Compression test analysis of cold-formed column in channel profile connection

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Abstract. This study analyzes the load capacity of the cold-formed steel column frame structure for multilevel buildings to withstand axial loads. The column frame structure will be modeled, analyzed and tested. In this paper, the study is about a cold-formed channel profile that is compressed. The research objectives are to determine (1) stress and strain, (2) damage patterns, and (3) research development. The test object is modeled by using finite element method with a scale of 1:1 and the loading used is linear static loading. The simulation with finite element method uses atrial and error method by entering the obtained parameters. The draft and design of channel profiles used in cold-formed steel material refers to several guidelines including SNI-7971-2013 on Cold Formed Steel Structures.

1. Introduction
Cold-formed steel havean advantages in production process which is easier to produce and also environmentally friendly because it does not produce waste that is harmful to environment. In the production process, steel are formed in such a way at a room temperature by a process of bending brakes, press brakes, and roll-forming machines. With cold formed method, the desired cross-section profile could be produced economically so that an increase in the ratio of strength to weight could be obtained [9]. According to [5], cold-formed steel has excellency in strength and stiffness that is quite high in value, does not shrink and expand easily when affected by weather, easy in fabrication and production, uniform in quality, non-flammable, more accurate in detailing, anti-termite and environmental friendly material, could be recycled, and have a high structural lifetime.

Research on light steel has improved greatly indetermining the right analysis and design. However the focus of attention when designing light steel are the ability to carry a compressive load that is buckling factor. Buckling is a phenomenon in construction materials, especially in structures that have a large slenderness ratio and a thin cross-section thickness. Buckling is a structural failure where the cross-section changes shape when or before the structure reaches its melting capacity. There are two types of buckling that often occurs in light steel and it is called local buckling and global buckling whereas one of the factors that made it happen is the geometry or cross-section of profile. According to [7] local buckling is a failure that often occurs in light steel compressed elements even when the light steel are given stiffener.

Some form and shape of cross-section of light steel that is available in the market are channel sections and box sections with varying sizes and needs for construction use. Channel shape is often used in the structural frame. According to [6] the same channel profile has different pressure capacities and bending behaviors. This is due to the modification of some of these channel profiles. Furthermore, according to [4] the pressure capacity calculated by the direct approach of a double channel cross section has
overestimate differences but it is still conservative when used. Of course, based on the theory that has been explained before, the cross sections provide different pressure capacities and behaviors. Analytically, the compressive capacity of a light steel section can be calculated based on SNI 7971: 2013 article 3.4. However, in essence the calculation of the critical buckling stress is not fully in accordance with the design requirements. Many parameters are in need to be found first for a more conservative calculation approach.

Based on the introduction above, it is necessary to carry out a finite element analysis. The analysis of light steel are pressure test to obtain the pressure behavior of several cross-sections of light steel by calculating the pressure capacity of cold-formed steel based on SNI 7971: 2013. The light steel profile that are tested is the C channel profile available on the market. The profile will be connected to a double channel back to back and a box using screws. This test uses a universal testing machine. Thus, the results of this study can be used as parameters for designing a lightweight steel structures, especially pressure elements.

2. Methodology

This study analyze the load capacity of the cold-formed steel column frame structure for multi level buildings to withstand axial loads. The column frame structure will be modeled, analyzed and tested experimentally using one type of test object. The test specimens consist of cold-formed canal profiles are tested in pressure test. This research objectives are to determine the stress and strain, to determine the damage pattern, and to find out the development in research. The test object is modeled using finite element method with a scale of 1: 1 and the loading used is linear static loading. Simulation with finite element method uses a trial and error method by inputting the parameters that are obtained. The draft and design of cannel profiles using cold-formed steel material refers to several guidelines including SNI-7971-2013 on Cold-formed Steel Structures, [9] on Cold-Formed Steel Design.

2.1. Modeling of test object

The Cold-formed steel used is consisting of a single channel profile joint (T1). The model will be given a load according to the results of the finite element method preliminary calculation.
The following is a specification of the cold-formed C cannel profile that will be used as a test object, as follows:

- Name: Truss C75.80 SNI
- Thickness: 0.8 mm
- Length: 6 m
- Material: Cold-Formed Steel

2.2. Joint tool
The joint tool used are self driving screw bolt with a type of 12-14 x 20. Here are the specifications:

2.3. Data processing
Data that is obtained includes:
- Strain & Tension/Stress, to find out the capacity of the C channel profile according to the modeling. It could be applied to pressure and pull tests.
- Damage pattern on channel profile C, to find out how much damage has occurred

2.4. Structural modeling
After obtaining the data, the next step is making structural model. Structure modeling are done by using finite element method. Structures being modeled according to building structure data, material specifications, and structural element data used. Structural modeling is made into 2 models namely face-to-face press and opposite press. Both models are made with channel profiles. Structure modeling figure as follows:
3. Results and Discussions

3.1. Stress/Tension and Strain Analysis in finite element method
Structural modeling drawings were made into 2 models namely face-to-face press and opposite press afterward they are analyzed to find out the yield stress and ultimate stress and how strong it is to be used as a channel profile connection.

![Figure 4. Structure modeling using finite element method](image)

![Figure 5. (a) Modeling of opposite press and (b) face-to-face press](image)

The following are the graphic results of channel profiles modeling with opposite press and face-to-face press.

![Figure 6. Opposite pressure tension graph](image)
From Figure 6, above it can be explained that the yield stress at this channel profile connection is 45.06 N/mm$^2$ and for the ultimate range is 84.31 N/mm$^2$. Test object experienced an increase and decrease in stress averaging of 26.57 N/mm$^2$, with a compressive load of 100 N. The strain on the object was obtained from the result comparison of the final length increase of 80.82 mm with an initial length of 300 mm so the strain value result are 26%.

![Face-to-face pressure tension](image)

**Figure 7.** Face-to-face pressure tension

From the figure 7, above it can be explained that the yield stress at this channel profile connection is 31.64 N/mm$^2$ and for the ultimate range is 66.36 N/mm$^2$. Test object experienced an increase and decrease in stress averaging of 26.73 N/ mm$^2$, with a compressive load of 100 N. The strain on the test object was obtained from the result comparison of the final length increase of 53.30 mm with an initial length of 300 mm so the strain value result are 18%.

3.2. **Damage Pattern**

The damage pattern of the test object analyzed by finite element method occur a buckling factor. The weakness of cold-formed steel structures is local buckling due to it’s thin cross-section elements. This causes structural failure to occur before reaching the highest load capacity. To reduce the likelihood of local buckling of cold-formed steel press structure components, a structured cross-section is used [7].

The following is a picture of damage pattern in the compressed face-to-face modeling which occurs a local buckling. Local buckling happen because of the large slenderness ratio of the cross-section element, so that the compressive stem capacity is determined from the bending of the element (local buckling) first and not from the global bending of the compressive stem.
For the joint in face-to-face pressure in Figure 8. When the ultimate loads are reached, the local buckling begins to occur in the wing side on the right and left. The wing side also began to deform towards the front, because the front wing was cut off. When the loads are increasing, bending begins to occur at the bottom of the sample and is followed by bending toward the inside of the wing. Increase in strength occurs due to increased stiffness in the part that has experienced bending. By the time the shortening reaches the displacement limit of 20 mm, the wing has been torn.

![Figure 8. Damage pattern on face-to-face press](image)

For the opposite join press in figure 9. When the ultimate loads are reached, local buckling begins to occur in the middle outer wing on the right side. When the loads are increasing, the wing on the lower side begins to bend and the outer wing begins to look wider. Increase in strength occurs due to the resistance of the screw. By the time the shortening reaches the displacement limit of 20 mm, the underside of the lightweight steel wing has experienced a huge buckling widening and the screw part has failed.

Every test object failure (face-to-face press and opposite press models) happen because a local buckling in the channel profile. This is caused by the changes in stress due to changes in channel cross-sectional area. finite element method analysis used are buckling analysis, with the assumption of using
elastic material so that the critical load obtained is far greater than the failure load obtained from experimental studies. Even so, the finite element method results show the same tendency.

4. Conclusion
It can be concluded that the modeling of opposite pressure channel profiles has an ultimate stress/tension of 84.31 N/mm² which is greater than that of the compressed channel profile face-to-face models which has an ultimate stress/tension of 66.36 N/mm². So a suitable connection for channel profile modeling is the opposite pressure which is strong enough to hold the load and has a high ultimate stress.

In the damage pattern of the opposite pressure channel profile and face-to-face pressure, there occurs a buckling factor. In both models there has been a local buckling due to the large slenderness ratio of the cross-section element, so that the compressive stem capacity is determined from the bending of the element (local buckling) first and not from the global bending of the compressive rod.

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Acknowledgement
This work was supported by PNBP research grant of Universitas Negeri Malang.