

## THE INFLUENCE OF LAP SIZE ON SHEAR STRENGTH OF ADHESIVE JOINTS

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### ABSTRACT

Adhesive joints may be used instead of forced-in joints, welded and riveted joints, soldered and twisted connections. They are characterized by a lot of advantages, thanks to them the adhesive joints are willingly used in manufacturing processes. These advantages include low price of joint, reduction of weight of the final construction, improvement of durability, reliability and quality and improving visual appearance. From this point of view it should be concluded that experimental tests of adhesive joints are grounded. In the paper the results of experimental tests of static shear strength of single-lap joints are presented. These joints are made with two constructive glues. The specimens made from AISI 4130 steel were glued. Their surfaces were prepared in two versions before gluing: grinded with abrasive paper by hand and cleaned by sand-blasting. The results were analyzed from variable size of the lap point of view.

**Keywords:** adhesive joints, lap size, shear strength.

## INTRODUCTION

Adhesive bonding consists of placing a thin layer of glue between bonded surfaces. This process allows to joint two objects with adhesive forces. Adhesive bonding also gives possibility to joint elements made from different materials – metallic with metals, ceramic, plastics or even glass. In practice it may be the only way to joint materials. Gluing is good manner to joint elements with different thickness or for such of them where jointing by other methods is impossible. Bonding is a simple and economic process, joints gives possibility to maintain high durability of construction, they do not provoke negative internal stresses because of small hardening shrinkage. The glue may function as a seal because of its chemical resistance. The modification of glue composition by fillers may lead to obtaining substances with unique characteristics. This special treatment may lead to significant changes of glue properties: they may be resistant to high temperature, conduct electricity or be dielectrics in reverse, have different flexibility, fatigue or impact strength, hardness, heat resistance

or life. These modifications are sometimes used in joints whose temperature of exploitation changes in great degree [1].

The bonding process entails several basic operations. The steps of the creation of each joint are almost the same and it is important to follow them in a precisely defined order. There are:

- preparing surface before glue covering,
- preparing and spreading the glue
- jointing the surfaces
- glue hardening – the joint making
- the finishing and quality control of joint [2–4].

In adhesive bonding the correct pretreatment of the surface is important – it is deciding factor to achieve durable joint. Thanks to these operations the elimination of every kind of pollution on the surface is possible, e.g. dirt, fat, corrosion products, dust. The surface may also expand and may achieve its proper energy state [2, 5, 6].

At present there are different ways of achieving technological effects described above. However, sometimes there are also some difficulties, e.g.: problematic inspection manners, the requirement

of retain short time between the following activities, the necessity of keeping the tools and equipment clean [2].

Typical actions performed during the pretreatment of surfaces are:

- Degreasing – in order to remove fats, lubricants, dust, organic and non-organic substances. This step may be realized in the steams and liquids of solvents. Typical substances to this purpose are: acetone, ethylic alcohol or other alkaline chemicals emulsified the lubricants and grease [2, 6, 7];
- Cleaning in acid or alkaline bath – it is removing oxides and scale from surfaces of the part; these layers are unnecessary and may lead to some problems in the next stage of surface pretreatment. Cleaning is conducting in the adjusted to the sort of material bath [3, 6, 8];
- Rinsing – in acid or alkaline bath, sometimes it is carried out also after special treatment. It is aimed at removing remains of galvanic or cleaning bath, dust after special treatment. Cold or hot, demineralized or distilled water is use. Next, the surface should be cleaned in ethanol. Even small parts of etching bath determine corrosion or other negative reactions in glues and prime coats [2, 6, 7].
- Drying – removing of remains of water from previously rinsed elements [2].
- Special treatment of surface – for preparing thin layers on the surfaces, they consist of salts (phosphates, fluorides, sulfates, nitrides, chromates, and other similar compounds), whose presence on the surfaces before gluing increases adhesive joints strength [5, 8].
- Coating with primer or glue – in time which lasts as short as possible. Parts with primer or other cover should be protected with fat-free paper and storing without the air access in the temperature 20 °C [2, 7].

All components should be mixed in correct proportions to receive gluing substance. The amount of glue and hardener, process of mixing and carefulness are important. In mixing of glues different kinds of mixers are used, this is a guarantee of precise in jointing different substances. Excess or lack of hardener and absence of thoroughness are the cause of low quality of joint. Then the joints may be soft, clammy and ductile or have low strength [3, 6, 9]. The consistency of adhesives and their homogeneity are the cause of quality of joint. Excess of glue gives thick joint

which dries a long time and has poor strength. Lack of glue makes problems with wettability of surface, gives thin and poor joint [4].

During the activity with the preparing of gluing mass it is absolutely necessary not to making accidental bubbles. The heating and mechanical mixing gives good results in this. The bubbles in the joint reduce the strength about 5–15% [3]. Another important problem is time of glue life. It starts while the mass is prepared and from this moment the adhesive properties depend in the joint. It is important also during the realization of technological process, while the sequence and length of operations are planning. After an opening of container with glue its properties are modified with time. What is more, length of life of glue is not synonyms to the time of storage [3, 6].

After the preparation of the mass the covering of jointed surfaces takes place. It is very important operation and its manner depends on the form of glue, its viscosity, shape of jointed elements or even on type of production [6].

During the surface covering by glue the same thickness, regular field and correct wettability are required. Elements may be heated for less viscosity and high wettability. Heating is required in the case of glue in a form of bars, solids or powder [8].

After the covering the surfaces by the glue the jointed parts should be connected to each other in the shortest time and fixed not yet hardened joint [10].

## THE METHODOLOGY OF EXPERIMENT

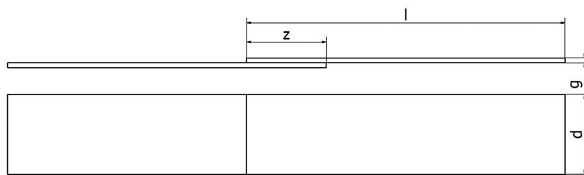
Because of many problems in gluing the experimental research was conducted. The influence of size of lap on the shear strength of a single-lap joints was investigated. To the preparation of test pieces the constructional steel AISI 4130 consisted of C (0,22–0,29%), Mn (0,40–0,70%), Si (0,17–0,37%), Cr (0,80–1,10%), Ni ( $\leq 0,30\%$ ), Mo (0,15–0,25%), V ( $\leq 0,05\%$ ), W ( $\leq 0,20\%$ ), Ti ( $\leq 0,05\%$ ), Cu ( $\leq 0,25$ ), As ( $\leq 0,08\%$ ) was used [11]. This steel is applied in the manufacturing processes of loaded parts, exposed to hitting, torsion and vibration for example in aeronautics [12].

The test pieces were joined by Araldite 2011 and 2014-1 glues. These glues are characterized by long life time, high shear strength and tear off strength, static and dynamic load resistance. They are different in time of bonding and the proportion of epoxy resin to the hardener (Table 1) [11].

**Table 1.** The properties of epoxy resins Araldite 2011 and Araldite 2014-1 [11]

Epoxy resin	Araldite 2011	Araldite 2014-1
Proportion of components	1:1	2:1
Life time (min)	100	60
Color (after mixing)	Wan-yellow	Grey
Time of bonding 20 °C (h)	7	3
Time of hardening w 20 °C (h)	36	36

For gluing the test pieces of dimensions  $d \times l \times g$ :  $25 \times 100 \times 1$  mm with 5-repetition was made. Variable value was the length of lap  $z$  and it was:  $z_1 = 8$  mm,  $z_2 = 12,5$  mm,  $z_3 = 16$  mm,  $z_4 = 24$  mm (Fig. 1).



**Fig. 1.** The scheme of adhesive joint in the experiment

The surfaces before gluing were made in two options: treated by abrasive paper P80 and mechanically by sand-blast cleaning (corundum A90). Then the pieces were cleaned in acetone in ultrasonic washer and dried in room temperature. Next, the bonded pieces were placed into the special bonding holder for hardening the joints. After the jointing the test pieces were broken in the Zwick/Roell Z100 tensile testing machine.

## RESULTS

In the experimental research the value of shear force  $P_t$  was obtained. The mean value of  $P_{t-m}$  and static shear strength  $R_t$  from the relation (1) were calculated:

$$R_t = P_{t-m} / A \quad (1)$$

where:  $A$  – the field of lap.

The results of tests and calculations are presented in the Tables 2–5. Mentioned below graphs

**Table 2.** The results for  $z_1$

The length of lap: $z_1 = 8$ mm; $A_1 = 200$ mm <sup>2</sup>				
Test piece number	Force $P_t$ [N]			
	Araldite 2011		Araldite 2014-1	
	handmade surface	sand-blast cleaning	handmade surface	sand-blast cleaning
1	3230.243	4580.718	3500.823	5498.408
2	3021.059	4501.421	4038.446	5059.642
3	3399.728	4553.418	3031.017	4697.395
4	3182.038	4711.192	2827.701	4849.223
5	2752.909	4898.991	2281.864	4763.577
$P_{t-m}$	3117.200	4619.150	3135.970	4973.650
$R_t$	15.585	23.246	15.68	24.868

**Table 3.** The results for  $z_2$

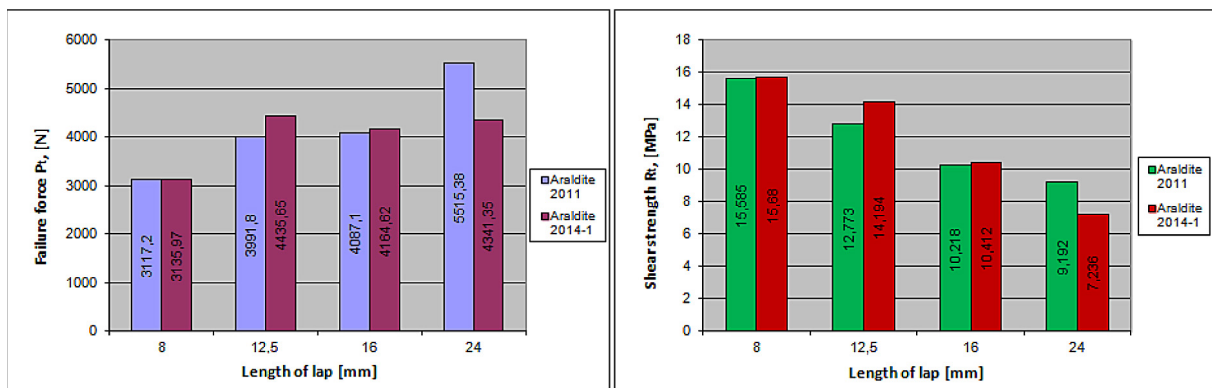
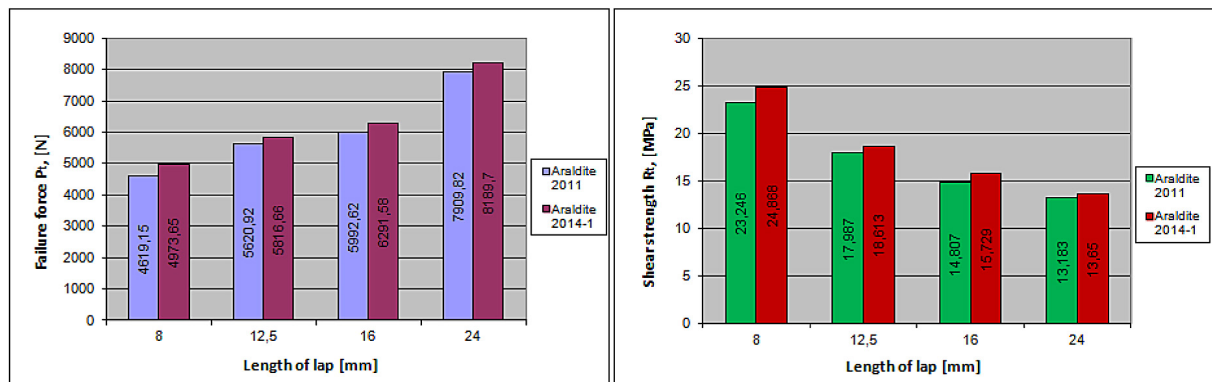
The length of lap: $z_2 = 12.5$ mm; $A_2 = 312.5$ mm <sup>2</sup>				
Test piece number	Force $P_t$ [N]			
	Araldite 2011		Araldite 2014-1	
	handmade surface	sand-blast cleaning	handmade surface	sand-blast cleaning
1	3478.465	5398.833	3742.796	5549.746
2	4284.306	5959.551	4442.110	6056.149
3	3904.567	5591.105	4807.640	5909.373
4	3884.153	5452.010	4362.317	5689.107
5	4407.530	5703.114	4823.385	5878.906
$P_{t-m}$	3991.800	5620.920	4435.650	5816.660
$R_t$	12.773	17.987	14.194	18.613

**Table 4.** The results for  $z_3$ 

Test piece number	The length of lap: $z_2 = 16$ mm; $A_3 = 400$ mm <sup>2</sup>			
	Force $P_t$ [N]			
	Araldite 2011		Araldite 2014-1	
	handmade surface	sand-blast cleaning	handmade surface	sand-blast cleaning
1	4193.315	6061.828	4843.896	6256.972
2	3897.565	5792.773	4361.675	6021.921
3	4143.484	5813.575	4353.719	6302.023
4	4130.527	6163.991	3762.965	6220.482
5	4070.587	5780.942	3500.831	6656.479
$P_{t-m}$	4087.100	5992.620	4164.620	6291.580
$R_t$	10.218	14.807	10.412	15.729

**Table 5.** The results for  $z_4$ 

Test piece number	The length of lap: $z_4 = 24$ mm; $A_4 = 600$ mm <sup>2</sup>			
	Force $P_t$ [N]			
	Araldite 2011		Araldite 2014-1	
	handmade surface	sand-blast cleaning	handmade surface	sand-blast cleaning
1	5693.161	7842.041	4364.676	8202.019
2	6573.163	7748.961	4734.915	8205.555
3	4785.892	7546.047	4221.458	8259.362
4	5127.682	8442.654	4402.663	7965.750
5	5397.028	7969.401	3983.050	8317.146
$P_{t-m}$	5515.380	7909.820	4341.350	8189.700
$R_t$	9.192	13.183	7.236	13.650

**Fig. 2.** Influence of length of lap on failure force (a) and static shear strength (b) of single lap adhesive joints which surfaces were prepare by treated by abrasive paper P80**Fig. 3.** Influence of length of lap on failure force (a) and static shear strength (b) of single lap adhesive joints which surfaces were prepare mechanically by sand-blast cleaning (corundum A90)

show graphic interpretation of influence of length of lap on failure force and static shear strength for both used adhesives and surface preparation methods (Figures 2 and 3).

## CONCLUSIONS

The length of lap has influence on the value of shear force and shear strength of single-lap joints. With the growth of lap size the value of shear force also increases. It has a direct relation with the growth of field of the lap. The shear strength decreases with the increase of length of the lap.

From the experiment it follows that with the same valued parameters of gluing by the epoxy resins Araldite 2011 and 2014-1 the shear strength has not great differences between values.

Significant influence on achieved static shear strength with the same length of the laps has the manner of preparing the surfaces before gluing. In the case of sand-blasting the value of force was several times higher than in the case of handmade cleaning with the abrasive paper use. From this point of view the surface pretreatment has influence on the achieved results (not only joint construction).

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