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An Investigation On The Application Of Thin Cold-Formed Steel Angles In Lightweight Roof Structures

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ABSTRACT

The purpose of this study was to investigate the application of cold-formed steel thin angles in lightweight roof construction in Malaysia. The angles studied acted as a connector between the roof trusses and their supports. The loads carried by the trusses were transferred to the supports through the angles. When subjected to gravity loads, the angles were in compression and when subjected to uplift forces, the eccentricity of the connection causes the angles to act in moment-rotation behaviour. A total number of 33 tests had been conducted. The parameters studied were the plate thickness, width and length. A Universal Testing Machine was used to test the angle in tension and compression separately. It was found that the maximum average capacity of the angles in tension and compression lies in between 1.0kN to 2.5kN and 6.1kN to 15.3kN respectively.

1. Introduction

In today's industrial society, it has become increasingly important to prevent the pollution of our The use of cold-formed steel (CFS) structures in Malaysia have increased since the turn of the 21st century. The use of CFS structures is encouraged as it is non-combustible and termite proof. It also does not require any formwork and has a high strength-to-weight ratio. Besides, it is also easy to install resulting in a faster and cheaper total construction cost. All these advantages fulfil the requirement of the Industrialized Building System (IBS), which has been actively promoted by the Malaysian government (Kementerian Kewangan Malaysia, 2008). However, lightweight steel application is still limited to roof structures and building facades in Malaysia. It was found that the problem lies with the lack of knowledge and technical know-how in the subject (Anuar et al, 2007). Thus, there is a need to do research in this area to gain confident of its structural application.

In Malaysia a unique high strength petrochemical effluent is produced by the crude petroleum refining The area that has been identified in this study is about CFS angle connection. Literature review showed that a lot of research had been conducted on steel angle connections. However, they were mainly on mild steel angles with thickness greater than 3mm (Stefano and Astaneh. 1991 and Hong et al 2001). Limited research has been done on a thin CFS angle although it has been widely used in

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the local construction industry. It is the aim of this paper to study the behaviour of thin CFS angles connecting trusses to their supports. The loads carried by the trusses were transferred to the supports through the angles. When subjected to gravity loads, the angles were in compression and when subjected to uplift (tension) forces, the eccentricity of the connection causes the angles to act in moment-rotation behaviour.

2. Methodology

In this study, the angle specimens were cut and press-braked from G450 steel plates, with nominal yield strength 450 MPa. The test specimen as shown in Figure 1 was asymmetrical, the outstand leg; S1 was longer than the base leg, S2 to facilitate connection to the truss and its support. The angles were loaded slowly at 0.01mm per second using a Universal Testing Machine. A total number of 33 tests (15 in tension and 18 in compression) were conducted.

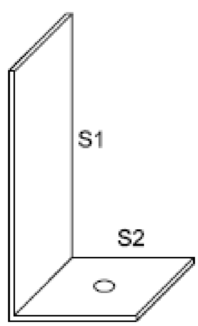


Figure 1: Test specimen

2.1Experimental Study on Angles in Tension

The tension test setup is shown in Figure 2. The angles were connected back-to-back to a 2.5mm thick plate using 6 Asteks screws in order to achieve concentric loading. The base legs were bolted to the test rig using M12 bolts and nuts. It was carefully designed that failure would not occur at the connection.

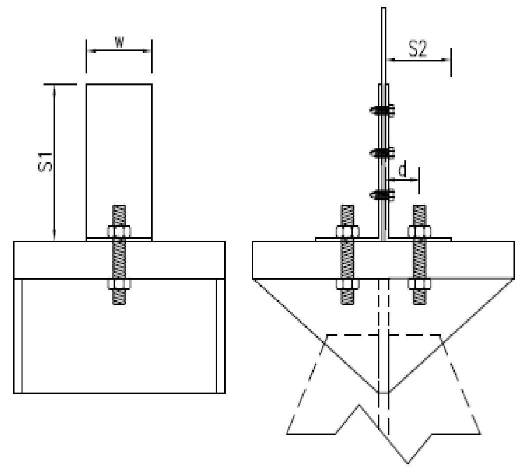


Figure 2: Test setup (Tension)

The parameters considered were the plate thickness, t, the bolt gage distance, d and the plate width, w. The nominal properties of the specimens are shown in Table 1. Three samples were tested for each configuration.

Table 1: Properties of test specimen (Tension)

Sample	Thickness, t (mm)	Width, w (mm)	Length, S1 (mm)	Length, S2 (mm)	Bolt gage distance, d (mm)
T1	1.6	50	100	50	25
T2	2.0	50	100	50	25
T3	2.5	50	100	50	25
T4	2.0	50	100	65	32.5
T5	2.0	75	100	50	25

2.2 Experimental Study of Angles in Compression

In this test, the angles were assumed to be laterally braced. The compression test setup shown in Figure 3 was similar to tension test setup except that the angles were bolted back-to-back to a 24mm thick plate. It was expected that the plates would bend inwards and a gap formed in between the plates allowed the angles to deflect horizontally when loaded.

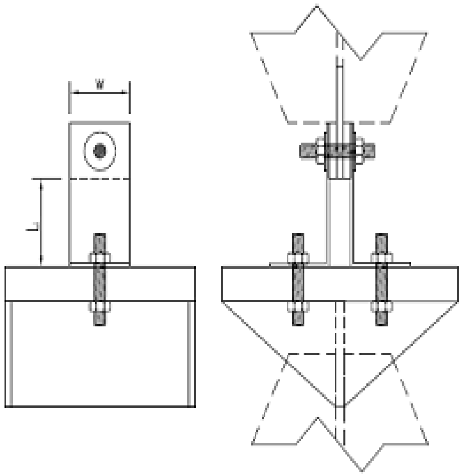


Figure 3: Test setup (Compression)

The parameters considered for the angles tested in compression were the plate thickness, t, and the effective length, L. Load was assumed to act at a distance,

L=75mm and L=100mm from the support. The nominal properties of the specimens are given in Table 2.

Table 2: Properties of compression test specimen

Sample	Thickness, t (mm)	Width, w (mm)	Bolt gage distance, d (mm)	Ultimate Load, F (kN)
T1	1.6	50	25	1.00
T2	2.0	50	25	1.60
T3	2.5	50	25	2.50
T4	2.0	50	32.5	1.20
T5	2.0	75	25	2.30

3. Result and discussion

3.1 Behaviour of Angles in Tension

It was observed that yielding of plate occurred along the edge of the bolt head during the experimental test. This happened after an initial elastic behaviour forming a plastic hinge in S2 and was followed by the straightening flexure deformation as observed by Hong et al, 2001 was not clearly shown throughout the test. The yielded specimen is shown in Figure 4.

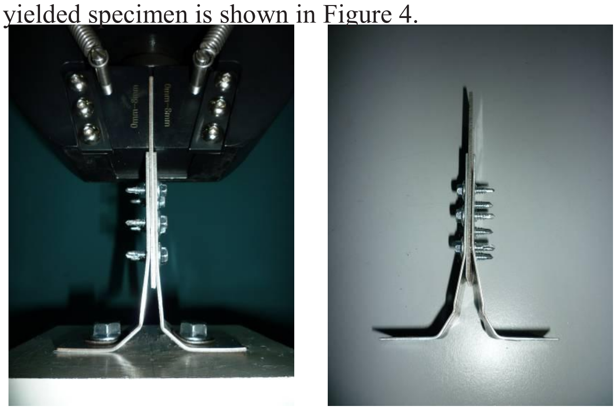


Figure 4: Yielded specimens

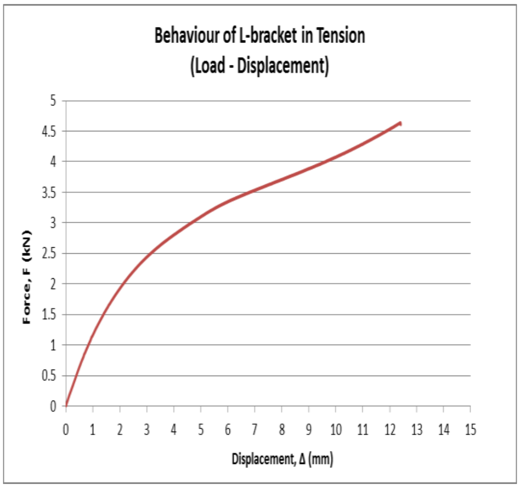
The load displacement graph of the angle intension is shown in Figure 5. The ultimate capacity of the angle was taken where there was a change in stiffness (Tang, 2006). The capacity of the angles was tabulated in Table 3.

Sample	Thickness, t (mm)	Width, w (mm)	Length, L (mm)
C1	1.6	50	75
C2	2.0	50	75
C3	2.5	50	75
C4	1.6	50	100
C5	2.0	50	100
C6	2.5	50	100

Table 3 Ultimate capacity of angles in tension

Results showed that the strength of the angle increased with the thickness of the plate. The strength also increased when the bolt gage distance decreased. This was because the lever arm was reduced. Nevertheless, the bolt gage distance was governed by construction practicality. When the width of the angle increased, there was also an increase in strength.

Figure 5: Load displacement behaviour of angle in tension



3.2 Behaviour of Angles in Compression

The strength of a roof support generally refers to its ultimate capacity. Thus, all angles were tested to failure. Initially, there was no noticeable change in geometry when the plate was loaded. However, it was observed that there was a slight movement at the corner radii. Upon reaching the ultimate load, the angles experience a large deformation and buckled inward as in Figure 6.

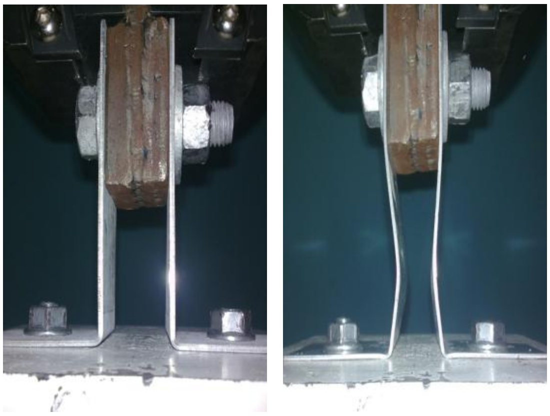
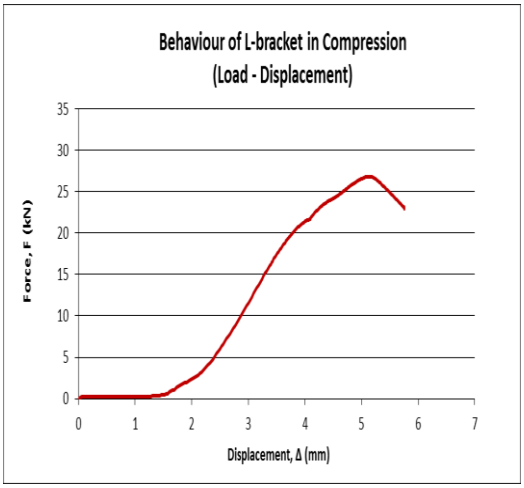


Figure 6: Buckled specimens

A typical load displacement curve is shown in Figure 6. It can be seen that there was a slip at the beginning of the test. This was caused by the movement in the clearance of the bolt hole and corner radii.

Figure 7: Load displacement behaviour of angle in compression



The ultimate capacity of the angles was tabulated in Table 4. Results show that the capacity of the angle increased with the thickness of the plate. However, the capacity of the angle decreases when the effective length increases.

Table 4: Ultimate capacity of angles in compression

Sample	Thickness, t (mm)	Width, w (mm)	Length, L (mm)	Ultimate Load, F(kN)
C1	1.6	50	75	7.30
C2	2.0	50	75	11.38
C3	2.5	50	75	15.31
C4	1.6	50	100	6.09
C5	2.0	50	100	9.25
C6	2.5	50	100	13.50

4. Conclusion

This paper summarises the preliminary experimental study of CFS angles. The experimental results showed that the capacity of the angles was affected by the plate thickness, width and length. It was found that the maximum average capacity of the angles in tension and compression lies in between 1.0kN to 2.5kN and 6.1kN to 15.3kN respectively. This data serves as a basic guidance in selecting the appropriate angles for roof truss application. The material properties of the plate are currently being tested and the data collected will be used to build a numerical model. It is planned that a parametric study be conducted using this model to come up with an optimum angle design.

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