Experimental Investigation on Flexural Behaviour with Cold-formed Steel Cut-Curved Channel

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Abstract. This paper investigates on flexural behaviour for cold-formed steel beam. Cold-formed steel is getting popular over the years in construction industry. However, due to its thin-walled behaviour, cold-formed steel is prompt to have buckling failure. Previous research were done to provide stiffener in order to overcome this problem. Furthermore, as addressed in this paper, curved section is introduced and studied to determine its behaviour compare to straight member in handling deformation. Both straight and curved cold-formed steel were tested under flexural with different length as the investigation variable. The results were analysed for comparison. Curved section of cold-formed steel behave differently in beam and column compared to straight section. Curved section has an advantage in reducing the deflection for structural members for flexural behaviour.

Introduction

Cold-formed steel structures have been used in industries for many years to fulfil various applications. In steel construction, there are two types of steel in term of fabrication, namely hot-rolled and cold-formed steel. Compare to hot-rolled steels, thinner cold-formed steels can be used for moderate loading and span. According to [1], cold-formed steel structures members are made by steel sheets, strip, plates, or flat bars in roll-forming machines or by press brake or bending brake operations in room temperature. The thickness of steel sheets used in cold-formed is usually 0.4 mm to 6.4 mm but steel plates and bars are as thick as 25 mm. Several research [2-5] have been carried out to investigate the flexural behaviour of straight cold-formed steel members.

With reference to [6], the idea of using its shape rather than thickness of the member to sustain loading from buildings. Cold-formed steel members offers many advantages including lightness, high strength and stiffness, mass production, fast and easy installation, transportation and assembling. Due to thinner member section, the larger corresponding value of second moment of inertia (I_{xx} and I_{yy}), it can withstand larger bending moment. The reduction of thickness of section indirectly reduce the weight. Hence, in mass manufacturing, it certainly produces economical material and reduces cost in transporting and erection.

Cold-formed steel section can be divided into stiffened and unstiffened element. Part of the section supported by webs along both its longitudinal edges is called a stiffened element. An unstiffened element is supported along one longitudinal edge only with the other parallel edge being free to displace. A wide section that is divided by intermediate stiffened at the web during rolling process producing two sub elements is an intermittently stiffened element. The elements are shown in Figure 1.

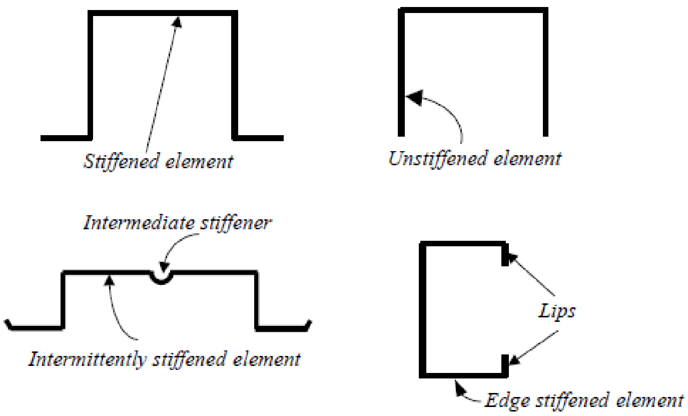

Figure 1: Stiffened and un-stiffened elements [7]

Theories on arch has been established given section only consist of solid rectangular, circular and diamond shape but for in cold-formed steel channel, arch is an innovation. Therefore, there is no specific formulas that indicate the deformation of curved cold-formed steel members. Straight members of cold-formed steel in a longer span used as a beam or column member will require bigger section to withstand bending moment and shear while reducing deflection of the member. Thus, it increases the construction cost. Construction management prioritize material cost and to save material cost, innovation leading to curved member of cold-formed steel has been introduced.

This paper investigates the flexural behaviour for cold-formed steel column and beam. The member length are 1000 mm, 1500 mm and 2000 mm for both compression and flexural behaviour. The deformed shape and deflection are recorded for further structural analysis.

Experimental Test

A total of 18 tests was carried out for both compression and flexural members. The details of the specimens are decribed in Table1. The experimental setup is shown in Figure 2.

Table 1: Details of the tested specimens

Specimen	Behaviour	Member	Length between Supports, mm
FS1000A FS1000B FS1000C		Straight	1000
FC1000A FC1000B FC1000C		Cut-curved	1000
FS1500A FS1500B FS1500C	Flexural	Straight	1500
FC1500A FC1500B FC1500C		Cut-curved	1500
FS2000A FS2000B FS2000C		Straight	2000
FC2000A FC2000B FC2000C		Cut-curved	2000

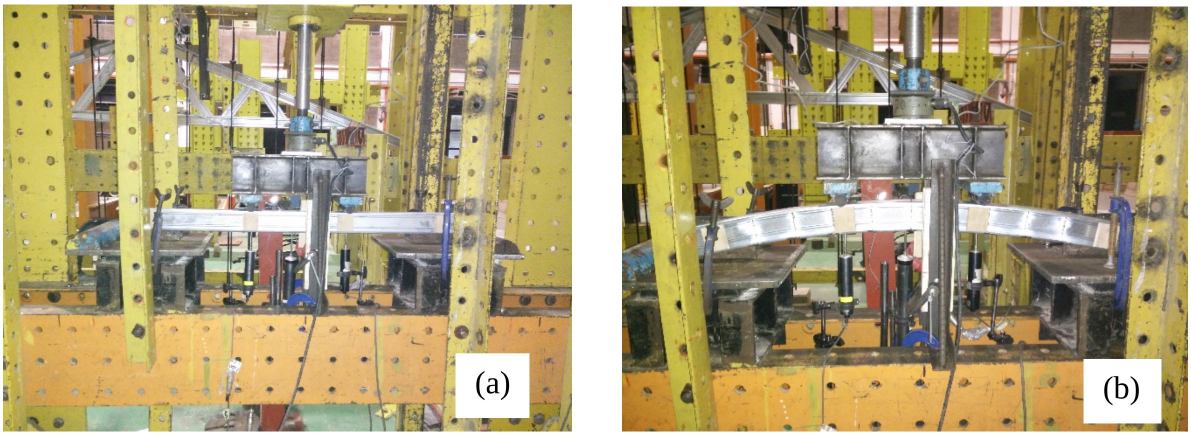

Figure 2: Flexural test setting up for (a) straight beam (b) curved beam

Results and Discussions

From Table 1, the failure mode for all of the samples were distortional buckling after it achieved ultimate load. Samples were restrained laterally to allow pure bending failure. The failure modes are shown in Figure 3 for straight member and Figure 4 for cut-curved member.


Figure 3: Distortional buckling of straight beam


Figure 4: Distortional buckling of curved beam

The flexural of straight section and cut-curving section beam were tested and the results are shown in Table 1. From the table, percentage different of ultimate load between FS1000 with FC1000 was noted of 7.69 %. The ultimate load was increased about 7.41 % when compared between FS1500 with FC1500 and 13.96 % when compared between FS2000 with FC2000. FC1500 was subjected the highest ultimate moment while FS1000 was the lowest. The percentage different between straight and cut-curved sections are still reasonable and below 50 % or half of the ultimate load of straight section. When comparing samples of all length, the highest percentage difference was recorded of samples FS1000 and FS1500 which was 26.39 % and the lowest percentage difference was between sample FS1000 and FC1500 which was only 3.08 %.

Table 1: The experimental results for flexural test

Specimen	Specimen label	Average Ultimate Load (kN)	Average Ultimate Moment (kNm)	Percentage Difference of S-C (%)	Failure shape
FS1000	N1	7.20	1.2	7.69	D
FC1000	C1	7.80	1.51		D
FS1500	N15	7.00	1.75	7.41	D
FC1500	C15	7.56	2.5		D
FS2000	N2	5.30	1.77	13.96	D
FC2000	C2	6.16	2.24		D

Note: D is the failure mode of distortional buckling

According the Figure 5, FC1000 sustain the highest load at the least deformation while FC2000 achieve ultimate load at the largest deformation. Curved beams of same length has proven higher load sustain with shorter deformation as compared to the straight beams.

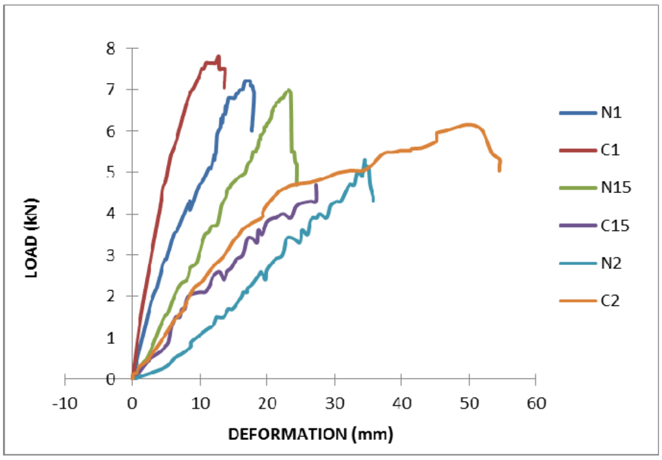

Figure 5: Load versus deformation of web

Based on Figure 6, the load and deformation for normal and curved samples are linearly proportional. The ultimate load of curved section between lengths of 1000 mm to 2000 mm is always higher than the ultimate load of normal sections. This shows that curved beam are stiffer compare to straight beams.

The results showed that curved beam can sustain a higher load as compared to straight beams. Curved beams also deform less than straight beams when subjected to ultimate load. As for the difference of length variable, shorter beam can withstand higher load compare to the longer beam regardless of curved or straight beams. Cut-curved sections proved to be a better selection in terms of reducing the deformation when subjected to load.

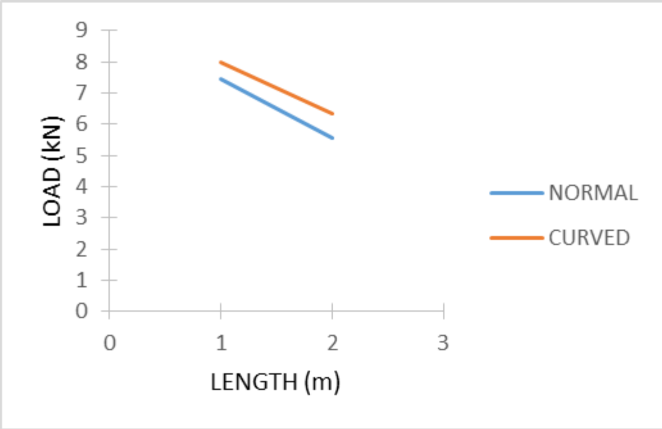

Figure 6: Comparison between ultimate load and length of samples.

Conclusion

The study on flexural behaviour of cut-curved and straight members were carried out for 1000 mm, 1500 mm and 2000 mm length of beam using cold-formed steel channel sections. The maximum deflection of curved sections for compression test when subjected to ultimate load is 12.86 mm at the web. The maximum deflection of curved sections for flexural test when subjected to ultimate load is 49.87 mm at the middle flange by length of 2.0 m. The failure mode for curved section CFS for compressive test is global buckling and twisting while for flexural test is twisting.

For compression test, normal section can sustain higher ultimate load compare to curved section but curved section deform less than normal section. The highest percentage differences in ultimate load is 38.0 % for length variable of 2.0 m. For flexural test, curved section can sustain higher ultimate load and deform less compare to the normal section. The highest percentage differences in load ultimate load is 13.96 % for length variable of 2.0 m.

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