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Application of polystyrene as binder for veneers bonding – the effect of pressing parameters

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Abstract

The possibility of veneer bonding with recycled polystyrene was examined. Five pressing regimes were studied. It was shown that low-pressure pre-heating is a necessary step allowing for increasing final shear strength of the wood-thermoplastic joints and avoiding indentation of thermoplastic particles to wood.

1 Introduction

Many research groups have paid attention to the bonding of wood with thermoplastics which becomes one of the most important directions in wood composites development. This type of material – commonly known as Wood Plastic Composites (WPC) – is mainly manufactured by extrusion process where plasticized mixture of fine wood powder or fibers and thermoplastic are employed (Tangram Techn. 2002, Pritchard 2004, Selke and Wachman 2004). Previous studies by the authors involving typical pressing procedure showed that larger wood particles – chips or veneers could be effectively bonded with thermoplastics (Borysiuk *et al.* 2006, Hu *et al.* 2005, Pawlicki and Nicewicz 2002, Youngquist *et al.* 1994). The main difference between those two approaches is that plasticizing of thermoplastic material occurs only during hot-pressing of the compressed set of veneers. A potential disadvantage of such a procedure is indentation of the tough unplasticized thermoplastic particles to wood and resultant collapse of the pores which become no longer accessible to the binder (thermoplastic). Polystyrene - the third most utilized thermoplastic in the world – has a glass transition temperature (Tg) of approximately 90ºC, and below this temperature PS is hard, rigid, and brittle. Bearing in mind the mechanical interlock theory of adhesion, it

is obvious that the phenomenon can deteriorate the bonding strength of the system. One should also have in mind that boards after pressing should be re-cooled, because directly after pressing the joint has no satisfying strength. In this paper, the effect of pressing conditions on the bonding strength of waste polystyrene bonded veneers is described.

2 Materials and methods

1.5-mm industrial grade pine and birch veneers were used. Waste polystyrene (PS) recovered from disposable plates and utensils was applied as binder. It was determined that possible impurity in waste PS does not influence its properties essentially. The glass transition temperature of waste PS, investigated with the Hoeppler consistometer, was approximately 94 ºC.

Triplicate 3-mm thick two-ply pine or birch boards were prepared. Initial experiments showed that the flow temperature of the PS is 180 - 185°C. Analysis of heating curves of the set of veneers showed that the temperature of 180 deg inside the bondline was reached within 200 s (platen temperature 200 deg). Thus, total pressing time of 300s is effective to obtain PS flow.

Subsequently, five pressing regimes presented in Fig. 1 were proposed. The bonding parameters were as follows: thermoplastic load - 750g/m2, press temperature – 200°C, maximum unit pressure – 1.5 MPa, total pressing time – 300 s. After pressing the boards were re-cooled and conditioned in a climate room (65 %, 20 °C) for 24 hrs. Tensile shear strength of the joints was tested according to EN 205:2005. Wet shear strength was measured after 24 hr water soaking. Twenty samples were tested in each series.

Figure 1

3 Results and discussion

The results obtained for pressing regimes II, III, and IV (Fig. 2) indicate that initial pre-heating of the assembly at low pressure (0.15 MPa) increased final strength of the joints when compared to pressing regime I where maximum unit pressure as high as 1.50 MPa was applied immediately. In the latter case indentation of the unplasticized polystyrene to the wood and collapse of pores occurred, binder-wood interactions were weakened, and strengths of the joints decreased. The effect is observed both for pine and birch veneers however, for pine it seems to be stronger. Assemblies bonded according regime I with a constant pressure of 1.50 MPa showed – for both species - the lowest bonding strengths which supports the supposition of the authors regarding indentation of PS and reduced contact area. Regimes II-IV including low-pressure pre-heating of the assembly allowing for achieving plastic state to the thermoplastic binder provided a 26-39% increase in dry shear strengths and 109-143% increase in wet shear strengths.

Figure 2

It is worth noting that the differences between strengths obtained for regimes II-IV are statistically insignificant except for dry pine of regime III as well as for wet pine of regime V.

In general, changes in strengths obtained for pine were smaller than those for birch. The difference comes from the hardness of the species and remains in accordance with the explanation based on indentation of unplasticized polystyrene particles to the wood. Pine veneers being a lot softer, less dense and rougher than birch exhibit higher susceptibility to this process. Moreover, the phenomenon resulted in variation in the bondline thickness.

The strengths obtained for pressing regimes II-IV confirmed the role of low-pressure pre-heating in sufficient plasticizing of the thermoplastic binder.

4 Conclusion

It was shown that efficient bonding of wood-thermoplastic system can be achieved only if the thermoplastic binder is sufficiently plasticized to be easily extruded to the pores of the adherend which means that a low-pressure pre-heating step is necessary. Omitting low-pressure pre-heating step and immediate application of work pressure result in lower bonding strengths of the joints. Birch wood having higher hardness occurred to be less indentation-sensitive and subsequently gave higher bonding strengths.

Acknowledgements

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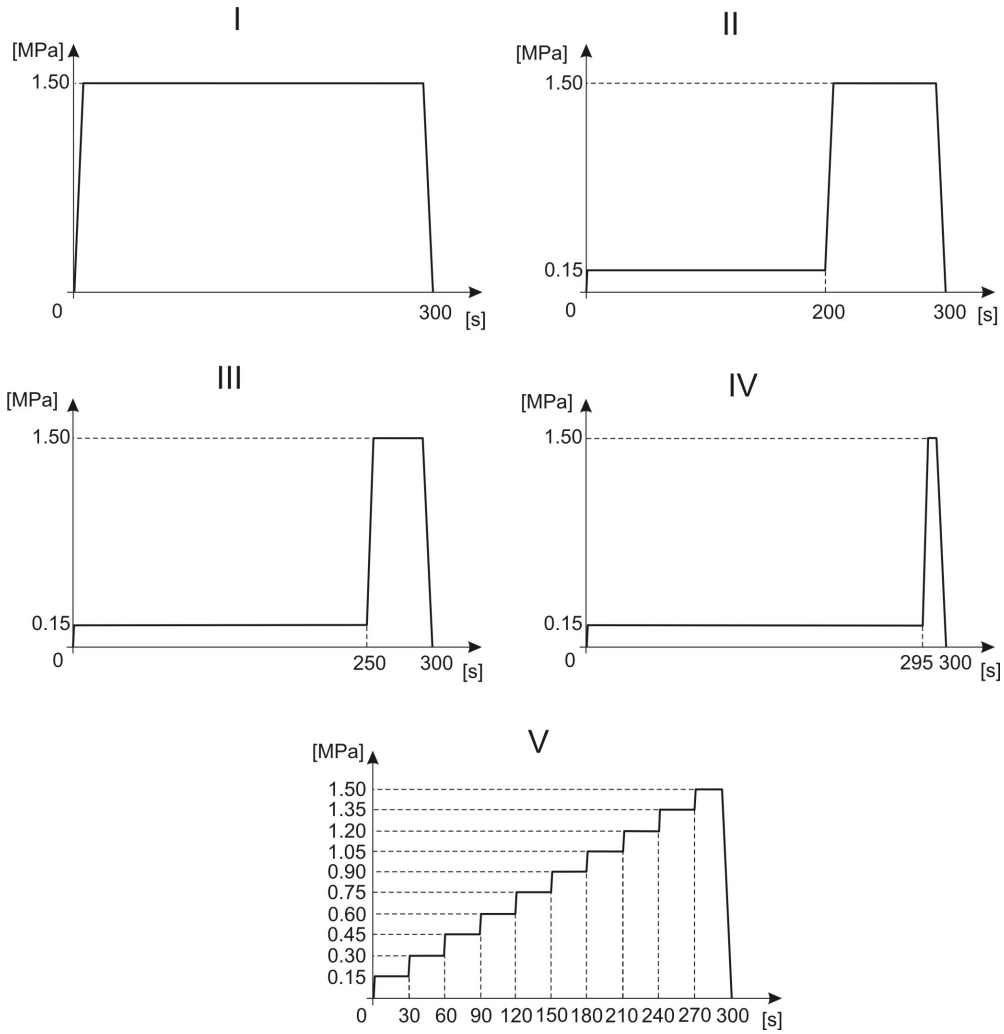
Fig. 1. Studied pressing regimes

Abb. 1 Untersuchte Pressprogramme

Fig. 2. Shear strengths of the PS-bonded joints (white – dry, grey – wet)

Abb. 2 Trocken- (weiß) und Nass- (grau) Scherfestigkeiten der Verklebungen mit recycliertem Polystyrol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60
90
120
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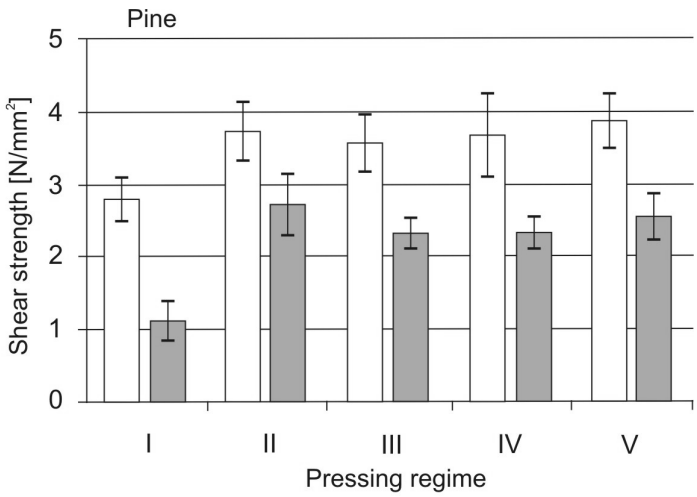
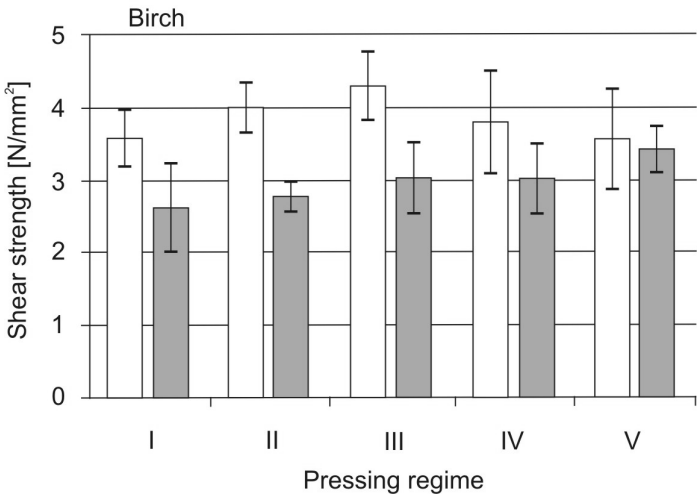

Pine
Shear strength [N/mm²]
0
1
2
3
4
5
I
II
III
IV
V
Pressing regime


Birch
Shear strength [N/mm²]
0
1
2
3
4
5
I
II
III
IV
V
Pressing regime