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Experimental study on the adhesive performance of lignins under different pressure and temperature conditions

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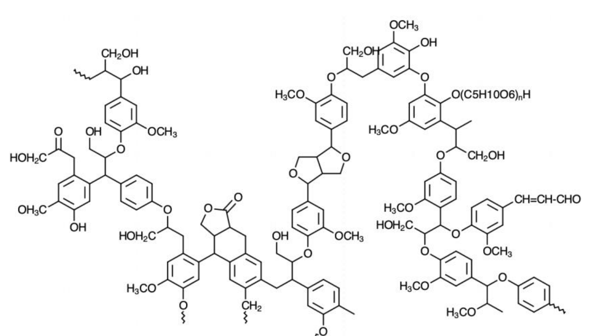
Motivation

Lignin is the glue of nature and a completely underestimated natural resource. This study aims to reveal its potential as natural binder and use it in it´s original purpose, as adhesive. Lignin shall be used to re-assemble sawmill by-products to produce structural timber to encounter the massive waste of wood and further binding CO_2 for longer inside the wood. The wood chips and dust are treated chemically to be able to reassembled by adding lignin as binder and hot-pressing them to a new wood-based bio-composite. This is a huge approach in reducing emissions and increasing recycling and sustainability of wood products.



Part of the molecular structure of lignin

New wood-based bio-composite

Materials

As test specimen spruce veneers with a thickness of 1.5 mm were cut into pieces of 117 mm length and 2 mm width. To investigate the adhesive properties of lignin it was solubilized in ethanol, by mixing 1 part of lignin powder with 4 parts of ethanol. The insoluble part was removed through centrifugation and the supernatant was used for further testing. Eight different lignins, differing in extraction method and origin, were chosen. In one approach it was applied as adhesive and in the other one it was used to impregnate the veneers after the same pretreatment, that was conducted to the sawmill by-products.

Lignin powder

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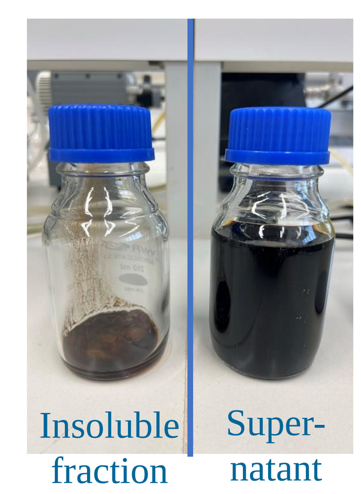
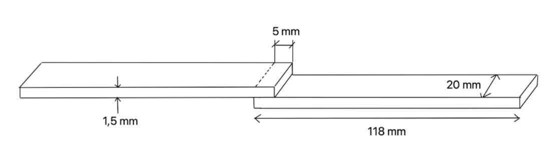
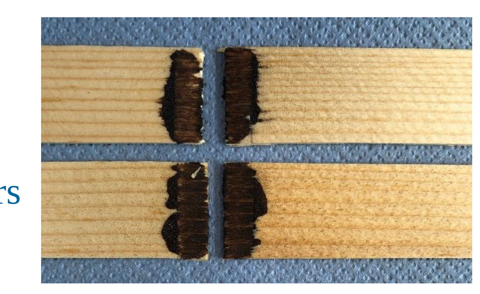


Insoluble fraction | Super-natant



Sketch of glued veneers

Glued and tested veneers



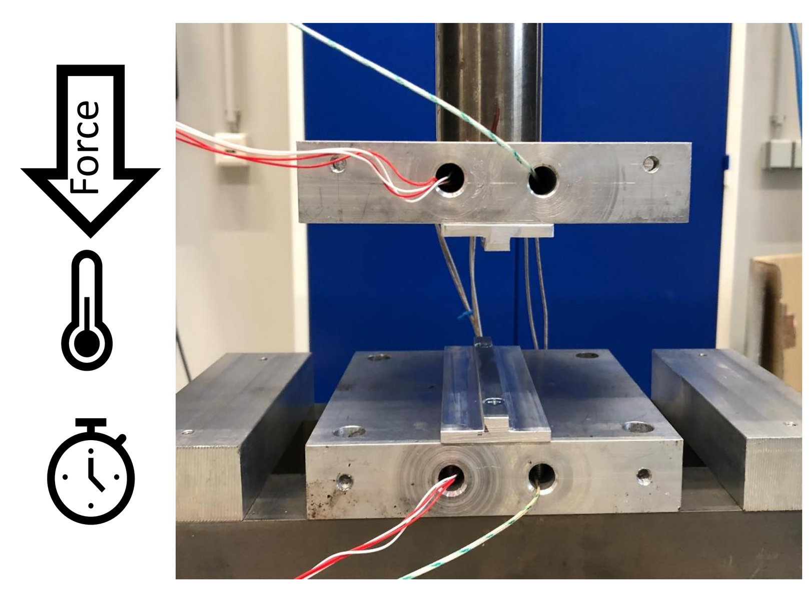
Methods

The pretreatment of the veneers was done by delignification with peracetic acid and followed by swelling in sodium hydroxide. In a next step, the veneers were subjected to lignin supernatant and dried before pressing. For lignin applied as adhesive, the supernatant was produced in different concentrations. Two mg of the supernatant were spread on a defined area on the tip of the veneers [1]. The tests were conducted by an ABES-inspired testing system (ABES: Automated Bonding Evaluation System). The differently prepared veneers were both subjected to elevated temperature between 100 – 190 °C and a pressure of 45 MPa for 20 minutes [2]. Afterwards, the glued veneers were pulled apart to gain the ABES Shear Strength ($\sigma_{ABES} = {}^{F_{max}}/_{A_{glued}}$).

Delignification of veneers with peracetic acid

Impregnation of treated veneers with lignin supernatant

Impregnated and pressed veneers

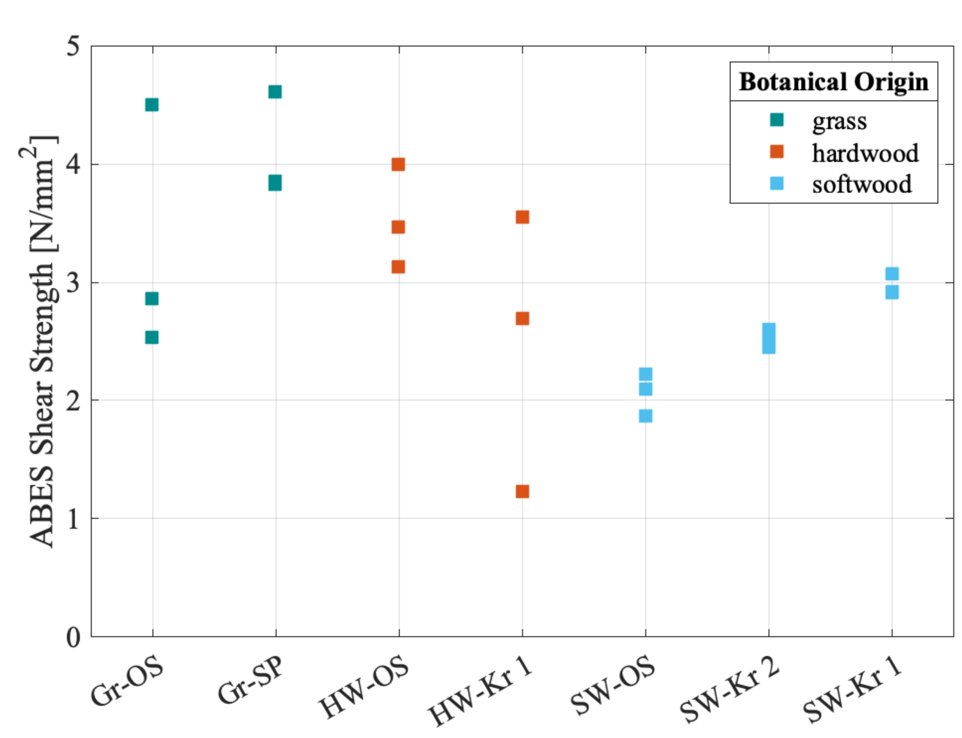


ABES-inspired pressing system

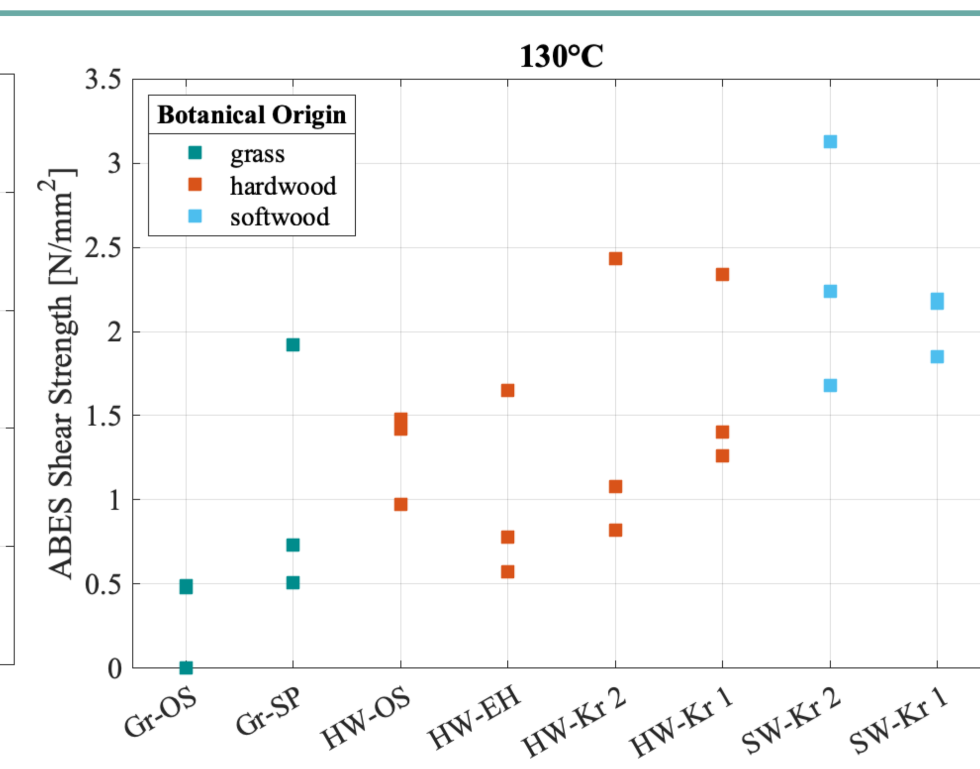
Testing of the veneers

Results

The ABES Shear Strength was calculated by dividing the maximum needed force to separate the veneers by the glued area. A difference in the application method has been observed. The best results for the impregnated veneers were obtained by soft wood at a pressing temperature of 130°C. Meanwhile, for the untreated veneers glued with supernatant the best lignin was gained from grass via soda pulping. For further investigation of the properties of lignin within the composite, paper was produced with the fibers extracted from the sawmill by-products. Again, it was impregnated with the supernatant and pressed and tested like the veneers.



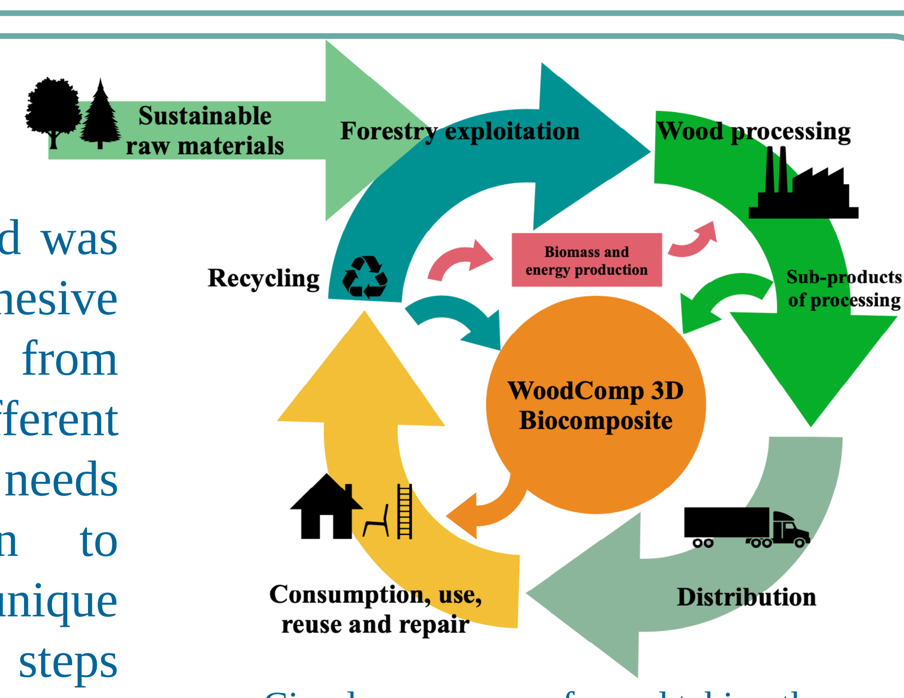
Results for supernatant as an adhesive



Results for supernatant as impregnation agent

Conclusion

A swift and uncomplicated method was established to maintain the adhesive performance of lignins gained from different sources and different production processes. Lignin still needs a more detailed investigation to understand and maybe tailor this unique and complex polymer, but first steps have been very promising.



Circular economy of wood taking the WoodComp 3D innovation into account

References

[1] R. Hellmayr et al., "Heat bonding of wood with starch-lignin mixtures creates new recycling opportunities"

[2] G. Yang et al., Bonding wood with uncondensed lignins as adhesives

Acknowledgements

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