HEAT RESISTANCE OF PUR ADHESIVE JOINTS OF WOOD CONSTRUCTIONS

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ABSTRACT

The significance of this work consists in pointing out the fact that adhesive joints may be at conditions of increased temperature the weak points of the wood glued structure. The aim of this work is to find out if there is a relationship of the strength of glued joints at increased temperature determined as shear and bending strength of glued joints. The work determines strength properties of beech (*Fagus silvatica*) and spruce (*Picea abies*) glued joints at thermal load at 20 °C, 50 °C, 80 °C and 110 °C. For gluing of wood samples, there were applied adhesives from two producers of one component polyurethane (1C PUR) adhesives Jowapur 686.60 and Kestopur 1030. Both types of PUR adhesive systems showed a softening of the joints and also decreasing in shear and bending strength.

Key words: polyurethane prepolymer, lap joint, finger joint, wood construction

INTRODUCTION

PUR prepolymers are relatively new generation of reactive adhesives, there are liquid and high viscous resins at normal temperature. Hardening process runs at normal temperature, one component system cross-links by reaction of free isocyanate groups with water molecules, urea bridges are formed in each intermediate stage (Sedliačik 2005). The thermal stability of adhesives for load-bearing construction has been one of their key parameters since engineered wood products were introduced in timber construction (Dudas 2008, Štefko 2006).

In the case of one-component moisture-curing polyurethane (1C PUR) adhesives, knowledge about relationships between their chemical structure and the resulting bonding properties is limited, especially under high-temperature conditions. The study by (Clauss, Dijkstra *et al.* 2011) describes the structure property relationships of 1C PUR prepolymers, which were analysed in the temperature range from 20 to 200 °C by means of mechanical and rheological tests. NCO-terminated urethane prepolymers were prepared from systematically varied MDI and polyether mixtures. The structural parameters investigated were the urea and urethane group content, cross-link density, ethylene oxide content and the adjustment of functionality via NCO or polyether component. Bonded wood joints were tested for their tensile shear strength and polymer films were analysed by means of DMA and DSC. The results revealed a significant influence of hard segment content and cross-link density on the thermal stability of the prepolymers.

The relationship between the chemical structure of commercial polyurethanes and temperature-dependent creep properties was determined by (Richter *et al*. 2006) in full scale tests and the results were compared with thermomechanical analysis. Comparison of mechanical performance with ^{13}C-NMR spectroscopy studies elucidated important structure-property relationships, which either allows the reduction or elimination of temperature-dependent creep in 1C-PUR adhesives for wood. The combination of the relative content of still reactive, free – NCO groups on the polyurethane, careful selection of the degree of resin polymerization and a slower rate of reaction are the three most significant parameters that have to be controlled to overcome the problem of temperature-dependent creep found in 1C-PUR adhesives. The results obtained indicate that adhesives presenting a combination of a higher content of still unreacted – NCO groups, a lower degree of polymerization and slower reaction rate are capable to counteract problems of high sensitivity of polyurethane to temperature-dependent creep.

The thermal stability of glued wood joints is an important criterion to determine the suitability of adhesives in the field of engineered wood. Thereby the cohesiveness of the adhesive must not degrade under heat load. The current investigation by (Clauss, Joscak *et al*. 2011) covers the influence of temperature (T = 20 to 220 °C) on the shear strength of glued wood joints. Different adhesive systems were investigated. With increasing temperature, the shear strength of solid wood and also of glued wood joints decreased. There were big differences in thermal stability and failure behaviour between the adhesive systems as well as within the polyurethane group. The thermal stability of one-component polyurethane systems can be greatly varied by modifying their chemical structure. Well adapted one component polyurethane adhesives reach strength similar to that of phenol resorcinol resin.

The main aim of this research is determination of thermal stability of lap and finger glued joints of wood constructions at various increasing temperatures from 20 °C to 110 °C. Testing of shear strength of lap joints and bending strength of finger joints were carried out on samples of hard wood and soft wood species, beech and spruce.

METHOD

Thermal stability of lap and finger joints in shear and bend strength will be determined according standards:

EN 302–1: 2004 Adhesives for load-bearing timber structures. Test methods. Part 1: Determination of bond strength in longitudinal tensile shear strength.

EN 408: 2010 Timber structures. Structural timber and glued laminated timber. Determination of some physical and mechanical properties.

EN 14257: 2006 Adhesives. Wood adhesives. Determination of tensile strength of lap joints at elevated temperature (WATT '91).

Used adhesive types, Jowapur 686.60 and Kestopur 1030 are 1-component, moisture curing polyurethane adhesives for joining wooden materials. Both products meet the requirements of EN 301/302 standards, stated at Norwegian Treteknisk Institute. Tests were carried out on testing equipment LaborTech 4.050 and TIRAtest 2850 according to figure 1.

All test results will be subjected to mathematical and statistical analysis (Klein 2002).

Fig. 1. Testing equipment with inserted samples

RESULTS AND DISCUSSION

Table 1 describes basic statistical evaluation of obtained results of shear strength of lap joints of beech wood samples measured at different levels of temperature.

Table 1. Shear strength of lap joints of beech wood

№	Temperature °C	Shear strength MPa	Std deviation MPa	Variable %	Number of samples
1	20	11,6	1,71	14,8	10
2	50	11,7	1,03	8,8	10
3	80	9,8	1,95	19,9	10
4	110	8,7	1,48	16,9	10

A detailed statistical analysis of Duncan's test showed a statistically significant difference in shear strength of glued joints between the temperatures of 50 and 80 °C. The temperature of 80 °C caused the significant decrease of shear strength of glued joint of beech wood samples. Shear strength of glued joints at temperatures above 80 °C fell below the standard EN 301 requirement of 10 MPa.

Table 2 describes basic statistical evaluation of obtained results of shear strength of lap joints of spruce wood samples measured at different levels of temperature.

Table 2. Shear strength of lap joints of spruce wood

№	Temperature °C	Shear strength MPa	Std deviation MPa	Variable %	Number of samples
1	20	6,8	1,26	18,6	10
2	50	5,9	1,12	18,9	10
3	80	5,8	1,22	19,9	10
4	110	5,5	1,02	16,9	10

A detailed statistical analysis of Duncan's test showed a statistically insignificant difference in shear strength of glued joints between the temperatures of 20 and 110 °C for spruce wood samples. The increase in temperature caused only a slight decrease in shear strength of bonded lap joints of spruce wood.

All these results of testing of lap glued joints for both wood species are comparable with results of (Clauss, Joscak *et al*. 2011), who stated the first decrease of shear strength over 50 °C, further increasing of temperature over 200 °C caused delamination of glued joints.

Table 3 describes basic statistical evaluation of obtained results of bending strength of finger joints of spruce wood samples measured at different levels of temperature.

Table 3. Bending strength of finger joints of spruce wood

№	Temperature °C	Shear strength MPa	Std deviation MPa	Variable %	Number of samples
1	20	41,7	11,50	30,0	6
2	60	34,2	9,96	31,7	6
3	80	36,3	2,56	7,0	6
4	110	35,3	7,96	24,4	6

Despite the high coefficient of variation, all values of bending strength of all tested samples were over the standard requirement. Bending strength of glued finger joints at increased temperatures generally do not fell below the standard EN 385 requirement of 24 MPa.

CONCLUSION

The importance of this work lies in pointing out the fact that glued joint may be under conditions of elevated temperature weak point of wooden structures. The aim of this thesis was to determine the behaviour of glued joints and their thermal resistance at temperatures, which can be increased at general conditions e.g. sunshine, heating of buildings, chimney from fireplace etc. Heat resistance of joints were tested at 20, 50, 80 and 110 °C. Both types of polyurethane adhesives showed a slight decrease in shear strength at elevated temperature. It was proved, that temperatures up to 110 °C do not reduce the strength of bonded joints under standard requirements.

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