Assessment on Ultimate Load of Cold-formed Steel Channel (CFSC) Stub Column

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Abstract. Cold-formed steel is used as the non-structural and structural material in civil engineering work and building. Cold-formed steel channel is selected and cut into 100 mm, 200 mm, 300 mm, 400 mm and 500 mm. The slenderness ratio is calculated and noted as a stub or short column because below 40. The column is tested by using Universal Testing Machine to determine the ultimate load of the stub column. Besides, the CFSC is determined the material properties of CFSC for checking it's the originality of steel based material. The experimental data are tested and compared with the Direct Strength Method (DSM). It showed that the CFSC1 with a height of 100 mm is reported to have a higher value of ultimate load when compared with other samples. When the height of the stub column increased, the ultimate load of the sample is decreased. Then, the CFSC1 also showed a higher in initial stiffness when compared with other samples. All samples are shown having a higher data in ultimate load when compared with the Direct Strength Method prediction. The ultimate load of experimental and DSM all gave a ratio below 1.03. Finally, all samples can further recommend determining the relation between the ultimate loads with variations of height of the column.

1 Introduction

Cold-formed steel (CFS) is a steel based material that utilised in construction work as non structural or structural material. CFS with thin surface, lightweight and corrosion resistance is becoming a popular material in civil engineering and building. Normally, application of CFS in construction is as roof truss section, purlins, wall panel and frame due to the advantages of CFS. Nowadays, many researchers have studied the CFS as the main structure in buildings such as column, beam and retaining wall. CFS became more popular when compared with other traditional material. CFS is formed by processing of steel with galvanised coating in rolling, pressing and bending method at ambient temperature. CFS is produced in varieties of shape such as channel, Z, hat and compound sections. Additionally, CFS is formed into varieties of thickness, grade and cross-section. The design procedure of CFS is followed the Eurocode 3 and AISI.

The column is an important structure which required a safety and stability of the overall building. There are three types of structural column that be used in building. There is stub column or short column, intermediate column and slender column. In the study, the stub columns are selected to investigate the compression member in the roof truss member. Many researchers are studied the relationship of height and dimension in stub column such as Reference [1-4]. Reference [5] has studied the ultimate load capacity of CFS stub columns with non-perforated and perforated equal angle and compared with the Finite Element Model. Reference [6] has investigated the CFS column with inclined simple edge stiffeners and pin-ended support condition. The height of stub column, 500 mm is failed due to local and distortional buckling. Reference [7] has determined the strength behaviour of cold-formed steel non-symmetric lipped angle column and compared with design strength by using North American Specification. It showed that the design strength was quite conservative. The data of the ultimate load of the CFSC stub column are important in the design to be a reference guide that suitable for Malaysian condition and material.

This paper describes the experimental activity of compression on the CFS stub column to determine the relationship of different height. This data would be used as a reference in roof truss system, especially the roof truss member that noted as compression member. The main objective of this paper is to present an experimental program on the CFSC stub column.

2 Experimental work

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Cold-formed steel channel (CFSC) section with the stiffener was used in the experiment. Normally, CFSC section is utilised in the roof truss system, especially as truss member, purlin, strut and bracing. Two steps in the preparation of the CFSC section for experiment were established. First Step, CFSC section is clean, clear and lastly, cut according to coupon tensile specimen that located at flat surface. The coupon tensile specimen is followed by a code of BS EN 10002-1, 2001 and used for checking the CFSC material properties. The coupon tensile specimens were extracted in the same direction of the column height that formed vertically and tested by using Universal Testing Machine (UTM) with a capacity of 100 kN. The extension control rate of 0.5 mm/min and the extensometer of 50 mm gauge length to determine the strain of the coupon tensile specimen were used. Second step, the CFSC section was cut into 100, 200, 300, 400 and 500 mm height to form a stub column. The section dimension and properties of the CFSC section is shown in Table 1. The dimensional ratio of CFSC section was calculated as 34.00 for *b/t*, 75.00 for *d/t* and 2.21 for *d/b*. The description, sample labels and the slenderness ratio of the CFSC section is shown in Table 2. All samples with the slenderness ratio below 40 were classified as stub column. The end support of the CFSC stub column was stated as a semi rigid support condition as shown in Fig. 1. The experimental result is compared with Direct Strength Method (DSM) by using software THINWALL.

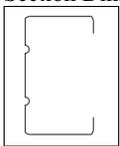**Table 1.** Section dimension and properties of Cold-formed steel channel section.

Properties	Symbols	Value
Section Dimension	Web, *d*	75.00 mm
	Flange, *b*	34.00 mm
	Lipped, *l*	8.00 mm
	Thickness, *t*	1.00 mm
Area	*A*	148.00 mm^2
Direct Strength	*γs*	550.00 MPa
Dimensional Ratio	*b/t*	34.00
	d/t	75.00
	d/b	2.21

Table 2. The description, sample labels and slenderness ratio of the Cold-formed steel channel column section.

No	Test sample labels	Column height (mm)	Slenderness Ratio
1	CFSC1	100	7.73
2	CFSC2	200	15.46
3	CFSC3	300	23.18
4	CFSC4	400	30.91
5	CFSC5	500	38.64

Figure 1. The configuration of CFSC stub column.

3 Result and discussion

3.1 Material properties

The CFSC flat coupon tensile specimen was tested and the result was shown in Table 3. The percentage difference between the web and flange for ultimate load and yield stress were recorded approximately 2.82 % and 3.05 % respectively. The ductility of the steel material is determined by using the ratio of *fu/fy* and compared to the limit of *fu/fy*. The ratio of *fu/fy* of the web and flange was stated same and more than 1.10 and classified as a good ductility.

Table 3. The material properties of CFSC coupon tensile specimen and comparison with others testing.

Sample	Ultimate Load (N)	Ultimate stress, *fu* (MPa)	Elasic Modulus, *E* (GPa)	Extension at Ultimate Load (mm)	Yield Stress, *fy* (MPa)	Yield Stress factory, *fyf* (MPa)	*fu/fy*	*fu/fyf*

| Web | 6906.53 | 603.67 | 204.00 | 4.53 | 550.03 | 550.00 | 1.097 | 1.097 |
| Flange | 7106.87 | 628.48 | 206.00 | 5.27 | 567.38 | 550.00 | 1.108 | 1.143 |

The compression of CFSC stub columns was tested and the results were tabulated in Table 4. The table was tabulated the ultimate load of experimental, load of Direct Strength Method (DSM) and the ratio of P_{DSM}/P_{ULT}. The ultimate load of the CFSC stub columns was decreased when the height of the column increased. From the table, percentage different of ultimate load and stress between CFSC1 with CFSC5 was reported 35.15 %. Comparison percentage of the CFSC1-CFSC2, CFSC2-CFSC3, CFSC3-CFSC4 and CFSC4-CFSC5 was recorded 6.00 - 15.00 %. The compressive extension at ultimate load of CFSC stub columns was increased by increasing the height of the column exclude CFSC1. The difference between CFSC1 and CFSC2 was stated about 5.48 %. The CFSC1 was shown lower than CFSC2 because the section was very short and difficult to get the accurate result. As a result, all CFSC stub columns were reported having a local buckling as shown in Fig. 2 and Fig. 3. From the observation, the flange and web at the middle height was moved inside or outside of the origin shape and line.

The highest initial stiffness is CFSC1 with 73199.65 N/mm and second highest among the CFSC stub column is CFSC3 with 44675.32 N/mm. Initial stiffness of CFSC2, CFSC4 and CFSC5 was noted approximately 42020.17 N/mm, 27664.33 N/mm and 29434.39 N/mm, respectively. The percentage difference between the CFSC1 (highest value) and CFSC4 (lowest value) was determined about 62.21 %. All samples were recorded between 0.60 – 1.03 of P_{DSM}/P_{ULT} when compared between ultimate load and load from DSM. From the calculation and observation, the relationship of the height of stub column and load of experimental and DSM was established as shown in Fig. 4.

Table 4. The result of the compression testing of CFSC column.

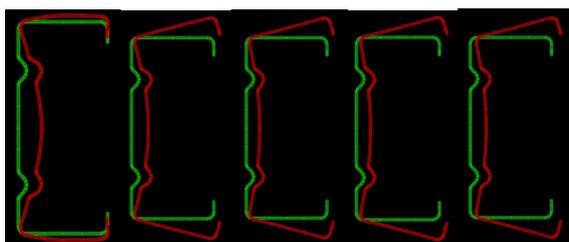| Sample	Ultimate Load, P_{Ult} (N)	Ultimate Stress (N/mm^2)	Compressive Extension at Ultimate Load (mm)	P_{DSM} (N)	Failure Shape	P_{DSM}/P_{ult}
CFSC1	68240.37	461.08	1.587	45540.00	L	0.67
CFSC2	60982.13	412.04	1.500	38890.00	L	0.64
CFSC3	51793.61	349.96	1.748	37430.00	L	0.72
CFSC4	47268.61	319.38	2.608	41340.00	L	0.87
CFSC5	44253.45	299.01	2.980	45370.00	L	1.03

Note: L – local buckling

Figure 2. The failure shape of CFSC1, CFSC2, CFSC3, CFSC4 and CFSC5 by using software THINWALL.

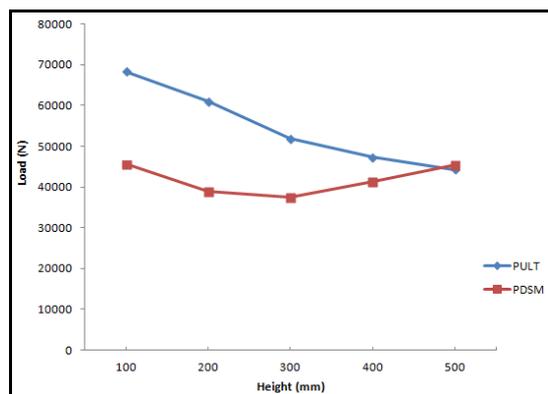**Figure 3.** The failure shape of CFSC1, CFSC2, CFSC3, CFSC4 and CFSC5 by experimental.

Figure 4. The relationship between the heights of the column with load of experimental and DSM.

4 Conclusions

A study of the CFSC stub column with different height of the column has been carried out and analysed in the paper. The verification of the experimental and standard also has been done to provide the reasonable data result. From the results, the following concluding statement can be drawn out:

1) From the experiment, the ultimate load and stress are calculated by depends on the height of the column. With an increment of the height of the column, the ultimate load of the experiment is reported decrease about 6 – 15 %. All samples of the column are reported to have the local buckling due to the slenderness ratio below 40 that classified as stub column.

2) The initial stiffness of CFSC1 and CFSC5 are noted 73199.65 N/mm and 29434.39 N/mm, respectively. Normally, the initial stiffness is depended on the height of the column.

3) All samples are noted approximately 0.60 to 1.03 of P_{DSM}/P_{ULT} when compared between the load of experimental and standard.

Further work should be done for varies of column length that classified as a stub, intermediate and slender column to produce the relationship in slenderness ratio and give a reference guide in design of compression member of cold-formed steel.

Acknowledgements

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