Behaviour of Cold-formed Steel Back-to-Back Channel Built-Up Sections under Bending

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Abstract. Cold-formed steel (CFS) structures have been widely constructed as main elements in light structures. In terms of increasing capacity, the built-up sections of cold-formed steel are used regarding larger span structure. In this study, nine cold-formed steel with back-to-back built-up section specimens with various thicknesses were experimentally investigated under three points bending scheme to obtain their capacity and failure type. Each specimen was assembled by using self-drilling screws in web of two built-up channels. Experimental results show that three various web thicknesses (1.3 mm, 1.5 mm, and 2.00 mm) in cold-formed steel of built-up section give the different moment capacity up to 22%. Then, failure types in all specimens are similar where local buckling is generated in compression flange around loading area and lateral-torsional buckling occurred along span. It is found that web thicknesses in back-to-back section have contribution to increase the stiffness and torsional rigidity. However, there is phenomenon when the load capacity decreased, the back-to-back sections act non-composite. Then, the failure apparently observed on that section is one-side twisting and web crippling in mid-span.

1. Introduction

The application of cold-formed steel (CFS) structures for residential and commercial buildings has been widely developed as main structures that accommodate the internal forces. Furthermore, built-up sections of cold-formed steel are used to uplift its capacity in torsional, compression, and tension. Besides that, connecting two sections is easily made by using self-tapping screws. Built-up sections are always used as compression members. Compared to a single section of cold-formed steel, the rigidity and capacity of built-up sections have been proven increased about 20%-50%[1,2,6], one is back-to-back channel sections. These sections were categorized as open sections which are assembled by connecting both webs. There were studies that revealed back-to-back sections are used as the members for long-span roof truss and many parameters govern their axial capacities and rigidity, including fasteners [2].

However, there is an issue concerning the built-up back to back channel sections when they are designed as flexural member. Most of cold-formed steel sections, which are subjected to bending, experience local and lateral-torsional buckling. These buckling dominantly happened due to beam span and web depth to flange width (d/b) ratio [3,4,5]. In Indonesia, the provision (SNI 7971:2013) consist of moment capacity calculation for double sections but it is not giving the specific equation relate to the failure type parameters for back-to-back instead of providing correction by case. It can be concluded that there is still little comprehension in terms of determining flexural capacity of back-to-
back sections. On the other hand, back-to-back sections are futuristic to be developed as the main structure specifically as flexural member [7].

In order to understand the structural behavior of cold-formed steel with back-to-back channel built-up sections under bending, this paper was presented. Furthermore, this study is focused to investigate the flexural capacity and the failure that shown along the beam specimens by doing experimental in three point bending scheme. The results of specimen with several thicknesses which are commercially used as common structures in residential buildings are shown and discussed.

2. Materials and methods

2.1 Test Specimens

The experiment is conducted by testing 9 specimens of back-to-back channel sections which have various thicknesses, each section has 3 specimens. Generally, the cold-formed steel profiles used in this test are single-channel section C 75.75, C 75.80, C 75.100 which has thickness respectively 0.75 mm, 0.80 mm, and 1.00 mm; the sections are shown in figure 1. Then, these sections were assembled by using screws in web; the details of specimen are shown in table 1. The abbreviation of BJR mentions about the specimen which has the same properties of material. Each specimen was tested by simply-supported beam with nominal length 65 cm and load scheme is three points bending.

![Figure 1. Section of Specimen](image)

| Specimen  | Lip, b_l (mm) | Flange, b_f (mm) | Web Depth, h_w (mm) | Thickness, t (mm) | Web Thickness, t* (mm) |
|-----------|---------------|-----------------|--------------------|------------------|----------------------|
| BJR-1-65  | 3.0           | 32              | 75                 | 0.65             | 1.3                  |
| BJR-2-65  | 3.0           | 32              | 75                 | 0.65             | 1.3                  |
| BJR-3-65  | 3.0           | 32              | 75                 | 0.65             | 1.3                  |
| BJR-1-75  | 3.70          | 35              | 75                 | 0.75             | 1.5                  |
| BJR-2-75  | 3.70          | 35              | 75                 | 0.75             | 1.5                  |
| BJR-3-75  | 3.70          | 35              | 75                 | 0.75             | 1.5                  |
| BJR-1-100 | 3.50          | 36              | 75                 | 1.00             | 2.00                 |
| BJR-2-100 | 3.50          | 36              | 75                 | 1.00             | 2.00                 |
| BJR-3-100 | 3.50          | 36              | 75                 | 1.00             | 2.00                 |

2.2 Experimental Set Up

The bending tests were conducted by universal testing machine (UTM) to investigate the moment capacity and the failure modes of cold-formed steel back-to-back channel built-up section beams. The three-point bending tests were loaded at the mid-span to the load transfer plate through round bar, as shown in figure 2 and figure 3. The result would be generated automatically through computer so as the load-vertical displacement curve will be obtained for all specimens.
3. Results and discussion

3.1 Experimental Results

The graph of load-deflection which is generated from UTM was obtained and shown in figure 4. Generally, the graph shows that each specimen has slightly different stiffness for every thickness. The
cold-formed steel built-up section with web thickness \((t^*) = 2.00\) mm (BJR-100) has the highest stiffness value compared to others. Moreover, these specimens have the highest load capacity. Moment capacity of these built-up sections is calculated by the simple formula for moment calculation in simple beam subjected one middle-point load and they are shown in table 2. It can be seen that the experimental moment capacity for specimen BJR-100 is higher than BJR-65 and BJR-75 about 21.9 % and 10.7 % respectively. Furthermore, the failure mode is observed having similar type for these specimens, local buckling and lateral torsional buckling.

### Table 2. Experimental Moment Capacity and Failure Mode.

| Specimen     | \(M_{\text{Exp}}\) (kN.m) | \(\text{Avg} \ M_{\text{Exp}}\) | Failure Mode |
|--------------|---------------------------|-------------------------------|--------------|
| BJR-1-65     | 0.468                     |                               | L+ LTB       |
| BJR-2-65     | 0.488                     |                               | L+ LTB       |
| BJR-3-65     | 0.455                     |                               | L+ LTB       |
| BJR-1-75     | 0.539                     |                               | L+ LTB       |
| BJR-2-75     | 0.536                     | 0.537                         | L+ LTB       |
| BJR-3-75     | 0.536                     |                               | L+ LTB       |
| BJR-1-100    | 0.598                     |                               | L+ LTB       |
| BJR-2-100    | 0.604                     | 0.602                         | L+ LTB       |
| BJR-3-100    | 0.604                     |                               | L+ LTB       |

L: Local Buckling LTB: Lateral Torsional Buckling

3.2 **Local Buckling**

Local buckling failure in built-up specimen BJR-75 can be seen in figure 5(a). Apparently, the local buckling generated in compression flange due to load concentration around that area. However, the local buckling exactly happened when inelastic zone is reached, it is shown in figure 5(b). The other specimens have the similar phenomenon when local buckling is generating in compression flange. It can be stated that thickness (0.65 mm, 0.75 mm, and 1.00 mm) in each specimen contribute to increase the rigidity in compression flange before local buckling is generated.

![Local Buckling in Compression Flange](image)

**Figure 5.** (a) Local Buckling in Compression Flange of BJR-75 (b) Local Buckling Point

3.3 **Lateral-Torsional Buckling**

Lateral-torsional buckling is the common phenomenon that happens in cold-formed steel due to thin web. Figure 6(a) shows that the lateral-torsional buckling failure generated along the span. It also confirms that all specimens have similar pattern in terms of lateral deflection and twisting in anti-clockwise. However, the load capacity of these built-up sections still gradually increases until it reach the ultimate load capacity. Increasing thickness whether at web or at compression flange apparently
leads higher torsional rigidity and it may cause reduce the angle of twist before it continues increasing the deflection after ultimate load capacity is reached.

![Image](a)

**Figure 6.** (a) Lateral-Torsional Buckling along Span (b) Ultimate Load Capacity

![Image](b)

**Figure 7.** Failure after Ultimate Load Capacity

In figure 6 (b) shows that the load starts to decrease while the back-to-back sections start to act non-composite. It is observed in figure 7 that the continuous failure due to twisting happens in just
only one side section. Then, when the deflection continues to increase, the web in mid-span generate the crippling failure.

4. Conclusions
This research aimed to comprehend the bending behavior of cold-formed steel of back-to-back built-up section with various web thicknesses. Based on the experimental results, there are conclusions can be listed as follows if there is the development in terms of bending capacity:

1. Increasing web thickness in cold-formed steel of back-to-back built up sections will increase the moment capacity about 10%-20%.
2. The observed failures for all specimens are local buckling and lateral torsional buckling.
3. Effects of web thickness in all specimens are increasing the stiffness, compression flange and torsional rigidity as long as local buckling and lateral torsional buckling is generated along section and span.

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