 150 x 75 x 5 section.

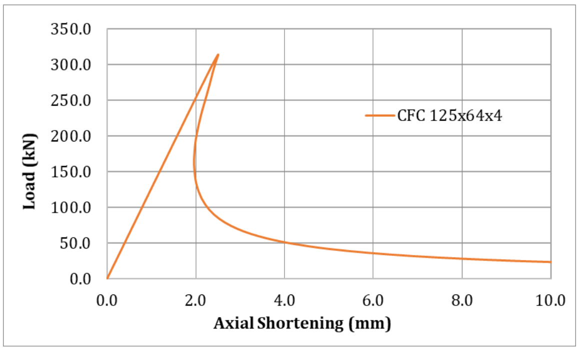

Figure 11. Axial shortening behavior of 125 x 64 x 4 section.

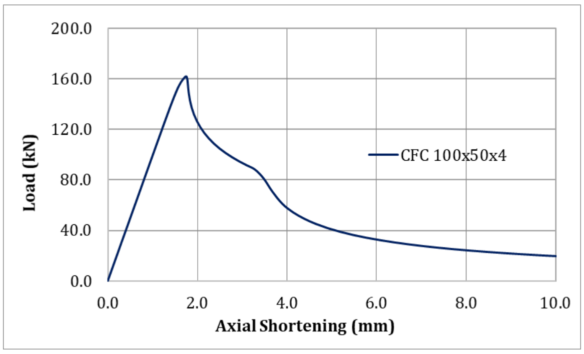

Figure 12. Axial shortening behavior of 100 x 50x 4 section.

The load curve versus axial shortening in Figure 8–12 describes the decrease in stiffness with increasing load. a long horizontal curve after the ultimate load is reached indicates a high degree of ductility.

5. CONCLUSION

Performing numerical analysis of unlipped channel Cold-formedsteel using the finite element method at ABAQUS due to axial compressive loads, the results show that the ultimate load value has a good correlation with the ultimate load value obtained using SNI 7971 2013 or AS/NZS 4600. Differences The big problem that occurs in elements that have large dimensions can occur because when doing finite element modeling with the same mesh for all elements, the 300 x 90 x 6 elements have not yet reached the fine elements. It can be concluded that SNI 7971 2013 or AS/NZS 4600 can predict the ultimate load of elements subjected to axial compressive loads.

Acknowledgments

The authors would like to thank Universitas Muhammadiyah Jakarta for providing financial support through the 2022 LPPM Internal Research Grant Funding.

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