EXPERIMENTAL STUDY OF FLEXURAL CFS BEAM DOUBLE CHANNEL FACE TO FACE IN LENGTH VARIATIONS

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Abstract: The application of cold formed steel material as a structural element of buildings has begun to be considered because the material is strong and light. The capacity of single-section cold formed steel can be increased by combining the sections. There is less research on cold formed steel beams than columns. Research on the failure pattern of cold formed steel with variations in length has not been done before. This study aims to obtain the value of flexural capacity, deflection at maximum load, and collapse pattern of cold formed steel beams. The research was conducted experimentally on a simple supported face to face cold formed steel beam (roll-joint) by applying a four-point bending load to obtain failure due to pure bending. The results of this study indicate, the longer the face to face cold formed steel beam, the smaller the value of the load capacity that can be held and the greater the deflection value that occurs when the maximum transverse load is the Double cold formed steel beam arranged face to face experiencing instability from the beginning of loading so that the pattern failure that occurs in the form of lateral torsional buckling. Beam instability increases with increasing beam span length. A cold formed steel beam with a span length of 700 mm has a load capacity of 6.4 kN and a deflection of 14.5 mm. The failure pattern that occurs is in the form of lateral torsional buckling with a torque value of 0.74° and a lateral deflection of 0.12 mm. Cold formed steel beams with a span length of 1300 mm are capable of withstanding a maximum load of 4, 8 kN and deflection at maximum load of 32.37 mm. The beam experienced a failure pattern in the form of lateral torsional buckling with a rotation of 1.57° and a lateral deflection of 0.74 mm. The cold formed steel beam with a length of 3900 mm has a rated load capacity of 1.7 kN and a deflection of 91.49 mm. The failure pattern that occurs when the maximum load is in the form of torsional buckling of 4.02° and lateral deflection of 2.41 mm. The load capacity of the cold formed steel beam with a span length of 4300 mm is 1.4 kN and the deflection at maximum load is 99.43 mm. The beam experienced a lateral torsional buckling failure pattern with a turning angle of 12.56° and a lateral deflection of 4.84 mm. The cold formed steel beam with a length of 3900 mm has a rated load capacity of 1.7 kN and a deflection of 91.49 mm. The failure pattern that occurs when the maximum load is in the form of torsional buckling of 4.02° and lateral deflection of 2.41 mm. The load capacity of the cold formed steel beam with a span length of 4300 mm is 1.4 kN and the deflection at maximum load is 99.43 mm. The beam experienced a lateral torsional buckling failure pattern with a turning angle of 12.56° and a lateral deflection of 4.84 mm. The cold formed steel beam with a length of 3900 mm has a rated load capacity of 1.7 kN and a deflection of 91.49 mm. The failure pattern that occurs when the maximum load is in the form of torsional buckling of 4.02° and lateral deflection of 2.41 mm. The load capacity of the cold formed steel beam with a span length of 4300 mm is 1.4 kN and the deflection at maximum load is 99.43 mm. The beam experienced a lateral torsional buckling failure pattern with a turning angle of 12.56° and a lateral deflection of 4.84 mm.

Keywords: Cold Formed Steel Beam, Bending Capacity, Deflection, Collapse Pattern.

1. PRELIMINARY

Innovation and creativity in the application of cold formed steel materials began to be considered along with the development of technology (Lisantono et al., 2013). The most widely used type of cold formed steel section is the canal section with or without lip because of its easy and fast production (Yasinta et al. 2020). Cold formed steel with a C channel profile type has a lighter weight compared to other profiles and a thinner cross section (Tampubolon 2019).

Research on type C double cold formed steel has been carried out before, one of which is to find out whether screw spacing affects capacity and how the behavior of the cross section is tested. The result of this research is that there is an effect of screw spacing on the pattern of beam failure with a face-to-face structure of cold formed steel. The pattern of failure at screw spacing of less than 200 mm in the form of local buckling and cross-sectional failure pattern with screws more than 200 mm in the form of lateral torsional buckling (Yasinta et al. 2020). The recommended screw spacing for double cold formed steel beams joined face to face is L/4 or less (Chea et al., 2017).

Alexander Chajes in his book entitled Principles of Structural Stability Theory reveals that the concept of stability is like a straight configuration that can change shape when it receives a load, but can still return to its original shape if the load received is very small. Cold formed steel sections are included in thin-walled structures that often experience stability problems (Chajes., 1974). The capacity of a section is called the critical load. If the load received by the cross section has reached the critical load, the configuration is no longer stable and structural failure occurs.

The capacity of single-section cold formed steel can be increased by combining the sections. Laminated wood combined with cold formed steel has an effect on increasing strength and stiffness by reducing buckling that occurs (Awaludin et al., 2015). Single sections of cold formed steel which are combined into structured sections can be formed by connecting 2 (two) single sections using screw connectors or the like (Wang and Young., 2018). The combination of a single cross section with screws into a double symmetrical cross section face to face into a closed cross section has a torsional stiffness that is relatively larger than the open section type (Yasinta et al., 2020).

Previous research was carried out using numerical methods using one beam size with a given moment and load variation. (Wiguna and Walujodjati,. 2015). From the research conducted, it is necessary to do laboratory tests to get more accurate results. Variations in beam length and repeated analysis are needed to get more efficient results. SNI 7971-2013 mentions the moment capacity of the box-shaped cross section that has failed local buckling and lateral torsional buckling.

Type C cold formed steel profiles are applied in the form of simple beams with roll-joint supports. The cross-sections are formed face to face which are joined by self-drilling screws with a diameter of 5.49 mm with a distance less than L and not greater than 150 mm. The study was conducted to determine the load capacity, deflection and failure patterns that occur in cold formed steel beams with face to face cross section at each length of the test object. The applied load is four point bending to get the largest deflection due to pure bending.

2. METHOD

The research was carried out using experimental methods to obtain a quantitative approach. The experimental method was carried out to obtain the flexural capacity, deflection, and failure pattern of cold formed steel beams for each variation of the length of the rod tested. The research uses 3 (three) variables as follows.

1. The independent variable in this study is the variation of the length of the cold formed steel beam
2. The dependent variable in this study is the flexural capacity, deflection and failure pattern of cold formed steel beams.
3. The control variable is the type of cold formed steel section type C Taso brand with dimensions75 x 33 x 35 x 8 x 0.75 mm joined face to face, the use of screw

connection type*self drilling screw*5.49 mm. diameter and four point bending loading.

In this study, the length of the beam tested was more than the length without lateral bracing according to SNI 7971-2013.SNI 7971-2013 concerning cold formed steel states that the length of the structure without lateral bracing is calculated by equation (2.1).

$$l_u \quad = \frac{0{,}36 C_b \pi}{f_y z_f} \sqrt{EGJI_y}$$

$$Mb \quad = Z_c x\ Fc$$

$$Fc \quad = \mathrm{Mc/Zf}$$

Information

l_u	Unbraced length limit where lateral torsional buckling is unnecessary calculated, mm
E	The cross-sectional modulus of elasticity, MPa
G	Shear modulus of cross section, MPa
J	Torque Constant, mm^4
y	Inertia of the y-direction section, mm4
Cb	The coefficient that depends on the moment distribution on the segment that does not lateral braced
Mb	Nominal member moment capacity, Nmm
Zc	calculated effective cross-sectional modulus at stress Fc, mm3
Fc	Service load voltage, N
Mc	Critical moment, N.mm
Zf	Modulus of intact cross-section without reduction in the outer compression fiber, mm^3

The critical moment value is determined by the following equation.

For b 0.6 $\quad M_c = \mathrm{My}$

For 0.6 < b < 1.336 $\quad \mathrm{Mc} = 1.11\ \mathrm{My}\ )(1 - \frac{10\ \lambda_b{}^2}{36}$

For b 1.336 $\quad M_c = My\ (\ 1/\ b\ 2)$

Where is b $\quad = \sqrt{\frac{M_y}{M_o}}$

My the moment that causes the first yielding of the outer compression fiber Full cross section, Nmm

$b = Zf\ x\ fy$

$\mathrm{M_o}$ Elastic bending moment, Nmm

$$\mathrm{M_o} = \frac{C_b \pi}{l} \sqrt{EGJI_y}$$

The ultimate moment of consequencethe loading of the four point bending rod with joint and roll support is

$$M = \frac{1}{2} Pa\ maka\ P = \frac{2M}{a}$$

Information:

M	Ultimate moment, N.mm
P	Load, N
a	load distance to nearest support, mm

Calculation of Lu SNI 7971-2013 obtained a value of 191 mm. Taking the length variation, 4 variations are taken with a value greater than Lu. The design drawing of the test object can be seen in Figure 1. The length shown is the length of the rod from the axle to the axle which can be seen in Table 1.

Table 1. Cold Formed Steel Test Object Variation Notation

Length Variation	700 mm	1300 mm	3900 mm	4300 mm
Notation/repeat	FF 070 1 FF 070 2 FF 070 3	FF 130 1 FF 130 2 FF 130 3	FF 390 1 FF 390 2 FF 390 3	FF 430 2 FF 430 3 FF 430 1

Information :

FF : Double cold formed steel test specimen code*face to face*

The value of the deflection at the yielding section with the loading of four point bending is known by using the equation below.

$$y = \frac{\left(\frac{48EI_x}{3aL^2 - a^3}\right)}{P}$$

Information

E	Modulus of elasticity, kN/mm^2
ix	Inertia of the x-direction, mm^4
a	Distance from load to pedestal, mm
P	Maximum load, kN
L	span length, mm
y	deflection, mm

The specifications of the cold formed steel section used are as follows.

Web height (h) = 75 mm

Wingspan top (b1), bottom (b2) = 33 mm; 35 mm

Lip width (c) = 8 mm

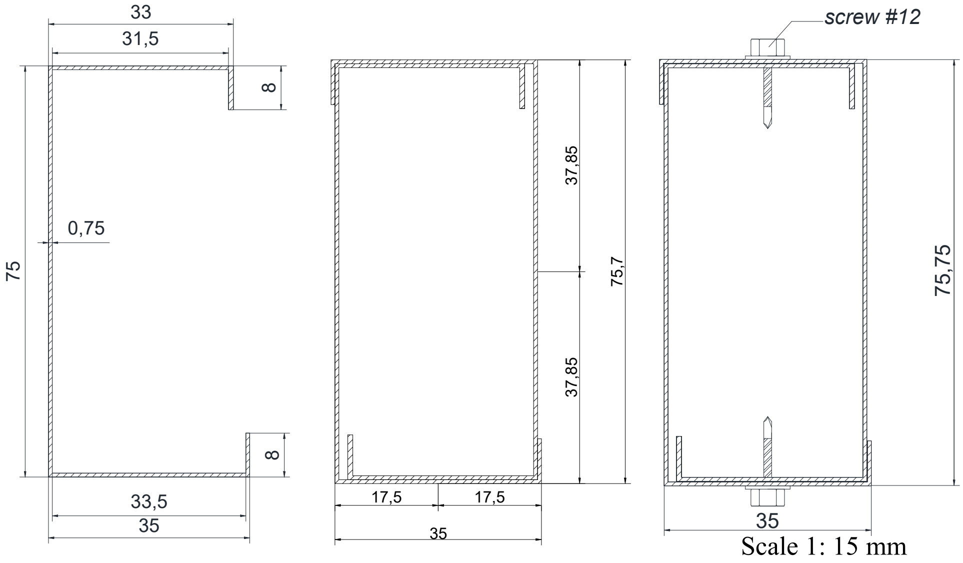
web thickness (tw) = 0.75 mm

Effective Height (h0) = 72.2 mm

y (1/2 h) = 37.5 mm

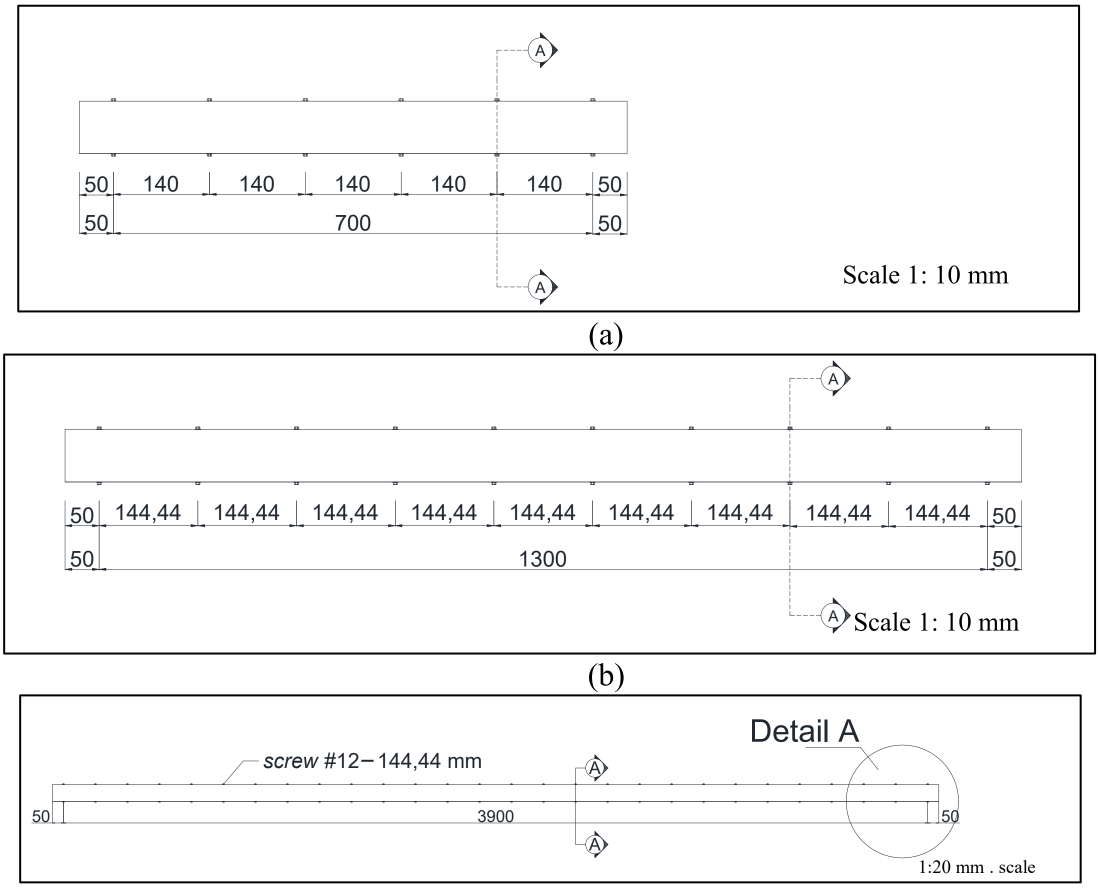
Modulus of Elasticity (E) = 200,000 MPa(N/mm2)

Steel Quality (Fy) = 550 MPa



(a) (b) (c)

Figure 1. Cross Section of Single C (a) Channel Profile; (b) Double Face To Face; (c) Double Face To Face Attached with Screws



(a)

(b)

(c)

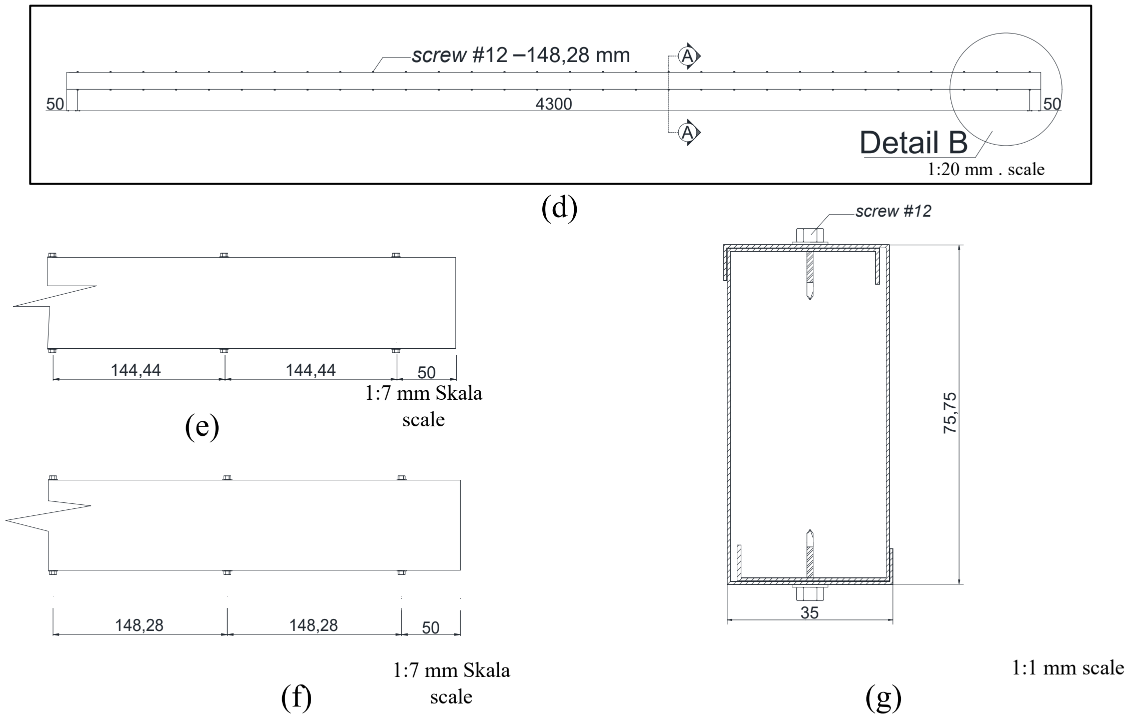
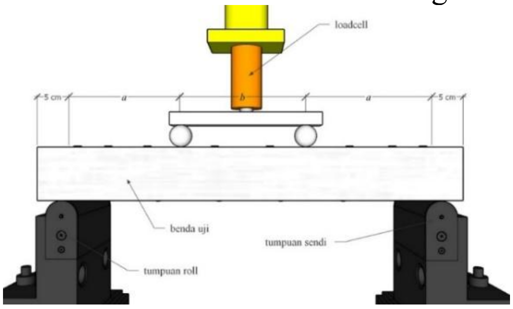


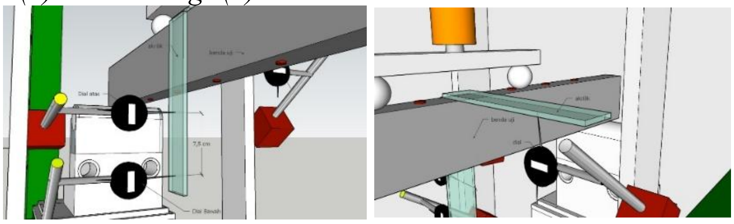
Figure 2. Design of the test object (a) Front view of the test object l = 700 mm; (b) Front View of Test Object l = 1300 mm; (c) Front View of Test Object l = 3900 mm; (d) Front View of Test Object l = 4300; (e) detail A; (f) Details B); (g) AA deductions.

Type C cold formed steel profiles are applied in the form of simple beams with roll-joint supports. The distribution of the two loads placed at the same distance from the center of the span is carried out with the aim of producing the largest deflection due to the pure maximum bending moment without any shear forces in the cross section. The pedestal used in this test is a roll joint pedestal which can be seen in Figure 2. The placement of the dial to read the test results can be seen in Figure 3.



(b)

Figure 3. Illustration of Bending Strength of Double Cold Formed Steel Beams*Face to Face (a) Tool Settings (b) Focus and Load details.*



(a) (b)

Figure 4. Placement of the dial gauge (a) to determine the torsion angle of the cross section; (b) to find out the deflection

3. RESULTS

Cold formed steel tensile specimen specimens refer to the ASTM E3-04 Standard Test Methods for Tension Testing Of Metallic Materials. Cold formed steel tensile testing is carried out using a UTM (Universal testing machine) with a capacity of 10 kN. The average value of the peak stress from the results of the tensile test carried out is575,644MPa. The average yield stress of the three tested specimens is553,849MPa. The mean modulus of elasticity is obtained182788MPa. The graph of the tensile test specimen test results can be seen in Figure 5.

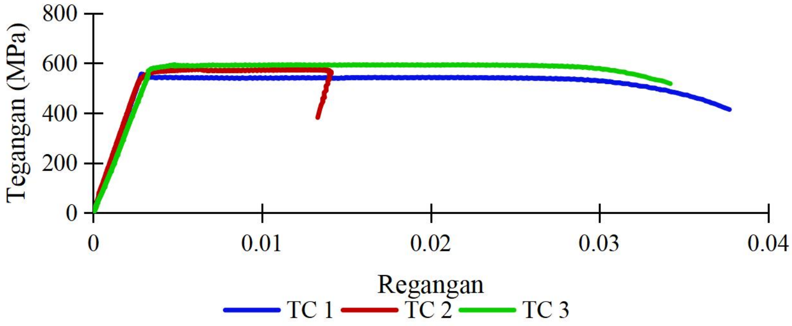
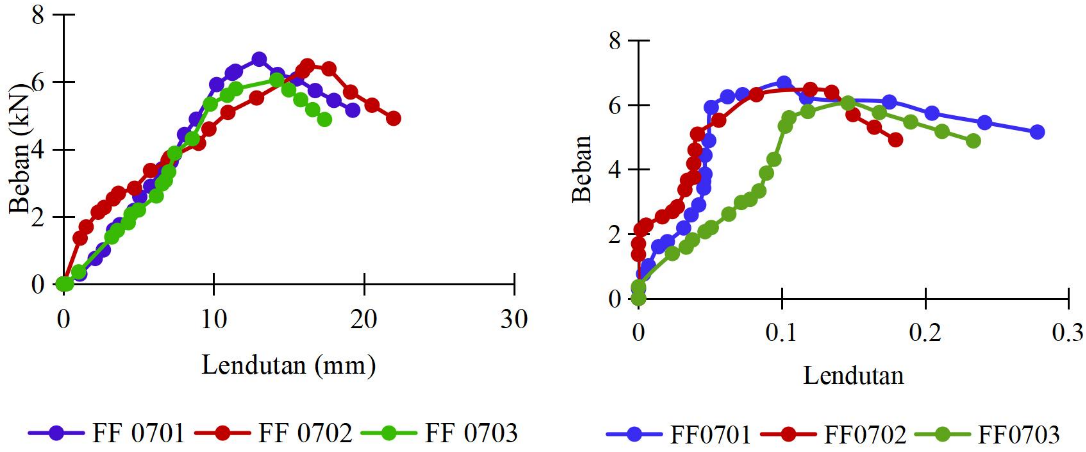


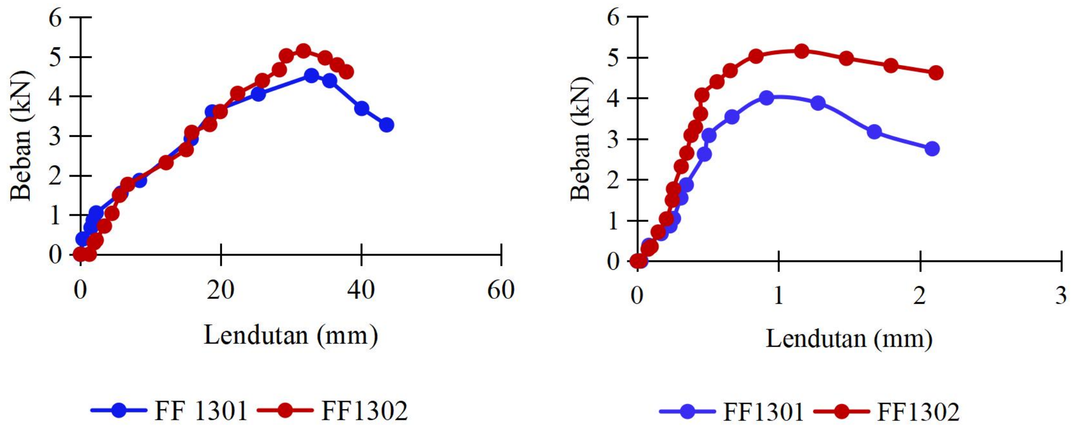
Figure 5. Tensile Test Specimen Stress-Strain Graph

The average value of cold formed steel flexural capacity with a span length of 700 mm has the largest capacity value compared to other length variations, which is 6.4010 kN, a span length of 1300 mm has a flexural capacity value of 4.8365 kN, a span length of 3900 mm has a flexural capacity value of 4.8365 kN. the flexural capacity of 1.6602 kN, and the span length of 4300 mm has the smallest value of flexural capacity compared to the variation of the length of the other specimens, which is 1.3780 kN. The smallest deflection occurs at a span of 700 mm with an average deflection of 14.5 mm. The average deflection of a span of 1300 mm is 32.37 mm. The average deflection at a span length of 3900 mm is 91.49 mm. The largest deflection occurs in the longest span at a span of 4300 mm with an average deflection value of 99.43 mm.



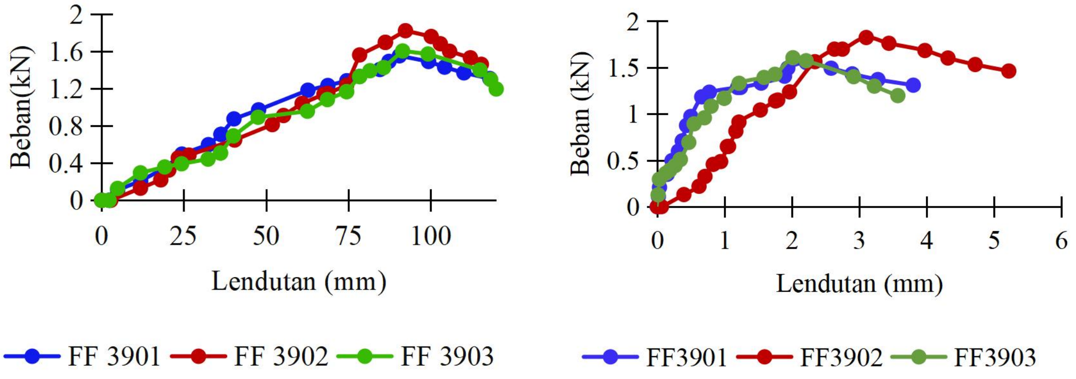
(a) (b)

Figure 6. Graph of Load-Deflection Relationship Type FF070 (a) Vertical; (b) Horizontal



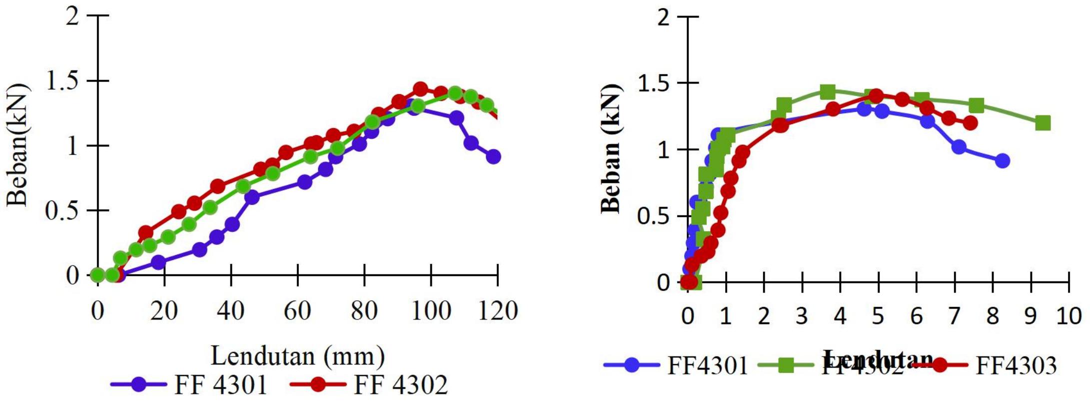
(a) (b)

Figure 7.FF130 Type Deflection Load Relationship Graph After Data Reduction*Outliers (a) Vertical; (b) Horizontal*



(a) (b)

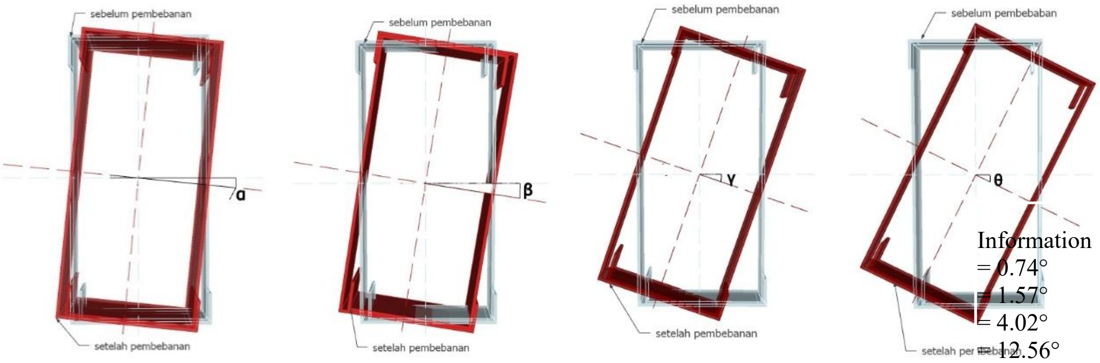
Figure 8. Load-Deflection relationship graph Type FF390 (a) Vertical; (b) Horizontal



(a) (b)

Figure 9. Graph of load-deflection relationship type FF430 (a) Vertical; (b) Horizontal

The test results obtained that the average torsion angle at a span length of 70 cm is 0.74° with a lateral deformation of 0.12 mm. The torsion angle at a span of 130 cm is 1.57° with a lateral deformation of 0.75 mm. The torsion angle at a span of 390 cm is 4.02° with a lateral deformation of 2.41 mm. The torsion angle at the span of 430 cm is 12.56° with a lateral deformation of 4.84 mm. An illustration of the torque that occurs can be seen in Figure 9.



Information
= 0.74°
= 1.57°
= 4.02°
= 12.56°

Figure 10. Torque Angle at Maximum Load

4. DISCUSSION

The span with a length of 1.85 times longer than 700 mm experienced a load reduction of 28.77% from the maximum load of the type FF070 test object. The span length of 5.6 times the shortest span experienced a load reduction of 74.06 % from the maximum load of the FF070 type specimen. The span length 6.1 times the shortest span experienced a maximum load reduction of 78.47% from the FF070 type specimen. The maximum load at each length of the test object is depicted in the graph in Figure 11.

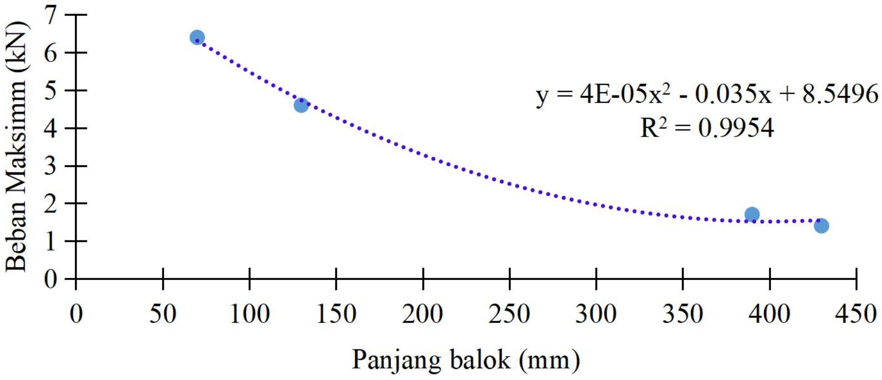


Figure 11. Graph of Maximum Load Against Beam Length

The distribution of the load from the point of loading to the support is influenced by the distance of the load to the support which is called the force arm. The longer the distance between the load and the pedestal, the distribution of the load to the pedestal is not optimal due to the concentration of the load at the point of loading which causes structural failure. Beams with short spans will experience stress distribution from load to support. Beams with long spans will only experience load distribution up to the span so that the stress is not distributed to the support. Tests in the research conducted showed the occurrence of damage at the point of loading before the load reached its maximum. This happens because the thin cross section is prone to wrapping or destruction before the structure reaches its maximum load.

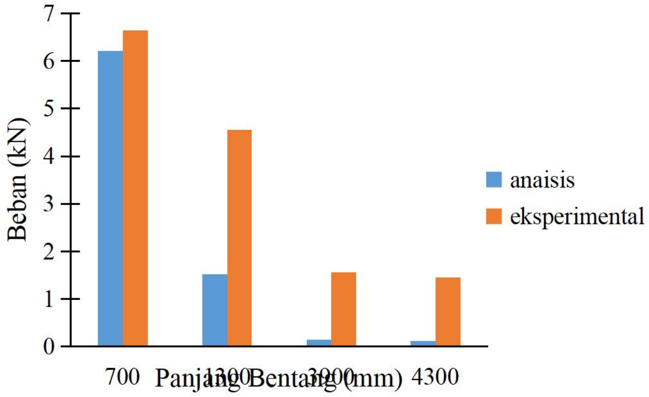


Figure 12. Design load diagram according to SNI 1729-2020 and experimental test of cold formed steel flexural bar

Analysis of the load at the span of 700, 1300, 3900, 4300 mm obtained a difference of 7,1% successively; 54.0%; 86.7%; 88.3% of experimental load.Figure 12 shows the analytical load is smaller than the experimental load. The instability experienced in accordance with the results of the study is a snap-through instability. The graph of the deflection load on the beam with Snap-through instability can be seen in Figure 12(Lui et al., 2020). This instability condition is caused by a cross-sectional displacement due to loading that is not in the proper direction. The beam is planned to experience deflection in the vertical downward direction, but the results of this study indicate a lateral deflection and torsion angle due to loading.

The percentage increase in the value of the deflection with a span length of 1.86 times 700 mm is 163.8 % of the average deflection that occurs at a span length of 700 mm. The percentage increase in deflection with a span length of 4.47 times 700 mm is 531% of the average deflection that occurs at a span length of 700 mm. The percentage increase in the deflection value with a span length of 6.14 times 700 mm is 586% of the average deflection that occurs at a span length of 700 mm. The relationship between the length of the beam and the maximum deflection of the cold formed steel beam is depicted in the graph in Figure 13. The graph of the load relationship and the deflection of the cold formed steel beam illustrates the stiffness of the beam.

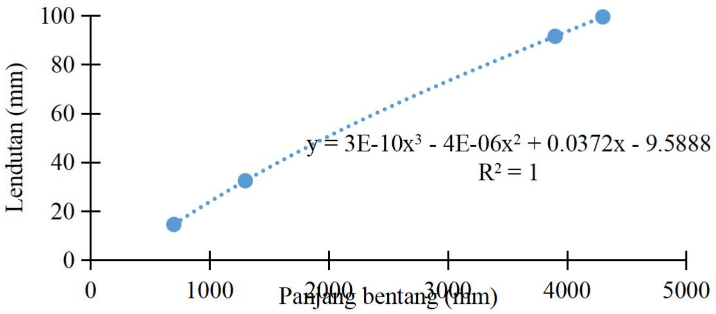


Figure 13. Graph of Deflection Against Span Length

The difference in length variation causes differences in stiffness which affect the deflection experienced at maximum load.Sugihardjo (2010)in his research showed that cold formed steel beams with an additional stiffness of 38% were able to increase the load capacity by 35.9%.The longer the beam span, the smaller the stiffness value and the greater the deflection valueDeflection is affected by the magnitude of the applied force or the applied load.

Figure 14 shows that the longer the span, the more sloping the graph of the load and deflection relationship will be. It can be interpreted that the longer the span of the double cold formed steel beams arranged face to face, the lower the stiffness value.

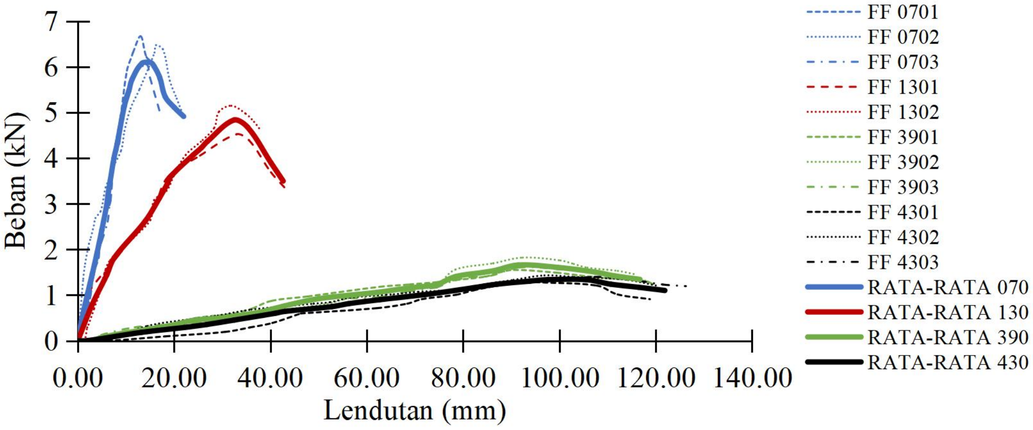


Figure 14. Graph of Load and Deflection Relationship of Double Cold Formed Steel Beams Arranged Against (*face to face*)

Figure 15 shows that the deflection of the experimental test results is smaller than the calculated analysis. The difference between experimental deflection and analysis results is getting bigger with increasing length of beam span. This is because the instability experienced by the beam since the beginning of the loading affects the deflection when the beam is still in an elastic state. The instability experienced by cold formed steel beams increases with increasing variations in length.

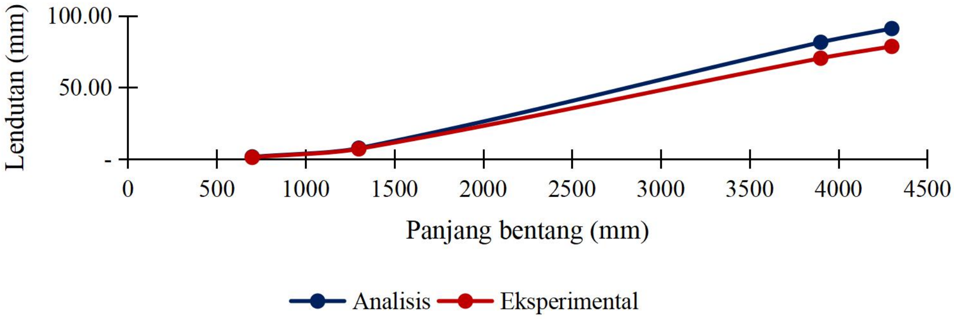


Figure 15. Graph of Comparison of Deflection of Analysis and Experimental Test Results on Each Variation in Length

The failure pattern of the cold formed steel beam specimen was observed when the beam reached its maximum load. The longer the cold formed steel beam, the greater the structural instability experienced. The shortest test object experienced the smallest torsional rotation and lateral deflection. The longest specimen experienced the largest rotation and lateral deflection. The failure pattern that occurs in all cold formed steel beam specimens is lateral torsional buckling.

5. CONCLUSION

The conclusion of this research is as follows.

1) The flexural test of double cold formed steel arranged face to face with variations in length shows that the longer the test object, the smaller the value of cold formed steel flexural strength.
2) This study shows that the longer the span tested, the greater the deflection that occurs.
3) The cold formed steel beam experiences torsional rotation which indicates the occurrence of buckling in the cross section. There is a lateral distance before and after loading due to the maximum load which indicates the occurrence of a lateral failure pattern. The longer the cold formed steel beam span, the greater the torsional angle and lateral distance due to the maximum load received by the beam caused by the instability of the beam structure. The failure of the cross-sectional structure occurs at the point of loading. The failure is in the form of local buckling caused by the stress concentration that occurs.

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