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PERFORMANCE OF SINGLE LAP JOINTS USING ADHESIVE AND SELF-DRILLING SCREW FOR COLD-FORMED STEEL UNDER TENSILE LOADING

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Abstract: Adhesive and screw connections are usually used in single lap connections for cold-formed steel. In this study, the work focuses on the joints strength of connection for both adhesive and self-drilling screw on tensile performance. Experimental investigations were conducted on the single lap joints design. The average failure load (joints strength) of adhesive connections was found to be 50% higher than the screws joints. More often than not, the joint effectiveness of adhesive is based along the area of adhesive meanwhile for screw depends on the number of screws used.

Keywords: *Cold-formed steel, adhesive, failure, tensile strength, joint*

1.0 Introduction

In industrial and residential building construction, bridges, automotive, drainage facilities and other applications the use of cold-formed steel sections are getting famous now days (Taib *et al*., 2006 &Wahyuni and Suprobo, 2014). Mostly cold-formed steel sections are made from low alloy steel sheet or strip in cold-rolling machines or by press brake. Normally, steel members are connected by using bolts, rivets or welds. Nowadays, self-drilling screws are frequently used in cold-formed steel structural joints because of ease installing and provide a rapid joint. The self-drilling screws do not need prior drilling, they are made by special appropriative electric tools and the drilling, taping, fixing, locking can be finished at once , so this connection type has advantages of simple process, rapid construction and being good shape (Lu *et al*., 2012). The fabricating process of thin cold-formed steel members induces residual stress and plastic strains through the sheet thickness. During the installation process a premature collapse of cold-formed steel structures may be occurring. This could happen because of local buckling, torsional buckling, lateral buckling and/or residual stresses. Therefore to overcome such a problem and adhesive bonded was introduced. Compared with common technic of connection, like bolts, rivets and welds, the technique of adhesives has many advantages. Adhesively bonded composite joints provide advantages such as weight reduction and damage tolerance over traditional mechanical joining methods (Adam *et al*., 1997 & Bak *et al*., 2011). Figure 1 shows different stress distributions (Pasternak *et al*., 2004). There is a uniformly distributed transmission of forces causing a uniformly distribution of stress vertical to the loading plane. In addition, bonding can reduce stress concentrations and thus increase fatigue and damage resistance of bonded structural assemblies (O'Mahoney *et al*., 2013).

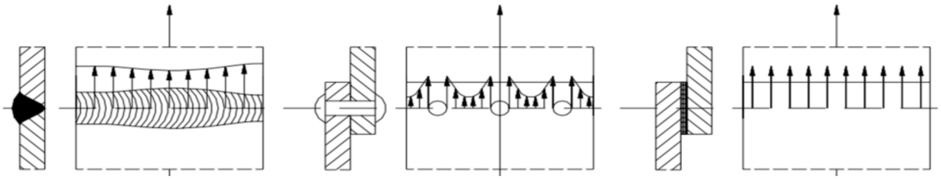

(a) Welded (b) Bolt & Nut (c) Glued/bonded

Figure 1: Stress distributions of different joints

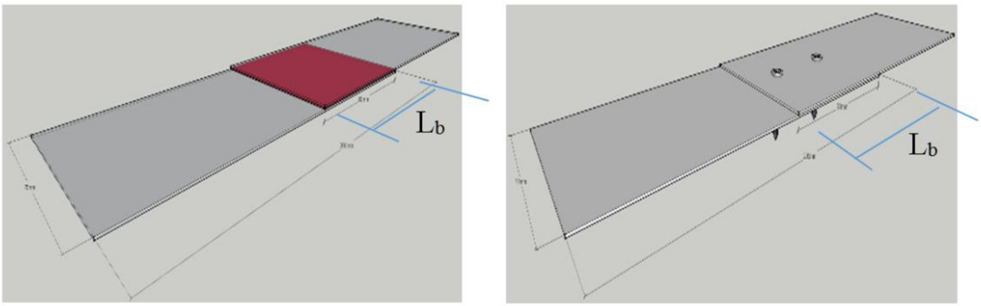
2.0 Test Procedure

The joints tested in this research were made of cold-formed steel substrates bonded with Pioneer all-purpose adhesive and self-drilling screws. Pioneer all-purpose adhesive has two component multipurpose thermosetting plastic materials. It will form chemical bonds in many rigid materials like glass to glass; glass to metal; and some metal to metal joints. It is also applicable to joints between these materials and ceramic, concrete, wood and plastics (except polyvinyl chloride, Teflon and Kel-F). Pioneer All Purpose Adhesive is resistant to water, many organic solvents, diluted acids, alkalis and other chemicals. The component comes in a red colored compound and a white compound in separate containers contain epoxide compound as shown in Figure 2 respectively. Properties of adhesive used in this experiment are shown in Table 1 (Lee *et al*., 2006). The effect of adhesive thickness was analyzed by varying the adhesive thickness as 0.5mm and 0.7mm using a varied adhered thickness of 0.75mm, 1.0mm and 1.2mm and an overlap bonded length, L_b of 60, 80 and 100 mm as shown in the Figure 3(a) and 3(b) (Arenas *et al*., 2010). The schematic diagram adhesive and screw specimen under tensile loading are shown in Figure 4. The tensile testing was conducted using Tinius Olsen Universal Testing Machine Super L 400. After attaining proper combination test pieces were fixed in a gripper and load was applied till the joint torn apart. The tensile loading was applied incrementally through a load actuator. Observation and recording of results were conducted, including loading data and displacement of the specimen. A total of 144 tests were carried out with 3 samples each and the results of Load-displacement curve were plotted.

Table 1: Properties of Pioneer All-Purpose Adhesive

Component	A(Pink) & B(Beige)
Cure method	26°C, 6 – 8 Hours
Shear strength	13.79 MPa @N/mm^2
Tensile strength	17.24 MPa @N/mm^2
Compressive strength	55.16 MPa @N/mm^2

Figure 2: Pionner all-purpose adhesive



(a) (b)

Figure 3: Specimen dimension Adhesive and Screw specimen (all units in mm)

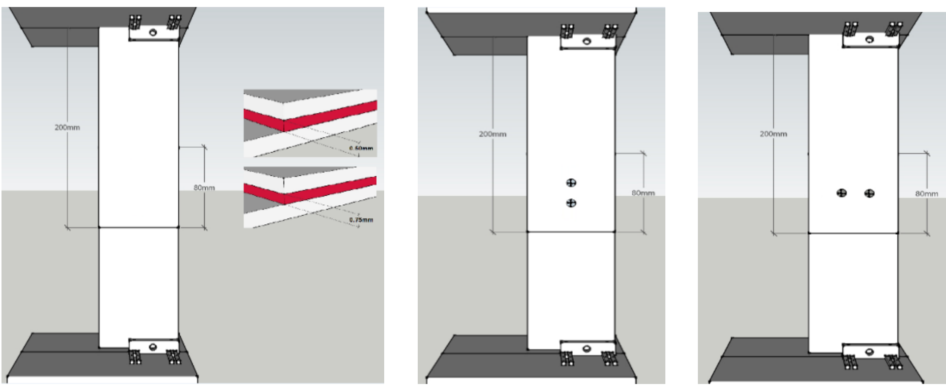


Figure 4: Schematic diagrams Adhesive and Screw specimen under test loading

3.0 Results and Discussion

3.1 Connection Strength of Adhesive Joint on the Splice Cold-Formed Steel Joint

The average ultimate failure load of each specimen was tabulated in Table 2 and 3. After the tests were completed, the specimen displacements and the failure loads were recorded. In general for 0.5mm thickness adhesive connections specimens, lapping length 80mm gives the highest failure load recorded with value range from 13.8kN until 23.83kN Figure 5 and 11.79kN until 41.77kN Figure 6. While bonding strength for both joints obtain f_a is less than tensile design capacity for all specimens. It shows that the connections specimens conducted for the test was accepted. It can be conclude that, lapping length of 80mm is the best. The highest average failure loads of bonded lap joints with adhesive thickness of 0.5mm and 0.7 mm for specimens C75 were found to be 28.6kN, 16.90kN, 37.60kN and 25.67kN as shown in the Figure 5 and Figure 6. While for specimen C100 were found to be 23.83kN, 19.73kN, 41.77kN and 16.97kN respectively as shown in the same figure. Figures 5 and 6 show that the lowest failure load was determined at adhesive thickness of 0.7mm thickness adhesive and the highest failure load was determined at adhesive thickness of 0.5mm thickness adhesive for constant overlap length area 80mm. In addition, the failure load increased with the increase of overlap thickness area for constant overlap length area. In other words, the increase in thickness of glue will produce high ultimate load. Meanwhile, when an adhesive area increased it increase the ultimate load too.

In general, the experimental results show that all the specimens failed in these two major failure modes which is cohesion bond failures and adhesive failures. It implies that there should be an optimum thickness which will result in the most effective bonding. Cohesion bond failures result in fracture of the adhesive and are characterised by the clear presence of adhesive material on the matching faces of both adherends. Failure is usually by shear, peel stresses or a combination of shear and peel may also cause a cohesion failure. In cohesion failures, the adhesive surface typically appears rough as shown at Figure 7. Adhesion failures are characterised by the absence of adhesive on one of the bonding surfaces (Kim *et al*., 2003). Failure occurs along the interface between the adhesive layer and the adherends and is due to hydration of the chemical bonds which form the link between the adhesive and the surface.

Table 2: Test result for 0.5mm thickness adhesive connections

Sample: **C75/0.75/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	18.2	19.9	47.7	28.60	4500	6.35	13.79	14060
80	28.4	19.9	21.4	23.07	6000	3.85	13.79	14060
100	21.4	16.2	16.7	18.10	7500	2.41	13.79	14060
Sample: **C75/1.0/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	6.83	15.6	22.1	14.84	4500	3.29	13.79	18750
80	16.6	12.4	12.4	13.80	6000	2.30	13.79	18750
100	24.1	19.6	7.13	16.90	7500	2.25	13.79	18750
Sample: **C100/1.0/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	20.1	20.8	18.2	19.70	6000	3.28	13.79	25000
80	23.9	29.3	18.3	23.83	8000	2.97	13.79	25000
100	15.9	20.7	23.7	20.10	10000	2.01	13.79	25000
Sample: **C100/1.2/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	12.3	11.8	11.8	11.97	6000	1.99	13.79	30000
80	20.7	10.8	27.7	19.73	8000	2.47	13.79	30000
100	17.2	14.9	20.8	17.60	10000	1.76	13.79	30000

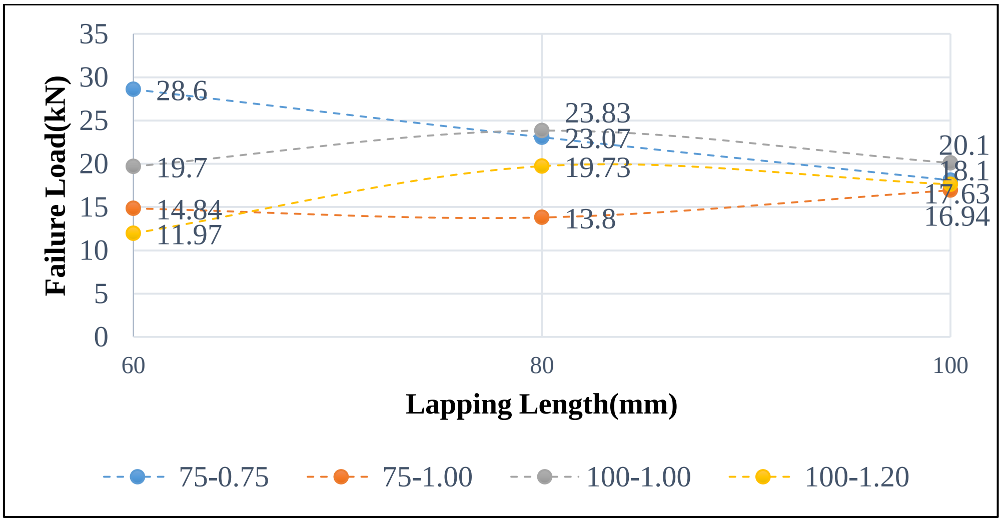


Figure 5: Failure load vs lapping length for 0.5mm thickness adhesive

Table 3: Test result for 0.7mm thickness adhesive connections

Sample: **C75/0.75/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	10.5	10.5	14.0	11.67	4500	2.59	13.79	14060
80	29.3	38.2	36.1	34.53	6000	5.76	13.79	14060
100	39.4	40.0	33.4	37.60	7500	5.01	13.79	14060
Sample: **C75/1.0/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	26.8	33.9	16.3	25.67	4500	4.28	13.79	18750
80	26.7	21.7	20.9	23.10	6000	3.85	13.79	18750
100	24.8	25.7	25.7	25.40	7500	3.39	13.79	18750
Sample: **C100/1.0/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	20.8	18.3	39.8	26.30	6000	4.38	13.79	25000
80	43.3	43.3	38.7	41.77	8000	5.22	13.79	25000
100	28.1	38.9	36.9	34.63	10000	3.46	13.79	25000
Sample: **C100/1.2/100**	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Bonded Area, **A** (mm^2)	Bonding Strength $f_a=P_{Avg}/A$ (N/mm^2)	Adhesive Shear Strength F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
L_b(mm)	1	2	3					
60	17.4	16.7	16.8	16.97	6000	2.82	13.79	30000
80	13.9	13.9	7.57	11.79	8000	1.49	13.79	30000
100	10.9	11.9	12.8	11.87	10000	1.19	13.79	30000

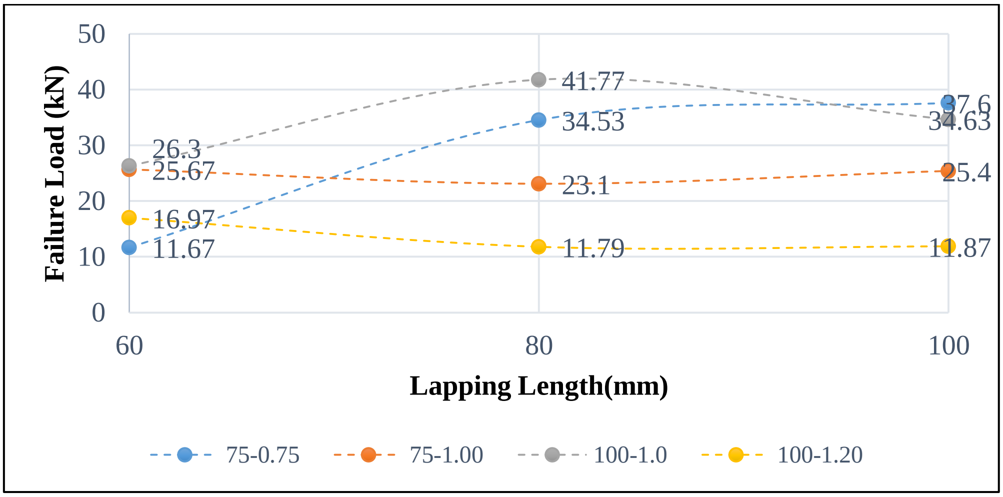


Figure 6: Failure load vs lapping length for 0.7mm thickness adhesive

Figure 7: Typical failure modes of adhesive joints

3.2 Connection Strength Self-Drilling Screws Joint of Cold Formed steel

Generally, the installation of cold-formed steel structures uses screws as the joint. Self-drilling screw provides a rapid joint of sheet metal and roofing to framing members. Tensile test of self-drilling screws was carried out to compare with the strength of adhesive joint on the cold formed steel structures, for similar area of overlap. Tests were conducted on the tensile connection with a length of 80 mm and a width of overlap 75mm and 100mm respectively. Varied numbers of screws and orientations were used during the test. Table 4 and Table 5 above shows the result obtained from the total number of 72 specimens. For these two specimens having different thickness and screw orientations, two graphs of failure load vs number of screws were plotted as shown in Figure 8 and Figure 9 respectively.

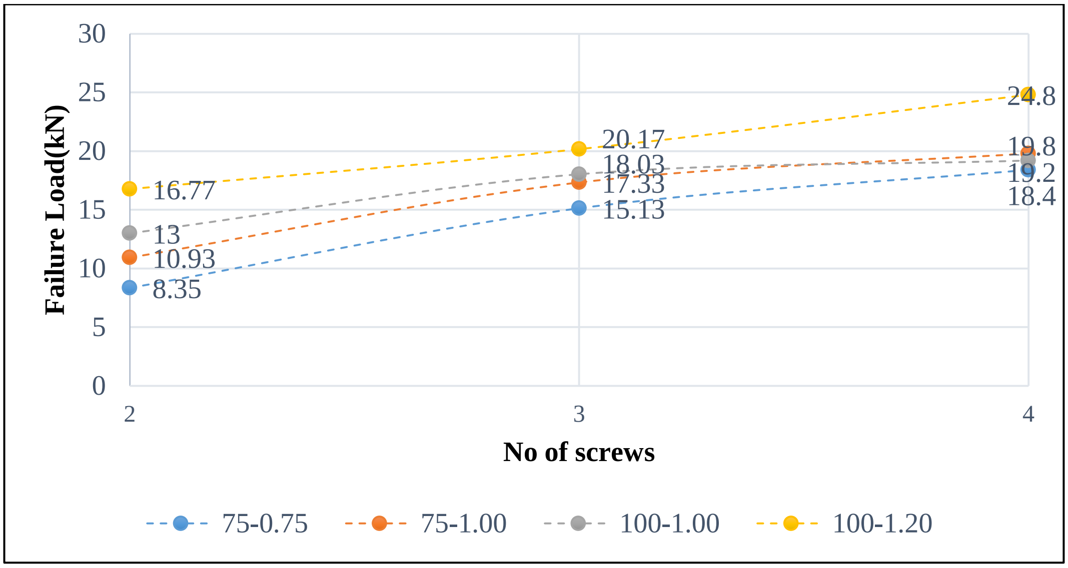


Figure 8 Failure load vs number of screw arranged in parallel with the load

Table 4: Results for screw arranged in parallel with the load

Sample: **C75/0.75/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, $A=2r*t$ (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	8.42	8.32	8.32	8.35	4.50	1855.56	2.48	14060
3	15.2	15.3	14.9	15.13	6.75	2241.48	3.72	14060
4	20.2	20.2	15.0	18.40	9.00	2044.44	4.96	14060
Sample: **C75/0.75/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, $A=2r*t$ (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	11.1	11.2	10.5	10.93	6.00	1821.67	3.30	18750
3	16.0	16.0	20.0	17.33	9.00	1925.56	4.95	18750
4	20.8	20.8	18.0	19.80	12.00	1650.00	6.60	18750
Sample: **C100/1.0/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, $A=2r*t$ (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	11.0	10.8	17.2	13.00	6.00	2166.67	3.30	25000
3	17.3	16.8	20.0	18.03	9.00	2003.33	4.95	25000
4	20.0	20.0	17.6	19.20	12.00	1600.00	6.60	25000
Sample: **C100/1.2/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, $A=2r*t$ (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	15.7	19.0	15.6	16.77	7.20	2329.17	3.96	30000
3	19.0	19.0	22.5	20.17	10.80	1867.59	5.94	30000
4	22.3	27.0	25.2	24.80	14.40	1722.22	7.92	30000

Table 5: Results for screw arranged not parallel with the load

Sample: **C75/0.75/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, **A=2r*t** (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	12.78	8.31	8.79	9.96	4.50	2213.33	2.48	14060
3	16.79	17.68	16.66	17.04	6.75	2524.44	3.72	14060
4	20.2	20.2	15.0	18.40	9.00	2044.44	4.96	14060
Sample: **C75/1.00/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, **A=2r*t** (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	12.07	13.36	12.62	12.68	6.00	2113.33	3.30	18750
3	17.51	17.68	16.66	17.28	9.00	1920.00	4.95	18750
4	20.8	20.8	18.0	19.80	12.00	1650.00	6.60	18750
Sample: **C100/1.0/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, **A=2r*t** (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	13.1	13.0	13.4	13.17	6.00	2195.00	3.30	25000
3	18.0	15.9	17.5	17.10	9.00	1900.00	4.95	25000
4	20.0	20.0	17.6	19.20	12.00	1600.00	6.60	25000
Sample: **C100/1.2/100** L_b=80mm	Failure Load (kN)			Average Failure Load, P_{Avg} (kN)	Screw Area, **A=2r*t** (mm^2)	Bearing Strength $F_b = P_{Avg}/A$ (N/mm^2)	Screw Bonding Strength Capacity F_s(N/mm^2)	Tensile Design Capacity F_{tp}(N)
Number of screws	1	2	3					
2	13.6	12.9	14.4	13.63	7.20	1893.06	3.96	30000
3	23.8	19.4	20.4	21.20	10.80	1962.96	5.94	30000
4	22.3	27.0	25.2	24.80	14.40	1722.22	7.92	30000

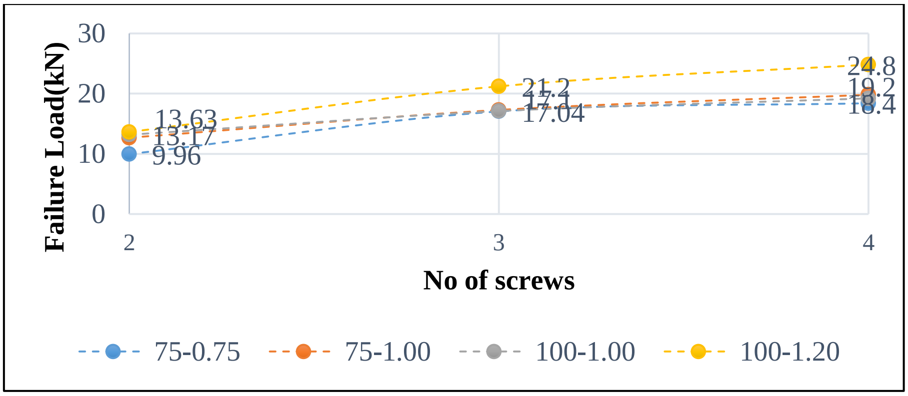


Figure 9: Failure load vs number of screw arranged not parallel with the load

Screw connection failures are bearing failures with maximum capacity as shown in Figure 8 and Figure 9. As expected as the number of screws increased, the average failure load also increased. For example, average failure load obtain for connections using 2 screws for specimen which has a width of 100mm and 1.00mm thickness is 13.0kN load and for 4 screws the ultimate load was 19.20kN as increase of 33%. Another observation was made to the same number of screws used for specimen 1.20 mm thickness the resistance achieved 16.77kN load and 24.80kN. Meanwhile, for screw arranged not parallel with the load for example specimen 1.20mm thickness width 100mm the average failure load found to be in range of 13.63kN until 24.80kN.

Figure 10: Failure mode of screw connections

Failure mode analysis for C75 0.75, C75 1.0, C100 1.0 and C100 1.2 plate specimen are shown in Figure 10 respectively. Experimental result of specimens (connecting with two, three and four screws) presents a failure mode of screws leaned, plate end tilted in the connection region and its direction displacement is biggish, that is to say the connection plates tilted very much. At the connections joints showed that there were excessive screws tilting, material piled up at the bearing area, and eventually material extruded out from the edge.

3.3 Comparative Analysis of Load-Displacement Curves

Figure 11 shows typical load-displacement curve of group 0.5mm thickness adhesive connection while Figure 12 shows typical load-displacement curve of screws connections. As the load increasing constantly, load-deformation curve slope of experiment keeps ascending until it reach the ultimate failure load and then drop down. The behaviour is linear up to approximately 5kN (approximately 40% of failure load). The ultimate average adhesives bonding strength was 4.20, 2.61, 2.75, 2.07 N/mm^2 for 0.5mm thickness and 4.45, 3.84, 4.35, 1.83 N/mm^2 for 0.7mm thickness. Meanwhile the manufacturer states a shear strength value of approximately 13.79 N/mm^2; in general the present test result is just 30% of the value given by the manufacturer. There are many factors that may have contributed to the degraded shear strength of the adhesive. One possible factor is the fabric layer. Load-displacement curves for specimen 0.7mm thickness adhesive were similar to those for specimen 0.5mm thickness adhesive. The behaviour was linear up to approximately 4kN (approximately 40% of failure load). The average failure load of 0.7mm thickness adhesive was 34.23kN, 32% higher than for specimen's 0.5mm thickness adhesive (23.26kN), and average global displacement was 2.03 mm. The design capacity of the cold-formed steel section can be calculated as follows:

Tensile yield strength, $f_y = 250N/mm^2$

For the 75x38 mm C-channel section, 0.75 mm thickness

$A_s = (75 + 38 + 38 + 8 + 8) \times 0.75 = 125.25mm^2$, the design capacity of cold-formed steel, F_{ts} is,

$$F_{ts} = 250 \times 125.25 \times 10^{-3} \times kN$$

$$F_{ts} = 31.31\ kN$$

The ultimate resistance that will be obtained from the test is not expected to be equal to the design capacity. It is due to the fact that the purpose of the adhesive under investigation is to give extra strength and stability to the connection. The tensile design capacity of 75 mm width 0.75 mm thick steel plate, F_{tp} can be estimated as follows:

$$F_{tp} = 250 \times 56.25 \times 10^{-3} kN$$

$$F_{tp} = 14.06\ kN$$

The experimental capacity of connection is determined based on the average failure load achieved for each specimen as shown in Table 2 and 3. The adhesive bonding strength is calculated by dividing the average failure load by contact area for each specimen. For example specimens in group C75 0.75, with the adhesive contact area of 75x60 = 4500 mm^2, the bonding strength, f_a is = 23.07x1000/4500 = 3.85 N/mm^2 and it less than design capacity F_{tp} = 14060N. Its shows that the connection specimen conducted for the test was accepted.

For specimens of group 0.5mm thickness adhesive C75 0.75 and C75 1.0 the average failure load of the adhesive joints are 23.26, 15.18, 27.73 and 24.72kN respectively. Compared the adhesive capacity with the design capacity of the full channel section of 31.31kN, the adhesive can provide 26%, 52%, 11% and 21% respectively, of the design capacity of the cold-formed steel section. This is a significant contribution to the integrity of adhesive self-driven screws connection. It is to be noted also that, if we consider only the 75 mm width web part of the section which has tensile capacity of 14.06kN, the adhesive strength are 65%, 8%, 97% and 76% compared with the tensile capacity of solid steel plate. Meanwhile for specimens of C100 1.0 and C100 1.2 the average failure load of the adhesive joints are 21.21, 16.43, 34.23 and 13.54kN.

The same observations also noted for specimens using self-drilling screws as show in Figure 12. The main difference between these two samples is that the value of load required to reach the failure of connection is relatively low compare to sample using adhesive. This indicates, using only self-drilling screws alone in the connection is not strong enough. The strengthening can be achieved by combining adhesive and self-drilling screws for future connections testing. Different self-drilling screws, orientation also influenced the strength of connections due to direction of loading was perpendicular with the self-drilling screws positions. The experimental capacity of connection is determined based on the maximum load achieved by each specimen as shown in Table 4 and 5. The screw bonding strength capacity of 1 screw for each thickness is 550 N/mm^2 x 3mm x 0.75mm x 10^{-3}kN = 1.24kN, 550 N/mm^2 x 3mm x 1.00mm x 10^{-3}kN = 1.65kN and 550 N/mm^2 x 3mm x 1.20mm x 10^{-3}kN = 1.98kN. Therefore for all specimens with difference width as follow; C75 0.75- 2 screw (2.48kN), 3 screw (3.72kN) and 4 screws (4.96kN), C75 1.00- 2 screw (3.30kN), 3 screw (4.95kN) and 4 screws (6.60kN), C100 1.00- 2 screw (3.30kN), 3 screw (4.95kN) and 4 screws (6.60kN), C100 1.20-2 screw (3.96kN), 3 screw (5.94kN) and 4 screws (7.92kN).

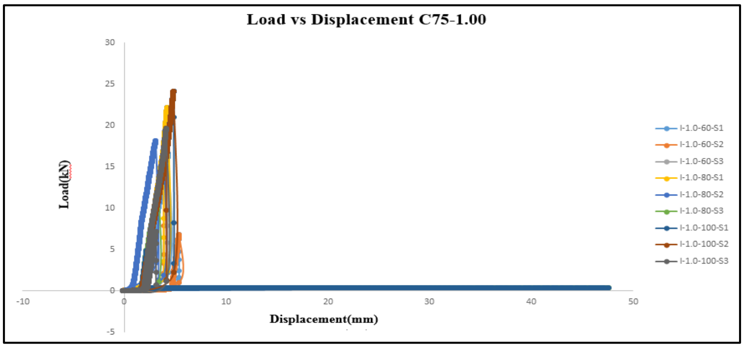


Figure 11: Load vs Displacement for adhesive

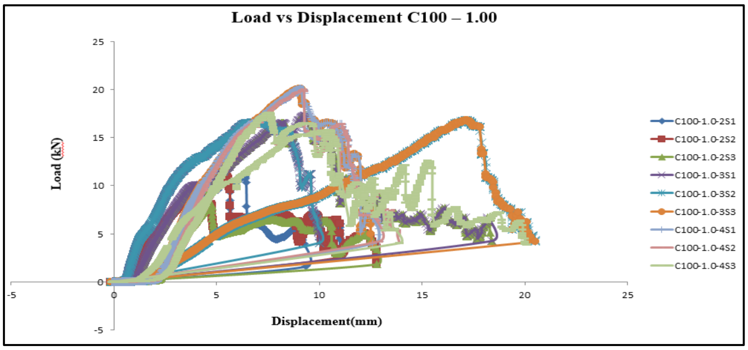


Figure 12: Load vs Displacement for Screws

4.0 Conclusion

Two groups of single lap cold-formed steel plate joint specimens have been tested to investigate the strength of splice joint in tension. The first group used adhesive and the second group used self-drilling screws. Total of 144 specimens were tested and examined to study the performance of the adhesive bonded and self-drilling screws connection. The thickness of cold-formed steel, thickness of adhesive and the area of bonded area were varied. In general, adhesive able to contribute a significant amount of resistance to shear strength of lap joint between two steel plates. The results showed that the strength capacity of adhesive joint depends on the thickness of adhesive and area of adhesive. In addition, it was found that failure mode of the joints is cohesion bond failures and adhesive failures. As what has been stated above, no matter the thickness plate of or thin plate self-drilling screwed connection specimens, the failure mode of joints can be identified as plate end tilted in the connection region and self-drilling screws leaned (Lu *et al*., 2012). In summary, it can be concluded as follows;

(i) The lap shear strength increases with the overlap area for steel flat sections specimens. Besides that, when adhesive thickness increases the lap shear strength also increase.

(ii) In general, mode of failure for specimens 0.5mm thickness adhesive used was almost equally distributed which is 47% cohesive failure and 53% adhesive failure. While for specimens 0.7mm thickness adhesive used was 69% cohesive failure and 31% adhesive failure.

(iii) The lap shear strength increases with the increased of number of self-drilling screws used for cold-formed steel flat sections specimens.

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