Compression Test on Cold-formed Steel Built-up Back-to-back Channels Stub Columns

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Abstract. Built-up sections are used to resist load induced in a structure when a single section is not sufficient to carry the design load for example roof trusses. In current North American Specification, the provision has been substantially taken from research in hot-rolled built-up members connected with bolts or welds [1]. The aim of this paper is to investigate on built-up back-to-back channels stub columns experimentally and theoretically using Effective Width Method and Direct Strength Method. Compression test was performed on 5 lipped channel and 5 back-to-back channels stub columns fabricated from cold-formed steel sheets of 1.2mm thicknesses. The test results indicated that local buckling is the dominant failure modes of stub columns. Therefore, Effective Width Method predicts the capacity of stub columns compared to Direct Strength Method. When compared to the average test results, results based on EWM are 5% higher while results based on DSM are 12% higher for stub column.

Introduction

Since 1850s, cold-formed steel has gradually become popular a structural building material. In Malaysia, the use of cold-formed steel in the construction industry is increasing, especially in the construction of roof trusses. In order to decrease weight and span over large area, built-up section is introduced. A built-up section can be made up of two single C-channels connected back-to-back using self drilling screws (Fig. 1). This type of section is relatively new. Moreover, existing design procedures in the specifications for built-up section are adopted from hot-rolled steel research. Thus, further research is mandatory. Research study presented in this paper focus on the compression test of cold-formed steel built-up back-to-back channels stub columns.

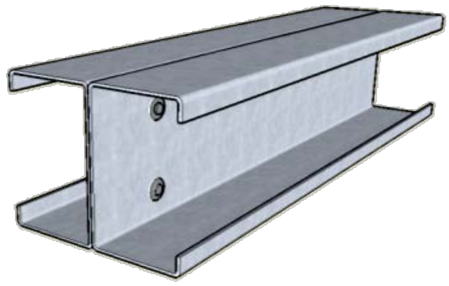

Fig. 1 Built-up Back-to-back Channels Section

Tensile Coupon Test

The material properties of the specimens were determined by tensile coupon tests. The coupons were cut from the centre of the web plate from the specimens that belong to the same batches as the column test specimens [1]. This is to ensure that the tensile coupons represent the material properties for tested column test specimens [2]. The coupon dimensions conformed to the

Australian Standard AS1391 (1991) for the tensile testing of metals using 12.5mm wide coupons of gauge length 50mm [3]. A data acquisition system was used to record the load and the readings of strain at regular intervals during the tests. Results are as shown in Table 1.

Table 1 Material Properties obtained from Tensile Coupon Test

Material Properties	Nominal	Coupon Test
Young's Modulus (GPa)	200	205
Yield Stress (MPa)	550	550.5

Compression Test

Specimens. Five built-up back-to-back channels stub columns were made up by connecting two single C-channels back-to-back at their webs. Dimensions of the specimens are tabulated in Table 2. Specimens were labeled with BU where "BU" refers to Built-up. Dimension of flange, thickness and length are also shown in the labeling with thickness denoted by "T" and length denoted by "L".

Table 2 Measured Dimensions of Back-to-back Channels Stub Columns

Specimen	Web, A' (mm)	Flange, B' (mm)	Lip, C' (mm)	Thickness, t (mm)	Radius, R (mm)	Length, L (mm)	Screw Spacing, s (mm)
BU75T12L250-1	76	18.0	9.5	1.2	1.5	252	49.5
BU75T12L250-2	76	18.0	9.5	1.2	1.5	250	49.5
BU75T12L250-3	75	18.5	9.0	1.2	1.5	253	50.0
BU75T12L250-4	75	18.5	9.0	1.2	1.5	252	50.3
BU75T12L250-5	75	18.0	9.5	1.2	1.5	250	50.0

Test Setup. Compression tests were conducted on 5 built-up back-to-back channels stub columns. Axial force was applied to the specimens via the GOTECH, GT-7001-LC60 600kN capacity Universal Testing Machine (UTM). The test rig and specimen setup is as shown in Fig. 1. 12.5mm thick plates were welded to the ends of the specimen to ensure a fixed rigid flat end. Load and shortening were recorded using the data acquisition software of the testing machine. Specimens were placed with their centroid at the marked loading point on the bottom bearing. Load cell at the top was then lowered until it touches the top end plate of the specimen. Level was used to check for the straightness of the specimen setup.

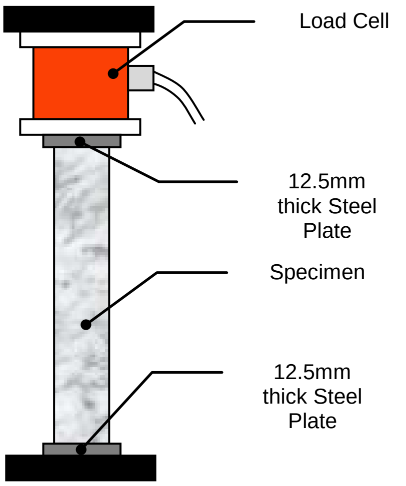

Fig. 2 Schematic Test Setup for Column Compression Test

Design Methods

North American Specification, NAS [1,4] and the Australia/New Zealand Standard design code (AS/NZS 4600) [5] adopts two design methods, namely Effective Width Method (EWM) and Direct Strength Method (DSM).

The effective width method (EWM) considers each element of a cross section individually in its calculation. This method uses reduced area (effective area), which involves tedious calculations, to account for the post-buckling effect of cold-formed steel members. A compression member can basically be divided into four types of elements, namely uniformly compressed stiffened elements, uniformly compressed stiffened elements with an edge stiffener, uniformly compressed unstiffened elements and uniformly compressed elements with multiple intermediate stiffeners. Depending on which type of element is being considered, the effective width (b_{eff}) calculation will be affected. The effective area is calculated by multiplying the effective width of each element to the thickness i.e. $A_e = b_{eff} \times t$ compressive capacity of cold-formed steel is then calculated by multiplying the effective area (A_e) with the nominal compressive stress (F_n) of the cold-formed steel [4].

A new method – Direct Strength Method (DSM) has been developed by Schafer and Pekoz [6]. To overcome some limitations in EWM, this method uses elastic buckling solutions and also takes into consideration of the interaction between elements. There are manual calculation and software (such as CUFSM, and THINWALL) available for calculating the elastic buckling solutions. However, one major drawback of the software is that it only predicts for pin-ended condition. In this study, fix-ended condition is investigated. Thus, manual calculations based on North American Specification are used to predict the member axial capacity (P_n). This method determines the strength for local (P_{crl}) and overall (P_{cre}) interaction and distortional (P_{crd}) and overall (P_{cre}) interaction and takes the lesser of the two as the strength (P_n).

Results & Discussion

Load Capacity. Table 3 compares the ultimate loads calculated using EWM and DSM to those obtained from the experiments. Results show that EWM predicts the load carrying capacity of stub columns better compare to DSM. The average ratio of P_{EWM}/P_{test} is 1.05 and P_{DSM}/P_{test} is 1.14. When compared to the average test results, results based on EWM are 5% higher while results based on DSM are 12% higher for stub column. EWM better predicts the stub column capacity because this method emphasize on the effectiveness of the elements of a cross section. Effectiveness of individual elements is important for stub columns because local buckling dominates the failure for stub columns. However, in DSM, distortional buckling and buckling interaction are the main consideration. These failure modes are significant in intermediate to slender columns but not in stub columns.

Table 3 Load Carrying Capacity of Back-to-back Channels Stub Columns

Specimen	P_{test} (kN)	P_{EWM} (kN)	P_{DSM} (kN)	P_{test} / P_{EWM}	P_{test} / P_{DSM}
BU75T12L250 – 1	122.50	115.89	106.65	1.06	1.15
BU75T12L250 – 2	118.50	115.93	106.68	1.02	1.11
BU75T12L250 – 3	121.90	115.86	106.60	1.05	1.14
BU75T12L250 – 4	121.80	115.87	106.60	1.05	1.14
BU75T12L250 – 5	125.50	115.82	106.73	1.08	1.18
Mean	122.04	115.87	106.65	1.05	1.14

Failure Modes. Failure of the specimens evolves from elastic to plastic to post buckling. From observation, buckling at web occurred as the initial buckling mode during elastic stage. Later, the tip of the flanges deflected inwards on one side and outwards on the other side when the load is close to the ultimate load. This occurs during plastic stage where the overall deformation increased rapidly. After reaching the peak, deflection in web and flanges increased and accompanied by a rapid drop in carrying capacity when the specimen failed. The failure of these stub columns resulted mainly from local buckling and significant distortional buckling only occurred when approached the ultimate load. Fig. 2 shows the failed shape of specimen.

BU75T12L250-1 BU75T12L250-2 BU75T12L250-3 BU75T12L250-4 BU75T12L250-5

Fig. 3 Failure Modes of Tested Specimens

Conclusion

Compression tests on 5 built-up back-to-back channels stub columns fabricated from high strength G550 steel has been performed. All stub columns fail in combined local and distortional buckling modes with local buckling as the dominant failure mode. It is observed that local buckling occurred before distortional buckling, and the ultimate load is usually achieved shortly after distortional buckling occurs. Comparing test and theoretical results, EWM from the North American Specification gives a better prediction than DSM.

Acknowledgement

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