ADHESIVE BONDS DEGRADATION

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Abstract. Setting in effect of the most various influences on adhesive bonds mechanical properties is essentially important for a suitable adhesive bond design. This step requires an understanding of the dependences influencing adhesive bonded complex strengthen properties. If the adhesive bonds are exposed to the effect of the environment, the undesirable changes of appearance and mainly of the mechanical properties show themselves. These processes are called the degradation (ageing). The knowledge of conditions under which the degradation affects and the way of their protection is very valuable information for the user's point of view. The aim of the carried out experiments was to evaluate the degradation environment influence on adhesive bond mechanical qualities change. A natural and a mineral fertilizer, machine oil and water were chosen as the degradation environment. The experimental programme itself and its conclusions bring new findings for making clear the possibilities and limits of adhesive bonds creation and their lifetime. The main factor for the application field of the adhesive bonding is especially the resistance characterizing.

Key words: adhesive bond, degradation, testing.

Introduction

An adhesive bonding technology usage is influenced by many factors. The knowledge of key requirements influencing an adhesive bond strength and lifetime is important for successful adhesive bonding technology application. The experiments proved that the degradation process had decreased the adhesive bond strength limits depending on the time and the degradation medium [1].

The environment spectrum which affects the adhesive bond in practice is extensive. It embraces water, extreme temperatures or chemicals.

Court et al. [2] studied three main effects of the adhesive bond ageing:

- decreasing of the tension at which the failure has started in the adhesive bond,
- decreasing of the final strength,
- change of the adhesive bond failure mechanism.

For the bonding technology limit determination in conditions of agriculture it is necessary to analyse the specific degradation conditions appearing just in this field. Fertilizers are the specific and at the same time the very aggressive category of degradation mediums [3].

The analyzing and quantification of the degradation process is significant for successful adhesive bonding technology application in practice.

Materials and methods

The evaluation of the degradation medium influence (natural fertilizer, mineral fertilizer, machine oil and water) on the bonded joint mechanical properties taking the bonded material corrosion in consideration has been the aim of laboratory experiments. The experiments were made according to the standard CSN EN 1465, which determines the tensile lap-shear strength of rigid-to-rigid bonded assemblies. The substance of the test is the determination of the maximal force, which acts parallel with the bonded surface and with the principal axis of the assembly till to the failure. This method corresponds to the operation stress. The measured force at the bonded joint failure is the test result. The tested assemblies are prepared by bonding of two adherents of dimensions 100±0.25 x 25±0.25 x 1.6±0.1 mm. The specified overlapping is 12.5±0.25 mm [4].

The laboratory tests were carried out using the standardized test specimens made according to the standard CSN EN 1465 from the constructional plain carbon steel S235J0. Ahead of bonding the surface of bonded specimens was blasted using the Al_2O_3 of F24 grain size. Using the profilograph Surftest 301 the following values were determined: Ra 2.4 µm, Rz 15.3 µm.

For bonding the two-component epoxy adhesive Bison Epoxy Metal was used. The components were mixed in the ratio 1:1, when the mixture is treatable till 60 min. The heat stability is from

–60 ˚C up to +100 ˚C. The adhesive is suitable for bonding of metals, ceramics and plastics. The perfect curing comes after 12 hours. The orientation strength of the bonded joint is of 18 MPa [5].

The assessment was left in the laboratory for in the instructions determined time (minimum 12 hours) for curing at the laboratory temperature of 23±2 ˚C. After curing the marking of single assessments and placing in the relevant medium followed. As degradation mediums water bath, engine oil, cow-dung, mineral fertilizer DAM and laboratory environment (measurement standard - etalon) were used. The bonded joints strength values influenced by these four basic degradation mediums which occur in agriculture were compared with the values measured at laboratory conditions (etalon). The degradation processes were running evaluated after the determined time intervals. The time between single intervals was 15 days starting from the day of total curing. The last measuring was carried out after 90 days in the degradation medium forasmuch as the strength occurred under the measurable range. Each cycle was finished by the destructive testing of bonded joints using the universal tensile-strength testing machine and the fracture type was determined according to ISO 10365 [6].

Results and discussion

The results of the laboratory experiments are presented in Fig. 1. The experiments were carried out according to the standard CSN EN 1465. Single bonded joints were destructively tested using the universal tensile-strength testing machine. From the results presented in Figure 1 the influence of various degradation mediums is evident. The time behaviour is illustrated by the polynomial function of the second degree, which was derived from the correlation field of the measured points showed in the XY graph.

It is important to take into consideration constructional calculations considering 15 % deviation from the supposed values relating to the optimum conditions when applying the adhesive bonds in practice [1].

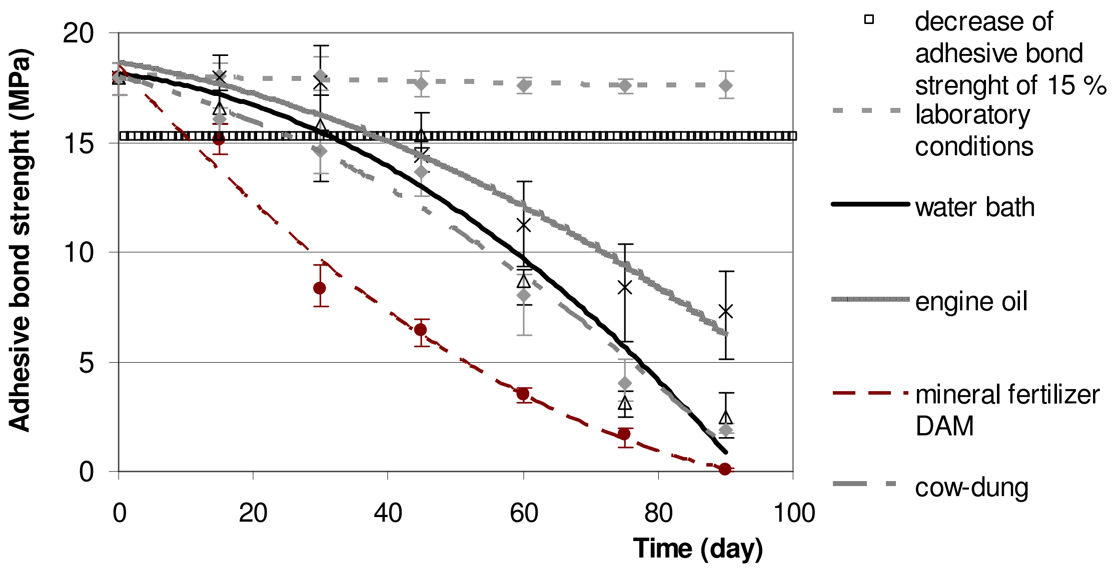

Fig. 1. Influence of degradation media on adhesive bond strength

For correct evaluation of the relations the closeness coefficient was calculated using the correlation analysis. The R^2 value can be from 0 to 1. The higher value corresponds to the higher telling capacity. The course of the above mentioned relations was described by the equations, too.

The equations 1, 3, 5 and 7 describe the relation between the shear strength τ and time behavior as showed in Figure 1. The closeness coefficient (2, 4, 6 and 8) is presented, too.

$$\tau_{water\text{-}bath} = -1.71 \cdot 10^{-3} \cdot d^2 - 0.0377 \cdot d + 18.13 \tag{1}$$

$$R^2_{water\text{-}bath} = 0.938 \tag{2}$$

$$\tau_{cow\text{-}dung} = -1.21 \cdot 10^{-3} \cdot d^2 - 0.0785 \cdot d + 17.967 \tag{3}$$

$$R^2_{cow\text{-}dung} = 0.975 \tag{4}$$

$$\tau_{mineral\,fertilizer\,\mathrm{DAM}} = 1.53 \cdot 10^{-3} \cdot d^2 - 0.3413 \cdot d + 18.468 \quad (5)$$

$$R^2_{mineral\,fertilizer\,\mathrm{DAM}} = 0.986 \quad (6)$$

$$\tau_{laboratory\,conditions} = 2.85 \cdot 10^{-5} \cdot d^2 - 0.00823 \cdot d + 18.051 \quad (7)$$

$$R^2_{laboratory\,conditions} = 0.792 \quad (8)$$

The orientation strength declared by the producer was reached. After curing the strength of the bonded joints was about 18 MPa. According to the behaviour of the curves it is possible to state that the strength decrease of single joints is expressive. By the comparison of the curve which represents the laboratory conditions and of other curves which represent the degradation mediums it is clear that the considerable danger of the stress decrease exists. This dangerous phenomenon should direct to the prevention from the mentioned degradation mediums access or at least to the limitation of their action time.

However, the experimental results found out in various environments/media confirm the statements of Kinloch [7] and Court [2] about negative and harmful effects of the surrounding environment to the adhesive bond.

It is desirable not to exceed the adhesive bond strength reduction of 15 %, which differed for each adhesives and media at preserving the security standards arising from the bond constructional design. The lower boundary rouged in the interval 9 – 33 days for each degradation medium.

On the basis of the picture analysis the failure type was determined. The cohesive fracture type was found at the specimens placed in the laboratory. The fracture types of the specimens placed in four degradation mediums were different. In the first phase the fracture type of all joints was cohesive. Later the fracture type changed in dependence on the degradation medium. When the adhesive failure was identified, at the same time the corrosion under the adhesive layer was found and in that way the adhesive strength decreased. This previous ascertainment offers the explanation of the bonded joints fast strength reduction. Not only the decrease of the cohesion strength by the diffusion of moisture and chemical substances, but the decrease of the bonding power – adhesion – occurred.

A mutual combination of the corrosion, the humidity and given medium diffusion into the adhesive bond causes huge strength losses. The main problem is to determine which form of the bond is interfered by the surrounding medium, whether the adhesive, the interface adhesive – adherent or the adherent alone. When specifying the "weak point" of the bond the knowledge of the authors Doyle and Pethrick [8], Sargent [9], Court et al. [2], Gledhill [10], Tailor and Kinloch [11] and Aglana et al. [12] were used which showed that the mechanical properties of the adhesive and the adhesive bond failure after occurred due to the aging effects.

Conclusions

On the base of the carried out experiments it can be concluded that the adhesive bond final strength is decreasing during the time and together with the effects of the surrounding environment. The strength decrease rate depends on the specific conditions of the surrounding medium.

The influence results of the degradation environment influencing the adhesive bonds can be quantified as following.

- Laboratory conditions – only minimum decrease of the strength of 2.11 % after 90 days occurred at the adhesive bonds under laboratory conditions.
- Oil bath – the adhesive bond strength decreased of 59.35 % after 90 days. Also the strength measure value result deviation increased with rising time of staying in the oil bath. The 15 % adhesive bond strength decrease was found out on the base of the corresponding functional equation after 33 days.
- Water bath – the adhesive bond strength showed the fall depending on the time of staying in the water bath. The cohesive bonds showed the rest strength 13.83 % of the initial strength at the end of the observed time and also the deviation of the measured values significantly rose to 30 %. The 15 % adhesive bond strength decrease was found out on the base of the corresponding functional equation after 30 days.

- DAM fertilizer – caused very negative influence on the adhesive bond strength properties. The measured value results showed not only the declining trend, but also huge deviation. The adhesive bonds exposed to the fertilizer for 90 days reached almost “zero” strength and showed huge result deviation, till 133 %. The 15 % adhesive bond strength decrease was found out on the base of the corresponding functional equation after 9 days.
- Cow dung – causes significant decrease of the adhesive bond strength during the time and an increasing trend of the measured result deviation. The 15 % adhesive bond strength decrease was found out on the base of the corresponding functional equation after 25 days.

The results showed that the corrosion of the adhesive bonded materials (adherents) is not in most cases a wholly definite agent influencing the adhesive bond strength. The presumption was confirmed that the adherent corrosion can cause the adhesive bond under corroding and subsequently the change of the cohesive failure to the adhesive one secondary reducing the adhesive bond strength.

Messler [13] came to the same conclusion when stated that the corrosion in the adherent or along the interface adhesive – adherent contributed in most cases to the bond degradation and connected strength fall.

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