Integrated Solutions for Infrastructure Development
Edited by Lau, H. H., Tang, F. E., Ng, C. K., and Singh, A.

ISBN: 978-0-9960437-3-1

NUMERICAL ANALYSIS OF AXIALLY LOADED COLD-FORMED STEEL BUILT-UP BOX SECTION

T. C. H. TING, H. H. LAU, and M. S. JOO

Dept of Civil and Construction Engineering, Curtin University, Sarawak Malaysia

Built up box section is a doubly symmetrical section in which two C-channel connected at the flange using self-drilling screw. They are generally used in the construction industry to obtain higher rigidity, when a single section is not sufficient. Despite being widely used in the construction industry, there are limited studies on built-up box section. Moreover, the current design code does not provide clear design guideline for the calculation of built-up box section. Therefore, research on the built-up box section is important. This paper presents a finite element model to predict the compressive strength and simulate the behavior of cold-formed steel built-up box section. The finite element model was developed using ABAQUS CAE/6.14. Comparison of the finite element and experimental results showed good correlation. The model well predicted the behavior of the built-up box column.

Keywords: Effective width method, Direct strength method, Finite element analysis.

1 INTRODUCTION

Cold-formed steel structural members are generally used for individual structural framing members such as purlin, joist and studs, panels and decks (Yu 2010). However, due to increasing demand, cold-formed steel are often used to stretch over large span. The major issue with large span is the deflection, lateral stability and constructability. In order to obtain higher rigidity, built-up section such as built-up box section is formed (Cheng & Schafer 2007). The built up box section used in this research is a doubly symmetrical section in which two C-channels are connected at the flanges using self-drilling screws (Figure 1).

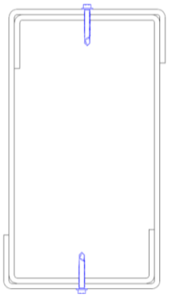

Figure 1. Built-up box section.

Finite element modeling has successfully been used in the past to predict the behavior of cold-formed steel structures. Finite element model could simulate the buckling and compressive strength of a cold-formed steel built-up column, provided that important parameters such as element type, mesh size, and surface contact of the finite element model are properly configured (Becque & Rasmussen 2009). In this research, finite element models were developed by using ABAQUS CAE/6.14. The finite element models were developed to simulate the compression test from the authors' previous publication (Ting & Lau 2010).

2 FINITE ELEMENT METHOD

Thin walled members such as cold-formed steel are modeled by using shell type element. Quadrilateral shell element (S4R) was selected to develop the finite element model. S4R account for three translational and three rotational degrees of freedom at each node of the element. The influence of shear flexibility in laminated composite shell models was taken into consideration by these elements. The element provides more flexibility to model curved and straight geometry such as the corner of the C-channel column.

In order to study the effect of the mesh size on the accuracy of the finite element analysis results, convergence study has been conducted. The mesh sizes modeled were 2mm, 5mm, 10mm and 15mm with total mesh number of 20700, 3780, 1125 and 570 respectively for a 450mm length column. Mesh size of 5mm × 5mm with a difference of 2.6% (with 2mm × 2mm as reference) is selected for the further analysis.

The Young's modulus of the steel is 20,500MPa and Poisson's ratio of 0.3 is used to simulate the elasticity and plasticity properties of the cold-formed steel. The yield strength of the cold-formed steel is 550.5MPa. The plastic behavior was analyzed by using Dynamic-Implicit method.

In the compressive test, the stub column has flat-end condition and intermediate column under pinned-end condition. In the finite element analysis, the ends of the stub columns were fixed, except for the y-axis displacement at the top end of the column. The displacement was imposed on the top end of the column. For the pinned-end condition, the rotation at weak axis (y-axis) was released. The automatic incrimination was used with a time period of 1 second for stable load incrimination.

In the compression test, the built-up box section was assembled together by using self-drilling screw. To simulate the fastener in the finite element analysis, discrete rigid 2mm thin strip was created to attach the outer flange and inner flange of the built-up box section, as shown in Figure 2 below. Discrete rigid part was selected because there is no failure in the screw connection during the compression test.

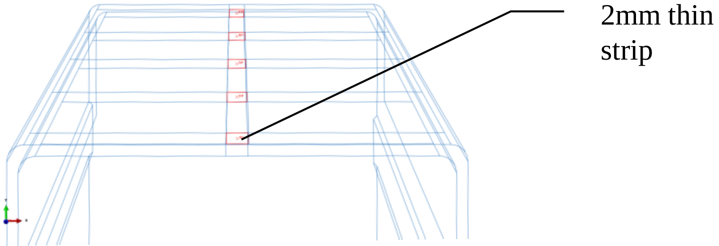

Figure 2. Screw connection in built-up box model.

3 RESULTS AND DISCUSSIONS

3.1 Load Carrying Capacity

Tables 1 and 2 show the comparison of test results to finite element results. Generally, the finite element model well predicts the compressive strength of the column. The test results for intermediate columns are higher than the finite element and design calculated results. This could be due to the end condition of the test specimens. The friction between ball bearing and the end plate causes the pinned-end condition to behave as partially fixed.

Table 1. Comparison of load carrying capacity for stub columns.

Specimens	**P_{Test} (kN)**	**P_{FE} (kN)**	$\frac{P_{Test}}{P_{FE}}$
C75-450-1	57.54	48.47	1.17
C75-450-2	55.50		1.12
C75-450-3	54.20		1.12
C75-450-4	57.74		1.19
Mean			1.15
B75-450-1	124.80	131.34	0.95
B75-450-2	127.52		0.97
B75-450-3	130.50		0.99
B75-450-4	129.70		0.99
Mean			0.98

Table 2. Comparison of load carrying capacity for intermediate columns.

Specimens	**P_{Test} (kN)**	**P_{FE} (kN)**	$\frac{P_{Test}}{P_{FE}}$
C75-1500-1	39.00	36.68	1.06
C75-1500-2	40.50		1.10
C75-1500-3	42.00		1.15
C75-1500-4	45.50		1.24
Mean			1.14
B75-1500-1	84.00	76.89	1.09
B75-1500-2	81.00		1.05
B75-1500-3	92.00		1.20
B75-1500-4	91.00		1.18
Mean			1.13

3.2 Buckling Behavior

The buckling behavior of stub columns is as shown in Figure 3. From observation, local buckling at web occurred as an initial buckling mode for the stub columns. Later, the flanges deflected when load was close to the ultimate load. After that, deflection in web and flanges increased and accompanied by a sudden drop in load when the specimen failed. The location of maximum deflection occurs near the mid-length of the column.

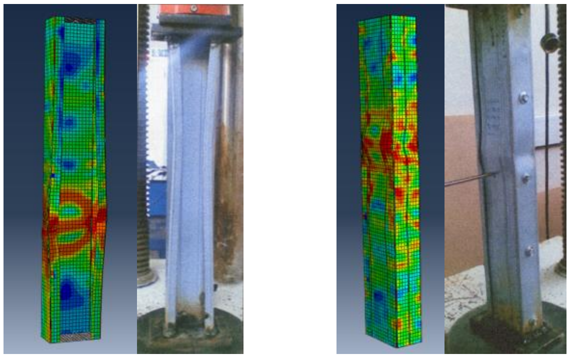
C75-450 *B75-450*

Figure 3. Failure mode of FE models and tested specimens of stub columns.

Figure 4 shows the buckling behavior of intermediate columns. At the initial stage of the compression test, the intermediate columns shows local buckling at web and then distortional buckling at the flanges. Significant global buckling only occurred after reaching the maximum load. This is because the high friction between the ball bearing and the end plates at both ends of the column restricted the rotation.

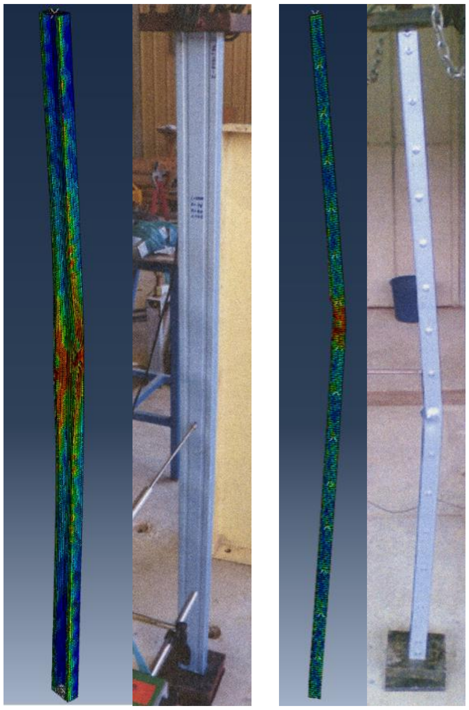
C75-1500 *B75-1500*

Figure 4. Failure mode of FE models and tested specimens of intermediate columns.

4 CONCLUSION

A finite element model was developed using ABAQUS CAE/6.14 to study the load carrying capacity and buckling behavior of boxed built-up stub column. The model was verified against previously published experimental results. Test data of eight C-channel and eight boxed built-up columns also show that the failure of stub columns was resulted from local and distortional buckling. Similar failure mode was observed during the tests with maximum deformation occurred near the mid height of the columns. Predictions correlate well with the test results.

Acknowledgments

The authors would like to acknowledge the the financial support under Curtin - EcoSteel Sdn Bhd Industry Research Grant and also acknowledge Mr. Chin Mei Chuo for his contribution towards this research project.

References

Becque, J., and Rasmussen, K.J.R., Numerical investigation of the interaction of local and overall buckling of stainless steel I-columns, *Journal of Structural Engineering*, American Society of Civil Engineering, 2009.

Cheng, Y. and Schafer, B.W., Simulation of Cold-Formed Steel Beams in Local and Distortional Buckling with Applications to the Direct Strength Method, *Journal of Constructional Steel Research* 63 (5): 581-590, 2007.

Ting, T.C.H., and Lau, H.H., Load Carrying Capacity of High Strength Cold-Formed Steel Built-up Box Sections, Proceeding of the 4th International Conference on Steel & Composite Structures, ICSCS, Sydney, Australia, 2010.

Yu, W.W., Cold-Formed Steel Design 4th Edition, John Wiley & Sons, Inc., 2010.