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To cite this article: Zamzami Septiropa *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **527** 012080

IOP Conf. Series: Materials Science and Engineering **527** (2019) 012080 doi:10.1088/1757-899X/527/1/012080

Effect of screw distance on combined profiles cold-formed steel in increasing the compression member capacity

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Abstract. The use of cold-formed steel (CFS) as a frame in a single-story structure building system has been widely applied. However, the use of cold-formed steel for multi-story buildings is still constrained in the structure system, especially column. In the conventional structure, columns used in large dimension, height, *h> 150 mm* and thickness, *t> 1.2 mm* which makes the construction cost expensive. An innovation of cold-formed steel combine profile into one compression member unit is very interesting to study, furthermore, previous research provides information on a variety of cold-formed steel behaviors with small dimensions of height, *h <150 mm* and thickness, *t <1mm*, which can be developed into columns with greater strength. There have been a lot of research on behavior on cold-formed steel, but the study on screw optimization especially on combined profile to become compression member still need to develop. From the compression test on double profile back to back and flange to flange length, *l = 300 mm* and screw distance variation, 25 to 150 mm with 50 mm intervals, indicating a response similarity at screw spacing 25 mm, 50 mm and 75 mm, while the screw distance 100 mm, 125 mm and 150 mm experienced backline capacity.

1. Introduction

The use of cold-formed steel as a structure especially in residential construction has been widely used in almost all parts of the world. This acceptance is due to its easily applicable, cost effective and, ease transportation and of fulfilment in quantity. Optimization of cold-formed steel framing system design is an important part to ensure the level of structural security and the cost-effectiveness of construction [1, 2]. To compile a Cold-formed steel framing system cannot be separated from the significant role of a system connection from the bottom structure to the top structure. Because the framing system is composed of connections of cold-formed steel profiles combined into a load-bearing structure. Study of the connection system in cold-formed steel has been done, especially in truss system and beam-column joint model. [3]

However, a study that specializes in connection on combined profiles to become a structural column is still deficient in literature. In the conventional structure, the columns used still in large dimension height, *h> 150 mm* in thickness, *t> 1.2 mm* which makes the construction cost expensive [4]. Innovation of cold-formed steel combine profile into one compression member unit is becoming a main objective in this study, furthermore, previous research provides information on a variety of cold-formed steel behaviors with small dimensions of h <150 mm and thickness t <1mm, which can be developed into columns with great strength. There have been a lot of research on behavior on cold-formed steel, but the study on screw optimization especially on combine profile to become compression member still need to be developed. Using the empirical approach compiled with finite element analysis using software and then validated experimental to meet the objectives, the optimum distance obtained can be used on connection between profiles to compile a unit compression member.

2. Parametric Study

2.1 Problem considered

The results of preliminary study obtained have shown that the cold-formed as columns provide a variety of behavior when receiving the axial load. There are differences in behavior between single profile, double profile, and triple profile CFS as a column. (Figure 1)

(a.) (b.)

Figure 1. (a.) Single and Triple profile behaviour: torsional buckling dominated, (b.) double profile behaviour: local buckling dominated.

In figure 1.a shown when profiles CFS is pressed, it will experience torque due to this profile is not only thin with a thickness of 0.75 mm but also the ratio between the length and dimension *(slenderness ratio, le/r)* more than the standard limit i.e. le/r> 40 [5, 6]. Also, from behavior of cold-formed steel in figure 1.a, it was observed that little load, the profile experiences torque. Figure 1.b shown double profile did not experience a significant torque behavior but buckling behavior which leads to total collapse and was noticed as the dominant behavior. This happened because there no enough connection to assemble these profiles into a unified element compression member. Figure 2 shown basic performance cold-formed steel when received axial load and many types of combined profiles.

Figure 2. Basic performance cold-formed steel when received axial load

Combining multiple profiles into a stronger element of compression member is one solution that can be sought. The constrain that is usually faces, is how to unite multiple profiles into a single unit. When designing combined multiple profiles into a single unit, the distance variable screws along the element compression member is not included in the design calculation. So, it can be understood that the calculation refers to the perfect condition of stringed element compression member into one unity like welded perfectly. However, this perfect welding condition is very difficult to achieve due to the thin profile [7]. Therefore, the best solution is to assemble it using screw, popularly known as self-drilling screw. Furthermore, the problem is how optimal the screw spacing can give the same strength with the welding connection for combine profile. Furthermore, determination of the optimum screw distance through experimental process becomes parametric analysis in this research. Screw type used is a type of screw with hexagonal head *(hex washer head, HWH)* and conventional screw *(Philips pan head, PPH)* [8], shown in figure 3.

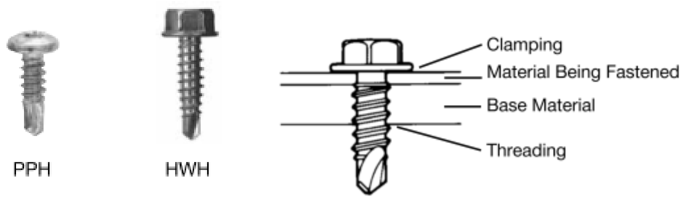

Figure 3. Type of Screw, Philip pan head, PPH and hex washer head, HWH. *(www.hilti.com.ca)*

Screw property used in the research is #8 diameter 4.165 mm with length 20 mm. In detail technical data of screw shown in table 1.

Table 1. Technical data of screw, ultimate strength Pullout Tension, lb (kN). *(www.hilti.com.ca)*

Screw Designation	**Nominal Diameter In.**	**Thickness of stel member not in contact with the screw head, ga (in.)**					
		20 (0.036)	**18** (0.048)	**16** (0.060)	**14** (0.075)	**12** (0.105)	**10** (0.135)
#6	0.138	190 (0.85)	250 (1.11)	320 (1.42)	395 (1.76)	555 (2.47)	715 (3.18)
#7	0.151	210 (0.93)	275 (1.22)	345 (1.53)	435 (1.93)	605 (2.69)	780 (3.47)
#8	0.164	225 (1.00)	300 (1.33)	375 (1.67)	470 (2.09)	660 (2.94)	845 (3.76)
#10	0.190	260 (1.16)	350 (1.56)	435 (1.93)	545 (2.42)	765 (3.40)	980 (4.36)

#12	0.216	295 (1.31)	395 (1.76)	495 (2.20)	620 (2.76)	870 (3.87)	1120 (4.98)
1/4 in.	0.250	345 (1.53)	460 (2.05)	575 (2.56)	715 (3.18)	1000 (4.45)	1290 (5.74)

3 Experimental Test

3.1 Test set-up and test procedure

In this research, series of tests have been conducted to study the basic performance of cold-formed steel, where the basic behavior of cold-formed is strongly influenced by the slenderness of the profile. To ensure that the behavior of cold-formed steel only applies local buckling deformation, this experiment uses the slenderness ratio of Le/r <40 [5].

Figure 4. Samples with variable screw distances.

Profile C75 channel lips was used for this research with dimensions: web, h = 75 mm; flange1, b1 = 37mm; flange2, b2 = 35mm; lips, c = 8.5mm and thickness, t = 0.75mm with le profile length = 300 mm. This dimension is chosen because the type of profile is widely used as a structure framing system in the building structure, not only because is cheap but also flexible in the fabrication of a structure. Profile C75 can be arranged into double profile back to back and further with the different dimensions of flange b1 and b2 really allow this profile to be assembled to close profile as shown figure 5.

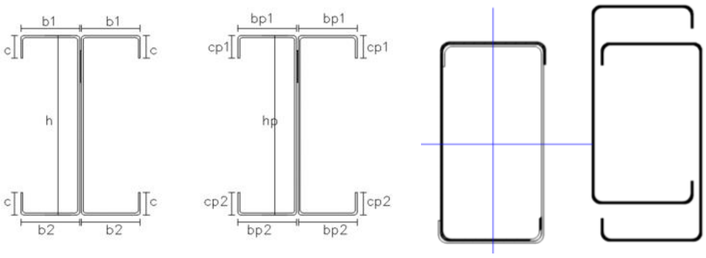

Figure 5. Double profile back to back and Double profile flange to flange or Close Profile.

For the length of sample le = 300mm has met the criteria as a short compression member Le/r = 20.30 <40 where with this provision is not expected to occur flexural buckling due to compression load [5, 6]. So, the purpose of this research can be achieved by getting the maximum load by varying the distance screws along the compression member.

$$3.h < k.l < 20.r \quad (1)$$

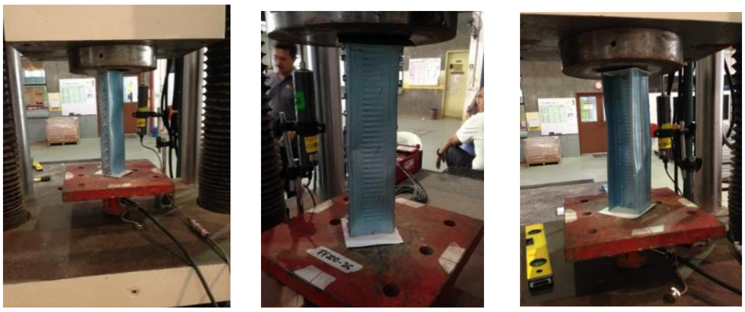

Figure 6. Compression test machine Tunius Olsen.

Figure 6 shows the test model for maximum load on combined profile, in this case double profile back to back 300mm long *(BB300)* and flange to flange length 300mm *(FF300)*. The screw variations used are shown in table 2.

Table 2. Type of profile combine and variation screws distance.

Type	*Length, mm*	*S1,mm*	*S2,mm*	*S3,mm*	*S4,mm*	*S5,mm*
Flang to Falange (FF300)	300	25	50	75	100	125
Back To Back (BB300)	300	25	50	75	100	125

The source of screw distance variation was informed by similar research conducted by Bondok et.al. [9] where minimum screw distance used is 0.57 in for vertical direction and 0.57 in for horizontal direction. While in this research, two variations are considered which are vertical distance FF300 and combination of vertical and horizontal BB300.

3.2 Analyse and calculation

The calculation was carried out based on Eurocode 3 *Part 1-3: General rules - Supplementary rules for cold-formed members and sheeting* [5, 10], and capacity compression member design combined with AS/NZS 4600 2005 [6, 11, 12].

$$N_{c,Rd} = A_{eff}\, f_{yb} / \gamma_{Mo} \qquad : A_{eff} < A_g \tag{2}$$

$$N_{c,Rd} = A_g(f_{yb} + (f_{ya} - f_{yb})\, 4(1 - \lambda_e/\lambda_{eo})) / \gamma_{Mo} \qquad : A_{eff} = A_g \tag{3}$$

$$N_{b,Rd} = \frac{\chi . A_{eff} . f_{yb}}{\gamma_{M1}} \tag{4}$$

$$M_{cz,Rd,com} = (W_{eff,com} \cdot f_{yb})/\gamma_{M0} \tag{5}$$

$$\frac{N_{Ed}}{N_{c,Rd}} + \frac{M_{z,Ed} + \Delta . M_{z,Ed}}{M_{cz,Rd,cm}} \leq 1.0 \tag{6}$$

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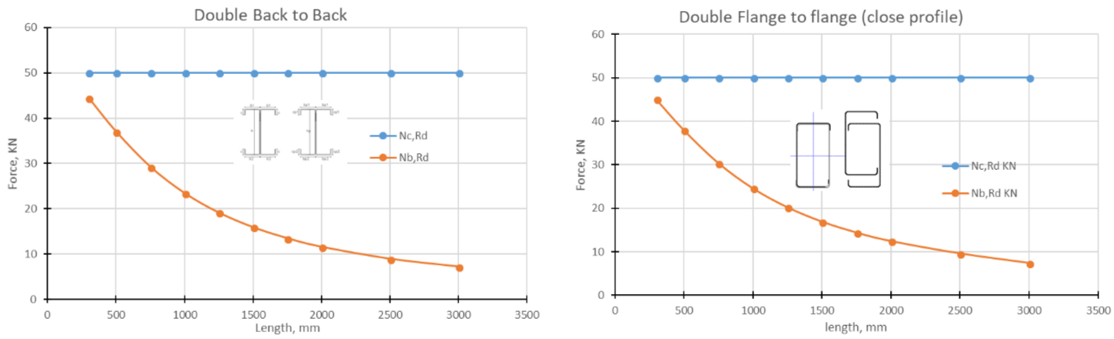


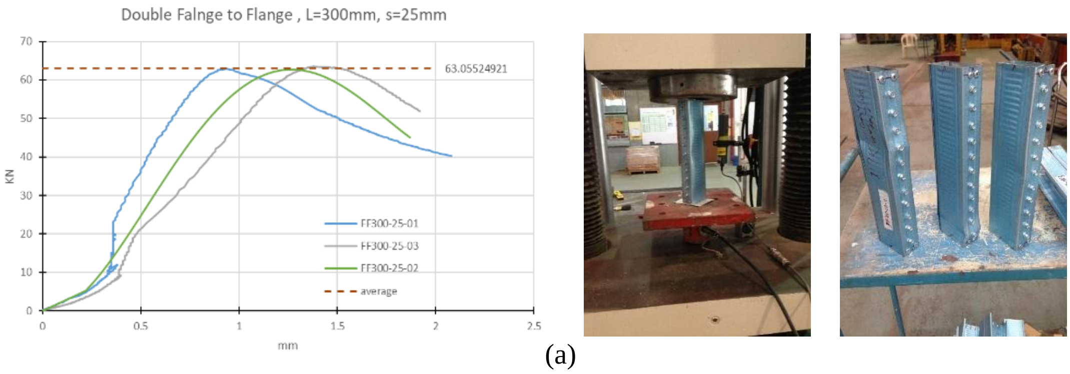
Figure 7. Calculation results double profile back to back and double profile flange to flange.

Figure 7 shows compression member calculation results for double back to back (BB) and flange to flange (FF) profiles. Resistance cross section, $N_{c,Rd}$ for double profile BB is 50.06 KN and double profile FF is 50.07 KN, it shows the similarity of the cross section capacities in the ability to accept the compressive style although different in the drafting model. As for the capacity of buckling resistance, $N_{b,rd}$ there is slightly difference where for the same length of rod is 500 mm, double profile BB 37.04 KN similar to double profile FF of 37.99 KN, this is because of the difference radius of Gyration between the two models of about 21 % where double profile BB is bigger than double profile FF.

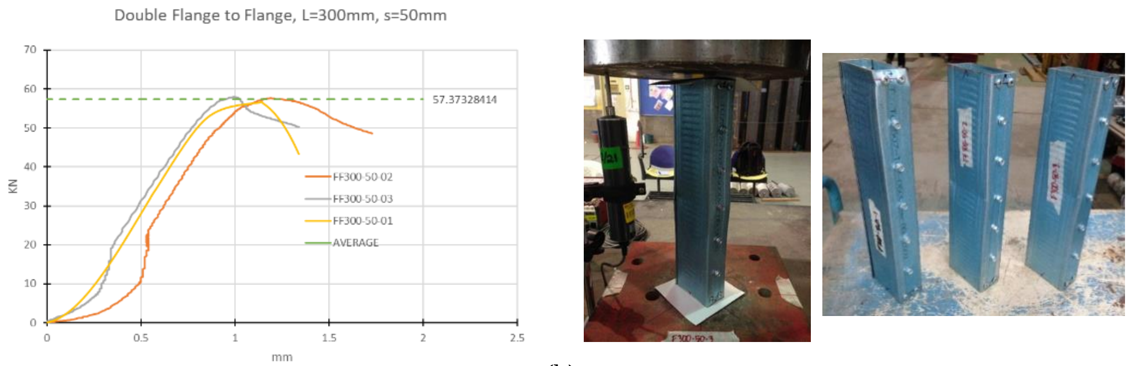
To obtain a constant value for this combination of profiles, the $N_{c,rd}$ values were not affected by the length of compression member under the slenderness ratio. In this case, the length of the double profile 300 mm with variation of screw distance as in table 1.

3.3 Cases analysed

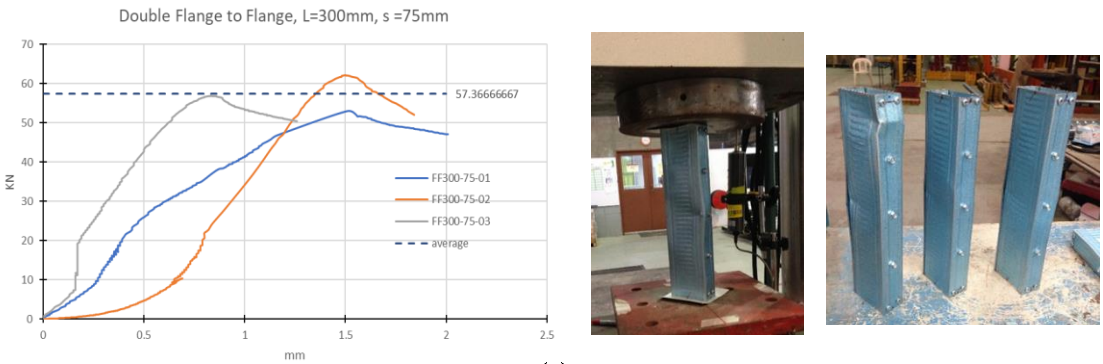
From the test result for double profile back to back Length, L = 300 mm with variation of screw distance obtained result as in graph and picture below:



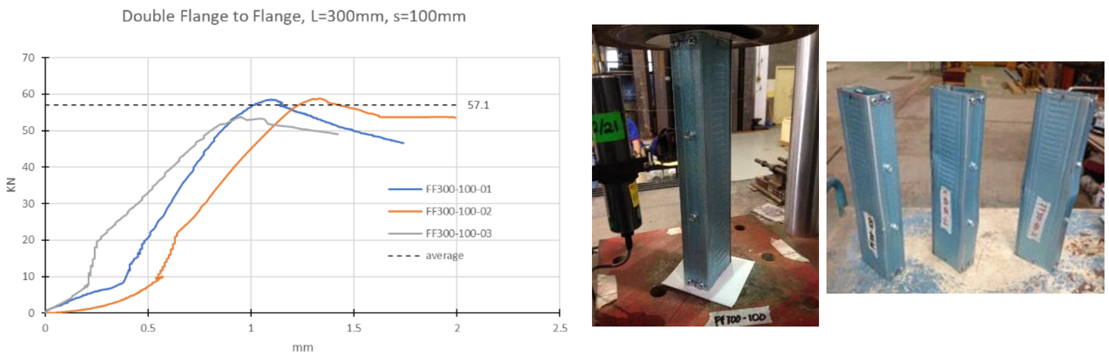
(a)



(b)



(c)



(d)

Figure 8. Graphic and picture testing results for double profile flange to flange, L=300 mm (FF300).

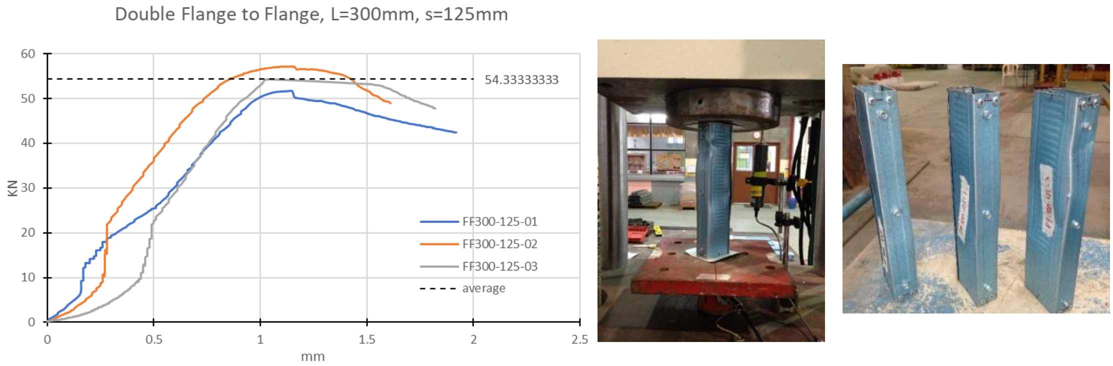


Figure 9. Graphic and picture testing results for double profile flange to flange, L=300 mm (FF300).

From the test results it appears that the more tightly screw distance is the greater the cross-sectional capacity in resisting the force. In Figure 8.a the deformation occurs indicating local buckling that is evenly distributed along the cross section, so it can be deduced that with a tight spacing the distribution of forces is evenly distributed along the cross section. A similar condition also occurs at screw spacing of 50 mm and 75 mm with a maximum force of 57 KN shown in Figures 8.b and 8.c. While for screw distance 100 mm (figure 8.d) and 125 mm (figure 9), there is a change of profile when receiving maximum load 57 KN and 34 KN for FF300-100 and FF300-125 respectively. More clearly the comparison of test results for double profile flange to flange length 300 mm as in the graph (figure 10).

Figure 9 explains that 50 mm screw spacing and 75mm screw spacing give the same result in holding the axial press. Not only in same capacity but, also the same in the form of cross-section deformation. In other words, the profile FF300-50 is identical to the FF300-75 profile. While for the FF300-100, although providing a response that is almost equal to the shorter screw distance, but the deformation is larger and even almost equal to the screw distance of 125 mm (FF300-125). So the profile FF300-100 is identical to FF300-125.

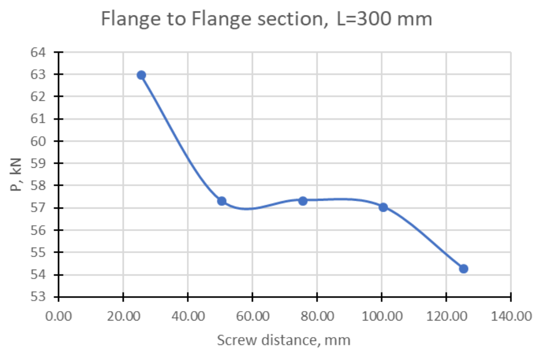


Figure 10. Graphic Screw distance and maximum load at double profile flange to flange.

Test results for double profile back to back with Length, L = 300 mm obtained results as in the picture and graph in figure 11 and figure 12. Figures provide information about the double profile back to back behavior in response to axial loads with screw distance variations of 25 mm - 125 mm with 25 mm increments respectively. Clearly shifted form changes from each model back to back double profile with length 300 mm (BB300).

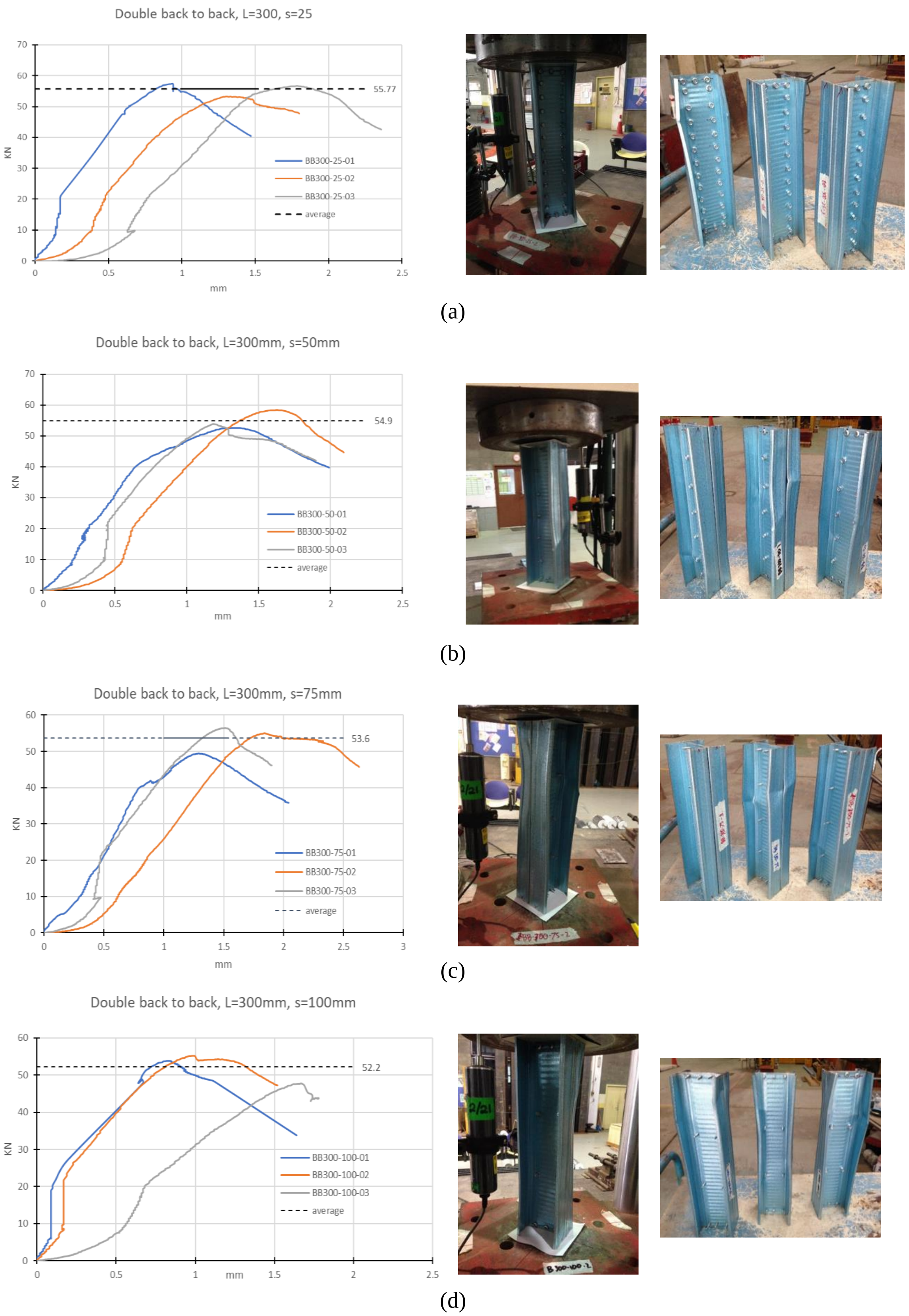


Figure 11. Graphic and picture testing results for double profile back to back, L=300 mm (BB300).

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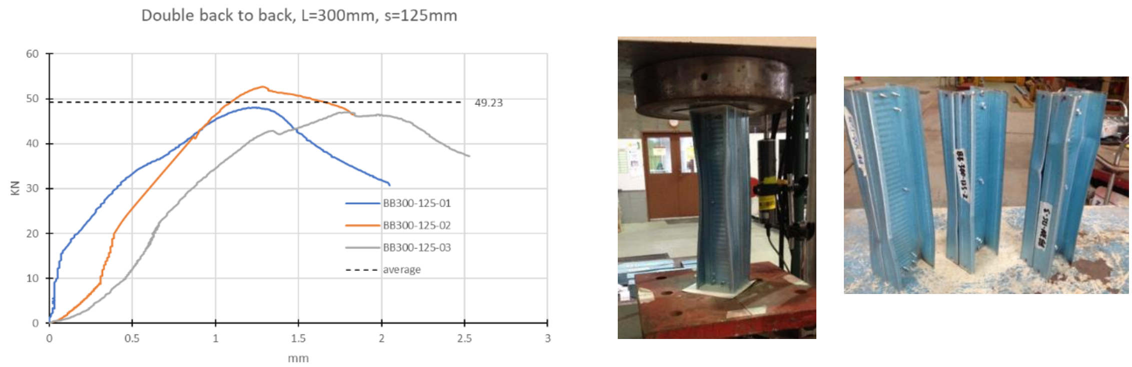

Figure 12: Graphic and picture testing results for double profile back to back, L=300 mm (BB300).

The consistent value occurs at screw spacing of 50 mm, 75 mm and 100 mm where not only the same cross-sectional capacity but also the profile change after receiving maximum load is also identical. More clearly the shape changes on the double profile with a 125 mm screw spacing, where almost as long as the profile there are elements that have deformation as in figure 9.e.

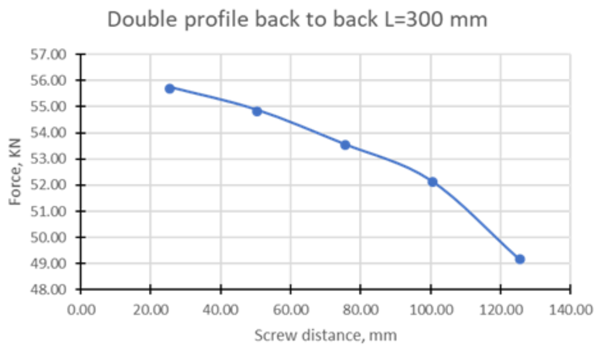

Figure 13. Graphic Screw distance and maximum load at double profile back to back.

From figure 13, it can be retrieved that for back to back model with screw distance of 75 mm and 100 mm as interconnection profile is enough to withstand axial load press which is almost identic with welding connection model used to compose double profile.

4. Discussion and Conclusion

The effect of distance screw in combined profile are significant influence in increasing strength capacity of combined profiles. The results in this study can explain that Double profiles Flange to Flange (FF300) that 50 mm screw spacing and 75mm screw spacing give the same result in holding the axial press. Not only in same capacity but, also the same in the form of cross-section deformation, so recommendation for combined profile flange to flange is 50mm -75 mm. whereas double profile double back to back with length 300 mm (BB300), the consistent value occurs at screw spacing of 50 mm, 75 mm and 100 mm where not only the same cross-sectional capacity but also the profile change after receiving maximum load is also identical, so recommendation for double profile back to back is 100 mm-125 mm.

The results of this study can be concluded that the cross-sectional capacity increases drastically if the profile is combined with other profiles. It is proven that if single profile the capacity is around 23 KN, whereas if combined into double profile its cross-section capacity becomes more than 50 KN, more details there is more than 2 times increase of capability of single profile based on the calculation on the paper. On the other hand, if validated by experiment with screw connection, there is a very significant increase that is more than 2.7 times larger double profile compared with a single profile. The ratio between calculation and experiment is 1: 1.14 or in other words $N_{cal} = \varnothing N_{exp}$ with value $\varnothing = 0.88$.

Finally, from the results of this study can be concluded that the assembly of CFS profile into a combined profile, especially double profile back to back and flange to flange can increase the capacity of the cross-section in receiving compression load.

5. References

[1] A. Ahmadi, C. Mathieson, G. C. Clifton, R. Das, and J. B. P. Lim, "An experimental study on a novel cold-formed steel connection for light gauge open channel steel trusses," *Journal of Constructional Steel Research*, vol. 122, pp. 70-79, 2016.

[2] L. Fiorino, G. Della Corte, and R. Landolfo, "Experimental tests on typical screw connections for cold-formed steel housing," *Engineering Structures*, vol. 29, pp. 1761-1773, 2007.

[3] X. Li and X. Zhang, "The strength analysis of steel sunk screw connections in the rocket," *Acta Astronautica*, vol. 137, pp. 345-352, 2017.

[4] D. C. Fratamico, S. Torabian, X. Zhao, K. J. R. Rasmussen, and B. W. Schafer, "Experiments on the global buckling and collapse of built-up cold-formed steel columns," *Journal of Constructional Steel Research*, vol. 144, pp. 65-80, 2018.

[5] E. C. f. S. Eurocode-3, *Eurocode 3 Design of steel structure part 1-3 (BS EN 1993-1-3-2006)* vol. EN 1993 - 1 - 3 British Stndard, 2006.

[6] A. N. 2005, *ASNZS 4600-2005 ColdFormed Steel Structure*. Australia: Standards Australia Limited/Standards New Zealand, 2005.

[7] S. Vijayanand and M. Anbarasu, "Effect of Spacers on Ultimate Strength and Behavior of Cold-Formed Steel Built-up Columns," *Procedia Engineering*, vol. 173, pp. 1423-1430, 2017.

[8] HILTI, "Product_Technical_Guide_for_Self_Drilling_Screws," in *Direct Fastening Technical Guide* vol. 1, hilti, Ed., ed: www.us.hilti.com, 2015.

[9] D. H. Bondok and H. A. Salim, "Failure capacities of cold-formed steel roof trusses end-connections," *Thin-Walled Structures*, vol. 121, pp. 57-66, 2017.

[10] E. C. f. Standardization, *Eurocode 3 : Design of steel structure (BS EN 1993-1-1-2005+A1-2014)*, 2009.

[11] V. U. Dan Dubina, Raffael Landolfo, *DESIGN OF COLD-FORMED STEEL STRUCTURES* Printed in Multicomp Lda, Mem Martins, Portugal: ECCS – European Convention for Constructional Steelwork, publications@steelconstruct.com, www.steelconstruct.com, WILEY BLACKWELL, 2012.

[12] D. Dan, "Eurocodes_Steel_Workshop Cold-formed Steel Design," pp. 65-70, 2014.

Acknowledgement
The author gratefully acknowledges the Institute for smart infrastructure and innovative construction (ISIIC) Faculty of Civil Engineering Universiti Teknologi Malaysia and Universitas Muhammadiyah Malang, Indonesia for their support in this research. This work financed by grand of Knowledge Transfer Program (KTP) py/2015/05230.