Proceedings of the International Convention of Society of Wood Science and Technology and United Nations Economic Commission for Europe – Timber Committee
October 11-14, 2010, Geneva, Switzerland

Recycling the Sliced Veneer Clippings into Value-Added Products – An International Research Effort

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Abstract

The increasing need for construction materials coupled with the decreasing quality and quantity of available raw materials triggered innovations and research works to meet challenges of demand and supply. Worldwide, the wood based composite and polymer-manufacturing industries successfully responded to these challenges. As a result, structural composite lumber (SCL) and wood-plastic (WPC) composite materials evolved that usually exhibit favorable and more consistent physical and mechanical properties compared to solid wood. However, underutilized hardwood species, byproducts and waste from different hardwood manufacturing processes still constitute potential raw materials for different, value-added composite manufacture. An ongoing international research project managed at the West Virginia University, Division of Forestry & Natural Resources and at the University of West Hungary, Institute of Product Development is aimed to explore potential hardwood materials for innovative composite manufacture.

This presentation summarizes the results of the research project presenting and characterizing the prototypes developed as well as the methodology used for product optimization. In the first part novel panel type composites are presented using the sliced veneer clippings and other wood strands as raw material. Physical and mechanical properties of the new products were optimized using advanced statistical process control methods including DOE and the response surface methodology. The second part of the article examine the global and local buckling behavior of engineered wood I-joists with corrugated web panels made of hardwood veneer clippings. Finally a compression and bending strength analysis of structural insulated panels with polyurethane foam core reinforced with veneer residues is presented.

Keywords product development, veneer clippings, composite panels, structural composites**,** optimization

Introduction

Innovative ideas, research and development play a vital role in developing methods that ensure the conversion of renewable wood-resources to value-added products through technologies allowing the re-use of wood waste. As a consequence, engineered wood products (EWPs) mean the future of wood-based construction materials because they offer the best hope for incorporating technological changes that make forest products cost competitive with all alternatives materials. These products have two major efficiency-related advantages: (1) improved mechanical properties that enhance design values and enable more efficient application and (2) more efficient conversion technologies which result in higher final product yield. These properties will help EWPs to compete head-on with steel and concrete in the construction market. Although the wood-based composite and polymer manufacturing industries with the aid of research institutions have made significant progress in using low quality fiber-based materials, there is still a great potential to enhance the exploitation of our renewable natural resources. For example, the underutilized hardwood species, byproducts and waste from different hardwood manufacturing processes still constitute potential raw materials for different value-added composite manufacture.

The present paper summarizes the results of an international research project managed at the West Virginia University, Division of Forestry & Natural Resources and at the University of West Hungary, Institute of Product Development, with the main objective of exploring potential hardwood materials for innovative composite manufacture.

This poster focuses on recycling of the sliced hardwood veneer clippings into novel type products and comprises three main chapters with different utilization areas of the high quality wastes:

- manufacturing of panel and beam-type products from veneer clippings as raw material and optimization of their physical and mechanical properties using statistical methods
- production of lightweight sandwich panels using preformed hardwood veneer residues/polyurethane foam core and different wood veneers as face layers
- development of wood I-joists with corrugated web panels made of hardwood veneer clippings, examination of the global and local buckling behavior and investigation on the effects of construction parameters such as depth of joists, web-web or web-flange joint strength, web panels thickness, etc. on bending performance of the joists

I. Wood panels made of sliced veneer clippings

The first series of experiments utilized veneer waste along with OSB strands and wood shavings in several different compositions (Denes et al., 2004). The second series was completed using just side and end clippings in various mixtures and final panel thicknesses (Figure 1.). Finally, a 2_{IV}^{7-3} type fractional factorial design was employed to screen out the significant structural and technological factors on the response of the bending strength and stiffness of composites made only from side clippings with uniform width. For the latter, two frequently utilized species for decorative veneer production in Hungary were selected as raw material, beech (*Fagus silvatica*) and maple (*Acer pseudoplatanus*) respectively. The first two experimental setups used a mix of three hardwood species, the mixture consisting of about 60 percent black cherry (*Prunus* *serotina*), 35 % red oak (*Quercus rubra*) and 5% maple (*Acer spp*.). The flexural properties of the specimens cut from panels were tested both flatwise and edgewise directions in accordance with the ASTM D-1037 standard. The individual effects of factors on the mean have been determined and analyzed.

a) Veneer-OSB strand composites

b) Short veneer mixed with shavings

c) Products made from side and end clippings

d) Panels and lumbers from shredded veneer

Figure1. Composite products manufactured from veneer clippings.

Analysing the sources of variation in the case of the modulus of rupture (Figure 2.) predicts that in edgewise direction almost all factors are significant, just the strand width can be neglected. In contrast, in flatwise direction three factors, the thickness, orientation and pressure are significant only. Setting these factors at their optimal level, the modulus of rupture of the panels increases with approximately 50% (Lang et al., 2006).

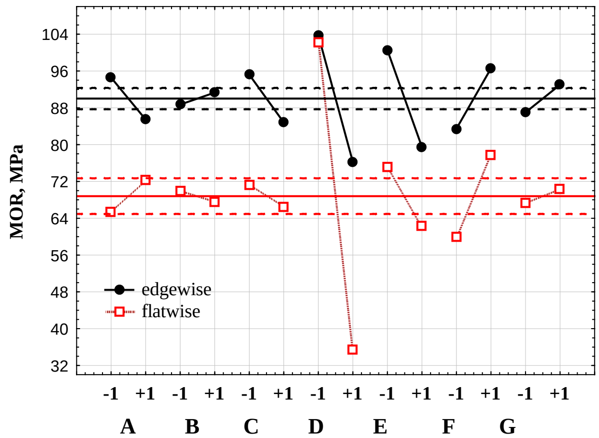

Figure 2. The effect of factors on the modulus of rupture.

II. Sandwich panels using veneer clippings/polyurethane foam as core material

The same mix of three dominant North American species for decorative veneer production was used as furnishes material for all panel types. The composite panels consisted of a blend of side clippings comprising the fiber and commercially available moisture-curing one-component polyurethane foam as a matrix material to formulate the core. The fully set polymeric diisocyanate –based foam is semi-rigid and predominantly close celled with good adhesion to wood. The veneer/polyurethane panels were further processed to create new types of lightweight panel products. Equal width slabs were cut out from panels then rotated with 90° and re-bonded with the same polyurethane foam to form a continuous mat. This core material was veneered on both sides using different wood species and veneer thicknesses (Figure 3.).

Figure 3. Veneer clippings/polyurethane foam composites

The effect of foam spread, pressure and temperature on the panels' compression strength was investigated adopting a two level factorial design with three center points added (Denes et al., 2008). Both specimen types having parallel and perpendicular strand alignment demonstrated significantly higher strength values than the pure polyurethane foam. This confirms that veneer strand reinforcements contribute significantly to the compression strength increase of porous foam materials. High variations experienced in several experimental runs can be attributed to the presence of noise factors such as alignment imperfections, uneven distribution of resin, strand etc. Analysis of Variance (ANOVA) at a significance level of $\alpha = 0.05$ confirmed the occurrence of statistical differences between the selected factors on the flexural properties. Analyzing individually the marginal effects of factors (Figure 4.), it does appear that adhesive content in the selected range play an insignificant role when the panels were compressed parallel to the strand alignment while pressure has a positive linear effect and temperature a negative one.

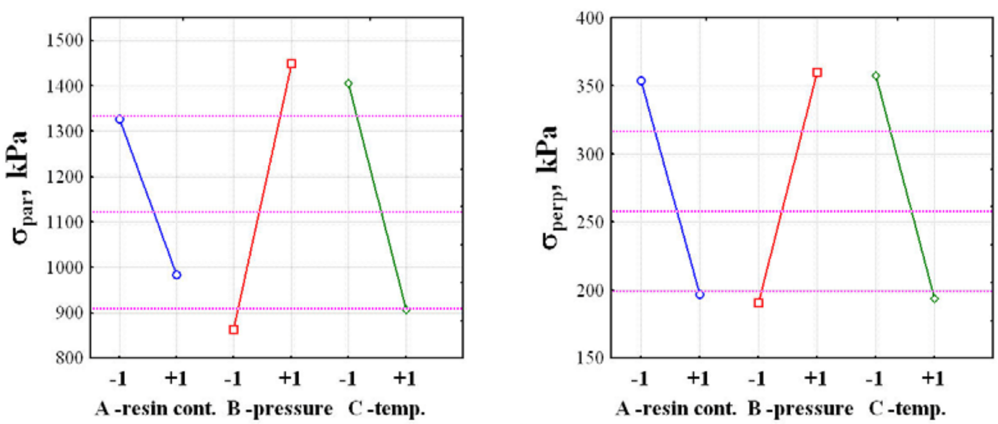

Figure 4. *Effect of factors on the compression strength*.

The highest compression strength values are obtained at the upper level of pressure and the lower level of temperature; the bending strength of the sandwich panels using a veneer/polyurethane foam core are remarkably higher than of honeycomb panels made of 8 mm particleboard skins and 36 mm thick expanded paper honeycomb core (Barboutis and Vassiliou, 2005).

III. Wood I-joists with corrugated web panels made of hardwood veneer wastes

Engineered wood I-joist composites are highly efficient, lightweight structural elements with a shape that maximizes the bending stiffness while minimizing the material used. However, the buckling characteristics of these composite panels discourage the use of I-joist under heavy concentrated loads. Profiling the web generally increases the stability of the I-joists and avoids the buckling failure of the beam. Different profiles have been developed, the most commons being the corrugated and trapezoidal ones. The corrugated profiles like of sinusoidal shapes have the advantage over trapezoidal profiling of eliminating the local buckling of the flat portions. The primary objective of this segment of research was to examine the global and local buckling behavior of engineered wood I-joists with corrugated web panels made of hardwood veneer clippings. This part of the study investigated the effects of construction parameters such as depth of joists, web-web or web-flange joint strength, web panels' thickness, etc. on bending performance of the joists (Denes et al., 2009).

The corrugated shape of the panels was provided by a set of aluminum templates, the pressing schedule was set up on load control with three pressure release steps before press opening. Two types of flange-web joints were used to fix the web panels to the flanges: tongue and groove and finger joint. The I-joists were produced in two lengths 12 and 8 feet using various structural composite lumber (SCL) as flange materials

Figure 5. Set up of the third point bending tests and I joist prototypes with corrugated veneer web panels.

Moment capacity, i.e. bending strength and modulus of elasticity results were determined and the moment of inertia of the web panels was approximated based on the unit volume, i.e. the thickness was increased in order to compensate for the higher web length. Despite high variations of the joists' geometrical characteristics the modulus of rupture and elasticity values show consistency except one extreme data for MOE. The obtained values are comparable with conventional I-joists' similar values; however, the possibility to increase them by the optimization of web-flange connection strength exists. I-joists with tongue and groove web-flange joints proved to have higher load bearing capacity than finger joints. Joist depth, web panel's thickness, flange material type had low influence on the flexural properties.

Conclusions

The results and the analytical works clearly indicate that decorative veneer residues can be successfully converted into value added products. The newly developed composites may aid the better utilization of the sliced veneer waste. Moreover, the engineering properties of these panels and composite lumbers can be controlled through different lay-ups, strand, strip orientations and pressing parameters. The long strand type furnish allows highly controlled alignment within the composite system and the properties of matrix materials can be manipulated to meet desired attributes. These facts warrant the successful development of highly engineered panels and structural products designated as veneer strip panels (VSP) and veneer strip lumber (VSL). The developed models that predict the effects of critical variables on the mechanical properties of the composites allow robust product designs and optimizations at the manufacturing facilities.

Acknowledgments

The authors wish to acknowledge the financial support of USDA Wood Utilization Research Grant, West Virginia University Wood Utilization Research Grant - Transforming Veneer-Mill Residues into Value-Added Composites and of the Hungarian National Science Foundation (OTKA), project number: T-25985. The authors wish to express their appreciation to Weyerhaeuser OSB plant, Sutton, WV, and to the Dean Company, Princeton, WV, for donating raw materials and for providing technical assistance.

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