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Influences of Yield Strength and Section Depth to the Compression **Capacity of Single Cold-Formed Channel Lipped**

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ABSTRACT

This paper presents a parametric study on single cold-formed channel lipped section subject to axial compression load. The aim of this study is to investigate the influences of yield strength and depth of the section towards the compression capacity of a thin channel section. The study started with the calculation of effective area of a channel section followed by the calculation of compression capacity in accordance to BS EN 1993-1-1. The capacity of the section is then checked with experimental results for validation purpose. Parametric study is conducted to investigate the relationship between the yield strength, section depth and compression capacity. It is concluded that increment in yield strength tend to reduce the effective area of a thin channel section. On the other hand, the increment in section depth has a very little influence to the effective area of a cold-formed channel lipped section.

Keywords: cold-formed steel section; channel lipped section; compression capacity; effective area; slender section

1. INTRODUCTION

Cold-formed steel section is categorized as lightweight material that is widely used in construction. The sections are usually rolled from pre-galvanized steel coil that is relatively thin (ranging from 0.9 to 3.2mm) and high strength (ranging from 300 to 550MPa) as compared to hotrolled steel section [5]. The cold-formed steel is usually coated with a layer of Z275 zinc to provide corrosion protection [7]. The sections used in light steel framing are typically C- or Z- shape sections. The sections are joined using bolting, self-drilling or self-tapping screws, rivets, clinching or press joining. The main advantages of cold formed steel sections in construction industry are the high strength to weight ratio, flexibility in internal planning, speeding construction on site, ease of transportation and handling, dimensionally accurate and reliable structural properties [4]. In Malaysia, the structural use of cold-formed steel section were limited to the roof truss and purlin structures. However, the application of cold-formed steel section as beam and column structural members are still not popular.

The structural design of cold-formed steel sections is currently covered by the provisions of BS EN 1993-1-1 [1] with reference to BS EN 1993-1-3 [2] and BS EN 1993-1-5 [3]. The principle design requirements given in the code mainly concern about the effective section properties, design of members in compression or tension, design of members in bending, design of members subject to combined compression and bending, and web crushing due to local point loads [6]. Since coldformed sections are thin walled members, thus these members are also classified as slender section in accordance to BS EN 1993-1-1. Therefore, it is important to determine the effective section properties of a slender section before the design process commence.

This paper investigate the relationship between yield strength, section depth and compression capacity of a single cold-formed channel lipped section. It is worth mentioning that yield strength and section depth are the components to be used in the calculation of effective section properties. Thus the aim of this study is to investigate the influences of yield strength and section depth towards the compression capacity. The effective area of the section is calculated in accordance to BS EN 1993-1-3 [2] with reference to BS EN 1993-1-5 [3]. Based on the effective area of the section, the compression capacity of the section is then calculated in accordance to BS EN 1993-1-1 [1]. The calculated compression capacity is then compared to a series of experimental results for

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validation purpose. Lastly, the parametric study is carried out by changing the yield strength or the depth of the section to compare the changes in terms of compression capacity.

2. THEORETICAL PREDICTION OF COMPRESSION CAPACITY

In BS EN 1993-1-1[1], the compression capacity of a member is checked for both cross section resistance and buckling resistance. For Class 4 slender section, the equation for cross-section resistance is given by:

$$\mathbf{N}_{c,Rd} = \frac{\mathbf{A}_{eff} f_{y}}{(\gamma_{MO})} \tag{1}$$

while the equation for buckling resistance is given by:

$$N_{b,Rd} = \chi \frac{A_{eff} f_y}{(\gamma_{M1})}$$
(2)

where A_{eff} is the effective cross sectional area; f_y is the yield strength of the material; γ_{M0} and γ_{M1} is the partial safety factor (taken as 1.0); and χ is the reduction factor. Both N_{c,Rd} and N_{b,Rd} will be calculated and the smaller of these two values will be taken as the compression capacity of the member. An excel spreadsheet has been developed to calculate the effective area of the section and compression capacity in order to carry out the parametric study.

3. VALIDATION WITH EXPERIMENTAL RESULTS

A series of experimental tests has been conducted to investigate the capacity of a single cold-formed channel lipped section subject to axial compression load. A total of 6 specimens have been tested in this study with two different cross section and the length of the section is 1m. Two types of cross section have been used in this study, which is 75W10 and 125W16. The dimension of the section is shown in Figure 1. A compression force is applied to the specimen using a 250kN capacity Universal Testing Machine. The setup of the testing is shown in Figure 2.



Figure 1: Typical Cross Section of Cold-formed channel lipped section

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Figure 2: Experimental setup for compression test

A constant rate of 0.2kN/s is applied to the specimen until the failure has occurred. The maximum applied force and the corresponding stroke are then recorded for comparison purpose. In order to obtain the actual material properties of the test sample, coupon test has been conducted to obtain the actual yield strength and tensile strength. Comparison between the theoretical predictions and experimental results are shown in Table 1.

Specimen No	Description	Experimental Compression Capacity, N _{b,exp} (kN)	Theoretical Compression Capacity, N _{b,theory} (kN)	Ratio of $\frac{N_{b,exp}}{N_{b,theory}}$
S1	75W10 Base metal thickness = 1.11mm (average value) Yield strength = 513.72 N/mm ² (average value)	24.28	22.20	1.09
S2		21.75		0.98
S 3		25.12		1.13
S4	125W16 Base metal thickness = 1.64mm (average value) Yield strength = 287.20 N/mm ² (average value)	48.06	37.39	1.29
S5		51.06		1.37
\$6		52.50		1.40

Table 1 Comparison between Experimental Results and theoretical predictions

It is shown that the experimental results are higher than the theoretical predictions with a ratio of difference ranging from 0.98 to 1.40, which indicated that good agreement has been achieved between theoretical and experimental results.

4. RELATIONSHIPS BETWEEN YIELD STRENGTH, DEPTH AND COMPRESSION CAPACITY

A parametric study has been conducted to investigate the relationship between yield strength, f_y , section depth, h and compression capacity, N_{Rd}. The range of the study is between 250N/mm² to 800N/mm² for yield strength and for section depth is between 75mm to 375mm. For the comparison of yield strength, the depth of the section is fixed to 150mm while for the comparison of section depth the yield strength is fixed to 350N/mm². The comparison between yield strength and compression capacity is shown in Figure 3 and the comparison between section depth and compression capacity is shown in Figure 4.



Figure 3: Relationship between Yield Strength and Compression Capacity



Figure 4: Relationship between Section Depth and Compression Capacity

From Figure 3, it is shown that the compression capacity of the cold-formed steel section increases proportionate to the yield strength of the steel structure. It is observed that the increment from 250N/mm² to 600 N/mm² shows a steep increment in compression capacity as compared to the yield strength ranging from 600N/mm² to 800N/mm². Based on the calculation, higher yield strength tend to provide a high reduction factor in the calculation for effective area, which the

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effective area of a channel section subject to compression forces reduced with the increment of yield strength. From Figure 4, it is observed that the compression capacity increases with the increment of the section depth. However, when the section depth go beyond 225mm the compression capacity starts to reduce.

It is due to higher reduction factor in the calculation of effective area, where the effective depth of the section is much lesser than its original length. In general, both yield strength and section depth contribute to the calculation of effective area of a section. At 600N/mm², the yield strength of the material will not contribute much to the compression capacity of a member due to the reduction in effective area. While for a depth of more than 225mm, the increment in depth is no longer economical in resisting compression force. Further studies and research is needed to obtain the optimum configuration between yield strength, section depth and compression capacity.

5. CONCLUSIONS

Based on the findings, several conclusions can be drawn from the studies:

- I. EN1993-1-1 is suitable to predict the compression capacity of a single channel lipped section. The comparison between experimental results and theoretical predictions is in the range of 0.98 to 1.40.
- II. The increment in yield strength will increase the compression capacity of a channel section. Further increment in yield strength more than 600N/mm² will not contribute much to the compression capacity due to the reduction in effective area.
- III. The increment in section depth will increase the compression capacity of a channel section. Further increment in depth more than 225mm is not economical and tend to reduce the effective area of a section.

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