Structural Wood Products

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Abstract

This paper provides a description of available structural wood products. Traditional products such as lumber and plywood are being supplemented by new products that include composite lumber and structural flakeboards. Designers now have a range of engineered wood products to choose from, including glulam timber, prefabricated trusses, and prefabricated I-joists.

The newer wood products are a response to both a changing timber resource and a demand for products that meet specific end-use performance requirements. These new products generally are processed with some degree of reconstitution that tends to decrease variability in strength properties and improve reliability. Future trends in these products will depend upon several factors including raw material availability and processing developments.

Introduction

Lumber and plywood have been the most popular wood products for buildings constructed during the 20th century. However, the production of these commodity-type products has become less profitable during the past few years. This economic factor plus the change in the nature of our forest resources has led to some changes in the types of structural wood products that are now available. The objectives of this paper are to review the various structural wood products that are available and to examine factors that will influence the future availability and trends in these wood products. A complete discussion of structural wood products is available in other references (USDA 1987, ASCE 1975).

Lumber Products

Sawn lumber, the most widely used of all wood products, is the result of cutting rectangular elements of various lengths from logs. Many species of logs are used and the quality of the lumber is a direct function of log quality. For marketing purposes, lumber of similar quality is grouped together by grading, using rules that are standardized nationwide. The types of grading rules that are applicable depend upon the lumber-use category. For example, most hardwoods are graded using rules that indicate the yield of cuttings for uses such as furniture manufacture. Another major use of lumber is for structural purposes, and the various rules used to grade lumber for this use relate to the strength properties of the lumber.

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Within the past few years, another type of lumber called structural composite lumber (SCL) has appeared on the market place. This general category of product consists of several types of materials produced in sizes similar to sawn lumber by gluing together veneers or strands.

In the following sections, methods of grading sawn lumber for structural purposes are reviewed, descriptions of the types of SCL are given, and end-jointed lumber is described.

Visually Graded Lumber

Most structural lumber used in North America is graded according to Voluntary Product Standard PS 20, American Softwood Lumber Standard (USDC 1970), commonly called the American Lumber Standard (ALS). Although titled a softwood lumber standard, several hardwood structural lumber grades have recently been added. The ALS describes a classification system for structural lumber and a standard set of grading rules based on visual characteristics.

Using the ALS as a basis, various regional associations have created grading rules applicable to the species grown in that region. Along with the grading rules that limit many visual characteristics, standard methods are followed to arrive at engineering design properties applicable to the species and grade. Different rules apply to structural lumber, depending upon the intended end use. Dimension lumber is 2 to 4 in. (50 to 100 mm) thick and graded for general use. Beams and stringers are 5 in. (125 mm) and thicker and graded for use as beams. Posts and timbers are also 5 in. (125 mm) and thicker and graded for use as columns. A complete listing of the various grades and sizes of lumber is given in the Wood Handbook (USDA 1987). An example of a grade mark required on ALS lumber is shown in Figure 1.

Many combinations of grades, species, and classifications of lumber are available in various regions of North America. Designers are advised to check on
availability prior to specifying lumber. To obtain design values, it is not necessary to contact each grading agency. Design values from all agencies have been combined in a table in the National Design Specification for Wood Construction (NDS) (NFPA 1986).

As previously noted, visually graded lumber is the most common type of structural lumber, and it has a history of satisfactory use in a multitude of structures across North America. In recognition of a changing forest resource featuring faster growing trees, grading agencies are monitoring the structural performance of this product so that grading rules can be adjusted to assure continued acceptable performance.

**Machine Stress-Rated Lumber**

Mechanically graded or machine stress-rated (MSR) lumber is graded using a combination of visual and mechanical methods. The stiffness, or modulus of elasticity, of each piece of lumber is measured and the grading is based on a correlation between stiffness and the strength in bending, tension, and compression. An approved MSR lumber producer must first demonstrate the grading system to be effective through a qualification procedure involving tests of the graded lumber for both strength and stiffness. Then, as part of production, a quality assurance program must include tests of periodic samples to monitor the engineering properties.

Machine stress-rated lumber also must conform to special provisions of the ALS. Design values for MSR lumber, established by the various grading agencies, are published in the NDS (NFPA 1986).

Most MSR lumber is either nominal 2 by 4 in. (nominal 51 by 102 mm) or 2 by 6 in. (51 by 152 mm), with small amounts of wider lumber also produced. The major use of this product is in the manufacture of other engineered wood products such as prefabricated trusses. The advantages of MSR lumber are (1) increased yield in value of lumber than by visual grading (in some instances) and (2) improved reliability in the engineering properties. Machine stress-rated lumber is advantageous for some trusses used on spans longer than the common 30- to 32-ft- (9.1- to 9.9-m-) long residential truss because of the recognized improved reliability. In addition, some MSR lumber is used for chords of prefabricated I-joists and for laminations in glued-laminated (glulam) timber.

**Structural Composite Lumber**

Structural composite lumber was developed in response to the increasing need for high-quality lumber at a time when it was becoming more difficult to obtain this lumber from the forest resource. Various products from structural composite lumber are available; all are characterized by smaller pieces of wood glued together into sizes common for sawn lumber.

One product is manufactured by laminating veneer with all plies parallel to the length (in contrast to plywood, discussed later). This is called laminated veneer lumber (LVL). Specially graded veneer is used and various types of end joints are commonly staggered in the layup of LVL that, when processed using
continuous presses, results in a product either 2 or 4 ft (0.6 or 1.2 m) wide and lengths limited only by shipping convenience, up to 80 ft (24.4 m).

Another SCL product, called parallel strand lumber (PSL), uses strands of wood or strips of veneer glued together under high pressures and temperatures. Product properties may be controlled using information on the wood properties. A third product of SCL is a laminated composite using layers of veneer glued over a particleboard or other type of core.

National standards are not available for either the production of SCL or its design values. Several manufacturers have received individual code approvals for their design values. Thus, the designer is referred to manufacturers’ literature for design information. A committee of the American Society for Testing and Materials (ASTM) is developing a standard method of obtaining design values for SCL.

Structural composite lumber is a growing segment of the engineered wood products industry, and it is anticipated that its growth will continue. One major growth area will be in the manufacture of other engineered wood products, such as in the flanges of prefabricated wood I-joists. One manufacturer of glulam timber now uses LVL as the outer-tension lamination for a portion of production.

End-Jointed Lumber

For some uses, sawn lumber must be end jointed for use as part of a longer engineered wood product. One type of structural joint commonly used is a finger joint shown in Figure 2, which is about 1-1/8 in. (28 mm) long with 4 fingers per inch. This type of joint is used extensively in the manufacture of prefabricated wood I-joists and glulam timber.
An efficient, structural end joint should result in strength properties that match or exceed lumber properties. By placing an efficient joint in a region of the lumber of relatively clear wood, a balance can be obtained between the strength of the lumber as controlled by knots or other strength reducing characteristic and the strength of the joint. Various grading agencies or associations that supervise the production and grading of end-jointed lumber have production and quality assurance standards. Many of these standards are based on the requirements for glulam timber discussed in a later section (ANSI 1983).

**Structural Panel Products**

For many years, plywood has been a familiar structural panel product used in house construction. Particleboard has also been used in applications such as mobile home flooring. Other structural panel products, called structural flakeboards, are available and widely used. Although their appearance and properties differ to a considerable degree, plywood and other structural panel products are marketed together as structural sheathing. Products such as plywood, waferboard, oriented strandboard, and veneer–particle composite panels are commonly available in 4 by 8-ft (1.2 by 2.4-m) panels in thicknesses of 1/4 in. to 1 in. (6.4 mm to 25.4 mm) and are used interchangeably to satisfy various structural requirements.

**Plywood**

Plywood is a glued-wood panel product made of relatively thin layers of veneer with the grain direction of adjacent layers at right angles. Most plywood constructions have an odd number of layers to maintain balance and thus dimensional stability. In some instances, two of the inner plies are glued together with their grains parallel to form a single layer; this results in a construction with an even number of plies. Veneer thickness near 1/8 in. (3 mm) are commonly used to make panels up to 1-1/4 in. (32 mm) thick.

Structural-use plywood should conform to PS-1 standard, which covers construction and industrial plywood (USDC 1983). Two methods qualify plywood products for structural applications: (1) a material specification that includes species and grade requirements for the veneers or (2) a performance standard that is described in the next section on structural flakeboards. Plywood properties depend on the properties of the outer plies, called the face and back veneer. The durability of plywood depends to a large extent upon the water resistance of the glue joint. Each panel must be stamped to certify that it is adequate for the specific uses (Fig. 1). Design information on plywood is available from the American Plywood Association (APA 1980).

Plywood manufacture depends upon the availability of logs of adequate size and quality to peel for veneer and an economical adhesive. New technology permits the use of smaller logs for plywood production. The decline in plywood production predicted several years ago as a result of the availability of alternate structural-use panels has not materialized. It appears that plywood products will continue to be readily available.
Structural Flakeboards

Waferboard and oriented strandboard (OSB) are two types of structural flakeboards (Fig. 3) that are produced from flakes or strands of wood obtained directly from logs. These flakes or strands are much larger than the particles produced from mill residue that forms the basic raw material for particleboard. Structural flakeboards are commonly made from low-density species, either softwoods or hardwoods, and are bonded with exterior-type adhesives.

Waferboard and oriented strandboard differ in the size of flake used in their manufacture. At one time, flakes used to manufacture waferboard (called wafers) were approximately square, ranging from 1 to 2 in. (25 to 50 mm) on a side. Strands in oriented strandboard were commonly 2 to 3 in. (50 to 75 mm) long and 1/2 to 1 in. (12 to 25 mm) wide. Wafers were placed randomly during the manufacture, whereas strands were oriented and layered within the panel during manufacture. Recent changes in manufacturing processes in both flake size and orientation, particularly for waferboard, makes it difficult to distinguish between the two products in today’s market.

These structural-use panels are manufactured to meet a set of performance standards that define the particular end use (APA 1982). The objective of these standards is to assure that the product will satisfy the requirements of the application for which it was intended. For example, panels intended for roof, wall, and subfloor coverings are rated with the requirement for support spacing. To meet the performance standard, the product must pass a set of rigorous qualification tests that include requirements in areas of structural adequacy, dimensional stability, and bond performance. Once qualified, the product must be produced under a continuous quality assurance program to assure the level of performance.

The raw materials used for the manufacture of plywood and structural flakeboards markedly differ. Whereas plywood requires logs to be peeled into
veneer, structural flakeboards can be manufactured from a much broader range of resources. For example, many flakeboard plants use previously underutilized species, such as aspen, and have the advantage of a low-priced raw material. Thus, structural-use panels made with flakeboard technology will continue to be an important construction material.

**Veneer–Particle Composite Panels**

Veneer–particle composite products are a hybrid between plywood and structural flakeboard, in that the faces are veneer and the core layer is made from strands, flakes, or particles. Sometimes referred to as COM-PLY, this product is manufactured to meet the same performance standard as structural flakeboards.

**Other Panel Products**

A variety of other panel products are used in semistructural applications in various types of construction. Particleboards are used for mobile home subflooring; fiberboards for some types of sheathing, hardboard for prefinished paneling and siding. The structural properties of these products are generally lower than for the structural-use panels previously described. Additional information on panel products is available in the *Wood Handbook* (USDA 1987).

**Round Timbers**

Round timbers in the form of poles, piles, or construction logs represent some of the most efficient uses of forest resources because of the minimum of processing required. Poles and piles are debarked or peeled, seasoned, and treated with a preservative prior to use. Construction logs are usually shaped to facilitate construction. Detailed information on applicable standards and specifications for round timbers are given in the *Wood Handbook* (USDA 1987).

**Poles**

Poles used to support utility and transmission lines range in length from 30 to 125 ft (9 to 38 m). Poles used for building construction rarely exceed 30 ft (9 m) in length. Southern pines account for the highest percentage of poles used in the United States because of their favorable strength properties, excellent form, ease of treatment, and widespread availability. For longer lengths of poles, Douglas-fir and western redcedar are widely used. Other species are also used to a lesser extent and are included in the ANSI 05.1 (ANSI 1987) standard that forms the basis for most pole purchases in North America.

**Piles**

The majority of piles used for foundations in the United States utilize either Southern Pine or Douglas Fir. Sizes and methods of specifying piles and material requirements are described in ASTM D25 (ASTM 1989). Design stresses for various species of piles are given in the NDS (NFPA 1986).
Construction Logs

Log buildings continue to be a popular form of construction, and ASTM D3957 describes methods of establishing stress grades for these logs (ASTM 1989). These logs are commonly air dried and fabricated into a variety of shapes prior to log-building construction. Logs are also sometimes used for construction of bridges in remote logging areas. Standards are not available for these log bridges but a design guide is available (Muchmore 1977).

Fabricated Components

Prefabricated component products manufactured using lumber or panel products have become familiar building materials for today’s construction industry. This section provides a general description of these products.

Glulam Timber

Structural glued-laminated timber, or glulam, is defined as the engineered stress-rated product of a timber-laminating plant, comprising assemblies of suitably selected and prepared wood laminations securely bonded together with approved adhesives. Glulam refers to two or more layers of wood glued together with the grain of all layers approximately parallel. The product may be either straight or curved with lamination up to 2 in. (50 mm) thick in straight members and thinner laminations in curved members. The lumber used in the manufacture has special grading and moisture content requirements. A national standard, ANSI A190.1 (ANSI 1983), contains requirements for production, testing, and certification of the product in the United States.

Straight members up to 140 ft (42 m) long and over 7 ft (2.1 m) deep have been manufactured, with the limitation on size resulting from transportation constraints. Curved members have been used in structures spanning more than 500 ft (150 m). Standards exist for manufacturing and designing glulam members from many softwood and hardwood species. The most commonly used U.S. species are Douglas-fir and the southern pines. Additional information on the manufacture of glulam timber is given in the Wood Handbook (USDA 1987).

Standard sizes and design values for glulam timber are given in AITC 117 and 119 (AITC 1987 & 1985a). Special design considerations for glulam timber are described in the Timber Construction Manual (AITC 1985b).

The vast majority of glulam timber is manufactured using visually graded lumber. However, the use of MSR lumber and LVL is increasing and will likely continue to increase because of the advantages of greater predictability in both strength and stiffness. Other techniques for identifying high-strength lumber through improved grading procedures are being developed and will likely be adopted by producers of glulam timber and other engineered wood products.

Prefabricated Wood Trusses

Some forms of wood trusses have been used for generations. The use of split-ring and shear-plate connectors made long-span trusses popular for indus-
trial and military buildings in the early part of the 20th century. Light-wood trusses with nail-glued plywood gusset plate connections began to be used near the middle of the century. This was closely followed by the development of toothed metal-plate connectors. This connector is now used on trusses that are available throughout North America for residential, agricultural, and industrial buildings.

Metal-plate-connected wood trusses are manufactured at hundreds of plants nationwide and are available directly from the plant or through building material suppliers. Truss design is available from the suppliers of the plates or by specialized structural designers. Standards for the design and manufacture of wood trusses and construction procedures are available from the Truss Plate Institute (TPI 1985).

Other types of wood trusses use connectors that include the web member as an integral part of the connector plate. Another type uses tubular metal webs connected to the wood flanges with pins. Both types of connectors are best adapted to parallel-chord trusses.

Most trusses used for residential applications use visually graded lumber, either 2 by 4 in. or 2 by 6 in., and are spaced on 2-ft (0.6-m) centers. Trusses for other applications will often use wider lumber, and the trusses may have wider spacings. A major use of MSR lumber is in this type of truss with various types of composite structural lumber also used.

Wood trusses are used in 80 percent or more of the roof systems of new low-rise residential structures and will continue to command a dominate share of this market because of the savings in both labor and materials. Similarly, many agricultural buildings use wood-truss roof systems. Parallel-chord trusses along with prefabricated wood I-joists, discussed in the next section, are used in an increasing share of residential floor systems. With the growth of trusses in residential applications somewhat limited, any major expansion of this industry will be in the industrial area.

Prefabricated I-joists

Built-up beams with plywood webs and lumber flanges, commonly referred to as I-beams or box beams, and have been used for many years. Box beams have often been site fabricated for specific applications. In recent years, the developments in both adhesives and manufacturing techniques have led to the development of a prefabricated I-joists industry. Not only are prefabricated I-joists replacing wider lumber sizes in floor and roof applications, but they also make possible longer spans than previously feasible.

Significant savings in material are possible with I-joists by using either plywood or OSB as the web material and small dimension lumber for the flanges. The product is popular with builders because of its light weight, dimensional stability, and ease of construction. Utility lines are easily passed through holes in the webs. Manufacturers supply these products to building material suppliers across North America, or they can be purchased directly from the 10 to 15 manufacturers.
Nationally recognized product standards for prefabricated wood I-joists do not exist. A design procedure is available from the American Plywood Association (APA 1980), and a standard method for developing design properties has been prepared by an ASTM committee and will soon be available. Thus, each manufacturer has developed their own code acceptance and provide catalogs with span tables and design information.

During the 1980s, the prefabricated wood I-joists industry was one of the faster growing segments of the wood products industry. As previously noted, I-joists are being used with parallel-chord trusses to replace sawn lumber in floor applications of residential structures. They are also used extensively in roof systems of industrial buildings, the area of projected growth.

Prefabricated I-joists have a requirement for a high-strength flange material in a relatively small size (38 by 38 mm or 38 by 64 mm) for most applications. It has been difficult to obtain the quality of visually graded lumber desired in these sizes; therefore, both MSR and LVL lumber are being used by several manufacturers. It is anticipated that in the future improved grading procedures for sawn lumber and various types of structural composite lumber will be used for the flanges of prefabricated I-joists.

Stressed-Skin and Sandwich Panels

Stressed-skin panels commonly consist of plywood or OSB faces glued to wood stringers. Sandwich panels are similar except that the core area is continuous and often made with some type of foam or formed sheet material. Both products can be engineered to provide high stiffness. Thinner faces can be used with sandwich panels because of the continuous support provided by the core. Design information for these products is available (APA 1980, USDA 1987). These products can serve as structural elements in construction and are popular for some wall applications.

Protecting Structural Wood Products

Wood is a natural material, and left unprotected, it will deteriorate and eventually become useless as a structural material. The method to use in protecting wood products depends upon the use and desired life of the structure. Wood products, depending on their use, may need protection from weathering, decay, and fire.

The most important aspect to consider when protecting structural wood products is its design. Many wood structures are several hundred years old, and we can learn from the principles used in their design and construction. For example, in nearly all of those old buildings, the wood has been kept dry by a barrier over the structure (roof plus overhang) by maintaining a separation between the ground and the wood elements (foundation) and by preventing accumulation of moisture in the structure (ventilation). Today’s engineered wood products will last for centuries if good design practices are used.
Protection From Weathering

The combination of sunlight and other weathering agents will slowly remove the surface fibers of wood products. By providing a wood finish, this removal of fibers can be greatly reduced and, if properly maintained, nearly eliminated. Information on wood finishes is available (Cassens & Feist 1986).

Protection From Decay

In many instances, structural wood elements are used in conditions where the moisture content of the wood will exceed 20 percent as in most conditions of ground contact or unprotected exterior use. Wood decays under these conditions, and in some instances, it may be acceptable to let the wood deteriorate naturally, recognizing there will be a finite life. The length of life will depend upon many factors, an important one being temperature, and it must eventually be determined when the structural element becomes unsafe or unusable.

Under conditions where a long life is necessary and it has been determined that moisture is present, it is recommended that wood be preservatively treated with a pressure-impregnated chemical. Such treatments have been shown to extend the life of wood products by manyfold over that obtained if left untreated. Standards for preservative treatment are published by the American Wood-Preservers’ Association (AWPA 1989), and detailed information on wood preservation is given in the Wood Handbook (USDA 1987).

Fire Protection

Fire protection, which involves life and property, encompasses the design of all materials in the entire structure, not just the structural wood elements. Fire protection includes preventing ignition, limiting the spread of fire once it has ignited, and providing elements that will maintain a predictable portion of their strength for a finite time. Most applications of structural wood products as effected by fire protection are covered in detail by the building codes. General information on fire protection in wood construction is provided in the Wood Handbook (USDA 1987); information applicable to light-frame structures is also available (Sherwood & Moody 1989).

Concluding Remarks

Available structural wood products have been described. Traditional wood products such as lumber and plywood are being supplemented by new products such as structural composite lumber and structural flakeboard. Prefabricated wood products such as glulam timber, trusses, and I-joists are available to support loads over long spans. All these products are a response to a changing timber resource and a demand for products that meet specific end-use performance requirements.
Appendix—References


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