METHYLMETACRYLATE (ADHESIVE) – INFLUENCE OF CLIMATIC CONDITIONS ON PROPERTIES OF ADHESIVE BOND

Petr Henc, Petr Chocholous, Miroslav Muller, Jiri Kejval
Czech University of Life Sciences Prague
henc@tf.czu.cz, chocholousp@tf.czu.cz, muller@tf.czu.cz, kejval@tf.czu.cz

Abstract: The resulting adhesive bond strength is affected by many factors such as surface roughness, thickness of adhesive bond and climatic conditions. The aim of the experiment was testing adhesive in various climatic conditions such as temperature below freezing point. New two-part adhesive by NAVATO s.r.o. was exposed to extreme climatic conditions. The adhesive is highly resistant to weather impact, solvents and achieves high strength because of its macrostructure. According to the measured values the curing time during temperatures below freezing is longer than the curing time under laboratory conditions. Curing is accelerated if the adhesive is exposed to temperature such as 50 ºC. Higher temperatures did not affect the final strength. The resulting bond strength is negatively affected by temperatures below freezing. The final strength is almost identical at higher temperatures (50 ºC) and under laboratory conditions.

Keywords: bonding, adhesion, cohesion, methylmetacpylate adhesives.

Introduction

Bonding technology is a very old method of joining materials. Initially, people used adhesive materials from natural resources – birch resin, animal sealing cements, later a mixture of glue and chalk [1]. Bonding technology is a devdloping area and for that reason bonding is now used in all industrial areas (e.g., engineering, electrical engineering, repair work etc.). Developing trends in the production of "new" types of glue (adhesive) require experimental testing associated with mechanical properties of adhesives and their mutual interactions between adhesive bonds. Conventional joining methods - welding, riveting, and screwing - do not reach the same properties and benefits as bonding (tightness adhesive bond and non-damage material structure). Almost any materials can be glued together between each other and also with different types of materials regardless of their thickness. Lower weight of adhesive bond is considerable, too. Some adhesives can be used for bonding a variety of materials but there is no universal adhesive. Only certain types of adhesives used for specific materials and under specific conditions will get optimal adhesive bond properties.

The degradation process depending on the time may decrease the strength limits of bonded joints obtained at the beginning of their life. Decreased bond strength depends on specific environmental conditions [2]. In practice, the adhesive bond is exposed to a variety of environments such as chemical reagents. The negative factors can be eliminated by proper bonding surface modification [3; 4]. In laboratory conditions (22±2 ºC, relative humidity 45±5 %) decrease of the final bond strength is low according to Müller results [5]. Cohesion type of damage occurred under laboratory conditions. For all bonded joints exposed to various degradation environments the bond strength decreased in the first measured period (after 15 days). Surrounding degradation environments are an important component of bonded joint quality. If the bonded joints are exposed to degradation environments it can lead to self-destruction at short time [5]. The influence of climatic conditions is evident from experiments carried out by Herák et al. 2009 [6]. The testing samples were exposed to tropical climate in Indonesia for eight months. Three regions with different altitude, daily temperatures and relative humidity were chosen (Medan, Pagarpatu, Balige). The bond strength dramatically decreased during short time in all three cases. The highest bond strength values were achieved in Balige (middle altitude, lower daily temperatures and humidity). The lowest bond strength values were achieved in region Medan (sea altitude, high daily temperatures and humidity). The bond strength decreased by 76% in region Medan. The prediction of further bond strength in these areas has found that for areas Pagarbatu and Medan the bond strength dropped to zero value in one year and in Balige area the bond strength reached zero value in 29 months. The bonded joints were not exposed to load. The expected results would be worse if the bonded joints were loaded [6].

Crocombe [7] found that the degradation of adhesive bonds depends on the type of adherent, adhesive, surface treatment, type of loading and on aging. According to a wide range of use of the bonding technology in various industries it is necessary to determine the mechanical properties in extreme climatic conditions. Müller and Hůrka [8] carried out an experiment for determining of the influence of the curing temperature. The experiments showed that the curing time is shorter with higher temperatures for all tested adhesives. The curing time can be accelerated by the right choice of curing temperature. The aim of the laboratory experiments was to determine the influence of climatic conditions on the bond strength properties. The published results will be presented in teaching courses focused on joining methods. Follow-up teaching courses based on the research are beneficial for student knowledge [9; 10].

Materials and methods

We have to make experimental tests after the degradation process because bonded joints are used under extreme conditions such as temperatures below freezing. An important aspect influencing the bond strength is the environment where the adhesive is applied. This fact led to determine the influence of temperature and time on the final bond strength. A new type of methylmetacrylate adhesive was used for testing. The adhesive bond properties were specified under several conditions:

- laboratory (23±2°C, humidity 24-37%);
- outdoor conditions (-7±8°C, humidity 60-90%);
- refrigerator (0±3 °C);
- drying oven (50±3 °C).

The testing times were specified by the adhesive manufacturer: 0.1 h (manipulative strength), 0.3 h, 1 h and 48 h. Specimen dimensions defined standard ČSN EN 1465. The tests were carried out using the duralumin AlCu4Mg specimens with dimensions 100 x 25 x 1.5 mm (Figure 1). The chemical composition of the bonded specimens detected by spectral analysis is shown in Table 1.

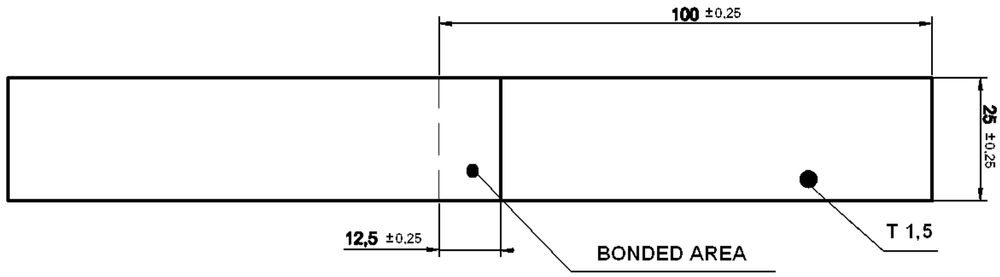

Fig. 1. **Shape and dimensions of specimen – tensile shear strength**

Table 1

Chemical composition of the bonded material (weight percentage)

Duralumin $AlCu_4Mg$	Mn	Cr	Ni	Al	Cu	Ti	Fe	Si	Mg	Zn
	0.510	0.003	0.003	93.197	5.012	0.013	0.304	0.350	0.571	0.014

The technology of grit blasting was used for the mechanical surface treatment. Corundum F80 under angle 90º was used for blasting. After the mechanical surface treatment the specimen was degreased by perchlorethylene. The surface was coated by adhesive and the thickness was defined by two spacer wires. The bonded joints were loaded by force. The bonding process took place under the specified conditions given above. The force required for breaking the specimen was measured on the universal tensile machine. After breaking for the specimen the maximum force and the bonded area were recorded. For calculation of the bond strength formula (1) was used. To evaluate the type of bond damage the standard ISO 10365 was used.

$$\tau = F/S \tag{1}$$

where τ – tensile shear strength, MPa;
F – force required to break specimen, N;
S – bonded area, mm^2.

For testing new adhesive NOVATIT was used. It is two-part adhesive with the methylmetacrylate substance. The adhesive does not trickle due to its high viscosity and is perfect for bonding aluminum, ceramics, wood and plastics with high impact resistance. It is also suitable for bonding all combinations of these materials. The product is durable and resistant to weathering, solvents, fuels and chemicals due to its macrostructure [11].

Results and discussion

The test criterions were set by the manufacturer recommendations. The experiment was carried out under laboratory conditions and under higher curing temperature (50 ºC). Another limiting factor was the test area which the manufacturer recommendations do not describe. The temperature during curing was equal to outdoor temperatures during winter months (0 ºC).

The experimental results are shown in Figure 2. The results clearly specify the time aspect of the curing process on the one hand and the impact of the climatic conditions on the other hand. Under laboratory conditions the bonded joints showed sharp increase of strength at interval 0.3 hour and subsequent stagnation. According to the results the manufacturer declared the curing time (6 hours) can be set shorter (0.3 hours). For that reason the production capacity can increase and the unit cost of the final product can be reduced. The curing process in the drying oven was very similar as the process under laboratory conditions. After one hour, a curing effect of higher temperature was observed when strength increase was recorded (see Figure 2). In practice, this fact can be used to get higher productivity and to achieve higher beginning strength. Higher beginning strength is useful at long-term aspects when bonded joints are exposed to degradation processes. These processes are generally characterized by decreased bond strength [5-7]. If the surrounding environment is heated the bond strength increases about 32 % compared to laboratory conditions. The effect of low temperatures is shown in Figure 2. After 0.3 hours the bonded joints reach only manipulative strength (2 MPa). The low temperature influence is eliminated with time and after 48 hours the bond strength is approximately the same as under laboratory conditions. This limiting factor may negatively affect bonding production under climatic conditions where temperatures do not exceed the freezing point. The time interval 0.1 hour was insufficient in any conditions to the measured bond strength on the universal tensile machine.

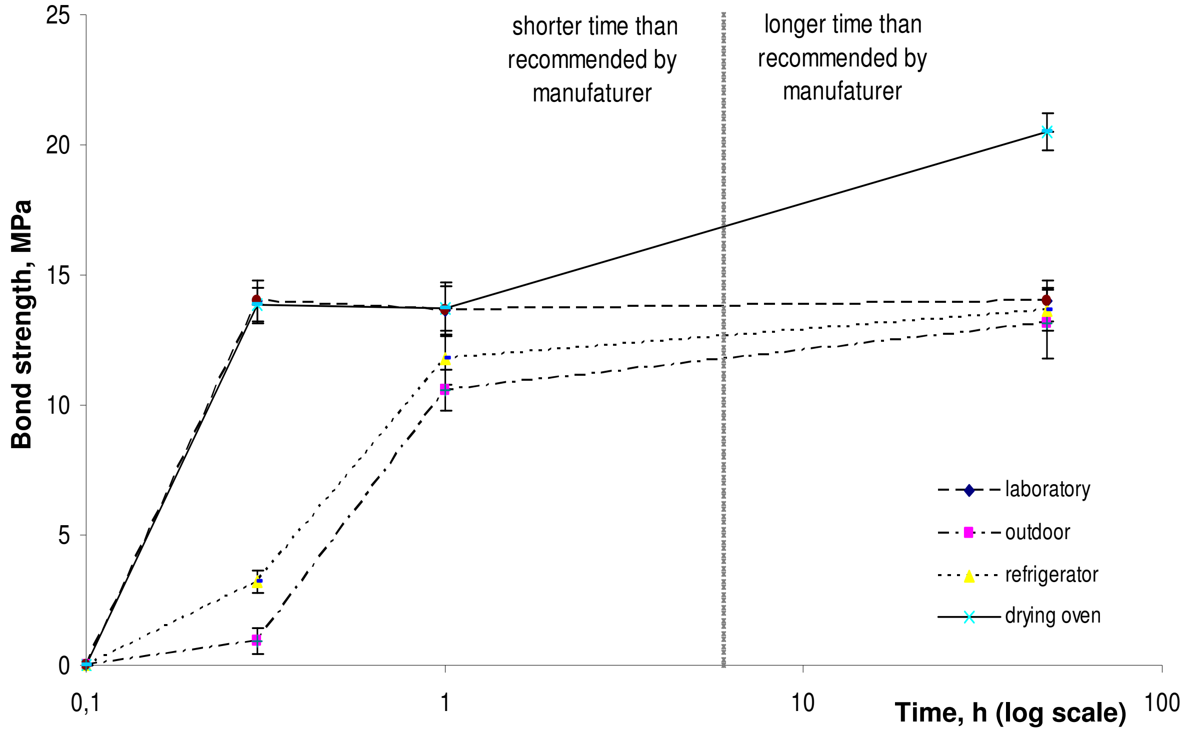

Fig. 2. **Influence of curing time on bond strength**

Uneven curing is caused by low temperatures and negatively affects the bond strength. Under laboratory and drying oven conditions the measured data do not show extremes or outliers. This fact shows that the curing process is even during higher temperatures. The results show considerable variance of the measured values under refrigerator and outdoor conditions. These environments have a significant impact on the curing process. The outlier values show that curing of adhesive is not consistent under lower temperatures.

Conclusions

The highest bond quality together with the bond guarantee lifetime in all industrial sectors is required. The lifetime is affected by many factors. Major impacts on the bond strength are by joint construction, surface treatment, time and temperature during curing. During testing different values were measured than given by the manufacturer. The reason for lower strength values could be caused by the different surface treatment process or by the deformation of the bonding materials where there was combined move – flaking stress.

The experiment results demonstrated the following:

- the curing process is not stopped during low temperatures and temperatures below freezing;
- methylmetacrylate adhesives can be applied under climatic conditions with temperatures about -15 ºC to +50 ºC;
- the time to reach the bond strength given by the manufacturer (6 hours) is achieved in a shorter interval and depends on curing temperature;
- curing during higher temperatures (50 ºC) shows about 30 % higher primary strength.

Acknowledgements

This paper has been done when solving the grant of the title "Interaction between segments of the bonding technology – adherent, adhesion, cohesion and aging process" Nr. 31140/1312/3115.

References

1. Peterka J., Lepení konstrukčních materialů ve strojírenství. Praha: SNTL,1980, p. 788 (In Czech)
2. Müller M., Valášek P. In 9th International scientific conference engineering for rural development. Jelgava: LUA, 2010, pp. 49-52. ISSN 1691-3043.
3. Müller M., Hrabě P., Chotěborský, R. Optimization of surface treatment parameters in adhesive bonding technology. In 7th International scientific conference engineering for rural development. Jelgava: LUA, 2008, pp. 214-219. ISSN 1691-3043.
4. Nováková A., Brožek M. Bonding of non-metallic materials using thermoplastic adhesives. In 8th International Scientific Conference „Engineering for Rural Development". Jelgava, Latvia University of Agriculture, Faculty of Engineering, Institute of Mechanics, 2009, pp. 261-264. ISBN 1691-5739.
5. Müller M., Chotěborský R., Hrabě P. Degradation processes influencing bonded joints. Research in Agricultural Engineering, 2009, vol. 55, no. 1, pp. 29-34. ISSN 1212-9151.
6. Herák D., Müller M., Karanský J., Dajbych O., Simanjuntak S. Bearing capacity and corrosion weight losses of the bonded metal joints in the conditions of Indonesia, North Sumatra province. Research in Agricultural Engineering, 2009, vol. 55, no.3, pp.94-100. ISSN 1212-9151.
7. Crocombe A.D. Durability modelling concepts and tools for the cohesive environmental degradation of bonded structures, International Journal of Adhesion & Adhesives, 1997, vol. 17, no. 3, pp. 229-238.
8. Müller M., Hůrka K. Temperature influence on curing time of adhesive joints. Strojírenská technologie, 2006, roč. 12, č. 1, pp. 9-15. ISSN 1211-4162.(In Czech)
9. Náprstková N. Students connecting to production problems resolutions in CAD/CAM area. In 9th International scientific conference engineering for rural development. Jelgava: LUA, 2010, p. 310. ISSN 1691-3043.
10. Náprstková N., Náprstek V. Surfcam and its Education at FPTM. In 6th International scientific conference engineering for rural development. Jelgava: LUA, 2007, pp. 232-235 ISSN1691-3043
11. Novato s.r.o., Material data sheet. [online] [3.3.2011]. Available at: http://www.novato.cz/download/cz/500000.pdf (In Czech)