Tensile test analysis of cold-formed column in channel profile

A A Aziz¹, N Nindyawati¹ and K Karyadi¹
¹Department of Civil Engineering, State University of Malang, Indonesia

nindyawati.ft@um.ac.id

Abstract. This study analyzes the joint capacity of cold-rolled steel frame structure for multi-level buildings to withstand axial loads. The column frame joint structures will be modeled, analyzed and tested. In this paper, the study is about cold-formed channel profile that will be tensile tested with 2 variations of the joint. The research objectives are (1) to determine the stress and strain, (2) the damage pattern. The test object is modeled using FEM with a scale of 1: 1 and the loading used is linear static loading. Simulation with FEM use a trial and error method by entering the parameters obtained. The draft and design of channel profiles using cold rolled steel material refers to several guidelines including SNI-7971-2013 on Cold Formed Steel Structures.

1. Introduction
Cold Formed steel is a structural component made of steel sheets that is processed with certain profile shapes using press-braking or roll forming processes. Cold-formed steel or also called as cold-formed because it does not require high temperatures in the manufacturing process as it does in making hot rolled steel. In general, cold-formed steel is a component that is lightweight, thin, easy to work on compared to hot-rolled steel [1].

The advantages of cold-formed steel are found in the production process which is easier and environmentally friendly because it does not produce waste that is harmful to the environment. In the production process, steel is formed in such a way at room temperature by using bending brakes, press brakes, and roll-forming machines. With cold-formed method, the desired profile cross section can be produced economically so that an increase in the ratio of strength to weight can be obtained [2]. According to cold-rolled 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 [3].

Tensile testing is used to determine the thermal and mechanical properties of an object that is deforming as material. Tensile testing is testing an object so that its strength can be known by pulling on both sides of the object tip slowly until it breaks. The material strength is when the material receives a stress/tension but does not experience a friction, so that the tensile strength and the compressive strength of the tested specimen can be determined. The test process is that the object is given a load so that it experiences stress strain and the extension of the material increases [4].

In tensile test, the results of the steel stress are given a symbol (σ) and strain with (ɛ) with the following formula: Stress/tension is also called the ratio of tensile loads acting against the cross-sectional area.
Tensile stress formula:

\[ \sigma = \frac{F}{A} \]

\( \sigma \) = Tensile stress (MPa)

\( F \) = Pull Load (kN)

\( A \) = Initial Cross-sectional Area (mm)

Strain is a change in the shape of a material after it is broken so that the material rod occurs an extension. To get the strain value, the final length minus the initial length of the test object then it is divided by the initial length.

\[ \varepsilon = \frac{L_f - L_o}{L_o} \times 100 \]

\( \varepsilon \) = Strain (%)

\( L_o \) = Initial length (mm)

\( L_f \) = Final Length (mm).

2. Methodology

This study analyzes the tensile strength of the joints due to the effect of the joint shape on the column frame. The type of joint is varied into 2 parts, face-to-face and opposite joint. The study was conducted by modeling and analyzing joint using Finite Element Method (FEM)-based software. The purpose of this study is to obtain the tensile strength that occurs in each type of joint, determining the pattern damage of joint, determining the appropriate type of joint for the column frame. The test object is modeled with a scale of 1:1 and the loading used is linear static loading. Simulation with FEM software uses a trial and error method by entering the parameters obtained. The draft and design of channel profiles using cold-formed steel material refers to several guidelines including SNI-7971-2013 on Cold-Formed Steel Structures.

![Figure 1. (a) Face-to-face (b) Opposite](image)

The modeling of test object in FEM software is adjusted to the profiles of cold-rolled steel used in experimental tests. Joint variations are varied into face-to-face (Type A) and opposite (Type B). The mechanical properties of cold-formed in modulus of elasticity are 200000 MPa the, the cold-formed steel melt stress value (Fy) extends from 165 MPa to 552 MPa [2], in this modeling the melting tension/stress is set at 550 MPa.

The restrain used are fixed support on the lower section of the joint and is loaded evenly on the top end of the connection with a total load of 100 kg as shown below.
The following is a specification of the cold-formed C channel profile that will be used as a test object, as follows [5]:

Name: Truss C75.75
Thickness: 0.75 mm
Joint tool: Self driving screw type 12-14 x 20
Steel Grade: G 550 (fy = 0.9 x 550 MPa).

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

| Nominal Size or Basic Screw Diameter | Threads Per Inch | T | I | P |
|-------------------------------------|------------------|---|---|---|
| 12                                  | 0.2150           | 14| 0.215 | 0.209 | 0.164 | 0.157 |

Data Processing

Data that is obtained includes:

- Strain & Stress, to find out the capacity of the C channel profile according to the modeling.
- Damage pattern on channel profile C.
Structural Modeling

After obtaining the data, the next step is making structural model. Structure modeling are done by using FEM, being modeled according to building structure data, material specifications, and structural element data used. Structure modeling are made into 2 type of model that is joint type A and type B. Structure modeling figure are as follow:

Figure 5. Structure modeling using FEM

3. Results and discussions

Modeling are done by simplifying the model using a vertical and transverse channel profiles then analyzed by using FEM

3.1. The results of strain-stress that occur in the screw joint area can be seen in the following tables and graphs:

| Table 2. Stress and strain result type-A joint |
|-----------------------------------------------|
| Stress (MPa) | Strain |
| 0           | 0      |
| 316,86      | 15,66  |
| 316,86      | 16,61  |
| 313,53      | 31,31  |
| 162,24      | 32,33  |
| 208,67      | 33,74  |
| 135,14      | 34,68  |
| 77,10       | 48,43  |
| 77,24       | 49,33  |
| 50,34       | 50,09  |
| 50,37       | 50,96  |

Figure 6. Type-A joint strain-stress graph
From the graph above it can be explained that the melting stress at the joint profile of type A channel is 316.86 MPa. The stress that occurs in type A joint move linearly toward its melting limit then slowly stretches to 313.53 MPa which then decreases where the joint has begun to experience damage and losing its strength. The strain on the test object are obtained from the result of the increase in the final length of 50.96 mm from the initial length of 300 mm, so that the strain obtained is 16.98%.

Table 3. Stress and strain result type-B joint

| Stress (MPa) | Strain (mm) |
|-------------|-------------|
| -1.02       | 0.00        |
| 0.01        | 25.39       |
| 3.24        | 48.99       |
| 25.77       | 74.33       |
| -0.40       | 102.88      |
| 0.31        | 128.01      |
| 1.22        | 129.08      |
| -3.30       | 142.85      |
| 17.84       | 144.16      |
| 84.31       | 145.70      |
| 84.31       | 169.44      |

The type B joint graph shows the up and down movement in stress value with the melting stress reaching 25.77 MPa which then slowly decreases and returns to reach the peak at 84.31 MPa and finally the joint loses its strength. Strain on the test object are obtained from the comparison of the final length increase of 169.44 mm with an initial length of 300 mm so that the strain obtained is 56.48%.

3.2. Visual analysis of the damage patterns at the joint results from modeling on FEM

The damage pattern of the test object that occurred after being analyzed by FEM resulted in damage form of local buckling. In type A joints, the screw section experiences a high stress accompanied by damage to the surrounding cold-formed support. Damage also occurs in the lower base of the upright profile which is stretched and bent so that the profile has a fracture potential.
Whereas in type B joints the damage pattern that occurs is a local buckling in the cross section profile due to tensile loads. The pattern of buckling opens out with a pressure that occurs at the base of the upright profile. In the joint area there is a large buckling in the wing section of the channel section c. This section is a critical part that is prone to break. The weakness of cold-rolled steel structures is local buckling due to its thin cross-section elements. This causes structural failure to occur before reaching the highest load capacity [6].

4. Conclusion
From the results of this study it can be concluded that each joint has their own advantages. Type A joint has a melting stress of 316.86 MPa with a strain of 16.98% and a type B joint produces a stress of 25.77 MPa with a strain of 56.48%. Meanwhile, when analyzed from the damage pattern, both type local buckling occurs in the screw junction area, so that the tensile rod capacity is determined by bending local elements where the type B joints are more resistant to overcome the tensile load on the cold-formed column frame structure.

References
[1] Mutawalli, M., 2007. Stability of cold formed steel frame connection type t to cyclic loading on the knockdown of a simple house. Postgraduate Thesis, Universitas GadjahMada, Yogyakarta, Indonesia
[2] Yu Wei-Wen, Ph.D., P.E. 2000. Cold Formed Steel Design Third Edition. Canada
[3] Meiyalagan, M. 2010. Investigation on cold – formed section long column with intermediate stiffner & corner lips-under axial compression. International journal of applied engineering research, Dindigul. Vol.1 No.1.
[4] Murtiono, A. 2012. Effects of quenching and tempering on hardness and tensile strength and microstructure of medium steels for palm harvesting blades. Jurnal e-Dinamis, September, Volume II, No.2.
[5] Standar Nasional Indonesia. 7971:2013. Struktur Baja Canai Dingin. Jakarta : Badan Standarisasi Nasional
[6] Sanjaya.2018. Experimental study of cold rolled cold pressed steel rods partially. Jurnal Teoretis dan Terapan Bidang Rekayasa Sipil. Vol. 25 No. 1.

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