Using wood-based structural products as forest management tools to improve forest health, sustainability and reduce forest fuels: A research program of the USDA Forest Service under the National Fire Plan.

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Currently, after logging or thinning operations much of the low value timber is either left standing or is felled and left on the ground, chipped, or burned because most North American mills are not equipped to handle this material. In many areas of Western U.S., this forest residue does not decompose if felled and it soon becomes susceptible to forest insect or disease if partially damaged or injured during logging.

A. A stand that has suppressed tree growth with 3 to 4 foot spacing before a thinning operation.

B. A thinned stand showing improved 7 to 10 foot spacing allowing improved tree growth. Note significant dry slash on the forest floor 15 years after thinning.

Figure 1. Comparison between a suppressed growth area of small diameter trees and a similar stand after thinning. (These two pictures above were taken only a few feet from each other in Wyoming.)

Two research projects are currently in their second year of a three-year project funded under the USDA Forest Service "National Fire Plan" (Hunt 2000). The goal of these two research projects is to maintain a healthy and sustainable forests through development of economically viable process(es) and product(s) that can utilize small-diameter timber, forest undergrowth, and whole tree trimmings from logging operations. In this way, "whole-site" forest management can be implemented to use all available living biomass material for optimum utilization leaving minimal impact in the forest for future insect, disease, or forest fire. By providing economical options for all these materials this can then encourage rural development and reduce costs to the federal government for improved forest health, eco-system and for minimized fire mitigation.

Project I: Research on utilization of small diameter, crooked timber in laminated structural lumber by developing new sawing, laminating, and drying processes

The goal of Research Project I is to help maintain a healthy and sustainable forest by developing uses for low-value or no-value curved and cull small diameter trees. Several technologies are being combined to determine if this material can produce a value added structural product(s). In the first phase, which is nearly complete, 726 curved and cull small diameter trees were cut from the Bighorn National Forest, WY and Wyoming State Forest lands (Figure 1 and Figure 2). Tree diameters ranged from 100 to 230 mm (4 to 9 inches) diameter at breast height. These trees were cut into 2027 - 2.4 m (8 foot) sections and taken to Wyoming Sawmill, Sheridan, WY. Using conventional saw processing equipment, the trees were cut into 2x4s. While their equipment was set-up to handle trees 300 mm (12 in) diameter and larger, we were able to process the smaller diameter material by paying special attention to some handling issues along the line. All trees were initially rough cut to 96 mm (3.77 in) thick flitches. Those flitches that would yield one or more nominal 2x4 studs continued through the process. A small amount of wane was allowed for this study. The tree sections with single sweep or small multiple curves were first rough cut with a "horns-up" arrangement (Figure 3). Because the sawing process was not optimized for small diameter trees a few trees were unusable but we were still able to cut approximately 2000 sections for this study.

A. A previously thinned stand where small diameter curved and cull material had already been cut down, but there still exists significant amount of standing material that are relatively valueless based on standard sawing practices because of their curvature.

B. Small diameter material removed for this study. The material was selected as having significant curvature or cull features to render the tree essentially valueless based on standard sawing practices because of the curvature.

Figure 2. Sample stand showing some of the curved trees to be cut (A) and small-diameter curved and cull trees (B) brought out of the woods for use in Project I.

Figure 3. Example of a 6% curve d small tree cut horns-up through a conventional band saw.

If the tree sections had curves greater than 2% then they were kicked off the conveyor system and stacked separately. A total of 251 single- and multiple-curved flitches with greater than 2% curvature were separated from the straighter flitches. Approximately 100 single-curved flitches were shipped to the Forest Products Laboratory for future curve sawing and microwave drying. Curved 2x4s will be cut following the curvature of those flitches and these will be used to evaluate the microwave press-drying process (Figure 4). The goal is to straighten the curved boards in the drying process.

Figure 4. View inside the microwave drying chamber showing the pressing bars that will be used to straighten and hold the curved 2x4s during drying.

The flitches that had little or no curvature continued through the cutting process to cut nominal 2x4s. They were conventionally dried and shipped down to the University of Wyoming, Laramie, WY to be non-destructively stress-graded using transverse vibration to determine dynamic modulus of elasticity (DMOE). After testing all the 2x4s in DMOE, a portion were destructively tested in tension, compression, and bending. The remaining material grouped according to DMOE (Figure 5) as following: 25% low, 50% medium, and 25% high DMOE. For each of these groups, the nominal 2x4s were laminated in sets of six 2x4s into 8-foot long nominal 4x9 beams (Figure 6). All beams were then vertically resawn to produce nominal 2x9 webs. The DMOE-rated materials were finger-jointed into 24 foot long members. The higher E-rated 2x4 beams were designated for use as flanges. Then some of the webs and flanges were laminated to form structural I-beams (Figure 7). The I-beams are currently being tested in bending and shear at the University of Wyoming. A matched series of web sections only are also being tested in bending and shear to compare results and determine the effect flange material has on beam properties.

Figure 5. Over 1000 2x4 material E-rated according to low, medium, and high dynamic Modulus of Elasticity and ready for fabrication into laminated I-beams.

Figure 6. Two beams made from six 2x4s 8 feet long being clamped in a gluing rack.

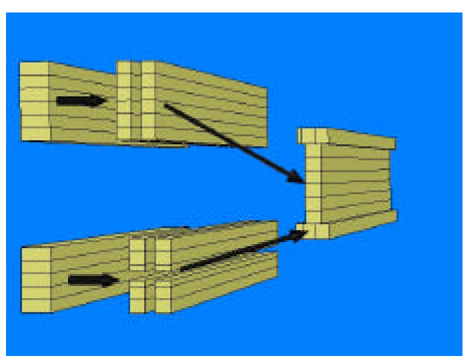


Figure 7. Low- or no-value 2x4 material are laminated into beams and then resawn into web and flange sections to fabricate a value-added laminated I-beam.

Using 2x4s to manufacture I-beams has several advantages. First, defects in the material whether due to curvature, knots, grain angle or wane are redistributed more evenly through the web section, thus reducing stress concentration effects and upgrading load carrying capability. Second, if curvature is the major defect for the individual 2x4 board, then laminating will help straighten the board. Third, a web section made from solid wood as compared to oriented strand board (OSB) webbed I-beam can carry substantially higher compressive loads without buckling. This is especially critical for beams used as load-carrying headers. Thus, a low- or no-value material can be engineered to produce a structurally strong and value-added product from virtually valueless small-diameter, fire-prone timber.

The second phase of this research is now being conducted at FPL to determine alternative methods to reduce some of the curved shape of the cut boards through the use of microwaves and clamping during drying. We are developing a prototype microwave press-drier (Figure 4) with integrated controlled restraint and heating that will be used to straighten the curved-sawn lumber during the drying process.

Our partners in this work Bighorn National Forest, Wyoming State Forester, University of Wyoming, and Genesis Laboratories of Batavia, IL. In the third phase of Project I, the FPL Economics group (RWU4851) will conduct an economic and technology assessment of the process.

Project II: Research on hazardous fuels reduction by harvesting underutilized trees, logging residual, and forest undergrowth to produce three-dimensional engineered fiberboard: a new structural product.

The goal of Research Project II is to help maintain a healthy and sustainable forest by developing uses for whole-tree material from underutilized trees, logging residuals, and forest undergrowth to produce value-added three-dimensional (3D) engineered fiberboard. Several technologies are being combined for this research to produce a value added structural product(s).

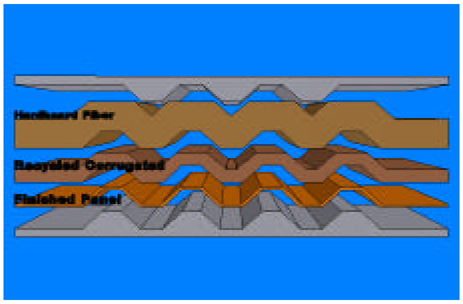
In the initial phase of this research project, we are developing processing methods to reduce the low-value material into fibrous material suitable for wet-forming into 3D fiber mats that are then press-dried to produce resin-free, fiber-to-fiber bonds. For the initial trial, we used tree top material (less than 100 mm (4 inch) diameter), which were the residuals (Figure 8) leftover from Project I. The trees and residuals were harvested from the Bighorn National Forest and Wyoming State Forest .

Small diameter, Lodgepole pine timber harvested from Wyoming and used for Lam-lumber (left) in Project I and 3D Engineered Fiberboard (right) in Project II.

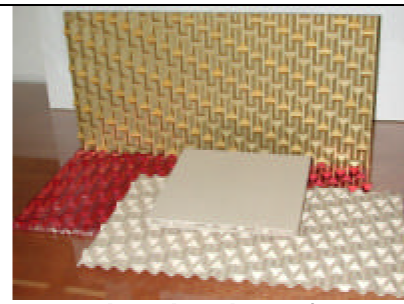
Example of the three processing steps of Chips, "Tornado" strands, and refined fiber used when producing 3D Engineered Fiberboard.

Figure 8. Tree top residuals were chipped, processed, and then refined to produce bondable fibers that will be used to form 3D engineered structural products.

The tree top residual material was first chipped (for ease of handling) with bark on, then fiberized using special equipment developed by Bolton-Emerson, called a Tornado, and finally refined using conventional refining techniques. Research is being conducted to determine the effects of different refining methods on fiber forming and panel strength characteristics. Flat panel boards 2.5 mm (0.1 inch) thick were made from 19 different refiner and chemical treatments used on the Tornado strand material. The flat panels have been tested both non-destructively and destructively. Based on the flat-panel tests and previous research (Danforth 1986, Gunderson 1984, Hunt and Vick 1999), optimized designs for 3D panels are currently being developed using finite element analysis. From that flat-panel study (Hunt and Winandy 2002), two processing methods have been selected for current work in processing fibers for use in making another group of larger panels for further testing and evaluation. Information from both groups of data will then be used in finite element analysis develop an optimized geometry for full-size panels (Figure 9a). The test data will also be used to model and design the structural features for the larger forming process and the molds. Based on properties of the material possible product applications in the furniture and housing markets will be determined.



A. Fiberboard panels can be formed achieve specific strength properties for flat or for molded structural panels.



B. Formed corrugated panels with specific strength properties can be assembled into variously sized structural panels. Relative thickness of core layers are from 12-30mm. Finished panel thickness is 25-50mm.

Figure 9. The structural 3D core molded (A) and then bonded to exterior skins (B) yielding a novel three-dimensional sandwich panel that exhibits a high level of strength and stiffness.

When the structural core is bonded to exterior skins, a novel three-dimensional sandwich panel is formed that exhibits a high level of strength and stiffness with minimal material and low weight (Figure 9b). The proposed technology has promising uses in the construction of pallets, bulk bins, heavy duty boxes, shipping containers, packaging supports, wall panels, roof panels, cement forms, partitions, displays, reels, desks, caskets, shelves, tables, and doors. The size of these potential markets is enormous. For example, according to 1996 statistics published in the Annual Survey of Manufacturers, the pallet industry has annual sales in the U.S. of over $3 billion, wood office furniture is a $2.4 billion market, wood partitions and fixtures are a $3.7 billion market, and wood doors account for $2.2 billion of the total door market. The economic feasibility of constructing panels from these materials is also being be assessed.

Preliminary data has also been gathered using the FT-NIR spectrometer. Correlations of the fiber's spectral features to final performance and physical properties of flat- and 3D Engineered Fiberboard-panels have been made. Further examination to understand and use these spectral results as a means of process control and product engineering is underway.

Government and industrial partners are working in cooperation to assess the engineering and economic feasibility for using this type of material. Whole tree material was obtained from the Bighorn National Forest, WY, and from the Wyoming State Forest lands. Bolton-Emerson Co., Lawrence, MA assisted in fiberizing and refining the material. Genesis Laboratories, Inc., Batavia, IL provided some preliminary 3D molds for initial studies on press-drying the material. The Forest Products Laboratory, Madison, WI is directing the research to determine fabrication and performance characteristics of both flat-fiberboard material and our new 3D Engineered Fiberboard structural panels.

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