APPLICATION POSSIBILITIES OF ADHESIVE BONDS – EUROPE, INDONESIA*

M. Müller, D. Herák

Czech University of Life Sciences Prague, Faculty of Engineering, Prague, Czech Republic

A common attribute of production companies is a requirement for a bond creation. An adhesive bonding technology research is significant in the mainly agricultural areas of Indonesia. The reason is low requirements for implementing this bonding technology. An adhesive bonding technology is a prospective method of diverse materials connecting. The unalloyed structural steel S235J0 was the material bonded using three different two-component epoxy adhesives BU, BM and A3 made in Holland and Singapore according to the standard ČSN EN 1465. The laboratory environment was the comparative standard. The operating conditions and degradation processes influence were examined in Central Europe, Indonesia and laboratory during 26 weeks. Secondarily the curing process influence on the bonded joint strength and service life were watched at the laboratory temperature, i.e. 22 ± 2 °C and at the increased temperature, i.e. 70 ± 2 °C. The strength of the bonded joint cured at increased temperature showed the increase of 10 till 30%. Owing to the globalised society and to the export potential of the Czech Republic the experimental study knowledge is essential.

bonding technology, degradation, strenght; steel; increased temperature

INTRODUCTION

A common attribute of production companies (engineering, agriculture, repairing etc.) is a requirement for a bond creation. An adhesive bonding technology is a prospective method of diverse materials connecting. The adhesive bond rise is influenced by a rise of chemical – physical bonds. These bonds are limiting aspects at the environmental affects causing a degradation process.

Messler (2004) defined the key requirements on the bonded joints as maximum strength and life span provision at minimum costs. Between the key requirements the taking into consideration of the environment influence occurred.

It is necessary to analyze the effect of various environmental influences on the bonded joints mechanical properties for the bonded joints suitable design, production and application. But for this step it is important to understand the dependences which influence the bonded joint strength properties not only in laboratory conditions, but in the direct connection with the application area. On the basis of these pieces of knowledge the experiments were carried out.

Adhesive bonds are threaten namely with the exposure of the high humidity effects. By experiments it was proved that in the situation when the adhesive is saturated by humidity, e.g. in water bath, the shear strength is much lower. During the first period of the bonded joint exposure to water the strength decrease is relatively rapid, afterwards the strength becomes stable on the constant level (Lancaster, 2001). At bonded joints exposed to humidity the adhesion failure is more common (Crocombe et al., 2006). The humidity absorption influences significantly the rate of the bonded joint failure during the process of the environmental degradation (Loh et al., 2003).

Peterka (1980) came to the analogous conclusion, when he tested the shear strength of joints of steel. After the two-year exposure to the conditions of the Capital Prague environment the strength fell by 77%. To the contrary the samples made under the same conditions and using the same adhesive, but placed in different geographical environment (Middle Moravia), did not show during 15 years the substantial strength decrease.

Taking into consideration the importance of various climatic conditions it is evident from experiments made by Herák et al. (2009), who judged the environment effects on the strength of the bonded joints exposed during 8 months (graded after 2 months) to the Indonesian tropical climate conditions, concretely

* Supported by project of foreign developing cooperation (ZRS) 136/05 – 09/MZe/B with the title'Building up consultation and advice centre for sphere of agricultural and environmental engineering at university UNITA in Tarutung'.

doi: 10.7160/sab.2013.440307

of three regions, which differ in altitude, daytime temperature and relative humidity:

• Region Medan – altitude 0 m, average daytime temperature 31 °C, relative humidity 90%,
• Region Balige – altitude 900 m, average daytime temperature 25 °C, relative humidity 80%,
• Region Pagarbatu – altitude 1350 m, average daytime temperature 24 °C, relative humidity 90%.

At all three cases it was found out that the bonded joints strength in the course of time relatively considerably decreased (Herák et al., 2009). The highest and stable strength values were reached in the region Balige, i.e. in the middle altitude, lower temperature and relative humidity values, while the lowest strength was measured in the region Medan, i.e. in altitude of sea, "high" values of temperature and relative humidity, where the strength decrease was of 76% (Herák et al., 2009). By the prediction of the further bonded joints strength development in these regions it was found out that in the regions Medan and Pagarbatu the strength would decrease to zero value within one year. In the case of region Balige the strength would decrease to zero value within 29 months (Herák et al., 2009). Within the environment influence the bonded joints were not loaded. In the case of loaded joints the expected results would be considerably worse (Herák et al., 2009).

The aim of the experimental research was to find out the climatic and geographic different environment influence on the strength characteristics and failure.

MATERIALS AND METHOD

The test samples were made according to the standard ČSN EN 1465 (Adhesives – Determination of Tensile Lap-shear Strength of Rigid-to-Rigid Bonded Assemblies) from the unalloyed structural steel S235J0 using the two-component epoxy adhesive BU (Bison epoxy universal/made in Holland), adhesive BM (Bison epoxy metal/made in Holland) and adhesive A3 (Altech 3-ton epoxy adhesive/made in Singapore). In the experimental part the environment of central Europe is marked with'E', Indonesia is marked with'I' and laboratory environment is marked with'L'.

The research was focused on testing the environment in the central Europe (CZ), Indonesia (North Sumatra). The laboratory environment was the comparative standard of the constant temperature 22 ± 2 °C and of the relative humidity 50 ± 5%.

The bonded material surface was mechanically prepared by corundum blasting of F24 and chemically cleaned. The surface roughness Ra was 4.84 ± 0.37 µm and Rz 29.63 ± 2.02 µm. The adhesive layer thickness was constant, namely of 0.142 mm. This layer was secured by putting two distance wires of a mean 0.125 mm. The adhesive surface treatment and the adhesive layer thickness were chosen on the base of optimum val-

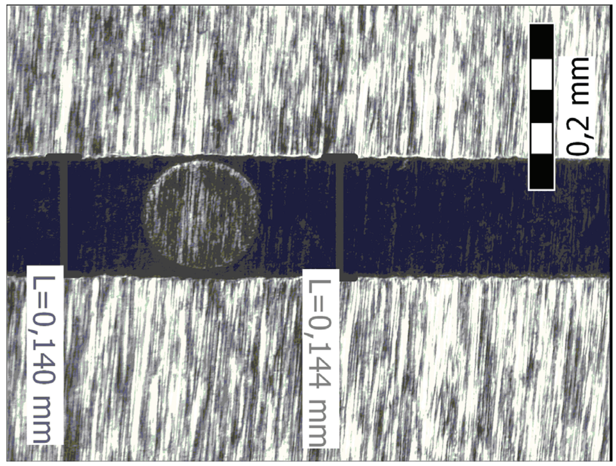

Fig. 1 Adhesive bond cut (adherent – distance wire – adhesive)

ues found out in the previous research. The adhesive layer thickness was found out by means of the picture analysis carried out by the microscope (Fig. 1). From the results it follows that for two-component epoxy adhesives the optimum adhesive layer thickness is in the range of 0.11 to 0.16 mm (Müller et al., 2007). The surface blasting by the artificial corundum of the fraction size F24 seemed to be the effective solution (Müller, Valášek, 2010).

The bonded joints were cured during 24 hours. The curing process of the first set was at the laboratory temperature, i.e. 22 ± 2 °C, of the second set at the increased temperature, i.e. 70 ± 2 °C. The curing process is accelerated with the increasing curing temperature ranging in the interval 60 till 90 °C as well as the resulted adhesive bond strength increase. The cured bonded joints were left 26 weeks in the environment of Europe, Indonesia and laboratory. The exposure of 26 weeks is in accordance with the standard ČSN EN ISO 9142 (2004). The destructive testing was carried out in laboratories of CULS in Prague using the universal tensile strength testing machine of the maximum tensile load 50kN.

After the planned time of exposure the bonded joints placed in Indonesia were put in the vacuum packing. After the bonded joints destruction the tensile lap-shear strength was calculated according to the equation (1) and the failure type according to ČSN ISO 10365 (1995) was determined (1997).

$$\tau = \frac{F}{l_u b} \qquad (1)$$

where: τ – tensile lap-shear strength (MPa), F – tensile force (N), l_u – bonded joint lapping length (mm), b – bonded joint lapping width (mm).

RESULTS

Three two-component epoxy adhesives BU, BM and A3 were subjected to the reference tests during

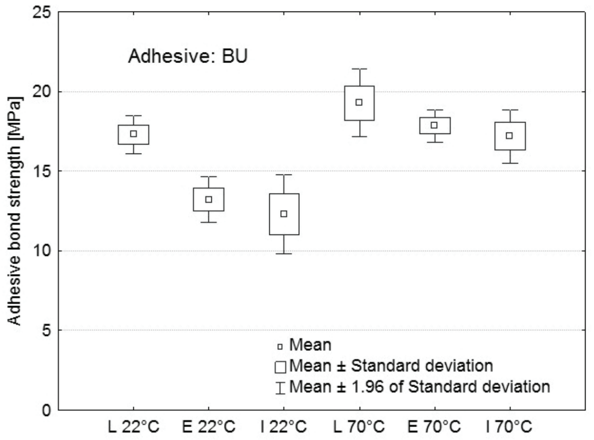

Fig. 2 Environment and curing temperature influences on the bonded joint strength after 26 weeks of exposure time – adhesive BU

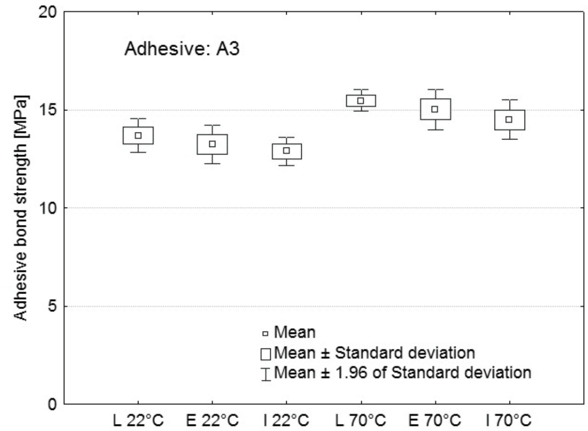

Fig. 3 Environment and curing temperature influences on the bonded joint strength after 26 weeks of exposure time – adhesive A3

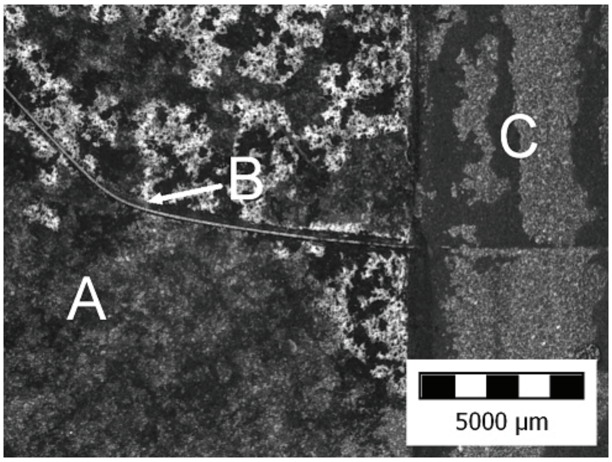

Fig. 4 Destructive tested sample: A – adherent corrosion, B – distance wire, C – adhesive/cohesive failure area of adhesive A3

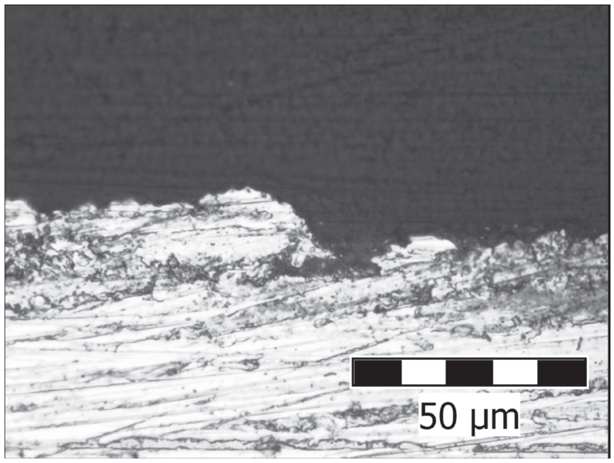

Fig. 5 Adhesive bond cut (adherent - adhesive)

26 weeks in the given environment. The reference test results of the adhesive BU after 26 weeks are evident from Fig. 2. The strength increase at the increased curing temperature of 70 °C is evident. The failure surface of the adhesive BU cured at 22 °C showed the mixed adhesive-cohesive failure type in the Europe and Indonesia destinations. The bonded joints cured at the temperature of 70 °C showed the mixed adhesive-cohesive failure type only in the Indonesia destination. Also here the perceptible diffusive seepage in the failure surface was determined.

The reference test results of the adhesive A3 after 26 weeks exposure time are evident from Fig. 3. The results showed the minimum difference. At the increased curing temperature of 70 °C the bonded joint strength increase of about 10% occurred. Also the climatic conditions were of the minimum influence. The results ranged between 3 and 6%. The change of the failure type from cohesive to adhesive-cohesive occurred only in the Indonesia destination. The diffusive seepage was not determined.

Fig. 4 shows the view on the destructive tested sample where the adhesive bonded adherent (structural steel S235JO) corrosion is visible.

At investigating the macro cut it was not found out the delamination of the adhesive layer from the adhesive bonded material that means from the adherent (Fig. 5).

The test results of the adhesive BM after 26 weeks of exposure time are evident from Fig. 6 The average strength decrease of the bonded joints placed in laboratory after 26 weeks was not considerable. At the set cured at increased temperature of 70 °C the decrease was of 5%. From the above mentioned it is evident the minimum time influence on the bonded joint strength. The more substantial decrease occurred at the bonded joints exposed in the environment of Indonesia. After 26 weeks the average strength decrease amounted 15%. At the bonded joints placed in Europe the strength decrease amounted 12.5% after the same time interval.

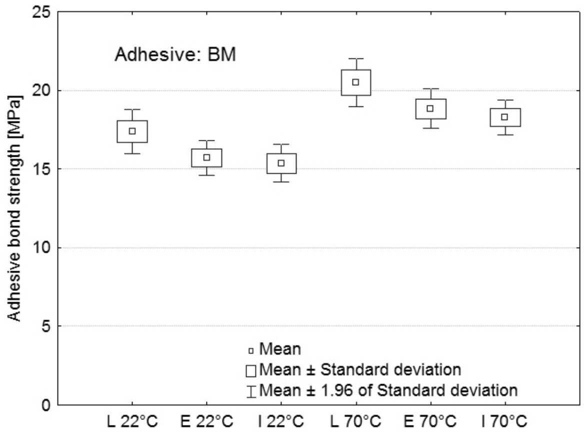

Fig. 6 Environment and curing temperature influences on the bonded joint strength after 26 weeks of exposure time – adhesive BM

DISCUSSION

Considering the results of the adhesive A3 towards the adhesive BU and BM it is possible to agree with the statements of Ducháček (2006) and Balkova et al. (2002) about the various resistance to degradation processes. The concrete adhesive chemical composition is rather the matter of experts in chemistry and above all of adhesive producers and it is their know-how secret.

The single adhesives different resistance to the environment was also studied by authors, who subjected bonded joints to a given environment for a much longer time, namely for 8 years (Ning Su et al., 1992). But the author states that the time needed for the determination of the bonded joint strength change owing to the ageing process caused by outer influences is already from six months (The critical period of the bonded joint potential strength decrease) (Messler, 2004).

The negative influences of the climatic environments of Europe and Indonesia are more considerable that the ones in the laboratory. For the not only environment negative influences minimization the bonded joints curing at increased temperature proved to be the most suitable.

For experiments the curing temperature of 70 °C was determined, in accordance with knowledge stated in literary sources (Balkova et al., 2002; Gledhill, Kinloch, 1974) and with the own experiments. From the above mentioned it follows the recommendation to use “in environment” bonded joints cured at increased temperatures. This statement is in accordance with results published by authors (Ning Su et al., 1992), who presents that joints cured at increased temperature are in total of higher strength during their whole lifetime.

CONCLUSION

The carried out experiments induced to those beneficial findings:

- The possibilities of the environment negative influences elimination by the effect of the curing process at increased temperatures. This state was found out at adhesives which are determined for the curing process at the temperature c. 20 °C. Adhesive bonds showed the adhesive bond strength increase of 10 till 28% depending on the location during the curing process. A significant difference was reached at the adhesive BU in Europe and Indonesia (25 till 28%).
- A significant aspect for exporters of machines containing adhesive bonds is the fact of minimizing the strength differences which amount 4.2% between tested series in Europe and Indonesia during 26 weeks of exposure.
- But it is the significant strength difference between the laboratory conditions and the real destination conditions of application owing to the temperature and relative humidity fluctuations. The strength decrease is 10.5% on average. The adhesive A3 showed only lower decrease of about 3% on average. The most significant decrease 25% was found out at the adhesive BU cured under the laboratory conditions.

REFERENCES

Balkova R, Holcnerova S., Cech, V (2002): Testing of adhesives for bonding of polymer composites. International Journal of Adhesion & Adhesives, 22, 291–295.

Crocombe AD, Hua YX, Loh WK, Wahab MA, Ashcroft IA (2006): Predicting the residual strength for environmentally degraded adhesive lap joints. International Journal of Adhesion & Adhesives, 26, 325–336.

ČSN EN ISO 9142 (2004): Adhesives - Guide to the selection of standard laboratory ageing conditions for testing bonded joints. Prague, Czech Standard Institute. (in Czech)

ČSN EN 1465 (1997): Adhesives - Determination of tensile lap-shear strength of bonded assemblies. Prague, Czech Standard Institute. (in Czech)

ČSN ISO 10365 (1995): Adhesives. Designation of main failure patterns. Prague, Czech Standard Institute. (in Czech)

Ducháček V (2006): Polymers, production, properties, processing, use. 1st Ed. Prague: VŠCHT Kanag print.. (in Czech)

Gledhill RA, Kinloch AJ.(1974): Environmental failure of structural adhesive joints. The journal of adhesion, 6, 315–333.

Herák D, Müller M, Dajbych O, Simanjuntak S (2009): Bearing capacity and corrosion weight losses of the bonded metal joints in the conditions of Indonesia, North Sumatra province. Research in Agricultural Engineering, 55, 94–100.

Lancaster JF (2001): Metallurgy of welding. 1st Ed. Cambridge: Abington Publishing.

Loh WK, Crocombe MM, Abdel Wahab IA (2003): Modelling interfacial degradation using interfacial rupture elements, Journal of adhesion, 79, 1135–1160.

Messler RW (2004):. Joining of materials and structures from pragmatic process to enabling technology. 1st Ed. Burlington: Elsevier.

Müller M, Chotěborský R, Krmela J (2007): Technological and constructional aspects affecting bonded joints. Research in Agricultural Engineering, 53, 67–74.

Müller M Valášek P (2010): Interaction of steel surface treatment by means of abrasive cloth and adhesive bond strength, Manufacturing technology, 10, 49-57.

Ning Su, Mackie RI, Harvey WJ. (1992): The effects of ageing and environmental on the fatigue life of adhesive joints. International Journal of Adhesion & Adhesives, 12, 85–93.

Peterka, J.: Bonding of structural materials in engineering. 1st Ed.Prague: SNTL, 1980. (in Czech)

Received for publication on November 14, 2012
Accepted for publication on March 14, 2013

Corresponding Author:

Doc. Ing. Miroslav M ü l l e r , Ph.D., Czech University of Life Sciences Prague, Faculty of Engineering, Department of Material Science and Manufacturing Technology, 165 21 Prague – Suchdol, Czech Republic, phone: + 420 224 383 261, e-mail: muller@tf.czu.cz