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Sustainable Lightweight Wood-Strand Panels for Building Construction

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ABSTRACT

Products such as oriented strand board (OSB) and oriented strand lumber (OSL) have shown that utilization of low value, small diameter timber to produce structural components is commercially feasible. While three-dimensional (3-D) panels for building construction have been studied for years, recent research at Washington State University has developed strand-based 3-D core element that shows promise for a variety of panelized construction applications, such as in a building envelope. Lightweight sandwich construction with a thin-walled core provides a structural and nonstructural panel using undervalued timber from forest thinning or fast growing plantations.

Analysis of the core design was investigated to determine a process that can be utilized for engineering design of future sandwich panel cores. Small-diameter Ponderosa Pine wood-strands were utilized in fabrication of a lightweight sandwich panel that has a specific bending stiffness that is 88% stiffer than commercial OSB. A case study was performed on the wood-strand sandwich panels to determine their potential in structural flooring as an alternative for OSB. The sandwich panel can support a 40 psf live load and a 20 psf dead load without exceeding IBC (2006) deflection limits.

This basic concept creates tremendous flexibility in designing panelized wall, floor, and roof elements for countless building construction applications. Compared to currently utilized oriented strand board (OSB), which represents over 60 percent of the sheathing market, the lightweight sandwich panel provides twice the specific flexural stiffness with over 40 percent less fiber. Resin consumption, which accounts for over 25 percent of the production costs in a typical composite panel plant, is reduced by over 40 percent. This presentation will focus on design of the composite panel and its properties and potential applications.

Key words Wood-strand; small diameter timber; sandwich panels; structural panel; OSB

INTRODUCTION

The concept of lightweight sandwich panels has been utilized extensively in the aerospace, marine, wind energy, and transportation industries [2]. However, sandwich panels have only just started to be utilized in the construction industry. Structural insulated panels (SIPs) have had the most success penetrating the construction market even though they only account for 2 % of the residential construction market in the United States [9].

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 [4, 5, 6, 7, 8]. The most significant advantage of re-pulping the recycled raw materials is that any virgin or recycled biofiber resource will be a viable raw material source for this product. 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 that is not possible to achieve using wood in fiber form. However, wood strands as currently produced in a typical OSB plant are not well suited to manufacture thin-walled 3-D cores for further fabrication of lightweight panels.

Development of thin-strand ply using small diameter Ponderosa pine at Washington State University [10, 11] was a natural progression towards developing thin-walled 3-D strand core and lightweight laminates. Thin-strand veneers or plies can yield strength and stiffness values that are 2 to 2.5 times greater than the parent material [10, 11]. 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.

MOLD DESIGN & LIGHTWEIGHT PANEL CONSTRUCTION

An Aluminum mold was designed for pressing a thin-walled core composed of small-diameter timber strands. 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.

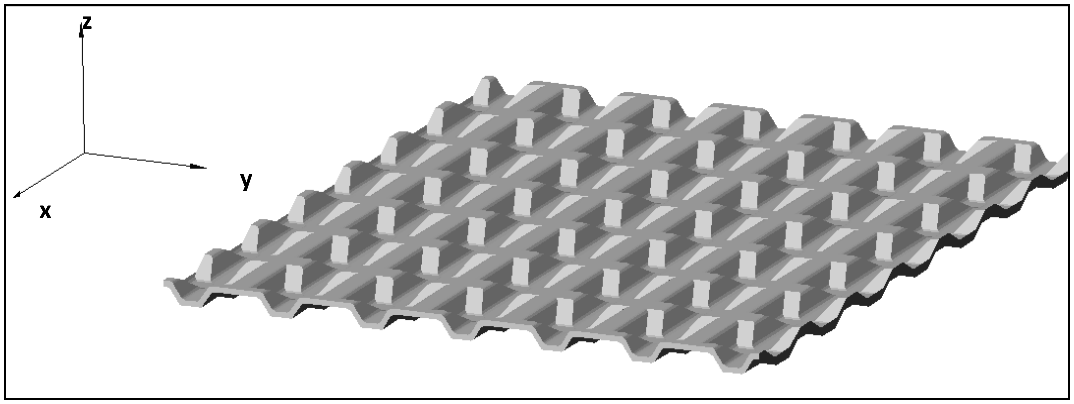

Figure 1. Geometry of aluminum mold for manufacturing wood-strand core.

A design methodology was implemented (Figure 2) to engineer the core geometry. Typical failure in lightweight sandwich panels composed of thin-walled cores could result from tensile or compression failure of the face plies, shear failure at the bonding interface between the core and face plies, or core crushing/ buckling at localized loading at supports [3].

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 for determination of their mechanical properties (Figure 3). 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. Specimen configurations with length oriented with strong axis (x-axis) and weak axis (y-axis) were evaluated for their properties.

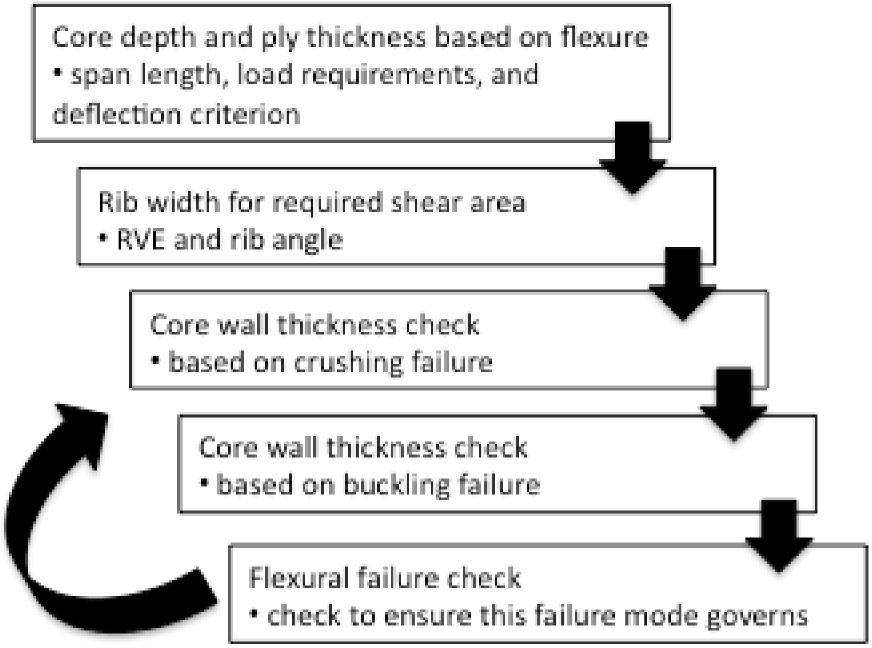

Figure 2. Design methodology for engineering core geometry.

Figure 3. Sandwich panels fabricated with thin stand plies and 3D strand core.

Results

The wood-strand ply tensile and internal bond (IB) properties are shown in Table 1. The data collected herein coincides with results obtained by Weight and Yadama [10, 11]. These ply properties were used as needed in determining sandwich panel properties.

Table 1: Wood-strand ply tensile specimen properties.

	Longitudinal Axis		Transverse Axis	
	Avg.	%COV	Avg.	%COV
Tensile Strength (psi)	4500	18.2	2860	55.4
E (psi)	924000	7.3	848000	19.1
IB (psi)	145	19		

Mean sandwich panel properties are summarized in Table 2.

Table 2: Sandwich Panel Properties

		Max Flexural Load (lbs)	Max Flexural Deflection (in)	Bending Stiffness (lb-in^2/in)	Panel Shear Rigidity (lb)	Core Shear Modulus (psi)	Comp. Strength (psi)	Comp. Modulus (psi)	Density (pcf)
Long Axis	Mean	609	0.56	91200	5440	980	61	1240	19.5
	%COV	16.6	24.9	25.4	49.3	50.6	29.9	41.6	5.9
Trans Axis	Mean	157	0.51	30600	3200	575	---	---	19.2
	%COV	17.4	34.0	23.4	24.1	24.4	---	---	1.2

Figure 4 compares the specific bending stiffness (bending stiffness normalized for density) of sandwich panels with that of OSB and 5-ply plywood panels. For the 5-ply plywood panels, longitudinal and transverse MOE values of 6.34 GPa (920 ksi) and 2.1 GPa (300 ksi) were assumed based on past published data [1]. Similarly, OSB properties for longitudinal and transverse MOE values were assumed to be 5.8 GPa (840 ksi) and 2.1 GPa (300 ksi) respectively [1]. The OSB and 5-ply plywood panels were assumed to have a density of 40 pcf. 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.

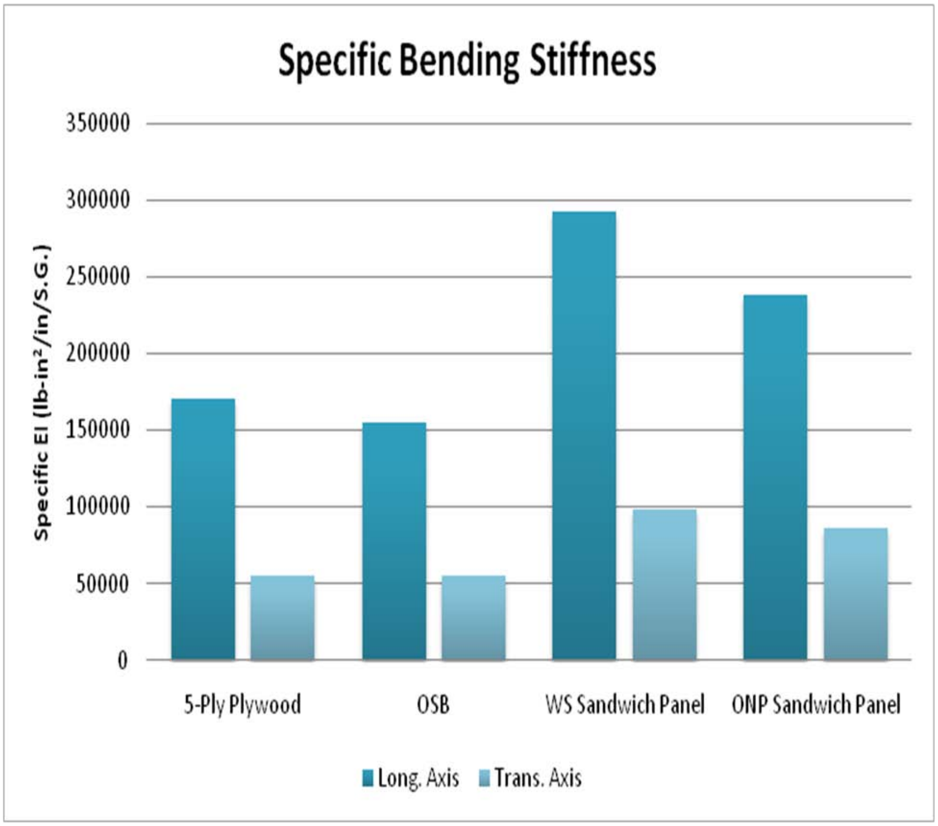

Figure 4. Comparison of specific bending stiffness of panels.

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.

Production of wood-strand sandwich panels using the matched-die mold design in this study can manufacture panels with 40 % of the materials required to produce a solid panel of same thickness. This will also significantly reduce the petroleum-based resin consumption which accounts for over 25 % of the production costs. These panels achieve significantly greater stiffness values than solid OSB panels using the same amount of constituent materials due to the 88 % increase in specific bending stiffness.

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. Innovative fasteners are necessary to improve their holding capacity, and innovative connection systems are required to have an effective interface between adjacent panels for load transfer. Insulation properties of the panels are under investigation to determine any potential advantages over conventional sheathing panels.

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