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Aspen wood products utilization: impact of the Lake States composites industry

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ASPEN WOOD PRODUCTS UTILIZATION: IMPACT OF THE LAKE STATES COMPOSITES INDUSTRY

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ABSTRACT.--The utilization of Lake States aspen for value-added products has increased dramatically in the last 15 to 18 years. This paper reviews aspen utilization for solid and composite wood products since 1970, discusses the forecasted future demand for wood-based composites, and reviews research that may influence future utilization of aspen in the Lake States.

INTRODUCTION

The proceedings for the first Aspen Symposium, which were published in 1972, included 26 papers, only two of which were on the subjects of trends and prospects for wood and fiber products. The program for the second symposium includes two plenary papers, eight technical session papers, and three technical poster displays, all on aspen products and utilization. Things have changed considerably in the intervening years. In 1972, Keays (1972) reported that the aspen harvest was roughly 50 percent of the allowable cut. He also predicted that within 30 years the allowable cut would probably double and that growth and use would be in close balance by the end of the century. These predictions have been proven accurate; however, the growth/cut balance was reached in only 17 years. In 1989, the concern is that the aspen cut is exceeding growth, and aspen supply will not be adequate to support the growing solid wood, composite, and paper industries in the Lake States region.

The Lake States of Michigan, Minnesota, and Wisconsin consist of a total of 122 million acres, 50 million acres (41%) of which are forested. Timberland represents 38 percent of the total land area in these three states, and the population is about 20 million. Moreover, more than 45 percent of the total U.S. and Canadian populations and total personal income are found within a 300- to 500-mile radius of the Lake States (Lake States Forestry Alliance 1987).

The purpose of this paper is to discuss the utilization of aspen for composite wood products in the Lake States by reviewing (1) the resource base available in the Lake States, (2) aspen utilization trends from 1965 to 1989, (3) aspen demand as opposed to availability, (4) the forecasted demand for aspen-based products, and (5) recent research that may affect aspen composite wood products in the near future.

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RESOURCE BASE IN LAKE STATES

As the demand for forest products of all types increases, pressures on the forest resource increase dramatically. The Lake States contain 45.9 million acres of timberland, which represents nearly 10 percent of all timberland in the United States (Lake States Forestry Alliance 1987). These resources are spread fairly uniformly across the Lake States: 13.6 million acres in Minnesota, 14.7 million acres in Wisconsin, and 17.4 million acres in Michigan. The species types of Lake States timber resources, which total almost 46 million acres, are shown in Figure 1 (Lake States Forestry Alliance 1987). The largest resource category is aspen-birch, followed by maple-beech-birch, fir-spruce-larch-cedar, and smaller amounts of other species.

ASPEN UTILIZATION

Aspen utilization has changed much over the past 25 years. Data compiled by the North Central and Northeastern experiment stations of the USDA Forest Service (Blyth and Smith 1988) show that aspen pulpwood production rose 150 percent between 1962 and 1986, from 1.6 to 4.0 million cords per year (Fig. 2). These figures understate the total use because they do not include aspen used by sawmills, veneer mills, specialty mills, and, lately, some waferboard mills.

Twenty-five years ago, most aspen was used for pulp, lumber, hardboard, and insulation board. Small volumes of higher grade logs were also used for veneer and miscellaneous items such as matches and tongue depressors. The advent of waferboard/oriented strandboard (OSB) has caused aspen utilization for solid-wood products to jump threefold since 1975 (Fig. 3) (U.S. Department of Commerce 1988, Anderson 1989, Anonymous 1988). In 1989, approximately 3.0 million cords of aspen will be used for solid-wood products.

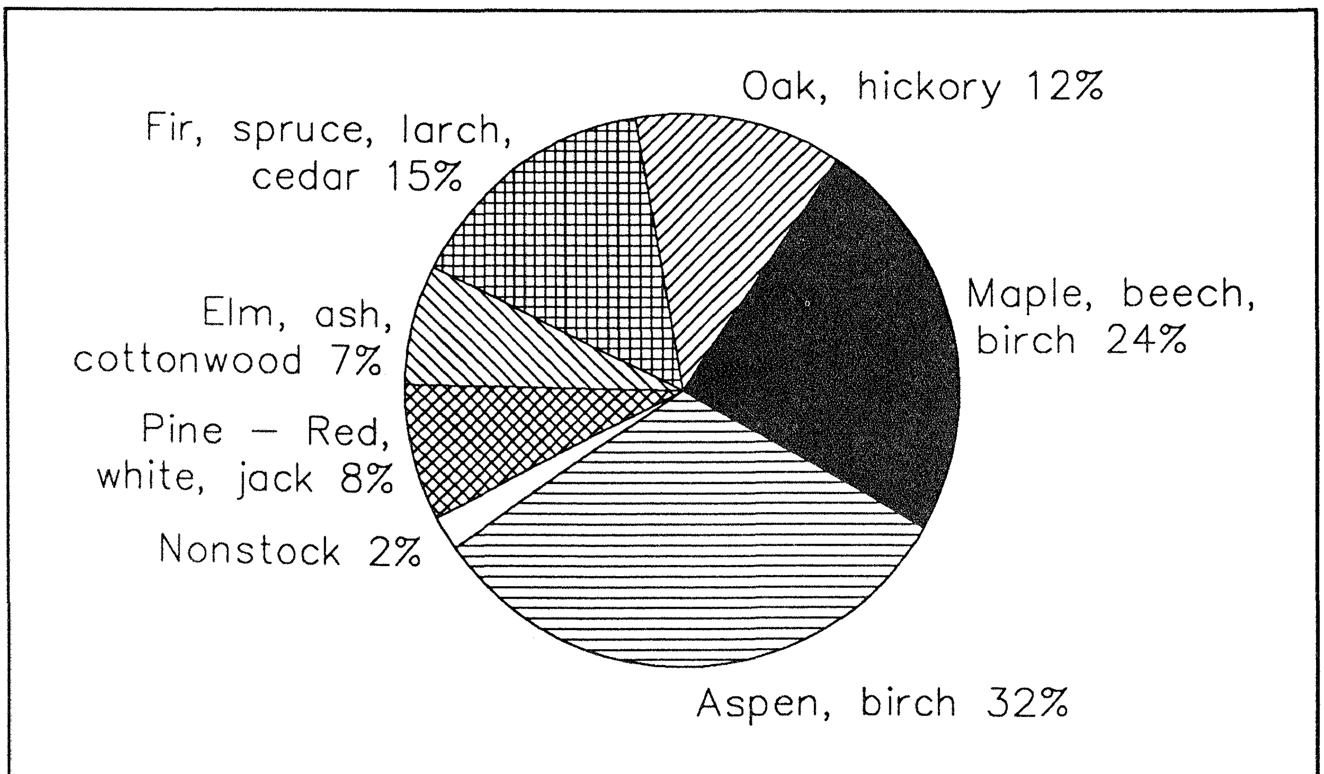

Figure 1.--Lake States timber resources by volume of timber type; 45,900,000 acres of timberland (10 percent of total U.S. timberland) (Lake States Forestry Alliance 1987).

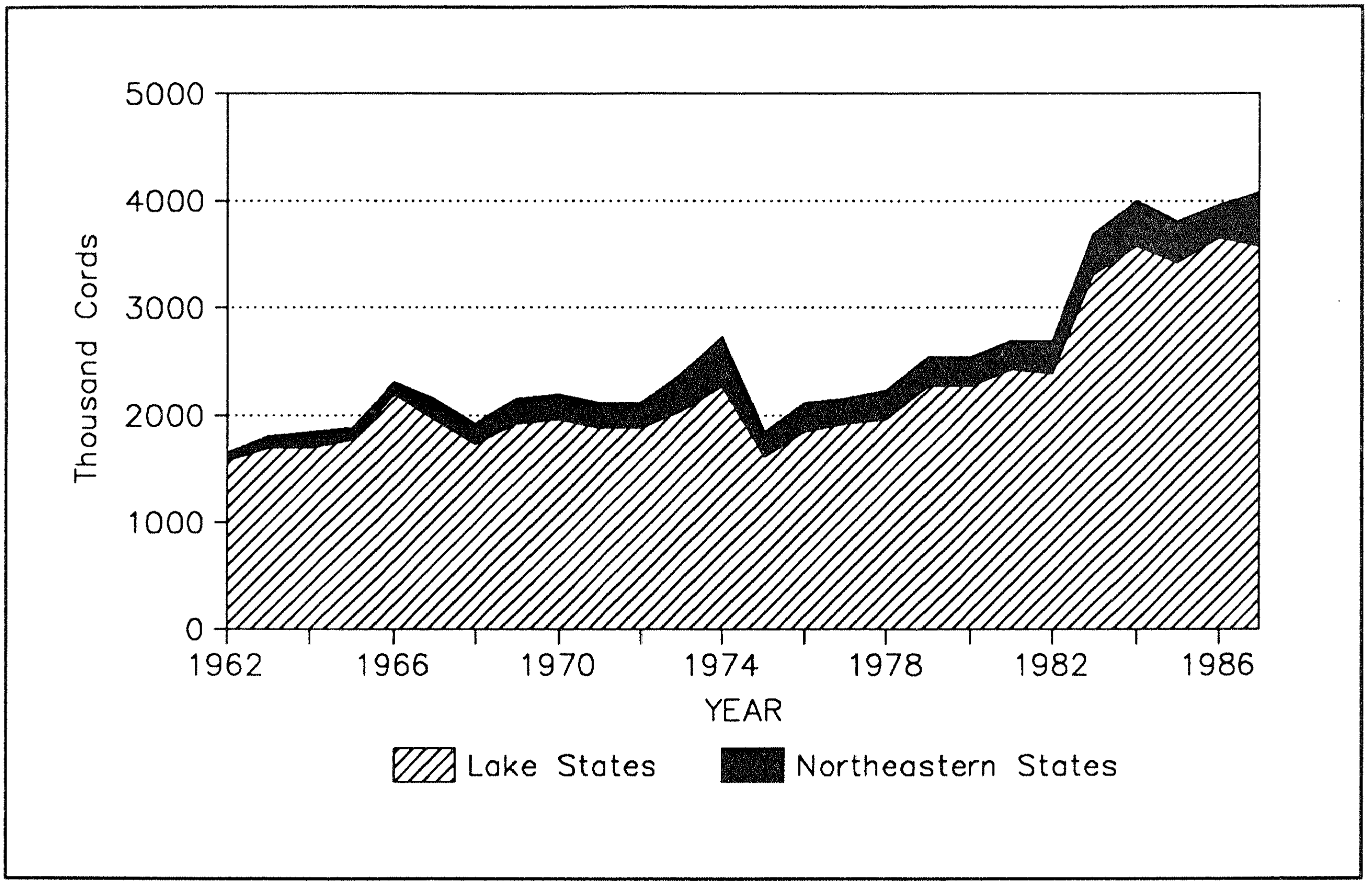

Figure 2.--Aspen pulpwood production in Northeastern United States (Blyth and Smith 1988).

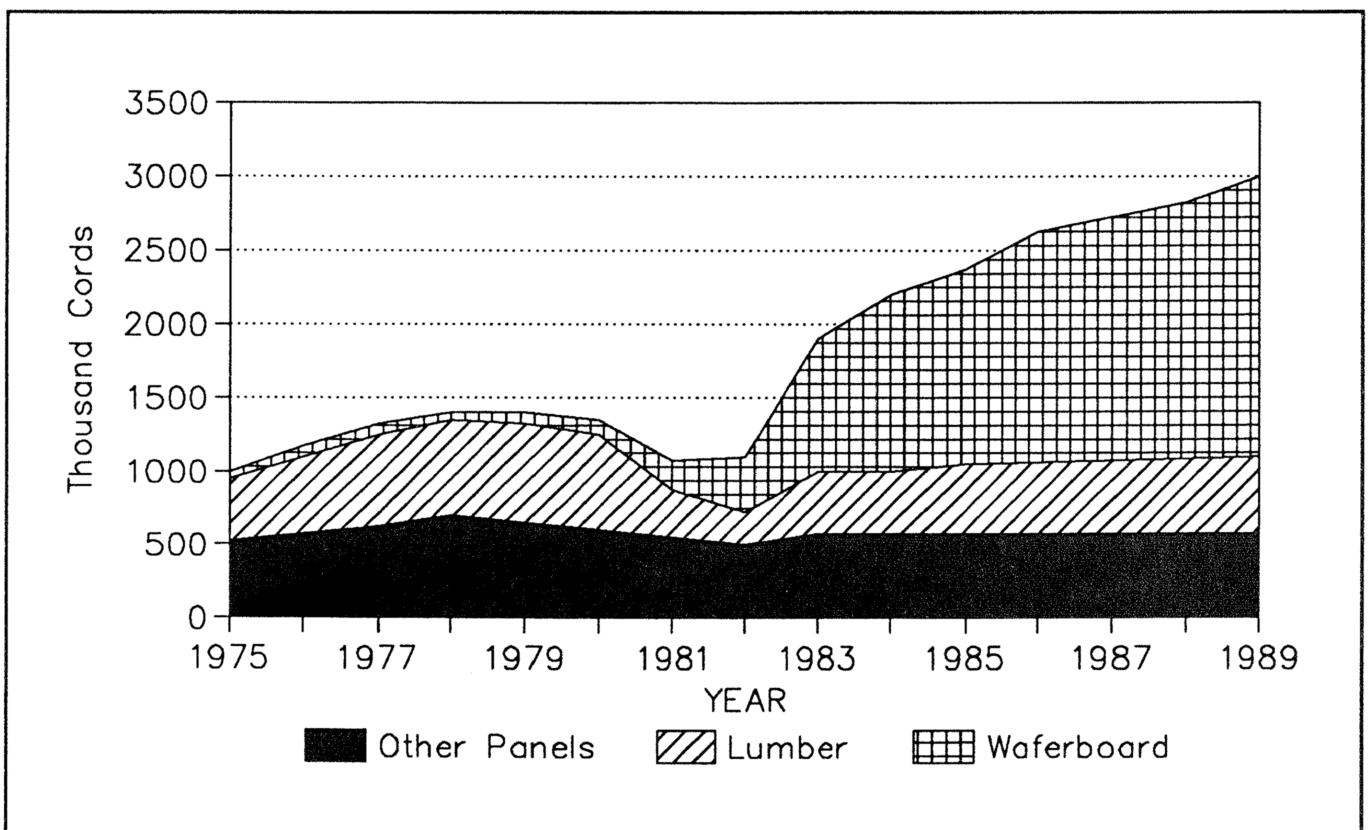

Figure 3.--Utilization of aspen solid-wood products (converted to cords) from 1975 to 1989 (Lake States Forestry Alliance 1987, U.S. Department of Commerce 1988, Anderson 1989).

In 1986, the most recent year for which all the data are available, waferboard/OSB accounted for approximately 59 percent of the solid-wood products total (Fig. 4). Waferboard is made from aspen almost exclusively, with only Northeastern mills adding other species (spruce-pine-fir) to their waferboard mix. Based on the production of new mills and mill expansions, the percentage of waferboard/OSB used should rise to around 63 percent in 1989. In the 1986 data, the next largest percentage of solid-wood products consists of lumber and hardwood (19 and 11%, respectively, of total products). Particleboard, which in the Lake States is made to a large extent from roundwood and chips rather than from mill wastes and residues, accounts for 4 percent of solid-wood products. Medium-density fiberboard, insulation board, and veneer accounts for the remaining 7 percent.

DEMAND OPPOSED TO AVAILABILITY

The growing stock of aspen is approximately 170 million cords. If we assume that the aspen growing cycle is 40 years, then the present use-rate of approximately 4 million cords per year is close to the sustainable yield level. The immediate outlook is for a continued increase in aspen demand. A collective look at Lake States capital investments in new or expanded wood-using facilities from 1979 to 1989 is presented in Table 1. This information is based on announced or projected capital investments by individual producing industries and includes $4.4 billion in facilities for pulp, paper, or paper products, $444 million for waferboard/OSB facilities, and lesser amounts for wood for energy, secondary manufacturing, sawmills, sheathing plants, and veneer (chopstick) facilities. These investments, which total over $5 billion, indicate that continued demand on the aspen resource will be high.

In some areas, harvests are presently below the allowable cut. In other areas, harvest is temporarily exceeding the allowable cut while overmature stands are being harvested. Forest managers generally feel, however, that by the early 1990s, when much of the overmature timber will be liquidated and the new or expanded wood-using facilities are in full operation, aspen supply will tighten in many areas of the Lake States.

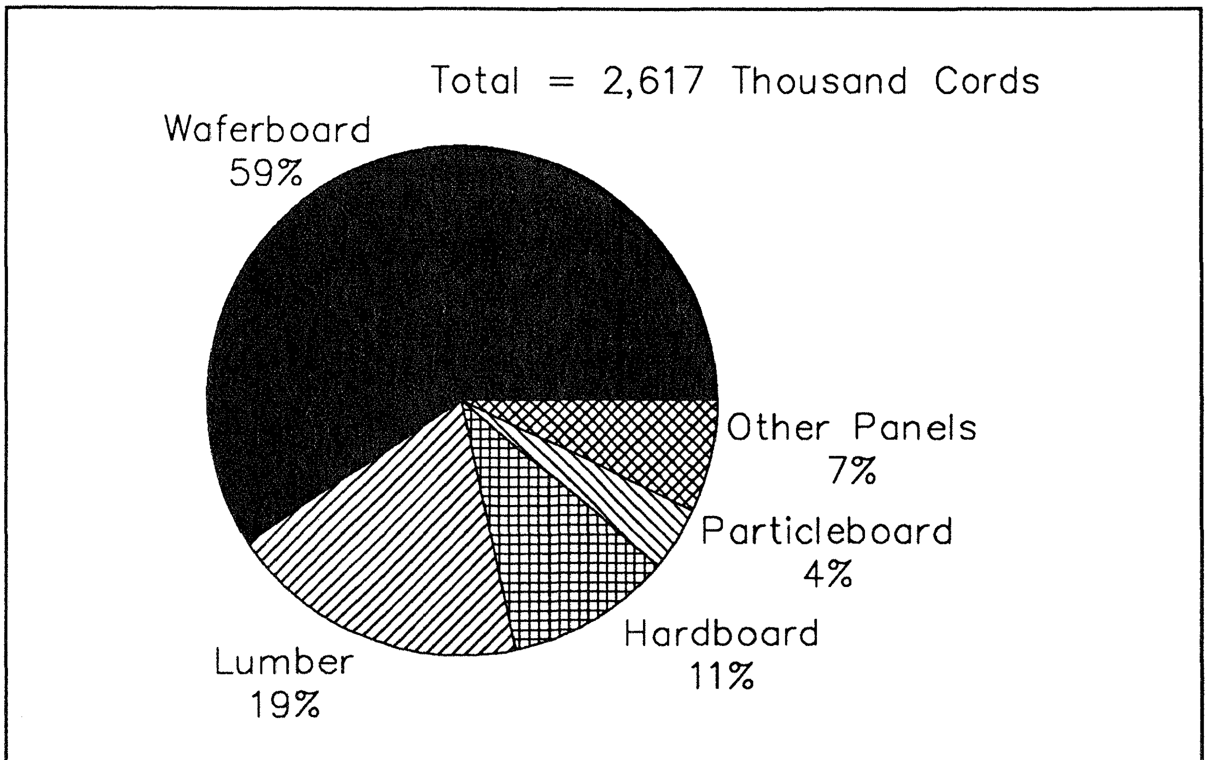

Figure 4.--Use of aspen solid-wood products in 1986 (Lake States Forestry Alliance 1987, U.S. Department of Commerce 1988, Anderson 1989).

Table 1.--Lake States investments in new or expanded wood-using facilities from 1979 to 1989.[1]

Product	Capital Investment (millions of dollars)	(percentage of total)
Pulp, paper, paper products	4,464	87.6
Waferboard, OSB	444	8.7
Wood for energy	93	1.8
Secondary manufacturing	68	1.3
Sawmill	15	0.3
Sheathing	12	0.2
Veneer (chopsticks)	6	0.1

Total	5,102	

[1]Lake States Forestry Alliance 1987.

One important consideration affecting availability is the price of aspen. In most areas, the delivered cost of aspen to mills ranges between $30 and $40 per cord. Stumpage prices average around $5/cord, with most sales between $4 and $10. Another approach for calculating the value of aspen is based on the residual value of the wood product after all manufacturing costs and normal operator overhead and profit are subtracted. Waferboard can be used as an example of such a calculation. Currently, waferboard selling prices are around $130 per thousand square feet (MSF) (3/8-in. basis). Mill labor costs are $10/MSF, energy $18/MSF, and adhesives $25/MSF. Capital depreciation expenses are about $12/MSF and overhead and profit are about $25/MSF. Harvesting and delivery expenses are about $30/cord or $26/MSF. Subtracting these costs leaves a residual value of $14/MSF or $16/cord, which is almost three times the current average stumpage rates for standing timber. This gap is the force that is attracting new or expanded mills into the region.

PROJECTED DEMAND FOR ASPEN-BASED PRODUCTS

According to the latest projection from the American Plywood Association (APA), the structural panel market will contract in 1989 (Anderson 1989). Over the long term, a moderate rebound will occur in the 1990s, but growth in demand for structural products will be slowed by the extended cyclical decline in demand for new homes resulting from decreasing population in the young, family-starting age group.

This modest outlook is bolstered for waferboard producers by the rapidly rising costs of western timber. Within the last 3 years, the doubling of western stumpage prices has placed panel mills in an unfavorable competitive condition. Accordingly, although overall panel demand may grow only moderately, waferboard demand should increase at a faster rate, and additional investment should take place in the Northeast aspen belt, from both expansion of old mills and installation of new mills.

LIKELY CHANGES IN THE LAKE STATES COMPOSITES INDUSTRY

In the following sections, only one or two specific examples of likely changes in the future are listed. In most instances, many more changes could be cited. By the time the next Aspen Symposium is held, additional changes will have certainly occurred.

ALTERNATIVES TO ASPEN FOR WAFERBOARDS

As the stands of pure aspen are being depleted, greater interest is arising in whether or not suitable waferboard/OSB products can be made by blending aspen with other plentiful species. Several studies have been made on this subject recently. A study by Gertjejansen and Hedquist (1982) indicated that a 10- to 15-percent substitution of paper birch for aspen resulted in little or no difference between aspen-birch and all-aspen boards. Panning and Gertjejansen (1985) reported that a mixture of 15 percent paper birch, 15 percent balsam poplar, and 70 percent aspen resulted in acceptable waferboard panels. Kuklewski et al. (1985) found that for both random and aligned boards, the properties of all red maple panels compared favorably with those of panels made totally from aspen. Other research studies have found that significant amounts of different species can be used in combination with aspen with no detrimental effects on the properties of the finished products. In general, these studies indicate that other species can be substituted for aspen, if necessary.

IMPROVEMENTS IN PROCESSING EFFICIENCY

Supplying wood products with consistent, predictable characteristics that provide good performance and reliability is essential for maintaining and improving the competitive position of the forest products industry, both domestically and internationally. Manufacturing products with the quality desired by the consumer at an investment return favorable to the producer is a key element to remaining competitive.

Differences among wood products are primarily related to differences in species, end-use specifications, and product quality. Lumber manufacturing and drying techniques are essentially the same for construction, industrial, and export lumber products. This is also true for panel manufacture and wood preservation methods. Consequently, manufacturing and quality control developments in the wood industry have a broad impact in many markets.

Product quality is of the utmost concern throughout the entire forest products industry. Improvement and consistency in product quality are needed in solid wood, wood fiber, and composite wood products for the construction and industrial markets. Export markets for wood products are especially sensitive to product quality.

Programs like the IMPROVE system now being developed at the Forest Products Laboratory (FPL) will continue to focus on increasing mill recovery and value potential by improving manufacturing efficiency. The IMPROVE system consists of eight major analysis programs: log processing, lumber manufacturing, lumber drying, dry end practices, veneer manufacturing, veneer drying, plywood manufacturing, and dry storage and shipping practices. The system will soon be expanded to include manufacturing operations in waferboard mills. Each of the programs consists of several routines that analyze various aspects of a given process. The routines can be used independently or in series, and they have been proven to improve quality and yield figures in actual mill trials (Lunstrum 1981).

INCREASED USE OF HARDWOOD FOR STRUCTURAL LUMBER

Until recently, structural lumber produced from hardwoods warped and twisted during drying. The Saw, Dry, and Rip (SDR) process eliminates this problem (Maeglin and Boone 1983, Maeglin 1985). As a result, structural grade lumber can now be manufactured from many low- to medium-density hardwoods. The most promising species are yellow-poplar, aspen, eastern cottonwood, sycamore, red alder, blackgum, paper birch, black willow, basswood, soft maple, sweetgum, and black cottonwood. In SDR, green logs are live sawn into 1-3/4-in. unedged planks called flitches. The flitches are dried to an average moisture content of 12 percent and then rip-sawed into studs. This process reduces warp by balancing stresses in flitches, restraining growth stress release, and reducing stress levels from drying. Drying at temperatures above 212°F also helps the studs remain straight. Stresses in the wood relax at this high temperature, and lignin, the bonding agent between fibers, becomes plastic and allows the wood fibers to slip past each other, minimizing the stress. As the wood dries, the lignin solidifies and holds the wood in an unstressed state.

The volume yields of SDR are comparable to conventional methods for manufacturing structural lumber. In addition, necessary equipment is readily available and existing mills may be easily adapted to the SDR process. The SDR process has the potential for making hardwood structural lumber a standard commodity and for relieving the pressure on the diminishing softwood resources in the West. This process should also benefit the Eastern states, particularly because most residential and light-frame building occurs in the East and low- to medium-density hardwoods flourish there.

INCREASED USE OF COMPOSITE LUMBER

Laminated veneer lumber (LVL) consists of parallel laminated veneer panels ripped into lumber widths. Researched extensively since the early 1970s, this veneer processing technology combines existing plywood manufacturing methods with new laminating techniques to develop a product with greater uniformity and predictability than solid lumber (Youngquist and Bryant 1979, Laufenberg 1983, Youngquist et al. 1984). Tests have shown that the strength of LVL specimens compares favorably with that of most high-strength lumber grades. As a result, LVL offers a viable alternative to structural lumber.

Most operations that produce LVL for structural use are similar to plywood operations. Veneer is rotary peeled, dried, spread with adhesive, assembled in the desired configuration, pressed either in conventional plywood presses or on a continuous or step basis, and then ripped to width. Modifications in the conventional process, such as continuous pressing, have been developed primarily to meet the performance requirements for specific end-products.

The furniture industry has used LVL for many years to produce curved furniture parts (Hoover et al. 1980). Recently, more LVL has appeared in the marketplace because high-quality, solid-sawn structural lumber has become more scarce and expensive. The markets for LVL appear limitless--it can be used for truss components, I-beams, bench seats, truck decking, door/window headers, scaffold planking, ladder stock, bridge stringers, and other interior and exterior applications.

Products made from LVL have several advantages over solid-sawn lumber products. For example, warping and checking are practically eliminated because the veneer is dried before gluing. Also, because laminating disperses wood defects, most mechanical properties will be more uniform than the same properties in solid-sawn wood of comparable quality. The yield of LVL products is 15 to 30 percent greater than that of solid-sawn products. In addition, preservative treatment of some species is more effective on LVL materials.

Over the last 15 years, the FPL has developed an extensive LVL database that focuses on raw material options, processing alternatives, product performance levels, system and product economics, and alternative marketing opportunities. This database has contributed significantly to the work of the American Society of Testing and Materials (ASTM). An ASTM task group is working on a general format for evaluating structural lumber substitutes and has developed two new U.S. standards. The first standard, developed by the American Institute of Timber Construction (AITC), provides for LVL as a substitute for tension laminates in glued laminated beams. The other standard, which is proposed by the APA, will use performance ratings and will provide for trademarking based on the mechanical capabilities of the product. Thus, the future for the LVL industry looks promising.

The importance of LVL products is expected to grow as the wood industry uses more small-diameter trees. The versatility of LVL is a good example of how our renewable forest resources can provide a broad array of structurally efficient products to benefit manufacturers and consumers alike.

LOW DENSITY, HIGH STRENGTH PANEL PRODUCTS

A steam injection process has been developed (Geimer 1982, 1983) that reduces press times for flakeboard, particleboard, and medium-density fiberboard production. Wood flakes are initially coated with a resin and formed into a mat. The mat is then loaded into a press and a burst of saturated steam is injected through perforated platens. Within several seconds, the temperature in the board center rises to approximately 220°F. As the board is compacted, the internal pressure increases, allowing the temperature in the board center to rise to between 280°F and 315°F. This high temperature accelerates the resin cure. Several seconds after the steaming period, the temperature falls to about 225°F and stabilizes there for the remainder of the press cycle. A computer used to control the steam injection schedule also monitors the rapidly changing press operation. It records time, temperature, and several other variables in 0.5-second increments.

Tests conducted at the FPL indicate that press time for a 0.5-in.-thick board can be reduced from 4.5 minutes to about 90 seconds. Also, the 45 minutes needed to conventionally press a 2-in.-thick board can be reduced to less than 5 minutes with steam injection.

This new steam injection process uses smaller equipment and less energy than conventional pressing methods. Steam injection also offers the possibility of incorporating additives that increase durability and fire resistance of the board.

STRUCTURAL PAPER PRODUCTS

Researchers at the FPL have developed a structural fiber concept called FPL Spaceboard (Setterholm 1985). To make the three-dimensional structural board, fibers are press dried against rubber molds with waffle-like configurations to produce two symmetrical halves. An adhesive is then used to bond the two halves, creating numerous small geometric-shaped cells in the board center. Using this technique, FPL Spaceboard can be made as a laminate or sandwich, thin enough for strong light-weight corrugated containers or thick enough for wall sections. The result is a fiber composite structural material that is strong in every direction. Laboratory tests show that FPL Spaceboard is between 30 and 200 percent stronger than conventional corrugated fiberboard. The strength of Spaceboard is due to the special configuration of the core and the superior strength of the press-dry method that molds the core and facing together.

With further refinement, FPL Spaceboard can provide the wet strength and dimensional stability necessary to build highly engineered structures as well as significantly improved fiberboard containers. The superior performance parameters of Spaceboard are as follows:

1. Improved strength-weight characteristics of press-dried fiber facings

2. Unequalled versatility in mechanical design variables--sheet size, cell size, sandwich thickness, and core density

3. Adaptability to a wide range of raw materials

The FPL Spaceboard is a concept in structural fiber construction and, as such, its full potential for application and the economic payoff are yet to be determined. Thus far, FPL scientists have made only a limited number of experimental samples. However, because of its many design and processing attributes, FPL Spaceboard has good potential for use in commercial and residential construction, mobile homes, recreational vehicles, packaging containers, and wall and ceiling panels.

WOOD STABILIZATION TECHNOLOGIES

A world-wide team of scientists, led by FPL Research Chemist Roger Rowell, is currently studying the chemical modification of wood and reconstituted wood products (Rowell et al. 1986). Studies on improving wood properties through chemistry began at the FPL in the late 1930s. They were expanded in 1972, with the advent of new technology, improved analytical instrumentation, and environmental concerns for toxic methods of wood protection.

Rowell and others established that chemical modification of solid wood by epoxidation or acetylation greatly improved dimensional stability. The mechanism of improved stability is based on bonding chemicals to the cell wall polymers resulting in bulking. Chemically modified wood swells to near its green dimensions, so little additional swelling occurs when the modified wood is wetted. The swelling of wood modified with anhydrides, epoxides, and isocyanates has been reduced as much as 65 to 75 percent at bonded chemical weight gains of 20 to 30 percent. Biological resistance is achieved as well when the bonded chemical is distributed in the polymers, which are available to attacking marine organisms, termites, and decay fungi.

In tests using Southern Pine, aspen and Douglas-fir flakes, acetylation reduced liquid water uptake by 50 percent and reduced thickness swelling by 85 percent in flakeboards made from the acetylated flakes. Repeated water soaking/ovendrying tests showed that both epoxidation and acetylation decreased reversible and irreversible (springback) swelling in flakeboard as compared to untreated boards. Springback is caused by the release of residual compressive stresses imparted to reconstituted boards during the pressing process.

The FPL modification methods developed for solid wood can be applied directly to reconstituted wood products with confidence because standard operating procedures in the composite panel industry are exactly those required for successful chemical modification. The requisites are dry wood materials, spray chemical addition for maximum distribution, small sample size for good distribution, and high temperature and pressure in product formation.

Particleboards made from acetylated chips also show greatly improved resistance to tunneling bacteria and brown-, white-, and soft-rot decay fungi as well as decreased hygroscopicity. The greatest potential for chemical modification appears to be in dimensionally stable reconstituted wood products, whose commercial application could be very wide. This and other ongoing research brings FPL scientists together with scientists in many other countries, including China, Sweden, Poland, the United Kingdom, Denmark, France, Germany, New Zealand, and Japan, in studies on acetylation and other chemical modification techniques.

WOOD/NONWOOD COMPOSITES

Combining wood with other materials to form new composites presents many opportunities for development in the forest products industry (Youngquist and Rowell in press). This is a very active research field; many new ideas are being examined. Many species of wood, including aspen, are being combined with other biomass materials, metals, plastics, glass, and synthetic fibers, and the properties of these new composites are under investigation. The new composites will be introduced on the market as low-cost substitutes for more costly materials or in applications where specific performance attributes are required. Through modification of either the wood or the nonwood part of the product or both parts, the new composites can have performance characteristics that are superior to products made from either component alone.

Technological innovation and new product development are vital to maintaining industrial competitiveness and increasing the efficiency of the manufacturing process. This in turn leads to economic growth and enhances the wealth of the nation. The forest sector of the economy particularly is influenced by the development of new materials such as plastics, metals, cement products, ceramics, and composite materials, which have displaced or have the potential to displace many wood-based products. In many nonwood industries, manufacturing process efficiency is increased by improvements in process systems and the amenability of metals and plastics to high-speed automated machines. Some processing concepts can effectively utilize wood in one form or another and are very amenable to high-speed processing (Marcin 1988).

One current processing option for using wood combined with plastics relies on extrusion or injection molding technology, in which thermoplastic resins are thoroughly mixed with finely ground wood particles or flour. This mixture is then forced out through a die to form a sheet product, which can be processed in a secondary manufacturing operation into a number of molded or corrugated shaped sections. When preparing fiber-reinforced composites using extrusion techniques, the amount of compounding that takes place prior to product formation must be optimized.

In another processing option, a high percentage of natural fibers are blended with synthetic thermoplastic or thermosetting fibers to form a nonwoven mat, which can be handled in roll form and which lends itself to automated handling and processing in subsequent operations. This mat can be made from a wide mix of synthetic and natural fibers resulting in products with properties suitable for the end-use intended. Subsequent processing options can then be used to fabricate flat sheet or panel products or deep-drawn molded configurations.

Because of the increased processing flexibility inherent in both the extrusion and nonwoven technologies, a host of new natural-synthetic fiber products can be made. These products can be produced in various thicknesses, from a thin material of 3 mm to structural panels up to several centimeters thick. A great variety of applications are possible because of the many alternative configurations of the product. The three major classifications of potential products are packaging products, manufactured products, and corrugated or sandwich-type configurations for floor, wall, and/or roof components.

CONCLUDING REMARKS

Technological advances have greatly expanded the value of aspen and its range of possible uses. The immediate impetus for the new-found importance of aspen has been the rapid expansion of the waferboard/oriented strandboard industry in the Great Lakes States and Northeast. We expect further growth in this sector along with growth in other reconstituted wood products such as oriented strand lumber or laminated veneer lumber. However, the sharp rise in the demand for aspen has resulted in a concern about the adequacy of future supply; data indicate that aspen use is nearing sustainable supplies. At the same time, research has indicated that partial substitution of different underutilized species for aspen can extend the fiber supply. The increasing demand for wood products, the decrease in supply from traditional wood-supplying regions, and the development of new potential markets through research on wood/nonwood composites, structural use of hardwoods, and composite lumber will augment the importance and value of aspen and other hardwood species in the Lake States and the Northeast.

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