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BONDING STRENGTH OF THERMALLY TREATED SPRUCE (*PICEA ABIES*) AND OAK WOOD

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Abstract

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Thermally modified wood has been widely reported to have improved durability and aesthetic appeal than its natural counterparts in same economic range. Due to this, there has been a constant effort to utilize its durability properties in different commercial products. Utilization of outer layer thermally modified wood on exposed surface is a classical idea, but bonding of thermally modified to natural wood has been a challenging part and needs extensive investigation on different species. In this study, we tried to investigate bonding properties of oak wood with thermally modified wood (spruce) and compared it with natural oak – oak bond strength. We observed a significant decrease of 47% in value of shear strength for thermally treated wood with natural wood when compared with natural oak – oak bonding. Thermally treated wood can be used as outermost layer in those products, where shear strength does not play a crucial role and more research is required to improve its bonding with natural wood to increase its applicability range.

Keywords: thermally treated wood, shear strength, outdoor application of wood

INTRODUCTION

Wood modification has been a constantly evolving branch of science due to growing human health and environment concerns. Technological advancement has allowed manufacturers to cater changing need of society by including greener and safer technologies. The thermal modification is one of the ecological branches where the wood as a natural resource is modified by various thermal-processing designs (Militz, 2002). The wood is generally treated by elevating temperature from 160 to 280 °C, for a time of 15 to 24h depending on method to increase resistance of wood to biological attack and to mitigate the shrinkage and swelling of final product (Kamdem *et al.*, 2002; Sanderman and Augustin, 1963). Utilization of thermally treated wood in different commercial products needs it to be tested at various fronts. Shear strength of thermally modified – thermally modified wood bonds with commercial adhesives has been investigated for various species (Dilik and Hiziroglu, 2012; Sernek *et al.*, 2007, 2008; Sahin Kol *et al.*, 2009; Ozcan *et al.*, 2012) where different degree of decrease in shear strength has been reported in various species, but there is still enough scope for thermally modified wood – natural wood shear strength investigations.

Modified – natural wood bond shear strength testing is crucial part of product development in wood based industry. Thermal modification brings in a compromise on mechanical properties, causing partial brittleness of wood. This decrease is reported by different values, related to treatment method or anatomical nature of the wood (Hilis, 1984). Combining durability properties of thermally modified wood with other woody material of enhanced mechanical properties is good approach leading to better product development. An extensive research on mechanical behavior of combination is very much required and shear strength is one of them. This research was done as part of new product development for an industrial partner (Agrospol Lužná, s. r. o, Valašská Polanka), where thermally modified – unmodified wood bond shear strength play an important role. This need of direct industrial application is reflected in the research design, whereas oak-lunawood (modified spruce) bonding is compared to the traditional product of the company i.e. oak-oak bonding.

MATERIAL AND METHODS

Lunawood® (spruce) was procured from lunawood company (Czech Republic branch) itself. Oak wood was bought from local market. Adhesives ("RAKOLL®" class D – 4 which meet standard DIN EN 14257) was purchased from local supplier. The samples of bonded Oak woods were used as control samples, whereas oak wood with Lunawood® were prepared as samples. The PVAC adhesive "RAKOLL®" class D – 4 which meet standard DIN EN 14257 was used for gluing in amount of 100 $g \cdot m^{-2}$. It was according to the technological recommendations of industrial partner. The pressure of 0.8 Mpa was applied for 40 minutes to achieve bonding of materials. All samples were conditioned for moisture content 10% and cut according to EN 205 (Fig. 1). The samples shear strength, with dimensions 20×14×100 mm were tested by ZWICK Z050® where loading speed was 5 $mm \cdot min^{-1}$, and break of glue-line was achieved in 45 sec. The shear strength in $N \cdot mm^{-2}$ was calculated as per EQ. 1. The measured data were statistically evaluated and mean value, standard deviation, minimal and maximal value were calculated. The ANOVA analysis to support significance of hypothesis was used for comparison with control sample.

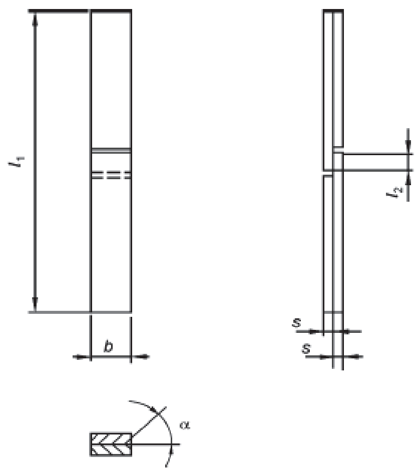
EQ 1. Equation for shear strength determination

$$\tau = \frac{F_{max}}{l_2 \times b}, \qquad [1]$$

F_{max} .....the applied maximum force in Newton (N),
l_2 ....the length of the bonded test surface in millimeters (mm),
b ....the width of the bonded test surface in millimeters (mm).

RESULTS

Glued wooden beams which are planned to be covered by Lunawood® are defined by following measured shear strength of glue line. The control samples oak – oak provided control measurement which was according to established industrial production. Nevertheless major task of this study was to evaluate the shear strength with commercial Lunawood®. Our shear strength evaluation carried out statistically different results of shear strength

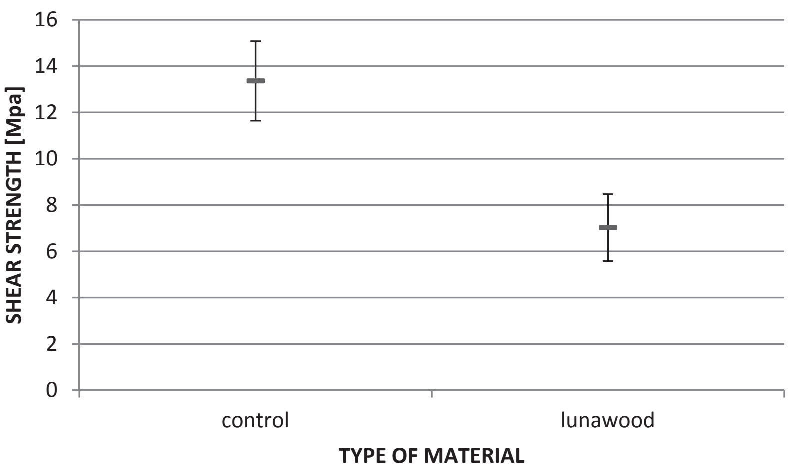


1: *Dimensions of the test sample*
L_1 – total length of test piece (150 ± 5 mm); b – width of test piece (20 ± 0.2); l_2 – length of overlap (10 ± 0.2 mm); s – thickness of the panels (5.0 ± 0.1 mm); α – angle between growth ring and surfaces to be bonded (30° to 90°); a – thickness of the thick bond line (1 ± 0.1 mm)

I: *Results of shear strength test*

Shear strength of tested samples				
	mean value	x_{min}	x_{max}	**st.dev.**
Control ●	**13.359**	10,006	16.36	1,717
Lunawood ●	**7.021**	4.103	10.439	1.447

● $p < 0.05$; Significance level of 0.05



2: *Comparison of tested samples*

supported by ANOVA test. Descriptive statistics in Tab. I provide basic results, where mean value, minimal (x_{min}), maximal (x_{max}) and standard deviation (st.dev.) are included. Comparison is in graphical form presented in Fig. 2 subsequently. The decrease by 47% was observed between control sample and Lunawood sample. The control sample reached 13.36 Mpa and sample with Lunawood® 7.021 Mpa.

DISCUSSION

It has been clearly stated in literature the strength properties of wood adversely influenced by heat treatment due to thermal degradation. This loss becomes more prominent if temperature and exposure time are increased. It is a well-known fact that polymers in the cell wall are depolymerized resulting in strength reduction of hemicellulose. The heat treatment of wood can change its surface properties and the changes might causes difficulties in the adhesion of adhesives. One reason in modification in wood surface behavior is that low-molecular weight wood extractives such as fatty acids, fats and waxes migrate to the surface of the heat-treated wood, thus interfering with the absorption process (Back, 1991; Hemingway, 1969). These extractives might affect the adhesion of bond line. Decrease of values is found to be assigned to the thermal modification itself, this treatment possibly degrade the wooden mass and due to that is decrease also strength properties of wood and gives different bonding properties, similar results were by (Dilik and Hiziroglu, 2012; Sernek *et al.*, 2007, 2008) reported.

SUMMARY

Increasing environment concern and strict European regulation controlling biocide utilization has forced wood based product industry to look for more greener and acceptable methods to improve durability of wood. Thermal modification of wood is one the classical methods, which fits into this criteria and offers a viable solution. Whereas, on the one hand improved durability is an advantage but a compromise has to be made in shear strength and surface properties. It necessitates intelligent product development and best utilization of this material in such way that durability can be utilized in best possible way with minimum effect on product performance. This study was done in cooperation with an industrial partner (Agrospol Lužná, s. r. o, Valašská Polanka), which aims to utilized Lunawood (commercial product of thermal modification of spruce) durability by using it as outermost layer to minimize weathering. As per requirements of industrial partner, shear strength of Lunawood and natural oak wood bond strength were measured with commercial adhesives and compared with natural oak – natural oak wood bonds. A very wide range of 15–20% decrease has already been reported many authors for various species. We observed a statistically significant fall 47% in shear strength with reference to control sample, which can be attributed to change in surface characteristic and mobilization of extractives to the surface. Nevertheless, difference in surface characteristics of bonded surface also a role. On the basis of observations, we conclude that outermost layer of lunawood will certainly improve durability to weathering but fall in shear strength has to be considered and addressed by effective product design before finalizing any product. More research is required to understand and improve surface characteristics for effective bonding of Lunawood – natural wood surface.

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