Tensile performance of adhesive joint on the cold-formed steel structure

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Abstract **--- In this paper, a preliminary research of new connection method on the cold-formed steel in civil engineering structures is presented. The study focuses on the durability of adhesive on tensile performance. A cold-formed steel – adhesive joints that have been loaded in tension until rupture. A comparison strength in tensile between mechanical joint and adhesive joint on the cold-formed steel was investigated. The increment strength of joints are about 27,11% with Sikadur 31 CF Normal adhesive and 81,84% with JB Weld 8265 epoxy. The joint strength of adhesive is based on the type of adhesive. The joint failure is adhesive failure (AF) for Sikadur 31 CF Normal and cohesive failure (CF) for JB Weld 8265 epoxy.**

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

I. INTRODUCTION

Cold-formed steel sections have been used in bridge construction, drainage facilities, metal building of industries, residential construction, automotive and others applicatons. Cold-formed steel sections are made from carbon or low alloy steel sheet, strip, plate or flat bar in col-rolling machines or by press brake. The manufacturing process of thin cold-formed steel members causes residual stress and plastic strains through the sheet thickness. The plastic strains increase the yield stress in the sheets of cold formed steel. Thin elements may cause buckling and web crippling in the design structure, [8,9].

Generally, cold-form steel structure joints uses self drilling screw to easy installing and provide a rapid joint. A premature collapse of cold formed steel structures can be occured, eventhough during instalation process [3]. This phenomena might be caused by local buckling, torsional buckling, lateral buckling and/or residual stresses [4,5,6,7]. The first factor are caused by the small thickness of structure and the second one is caused by stress gradient during instalation process. A new type of connection for predicting the static residual strengths of cold formed steel structures has already been developed. Mechanical joints of steel structures such as bolt, rivet, screw and welding have disadvantages. The disadvantage of bolt joint and rivet joints is the residual stress effects surrounding the holes. In addition to the effects of residual stress effect surrounding holes, screw joint can be applied for light loads only. The potential corrosion is the effect of welding joints; impossible to manufacture welding joint of cold formed steel because limited dimension of sections. To get a better performance of steel structural joints especially cold formed steel structures, an innovation joints method is needed. Adhesive joint is used in various industries because of the advantages over the mechanical fastening such as riveting, welding and bolting [1,2]. Adhesive joint can distribute the local stress become uniformly as well [3].

II. MATERIALS AND METHODS

Various test procedures were employed to obtain the mechanical properties of adhesive JB Weld and Sikadur 31 CF Normal. Experiments were conducted on bulk adhesives and adhesively bonded single lap joints (SLJs) under static loading .

2.1. Specimen Manufacture

Bulk adhesives and adhesively bonded cold-formed joints of single lap joint (SLJ) were used in the experimental work. Bulk adhesives of 0.75 mm thickness were manufactured for each types of adhesive. To investigate surface effects on bonding joints, the surface of some of the cold-formed steel specimens were roughened using medium grade abrasive paper.

The joints tested in this research were made of cold-formed steel substrates were bonded with Sikadur 31 CF Normal adhesive and JB Weld 8265S epoxy to manufacture the SLJs. Sikadur 31 CF Normal adhesive is structural two part adhesive, a solvent free, moisture tolerant, designed for use at temperatures between 10 ^{o}C and 30 ^{o}C and based on a combination of epoxy resins and special fillers. While, JB Weld 8265S epoxy is a waterproof adhesive, petroleum, resistant up to 500 ^{o}F, chemical and acid resistant on the fully cured.

The dimensions of the joints are illustrated in Fig. 1. The cold-formed steel surfaces were abraded with abrasive paper to enhance the joints strength.

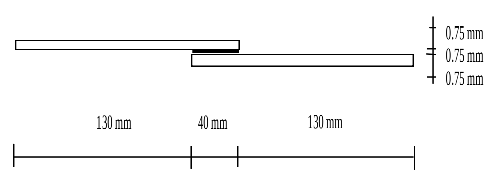

Fig. 1. Single Lap Joint Specimens (width 42 mm)

A jig was used to control the position of the substrates, the thickness of bond line and the appropriate pressure of joints. The substrates, adhesive layers and the spacers were pressed in the jig.

2.2. Specimen Testing

Quasi static testing were carried out on the bulk adhesive samples. The ultimate strength and strain in tensile of the joints was also measured.

III. RESULTS AND DISCUSSION

3.1 Tensile strength and compressive strength of Sikadur 31 CF Normal adhesive and JB Weld 8265S adhesive

Adhesive tensile strength was obtained by tensile test specimens (Figure 3) based on the recommendations of the ASTM D638 Standard Test Method for Tensile Properties of Plastics, using a Universal Testing Machine.

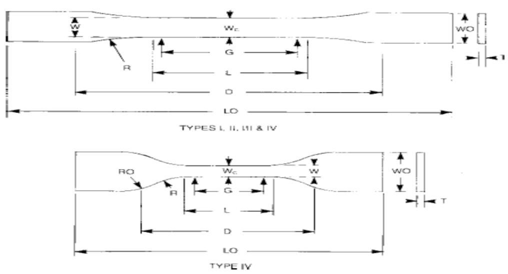

Fig. 2. Dimension of bulk adhesive

Table 1. Specimen Dimensions for Thickness, *T*, mm(in)

Dimension	7 (0.28 in) or under		Over 7 to 14 (0.28 to 0.55 in)	4 (0.16 in) or under		Tolerance
	Type I	Type II	Type III	Type IV	Type V	
W – Width of narrow section	13 (0.5)	6 (0.25)	19 (0.75)	6 (0.25)	3.18 (0.125)	±0.5 (±0.02)
L – Length of narrow section	57 (2.25)	57 (2.25)	57 (2.25)	33 (1.30)	9.53 (0.375)	±0.5 (±0.02)
WO – Width overall	19 (0.75)	19 (0.75)	29 (1.13)	19 (0.75)	-	+6.4 (+0.25)
WO – Width overall	-	-	-	-	9.53 (0.375)	+3.18 (+0.125)
LO – Length overall	165 (6.5)	183 (7.2)	246 (9.7)	115 (4.5)	63.5 (2.5)	no max
G – Gage length	50 (2.00)	50 (2.00)	50 (2.00)	-	7.62 (0.3)	±0.25 (±0.01)
G – Gage length	-	-	-	25 (1.00)	-	±0.13 (±0.005)
D – Distance between grips	115 (4.5)	135 (5.3)	115 (4.5)	65 (2.5)	25.4 (1.0)	±5 (±0.2)
R – Radius of fillet	76 (3.00)	76 (3.00)	76 (3.00)	14 (0.56)	12.7 (0.5)	±1 (±0.04)
RO – Outer radius (Type IV)	-	-	-	25 (1.00)	-	±1 (±0.04)

Fig. 3. Bulk adhesive of Sikadur 31 CF Normal

Table 2. Tensile strength of bulk adhesive Sikadur 31 CF Normal

No	Wide, b (mm)	Thickness, t (mm)	Area, bxt (mm^2)	Ultimit Load P_u (kg)	Tensile Stress (kg/cm2)
Sikadur 31 CF Normal					
1	18,7	3,1	57,97	900	155, 3
2	19,05	3,3	62,7	964	153, 8
JB Weld Epoxy					
1	10	1	10	2713	271,3
2	10	1	10	2687	268,7

Tabel 3. Compressive strength of bulk adhesive Sikadur 31 CF Normal

No	Diameter, Φ (mm)	Depth, h (mm)	Area, $1/4\pi\Phi^2$ (mm^2)	Ultimate Load P_u (kg)	Compressive Stress (kg/cm2)
1	20,2	40,4	320,6	1460	455,4
2	20,2	40,4	320,6	1370	427,3
3	Hammer test				526
4					537
5					560

While the values of fracture energy (G_f) and Poisson's ratio (ν) of Sikadur 31 CF Normal adhesive and JB Weld epoxy obtained respectively by 1.4 kJ or Nm, 0.28, 2.5 kJ and 0.3. Sikadur 31 CF Normal adhesive has compressive strength bigger than tensile strength about to 2,8 %. While, JB Weld epoxy has tensile strength only.

3.2 Tensile strength of self screw drilling joint and adhesive joint on the cold formed steel structures

Generally, the installation of cold-formed steel structures uses self screw drilling as the joint. Screw provides a rapid joint of sheet metal and roofing to framing members. Tensile test of self screw drilling is carried out to compare the strength of adhesive joint on the cold formed steel structures, for similar area of overlap. Tests conducted on the connection tensile joint of cold formed steel structure with a length of 40 mm and a width of overlap 42 mm, resulting in a total area A_{tot} = 1680 mm^2 connection and 6 mm of screw diameter. Screw connection failures are bearing failures with maximum capacity as shown in Table 4.

Table 4. The tensile strength of screw connections on the cold formed steel structures

Specimen	Wide (mm)	Thickness (mm)	Overlap Length (mm)	Area (mm^2)	Number of *Screw*	Hole area of *Screw* (mm^2)
1	42	0,75	40	1680	1	7,072
2	42	0,75	40	1680	2	14,144

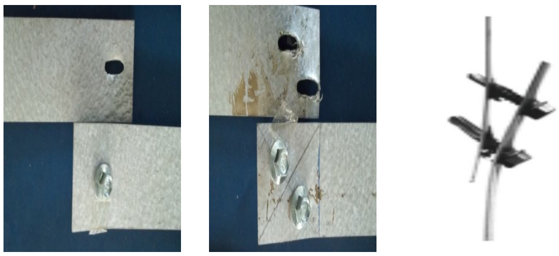

Fig. 4 Failure mode of screw connections on the cold formed steel structures

3.3 Tensile strength of adhesive joint on the cold formed steel structures

While the mode of adhesive joint failure varies between adhesive failure (AF) and cohesive failure (CF), depending on the pretreatment surface and substrates to be joined. Pretreatment affects the quality and load capacity of the adhesive bonding. In this researech, abrasive surface of joint surface is choosen as the pretreatment method.

Table 5. The tensile strength of adhesive joint on the cold formed steel structures

Wide (mm)	Thickness (mm)	Overlap Length (mm)	Area (mm2)	Adhesive	Adhesive Thickness (mm)	Ultimit Load (kgf)	Ultimate Stress (kgf/ cm^2)	Strain (mm)
42	0,75	40	1680	Sikadur 31 CF Normal	0,75	385	23,9	2,25
42	0,75	40	1680	JB Weld	0,75	1570	95,7	9,04

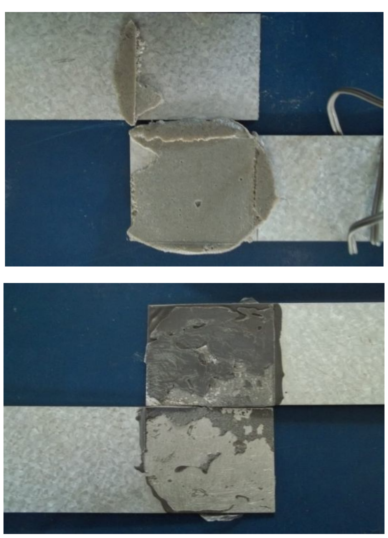

Fig. 5. Typical failure mode of adhesive joints in : a) Sikadur 31CF Normal b) JB Weld 8265 epoxy

3.4 Comparison

Adhesive joint as the connection of cold formed steel structures have been succesfully occured, see Table 6. The improvement strength of connection are about 27,11% for Sikadur 31 CF Normal and 81,84% for JB Weld 8265 epoxy. The joint strength of adhesive is based on the type of adhesive. The joint failure is adhesive failure (AF) for Sikadur 31 CF Normal and cohesive failure (CF) for JB Weld epoxy. Adhesive failure is occured on the Sikadur 31 CF Normal might be caused by no pretreatment on the cold formed steel surfaces. Abrasive surface as the pretreatment is applied on the JB Weld epoxy joit only.

On the next research, author will develop the effects of joint thickness, surface treatment method of metal substrates and joint combination to produce the best performance of adhesive joint on the cold formed steel structures under tensile and flexural loadings.

Tabel 6. Comparison of joint strength between adhesive joint and screw

Self screw drilling joint		Adhesive joint		
Number of *Screw*	Ultimate Stress (kgf/ cm^2)	Adhesive	Adhesive thickness (mm)	Tegangan ultimate (kgf/ cm^2)
1	17,335	Sikadur 31 CF Normal	0,75	23,9
2	17.409			
1	17,335	JB Weld 8265 epoxy	0,75	95,7

IV. CONCLUSIONS

Two groups of SLJ specimens, manufactured from cold-formed steel and adhesive, has been tested to investigate the joint strength of cold formed steel structures in tension.

The results showed that the strength capacity of adhesive joint depends on the adhesive type, which were about 27% for Sikadur 31 CF Normal and 81% for JB Weld 8265 epoxy.

Failure mode of the joints is influenced by surface treatment of substrates (cold-formed steel). Abrasive treatment of substrates causes cohesive failure (CF). No treatment of substrates decrease the joint strength, causes adhesive failure (AF).

Acknowledgments

Authors are grateful to Research Centre, Sepuluh Nopember Institute (ITS) Surabaya, Republic of Indonesia for the financial contribution of this project. We specially would like to express thanks to the Laboratory of Structure of Sepuluh Nopember Institute and Mulcindo Steel Company for the supporting experimental work.

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