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WOOD-STRAND SANDWICH PANELS FOR PANELIZED CONSTRUCTION

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Abstract

Changing resources and demand for reduced energy dependency have led to consideration of combining energy and structural performance codes for construction of sustainable buildings with low embodied energy materials and reduced operational energy (residential and commercial buildings account for almost 39% of the total U.S. energy consumption and 38% of U.S. carbon dioxide emissions). Washington State University has developed a wood-strand sandwich panel with a thin walled 3-D core that shows promise for use in building envelopes. This lightweight sandwich construction with a thin-walled 3-D core creates a structural panel using undervalued timber from forest thinning or fast growing plantations. Research is focused on replacing typical construction products such as oriented strand board (OSB) as sheathing with the possibility of creating a thicker built-up panel geared toward panelized construction similar to cross-laminated timber (CLT) and structural insulated panels (SIPs). Small-diameter ponderosa pine wood-strands were utilized in manufacturing of a sandwich panel that has a bending stiffness that is 21% stiffer than commercial OSB, but a density of approximately 300 kg/m^3. The desirable mechanical and thermal results allow for this material to be utilized in designing panelized wall, floor, and roof elements for countless building construction applications. Compared to currently used OSB, which represents over 60% of the sheathing market, the thicker lightweight sandwich panel is significantly stiffer in bending with increased R-value while utilizing over 40% less material than OSB of equal thickness. Resin consumption, which accounts for approximately 30% of the production costs in a typical composite panel plant, is reduced by over 40%. Incorporation of foam insulation into the cavities of the sandwich panel further increases its flexural stiffness and thermal properties. This presentation will focus on manufacturing, mechanical and thermal properties, and application of wood-strand sandwich panels.

Keywords:

Wood Strand Composite; Sandwich Panel; Structural Panel; OSB

1 INTRODUCTION

The concept of lightweight sandwich panels has been utilized extensively in the aerospace, marine, wind energy, and transportation industries [Black 2003]. However, sandwich panels have only just started to be utilized in the construction industry, such as structural insulated panels (SIPs) [Miller 2006].

The Forest Products Laboratory in Madison, Wisconsin, has developed a 3D fiberboard known as Spaceboard through a wet formed process that utilizes small-diameter timber and other cellulose based raw materials [Hunt and Winandy 2003, Hunt, Harper, and Friedrich 2004, Hunt 2004, Hunt and Supan 2006, Hunt, O'Dell, and Turk 2008]. However, because forming of Spaceboard is a wet process significant effluence is discharged into water system in a typical manufacturing facility. Additionally, wood-strand based panels can provide structural performance not easily achievable using wood in fiber form.

Washington State University has been developing wood strand based composites for building construction and furniture applications [Weight and Yadama 2008a,b]. Work presented in this paper is a first step towards developing a structural system based on the lightweight sandwich panels from wood strands. This paper briefly discusses the design and fabrication process of 3-D wood-strand core and presents properties of lightweight panels constructed with these cores.

2 MOLD DESIGN & LIGHTWEIGHT PANEL CONSTRUCTION

A design methodology, considering typical failure modes [Davies 2001], was implemented to engineer the core geometry [Voth 2009]. An Aluminum mold was designed for pressing a thin-walled core composed of small-diameter timber strands [Voth 2009]. The core geometry is a biaxial corrugated shape with continuous ribs in the x-axis and segmented ribs in the y-axis as shown in Figure 1.

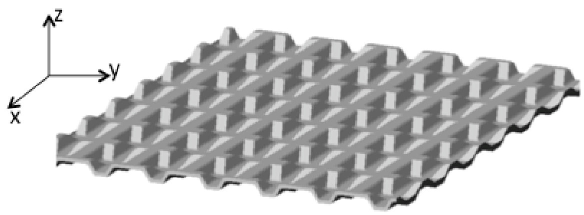

Fig. 1 : Aluminum mold for manufacturing wood-strand core.

Using this mold, 3-D wood-strand cores were manufactured using ponderosa pine strands bonded with 8% PF resin. Sandwich panels were fabricated with thin plies of wood strands and 3-D strand cores (Figure 2) for determination of their mechanical properties. The cores and face plies were bonded using a modified diisocyanate (MDI) adhesive. Specimens were cut and evaluated in flexure and compression for bending stiffness, panel shear rigidity, core shear modulus, and compression strength and modulus following ASTM standards for sandwich panel constructions [ASTM 200a,b].

Fig. 2: Sandwich panel fabricated with thin strand plies and 3D strand core

3 RESULTS

Mean sandwich panel properties are summarized in Table 1. Figure 3 compares the specific bending stiffness (bending stiffness normalized for density) of sandwich panels with that of OSB and 5-ply plywood panels (640 kg/m^3 density).

Tab. 1: Sandwich Panel Properties.

		Max Flexural Load (N)	Max Flexural Deflection (mm)	Bending Stiffness per unit width (Nm^2/m)	Panel Shear Rigidity (N)	Core Shear Modulus (MPa)	Comp. Strength (MPa)	Comp. Modulus (MPa)	Density (kg/m^3)
Long Axis	Mean	2700	14.22	10304	24198	6.76	0.42	8.55	312
	%COV	16.6	24.9	25.4	49.3	50.6	29.9	41.6	5.9
Trans Axis	Mean	698	12.95	3457	14234	3.96	---	---	307
	%COV	17.4	34.0	23.4	24.1	24.4	---	---	1.2

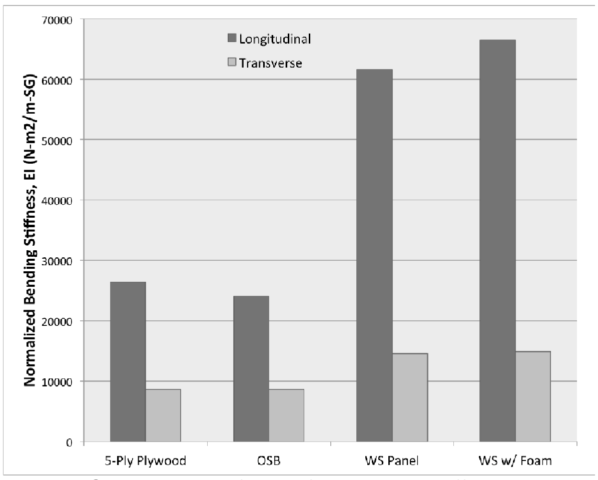

Fig. 3: Comparison of specific bending stiffness per unit width of wood strand sandwich panels (with and without foam) against typical plywood and OSB panels

The sandwich panel densities were calculated to be 310 kg/m^3 (19.5 pcf) based on the densities determined from the flexural specimens (Table 2). The sandwich panels' specific bending stiffness was 71 % greater than the plywood and 88 % greater than the OSB. These results indicate that material usage (wood and resin) can be more efficient with use of lightweight sandwich panels constructed with thin-wall strand core and thin strand-based plies. The sandwich panel utilizes only 40 % of the wood-strand furnish and 40 % of the resin when compared to the quantities utilized in a typical OSB panel of the same dimensions. These percentages are calculated based on the weight of the materials. Incorporation of foam insulation into the cavities of the sandwich panel further increases its flexural stiffness and thermal properties.

4 SUMMARY AND CONCLUSION

The successful implementation of products using small-diameter timber requires that the structural properties of such materials be comparable to products that are already commercially viable. With growing environmental concerns and increasing competition, any future development of product and process should strive to reduce material consumption, minimize emissions, and consume less energy. The structural sandwich panels discussed in this study are an attempt to develop products that can achieve those requirements.

This study is the basis for a larger work in determining all aspects of the structural design of lightweight sandwich panels with a thin-walled core. There are many steps between this investigation and commercial application. Future work in the development of these sandwich panels will include a finite element analysis of the complex core geometry to confirm its design for structural applications and refine the design as necessary.

5 ACKNOWLEDGMENTS

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