INFLUENCE OF OVERLAPPING LENGTH ON PEELING STRENGTH OF ADHESIVE BONDS

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Abstract. A peel test is one of the methods used to determine the strength of adhesive bonds. The most common tests include peeling tests at 90º and 180º. This paper is focused on the development of the T-Peel test of adhesive bonds under the angle of 180º, where structural steel S235J0 was used as an adherent. In the experiments 6 kinds of adhesives were used that were tested in 6 different widths of overlapping areas on the test specimens (15, 25, 35, 45, 55, 65 mm). The results show the influence of the length of the overlap of the adhesive bond on the final bond strength, as well as the numerical results and graphs show high strength in the initial interface of the adherent and the adhesive, which requires high stress at the beginning to fail the specimen.

Keywords: adhesive bond, peel strength, T-peel test.

Introduction

Adhesive bonds occupy a significant expansion in many sectors of industry and agriculture. Their use in manufacturing like, for example, welding is currently carried out in automated operations. However, in case of welding, heat affects the material, which affects the final strength mainly in the constituent material between the thermally affected and unaffected areas. In this case, the adhesive bonds offer clear advantages.

The main function of the adhesive bonds is to carry the load from one structural element to another [1]. Their strength depends on the adhesion and cohesion, which significantly affect the final bond strength. The total strength of the adhesive is determined by its adhesion and cohesion, which are the results from the interaction of physical forces, absorption, chemical bonds, intermolecular attraction of polymer molecules [2].

The actual bond strength, however, is influenced by many other external factors to which the adhesive bonds can be exposed, as can be seen in the results of other authors [3-5]. One of them is the effect of external loads such as tension, compression, bending, and others. Therefore, it is important to pay attention to all phases of the adhesive bond from creating its design, avoiding or minimizing certain kinds of stress, which may reduce the strength (especially peeling or bending) to which it has low resistance [1; 6].

Adhesive peel tests require at least one flexible adherent, where the flexible means the ability of the adherent to bend through 90º without any break or cracks [7]. The stability of the peel angle during a T-peel test is very important. As it was described in some research papers, the angle of peeling can be changed when the stress occurs, it affects the resulting values of peel strength [8]. It is necessary to take in to account also other significant variables, because of their influence on the strength of these bonds such as the bondline thickness, adhesive fillet size, rheology of the adhesive, etc. that are not exactly specified in the standard [8-11]. Also as in the testing of single lap-shear specimen, there is a significant need to ensure the surface treatment of the adherents that can be of different properties [12; 13].

The aim of this work is the research of structural epoxy adhesives in a peel test. A secondary consideration is assessing the impact of the length of the overlap.

Materials and methods

The surface preparation is important and should guarantee good strength on the boundary adherent/adhesive/adherent [14; 15].

The research was based on CSN 66 8516 (Peeling test) [16]. Peel strength is the force which is needed to break the adhesive bond under defined test conditions.

Test specimens were obtained consistently by separating them from semi-finished carbon steel S235J0 with using the cutting technology. The specimens were subsequently bent at a predefined distance of an angle 90º to create the overlap length 15, 25, 35, 45, 55 and 65 mm. The thickness of the adherent was 1 mm and the width of the test specimens was 35 mm. The bonded surface was

mechanically prepared by blasting. Corundum (Al_2O_3) was used for blasting with the size fraction F 80. The steel sheets were degreased in acetone bath after the mechanical preparation.

Five specimens from each series were prepared. For the research 6 binary structural adhesives have been used: Alteco 3-ton quick 4 minutes (marked 1); Alteco 3-ton quick 30 minutes (marked 2) Ceys Epoxy (marked 3), Loctite 7256 (marked 4), DCH Sincolor Gluepox Rapid (marked 5) and UHU plus endfest 300 (marked 6).

After the described surface preparation method, the adhesive material was applied and the adhesive bond was loaded with weight of 495 ± 5 g in laboratory conditions with the temperature 23 ± 2 ºC. The properties of adhesives and the applied loads affected the size of the adhesive layer (0.25 ± 0.13 mm). The thickness of the adhesive layer was determined by the optical analysis of the adhesive bond. The shape of the test specimen is shown in Fig. 1.

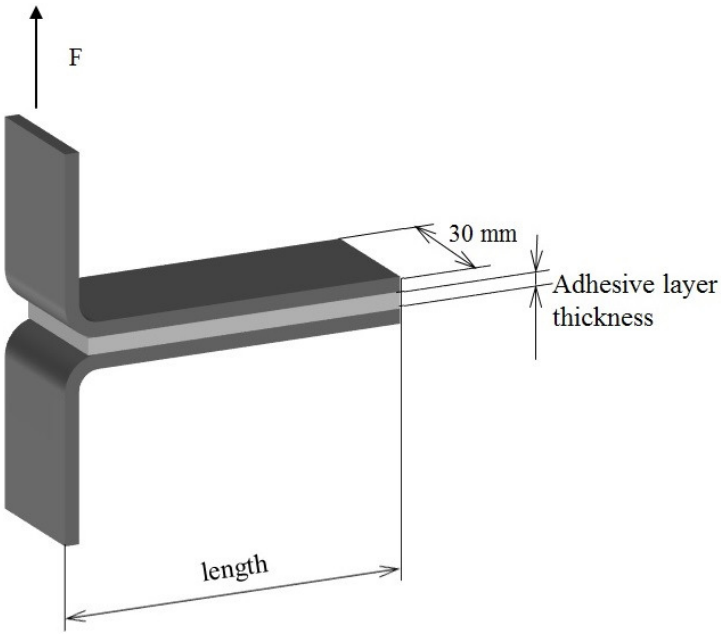

Fig. 1. **Specimen**

The peeling tests were performed using the universal tensile strength testing machine LABTest 5.50ST (sensing unit AST type KAF 50 kN, evaluating software Test&Motion). The speed of the deformation corresponded to 6 mm·min^{-1} till the tension of 40 N, then 2 mm·min^{-1} till failure of the specimens. The process of the test and delamination can be seen from Figure 2 and 3. The failure type according to ISO 10365 was determined at the adhesive bonds.

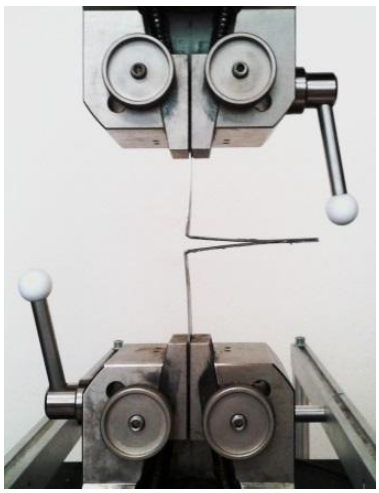

Fig. 2. **Process of test on Universal testing machine**

Fig. 3. **Elastic adhesive in bond – deformation of bonded material**

F-test was used for the statistical evaluation. The F-test is used for testing of the difference significance of two dispersion variances. An assumption is that a zero hypothesis H_0 is valid.

The zero hypothesis H_0 presents the state when there is no statistically significant difference ($p > 0.05$) among the tested sets of data in terms of their mean values.

For correct evaluation it is also important to determine the determination index R^2. It is the problem of the correlation analysis. The values of the determination index can be from 0 to 1. So far as R^2 equals to 1, there is a perfect correlation in this sample (so, there is no difference between the calculation and real values).

Results and discussion

The thickness of the adhesive layer is a significant factor which is affecting the resulting mechanical behaviour of the adhesive bond [17; 18]. The thickness of the adhesive layer is shown in Table 1. The results show that the adhesives 1-6 have different thicknesses of the adhesive layer. This is particularly due to the nature of the adhesive. Adhesives characterized by higher values of thickness of the adhesive layers are filled with metal particles (ie. liquid metals).

Table 1

Results of measuring thickness of adhesive layer

Adhesive No.	1	2	3	4	5	6
Arithmetical mean, mm	0.52	0.48	0.26	0.18	0.20	0.26
Mean deviation	0.13	0.12	0.12	0.10	0.09	0.11
Max, mm	0.80	0.74	0.55	0.49	0.48	0.64
Min, mm	0.27	0.33	0.12	0.05	0.07	0.12

The results of this experiment show that the peel strength decreases exponentially with increasing the length of overlap (Fig. 4). Adhesive No. 3 showed the best peel resistance. The second best was No. 6. All tested adhesives showed similar dependence of peel strength on the overlap length.

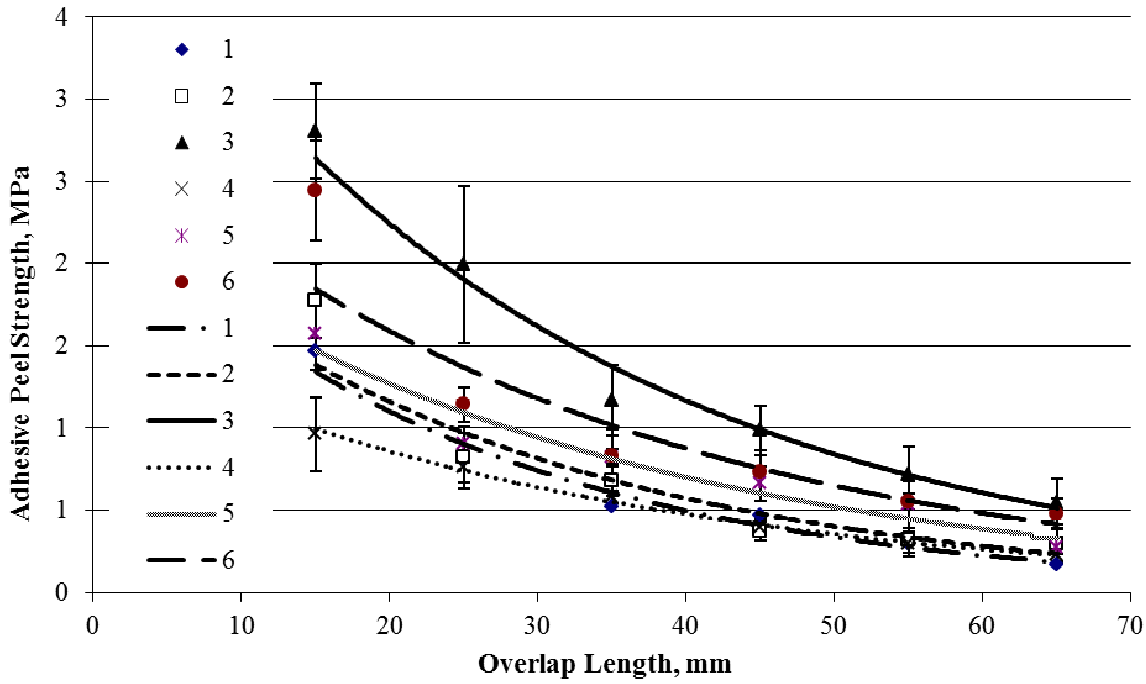

Fig. 4. **Effect of overlap length on peel strength**

Table 2 shows the results of the correlation analysis of the results stated in Fig. 4. Very strong functional dependence of the functions shown in Fig. 4 is evident from the results R^2.

Table 2

Equations of functions – influence of overlap length (x) on adhesive peeling strength (y)

Adhesive	Functional equations	R^2
1	$y = 2.4316e^{-0.04x}$	0.97
2	$y = 2.3498e^{-0.035x}$	0.91
3	$y = 4.3127e^{-0.033x}$	0.98
4	$y = 1.5493e^{-0.03x}$	0.99
5	$y = 2.2999e^{-0.03x}$	0.93
6	$y = 2.8868e^{-0.03x}$	0.90

In terms of influence of the overlap length on the peel strength of adhesive bonds, the F-test provides the results:

- Peeling strength: H_0 hypothesis was not confirmed in any of the tested adhesives (1-6, $p = 0.0000$), i.e. the difference in the level of significance of 0.05 between the particular tested overlap lengths.
- Peeling force: H_0 hypothesis was confirmed in the adhesive 3 ($p = 0.2453$) and the adhesive 6 ($p = 0.1861$), i.e. there is no difference in the significance level of 0.05 between the overlap lengths. For other tested adhesives 1 ($p = 0.0465$), 2 ($p = 0.0190$), 4 ($p = 0.0054$) and 5 ($p = 0.0070$) H_0 hypothesis was not confirmed, i.e. the difference in the level of significance of 0.05 between the particular tested overlap lengths.

The peel strength is much smaller than the shear strength. For comparison, there are the same adhesives tested in shear strength according to ČSN EN 1465: adhesive 2 was about 14 MPa, adhesive 4 about 11 MPa, and adhesive 5 - about 8 MPa [19].

Conclusions

This article concerns the strength of adhesive bonds in peel in the so-called T-peel test, which corresponds to the standard ČSN 66 8516 (this corresponds to the American standard ASTM D 1876-72, or DIN 53 282). The research focused on the influence of the overlap length on the peeling strength of two-component epoxy adhesives provides the following conclusions:

- Peel strength of six tested adhesives was in the interval from 0.17 to 2.81 MPa. With increasing the length of overlap the peel strength decreased. Statistical research showed the influence of the overlap length on the peel strength.
- The measurement results and graphical reports show that during peel loading the stress is not concentrated uniformly over the entire surface of the bond. The main part of the stress is concentrated at the edge of the bonds, where the force is applied and the adherent is significantly deformed.

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