INFLUENCE OF LAPPED LENGTH ON ADHESIVE BOND STRENGTH

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Abstract. The adhesive bonding technology is one of many bonding material methods. It is influenced by a number of factors, which affect the adhesive bond strength. Experiments focused on lapped length of adhesive bonds are essential because of the construction parameters and the economic costs. The optimum lapped length was searched from the length values from 5 to 50 mm. If we choose smaller lapped length than the optimum, the adhesive bond will be destroyed. On the other hand increasing the lapped length over the optimum value will cause a distortion in a basic material when loading and the weight of the adhesive bonding complex will rise up. The tests were carried out according to ISO CSN EN 1465 on two materials – steel and duralumin by means of two epoxy adhesives Bison epoxy metal and Alteco 3 - Ton epoxy adhesive 30 min.

Key words: Adhesive bonding technology, epoxy adhesives, lapped length, loading force, strength

1. Introduction

Adhesive bonding is one of many materials connecting methods. The use of bonding technology in the engineering and repairing industry brings considerable savings - in costs, in critical metallic materials and the decrease of the joint weight, too. Therefore the bonding technology pertains to the modern jointing methods even though it is the very old technique. The adhesive bonding technology is influenced by a number of factors, which affect the adhesive bond strength.

At bonded joints only one loading type very seldom occurs. Usually the combined load is found. Most often we meet with the tensile lap-shear stress. Using those joints the non-uniform stress distribution in the whole surface and in the bonded joint edges the so-called stress peak values occur (figures. 1 and 2).

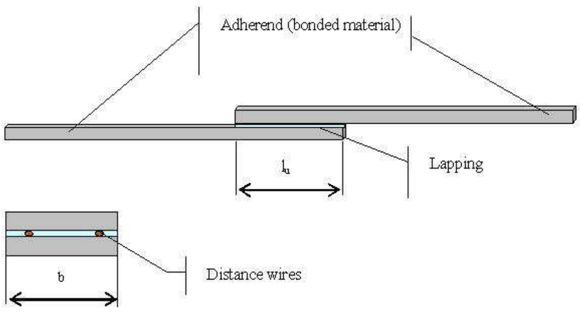

Figure 1. Lapped joint without design adaptations of sapling prevention

The non-uniform stress distribution in the adhesive line is caused by the bonded materials elasticity and deformation. By moment action of pair forces the stress concentration increases in the bonded joint edges. The pair forces evoke the tensile stress. Their maximum is in the joint edges and it is the cause of sapling. In this way the crack propagation and consequently the bonded joint destruction occur. The sapling stress level can be decreased not only by the bonded material strength and thickness increase, but by various design adaptations, too. Then the designed joint must be adapted to the bonding technology requirements. Optimally the stress distribution must be uniform as possible [2, 3].

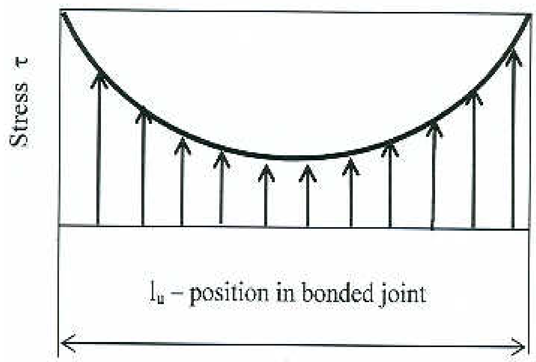

Figure 2. Shear stress distribution in the adhesive line over the lapped length

When the lapped joint without adaptations is stressed (figure 1), the force does not act in the plane of the adhesive line and when the force *F* increases the deformation of bonded materials (adherends) occur [4, 5].

The carrying capacity of the bonded joint strength depends on the load force F, lapping length l_u, joint width b and the thickness of the bonded material s_a. Looking on an arbitrary construction it is possible to see that the load F is chosen according to the real load. On the basis of the calculation we get the adherend thickness s_a, which can be taken by a constant. When speculating about the material choice it is necessary to take into account its mechanical properties, especially the tensile strength Rm [4]

The determination of the optimal lapped length is important. At minor lapped length the failure of the bonded joint occurs. On the contrary at its increase over the optimal value the failure of the basic material occurs and the bonded complex weight increases, too. By use of major quantity of adhesive and material at the same time the production costs increase. It is possible to set optimum sizes values by comparing the lapped length, the load force and the following adhesive bond strength.

2. Materials and methods

The aim of the carried out laboratory tests was to determine the lapped length of the bonded joint with regard to the load force, from which the bonded joint strength is derived. For tests two two-component epoxy adhesives were used:

- BISON epoxy metal [next text as “Bm”] – the two-component epoxy adhesive, ratio of mixture 1:1, usable life 60 minutes. Thermal fastness -60° C to +100° C. It is suitable for bonding of metals, ceramics and plastics. Perfect curing occurs after 12 hours. The presented orientation strength of the bonded joint is 18 MPa. The sale price is approximately 188 Kc for the packing of net 28 g [2].
- ALTECO 3-TON epoxy adhesive 30 min [next text as “A30”] – the two-component epoxy adhesive with metallic filler, ratio of mixture 1:1, usable life 30 minutes. Thermal fastness -20° C to +120° C. It is suitable for bonding of steel, cast iron, brass, aluminium alloys, wood, glass and plastics. Perfect curing occurs after 14 hours. Orientation strength is not presented. The sale price is approximately 61 Kc for the packing of net 56 g [2].

The evaluation of tests was carried out according to the standard CSN EN 1465 (Determination of tensile lap-shear strength of rigid-to rigid bonded assemblies). The tests were carried out using the steel and the duralumin specimens of dimensions 100×25×1.6 mm [1]. The length and the width of tested specimens were according to the standard. The lapping was not according to the standard, but it was graded in dimensions of 5 mm. At the first bonded series the lapped length was 5 mm, at the last – 50 mm.

On the basis of laboratory tests the optimal adhesive layer thickness and the surface preparation were determined for the chosen adhesives. By tests determined optimal values, which are presented in Table 1, were used for tests, which were needed for the lapped length determination with regard to the load force and subsequently for the bonded joint strength τ determination.

The steel and duralumin surfaces of the specimens were prepared using the optimum method, which was determined on the basis of the former preliminary tests. Measuring of the surface roughness Ra (the arithmetic mean of the departures of the profile from the mean line) was carried out using the Mitutoyo SURFTEST – 301 profilograph. After grinding or blasting and before surface roughness measuring and bonding all specimens were rinsed in perchlorethylene.

After the surface roughness evaluation the relevant thickness of the adhesive layer was laid on and the bonded parts were fixed. The relevant adhesive layer thickness was secured by means of two distance wires. At single series the lapped length was varied from 5 mm to 50 mm (figure 1).

Table 1. Optimal values of adhesive joint

Adhesive	Bonded surface preparation	Adhesive layer thickness [mm]	Mean surface roughness Ra of tested place [µm]
Bm - steel	blasted – corundum	0.11	2.85
Bm - duralumin	abrasive cloth 240	0.11	0.58
A30 - steel	abrasive cloth 320	0.22	1.69
A30 - duralumin	abrasive cloth 100	0.22	2.12

The tested bodies number of each series was determined according to the standard demands. The bonded bodies were left in the laboratory for the time, which was needed for the curing. The tensile-strength test was carried out using the universal tensile-strength testing machine ZDM 5t. After the failure of the tested body the highest force was read, the overlap surface was measured and the bonded joint strength τ was calculated.

For the correct evaluation the determination of the relation between the load force and the lapped length is important, too. It is the problem of the correlation analysis. The dependence is given by the determination index, whose value can be from 0 to 1. The determination index I^2_{yx} indicates how the dependent variable is affected by the independent variable. The percentage expression indicates how many percents of values variance of measured dependent variable is the consequence of the theoretical values variance of the dependent variable estimated on the basis of the regression curve. The regression curve is derived from the form of the correlation field, which is induced by the cross points of the dependent and independent variables.

3. Evaluation of laboratory tests

The measured and calculated values are shown in following graph (figure 3 and figure 4). The behavior of the given functions is expressed by the nonlinear regression curves of second degree. The value of the determination index $I^2_{Fx \text{ or } \tau x}$ of the relation between the lapped length and the force (strength) for the bonded joint destruction is very high (table 2).

Table 2. Determination index

Adhesive	Determination index I^2_{Fx} and $I^2_{\tau x}$
Bm steel - force	0,9408
A30 steel - force	0,9814
Bm steel - strength	0,8461
A30 steel - strength	0,9516
Bm duralumin - force	0,9879
A30 duralumin - force	0,9546
Bm duralumin - strength	0,9612
A30 duralumin- strength	0,7626

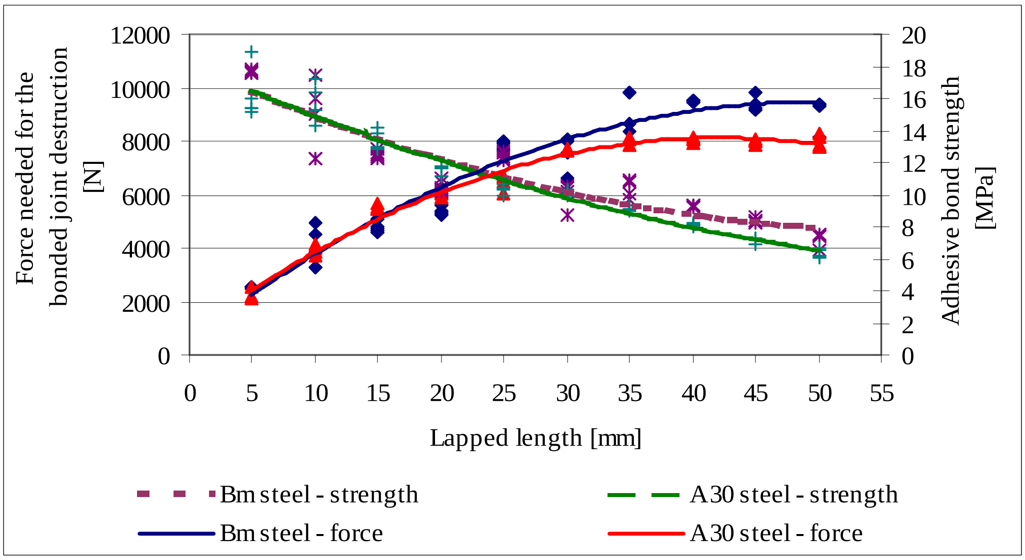

Figure 3. Influence of the lapped length on the load force and adhesive bond strength - steel

From the measured values of forces, which are needed for the bonded joint destruction it is possible to state that at both tested materials and adhesives the force F increases only to the destined maximum. After reaching this maximum the force F mildly decreases. This results in the increase of the sapling forces. From the lapping ends the plane of break begins to extend. Afterwards the joint destruction follows. The joint deformation depends on the strength and on the size of the bonded material. For the prevention of the joint deformation at the same joint size it is necessary to increase the adherend thickness or to choose the material of higher tensile strength.

The bonded material was tested using the static tensile test according to CSN EN 10002-1. For the steel the calculated tensile strength of the bonded joint was 370 MPa, for duralumin 390 MPa.

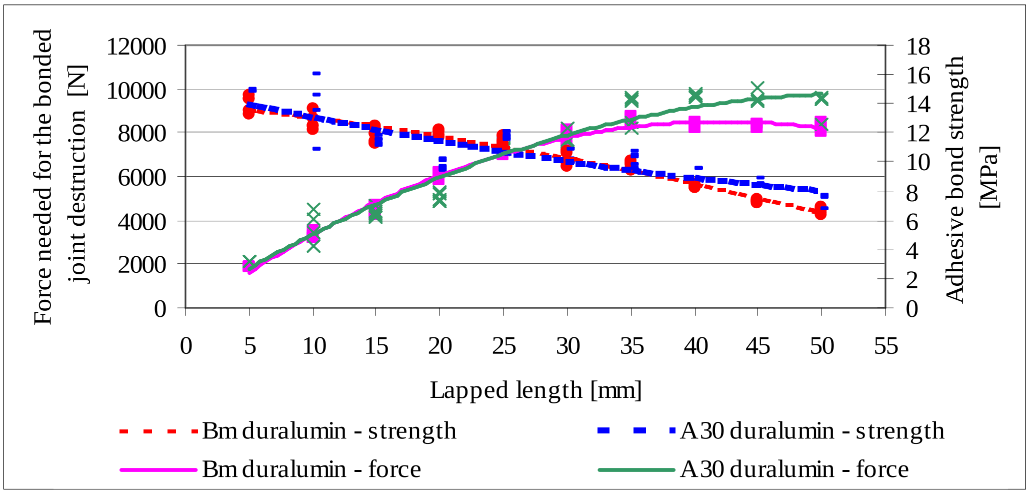

Figure 4. Influence of the lapped length on the load force and adhesive bond strength - duralumin

At the lapped length 40 mm by bonding steel as well as duralumin the sufficient reserve of force for the joint failure prevention was determined also at the use of the highest load force.

Both steel and duralumin specimens have the same roughness boundary Rm. Very similar intersection point of the force and the strength can be seen from the graphs 3 and 4. This intersection point can be considered as the suitable compromise in the constructional plan of the adhesive bond. As the optimum lapped length value l_u it is possible to considered 25 mm. The increase of the load force F and on the contrary the decrease of the strength τ will occur when raising the lapped length up to optimum. Also the costs of bonded material and adhesives would increase.

4. Conclusion

From the measured load forces and lapped lengths reduced to the bonded joint strength it is possible to state that at two tested materials the load force F grows only to a definite maximum. After reaching this force value the lapped length rise is not meaningful. At the constant force F and increasing lapped length the bonded joint strength τ decreases. Generally it is possible to say that the material of higher strength can reach the higher bonded joint strength. The bonded joint strength increases with the increasing adherend strength.

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