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SURFACE SOUNDNESS OF BASALT FIBRE REINFORCED POLYVINYL ACETATE PLYWOOD COATING

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Abstract:
Basalt fibres have become popular reinforcement of polymers due to their environmentally friendly properties. These properties constitute the basis for the enhancement of materials such as wood or WBP (wood-based panels). Other polymers than those commonly used for FRP (fibre reinforced polymers) may be applied. PVAC (Polyvinyl acetate) adhesive seem to be a promising choice as it safer substance. However basalt fibres do not create sufficient bond with many adhesives. In this study; bond strength of one polymeric emulsion adhesive, two PVAC adhesives, and one layer of basalt fabric and birch plywood were evaluated. Finally, the surface soundness of the best Ponal Super 3 with different amounts and one or two layers of basalt fabric were investigated. Surface layer was well bonded and failures were always located in the wood. Statistically evaluated data were not significantly different, proving that several layers of basalt fabrics can be bonded together, while variable amounts of adhesive do not affect the surface soundness of this reinforcing layer.

Key words: *surface soundness; plywood; PVAC; basalt fibres; reinforcement.*

INTRODUCTION

Wood is often utilized for WBP (wood-based panels) which are engineered materials produced with the aim either to obtain better and more homogenous material than solid wood or just to process the secondary products of sawmills or harvest residues. High quality veneers are used for the production of plywood, showing the best mechanical properties compared to other WBP-types. Since plywood is a layered wood-composite, it is still strongly influenced by the properties of its originated raw-material. Hence the perpendicular direction of surface veneer will always have detrimental effects on its mechanical properties (Varis 2018).

Better homogeneity could be achieved by reinforcing fabrics, mounted on the surface of the plywood. This potential is based on the structure of the fabric, which has warp and weft yarns knitted together in structure, which is much more homogenous than plywood itself (Hu 2004). One of the attractive materials is basalt. Fibres made of this rock have tensile strength superior to wood in its parallel direction. Moreover this material is interesting due to its costs and environmentally friendly properties (Fiore et al. 2011).

The most popular polymers for FRP are epoxy, polyester and vinyl ester resins, which can be also used for wood. However plywood with basalt fibres would have a better index in nature conservation if degradable polymers are used as well. Wood industry uses adhesives that fulfil this requirement and are much cheaper. However, basalt fibres may not be compatible with many polymers (Chen and Huang 2016) and thus several variants were tested to find satisfactory results in adhesion.

OBJECTIVES

Proper reinforcement of WBP can be achieved only with a good adhesion between materials. This study is based on materials which are sustainable, abundant in nature or their processing does not have

negative impact on the environment. Combinations of wood, basalt fibres and PVAC adhesive (Kim 2009) meet these requirements. In this study we tried two PVAC and one polymeric emulsion adhesives from different manufacturers. The objective was to find the best adhesion with basalt fabric and birch plywood.

MATERIALS, METHOD, EQUIPMENT

Three-layered birch plywood obtained from AZ wood a.s. (Brno, Czech Republic) was used as core of the tested composite. Its thickness was 4 mm. Basalt fabric had twilled weave and areal weight of 340 g·m^{-2}. Silane sizing, thin film that improves bond with polymers was applied by manufacturer. Fabric was obtained from Basaltex a.s. (Šumperk, Czech Republic). Three different adhesives were tested. The first one was Lignu Pro Free polymeric emulsion adhesive. This adhesive was mixed with Lignu Pro Free hardener. Manufacturer (Akzo Nobel BV, Arnhem, Netherlands) does not state the content of this emulsion. However it is similar in application, colour, viscosity, density and cleaning with other PVAC adhesives. The final solidified adhesive film meets the requirements of C4 class (EN 12765 (2002)) according to manufacturer's datasheet. This classification is used for thermosetting adhesives and is an equivalent to D4 class of thermoplastic adhesives according to EN 204 (2002) (Antonio and Mittal 2011). Second adhesive was PVAC Vinalep 840 D4 obtained from Stachema s.r.o. (Kolín, Czech Republic). The last adhesive was Ponal super 3 D3 PVAC. It was obtained from Henkel s.r.o. (Prague, Czech Republic). Both Vinalep 840 and Ponal Super 3 are one-component adhesives.

The first test was based on qualitative evaluation of bond strength. Two panels were coated with one layer of fabric on one surface only. Amount of the adhesive was 291 g·m^{-2}. The ready composition was placed in the hot-press. Pressing cycle was 20 min at 100 °C and 1.5 MPa. Surface was covered by waxed separating paper. 10 specimens were prepared for testing. After conditioning, the edges of coating were peeled off from the plywood, so it could be gripped between fingers. The quality of adhesion was tested by hand.

Based on the results, Ponal super 3 was used for the production of additional panels. Six variants were produced. Different amounts of adhesive at 238, 291 and 356 g·m^{-2} were used. These adhesive spreads were used for production of panels with 1 and 2 layers of fabric (Fig. 1). The amount of adhesive for two layers was doubled. These layers we symmetrical applied on both surfaces of plywood. Panels were further covered by PTFE (polytetrafluoroethylene) separator film and a layer of silicone rubber. Pressing parameters for one layer were the same as before. Pressing time was increased to 30 minutes for 2 layers of fabric.

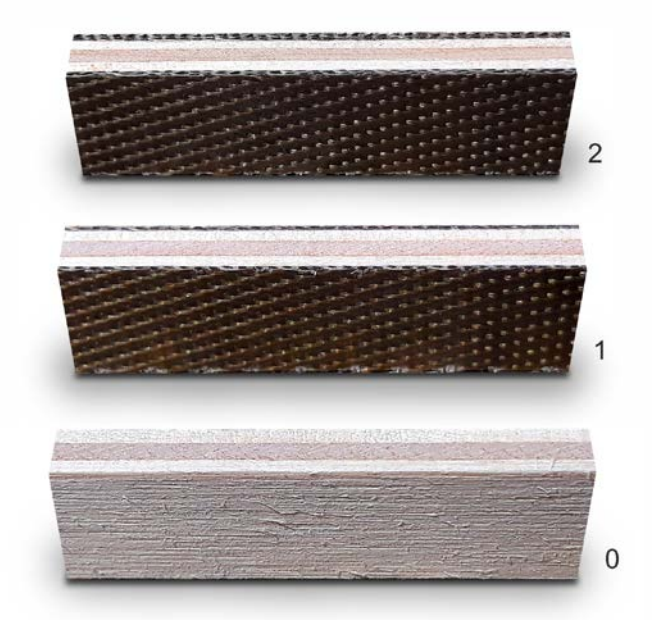

Fig. 1.
Sample of raw plywood (marked as 0), and plywood with 1 and 2 layers of basalt fabric.

Test of surface soundness was performed according to the method certified by Mendel University in Brno. This method is a modification of EN 311 (2003). The difference is only in the size of tested area. Circle with diameter of 20mm is grooved around the bonded metal disk of the same diameter. Specimens were

tested with Comtest OP1-P testing machine (Ostrava, Czech Republic). Twenty specimens were prepared from two panels per variant. All specimens were air conditioned before testing.

MANOVA (Multivariate analysis of variance) was used for statistical evaluation of data. At first, normality of data was evaluated by Shapiro-Wilk test. Levene and Brown-Forsythe test was used to prove homogeneity of variances. All data met the requirement of homoscedasticity, thus MANOVA could be used. Scheffe test was used for determination of significant differences between variants. Data were compared at 0.05 significance level alpha.

RESULTS AND DISCUSSION

Both Lignu Pro Free and Vinalep 840 exhibited poor bond during qualitative test. Basalt fabric could be removed by hand from plywood without damage to any of these materials. On the other hand Ponal Super 3 had very good adhesion and it was impossible to remove it without damage.

Satisfactory results were obtained during the test of surface soundness. All 120 specimens failed in the wood, but not in the adhesive layer (Fig. 2).

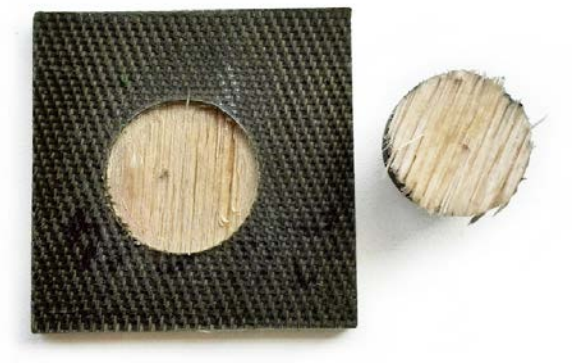

Fig. 2.
Sample of failure, which was always located in the wood.

All variants had non-different mean values according to MANOVA analyses and no trend was observed either with increasing adhesive spread or amount of basalt fabric layers. Therefore none of these variables had a significant effect on adhesion and neither there are significant interactions among them (Fig. 3).

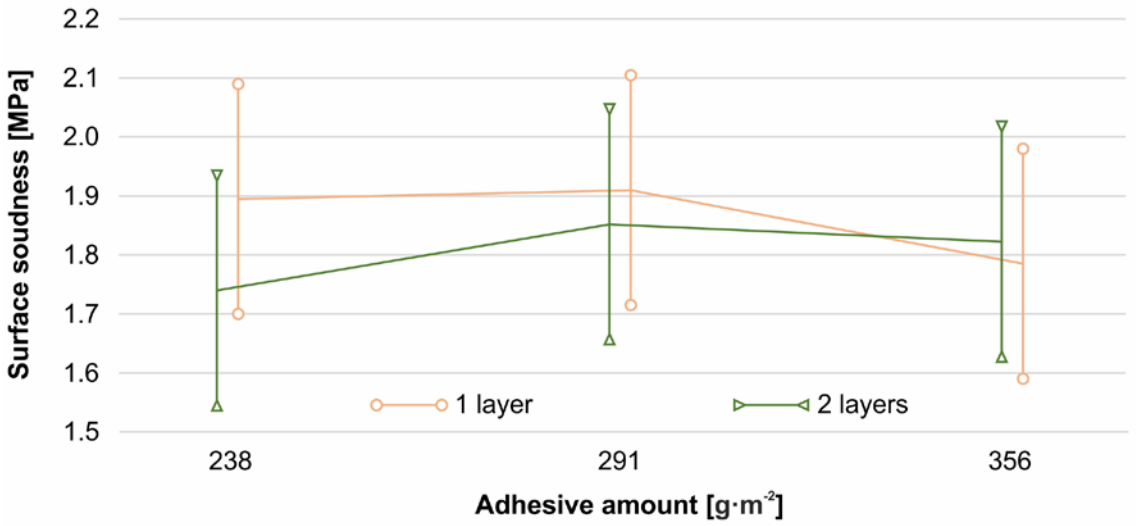

Fig. 3.
Graphical results of surface soundness evaluated via MANOVA analyses.

The average surface soundness among all tested specimens was 1.82 MPa. This value represents the tensile strength of birch veneer in radial direction (Ross 2010). Radial orientation is normal to surface of plywood, because its veneers are made by concentric peeling (Varis 2018). These results confirm flawless adhesion between basalt fibres reinforced PVAC coating and plywood. Possibly this type of reinforcement could be used for other WBP too.

CONCLUSIONS

Ponal super 3 PVAC was the only adhesive with good bond to birch plywood when compared to another PVAC and polymeric emulsion adhesive. These adhesives were filled with basalt fabric for reinforcement purposes. Results proved that PVAC can be suitable for basalt fibres which have problematic adhesion with many polymers.

It was also confirmed that more than one layer of basalt fabric can be bonded together and that the amount of used Ponal super 3 does not have any significant effect on the surface soundness. Failure of specimens always occurred completely in the wood. Therefore the combination of proper PVAC adhesive and basalt fibres can have a permanent - yet cost attractive - reinforcing effect on wood and WBP.

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