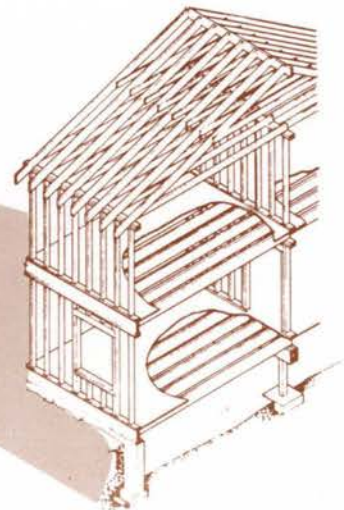
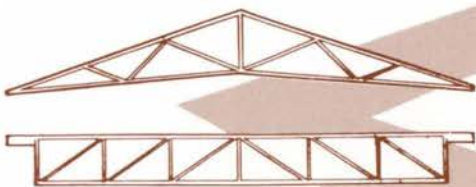
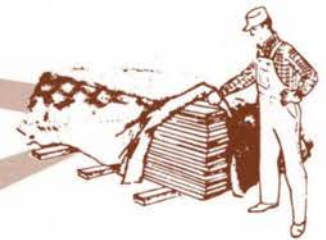


WOOD IN LIGHT FRAME CONSTRUCTION



RESEARCH REPORT 89-1

Research Report 89-1

WOOD IN LIGHT-FRAME CONSTRUCTION

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WOOD IN LIGHT-FRAME CONSTRUCTION

INTRODUCTION TO LIGHT-FRAME CONSTRUCTION

Light-frame wood construction utilizes nearly *half* of all the softwood produced in the United States. Originally, light-frame construction was defined as buildings with wood stud walls, floor joists, and joist and rafter roofs, and now includes manufactured components such as engineered trusses and panelized structural elements. Many wood products have been developed through the years to satisfy specific functions for homes and other light-frame wood buildings. In earlier days, where forests were abundant, homes were usually built with unprocessed hand-hewed logs and rough timbers. Light-frame construction began to appear around 1600, with the introduction of sawmills which could produce lumber and boards from logs, and is still used in one form or another today.

With the tremendous supply of timber and the many tree species available, there appeared to be an abundance of wood, and little thought was given to innovative ideas to conserve the supply and use the material efficiently. Some foresters and planners still predict an unlimited supply of timber, using modern forestry practices.

Wood is commonly separated into "hardwoods" and "softwoods", with some hardwoods being "softer" than some softwoods and vice versa. For instance, silver maple, a rather soft-textured wood, is in the hardwood classification, and longleaf pine, an extremely hard wood, is in the softwood classification. Generally, the common terminology separates the hardwood species, which lose their leaves in the fall, from the softwoods, which may retain their needles for years. Of course there are exceptions to this rule. There are many botanical differences between the hardwoods and softwoods, but they are not covered here because there are abundant references available for those who want to pursue the subject further.

The hardwoods generally grow in forests with a mixture of species, primarily through the middle and eastern sections of the country and up into New England. The oaks, hickories, tulip poplar, maples, etc., are examples of the hardwood group. The softwoods often grow in forests of a single species and are found in the northeastern and southern parts of the country and in the Pacific Northwest. Figure 1 is a map of the U.S. roughly outlining the areas of forest production. There are exceptions where hardwoods grow in the softwood regions and vice versa.

This publication will deal primarily with the structural species of softwoods and more specifically with the species that are used in light-frame construction.

It should be noted that the characteristics of the available wood are gradually changing. The virgin forests have been nearly consumed or are no longer accessible, thereby bringing about marked changes in wood utilization. For instance, wood species not generally used in earlier light-frame construction have entered the marketplace. They are not inferior species, but their use often requires more attention to their physical and mechanical properties, such as bending and tensile values, kiln drying and preservative treatment schedules, and modifications to the fastener calculations.

More efficient approaches to harvesting, processing, handling and end-use considerations have appeared. An example would be the active research in developing products made from less commonly used commercial species and from residues from processing plants. The introduction of non-veneered structural sheathing panels falls into this category. These newer panels are now replacing plywood as a sheathing material, just as plywood replaced board sheathing in the past.

Another example of more efficient use of the available timber supply is improved lumber grading techniques, such as machine-grading, and improved design procedures for engineered wood construction. The engineered wood truss, based on stress-rated lumber and computerized design, uses 30% less material than conventional joist and rafter systems.

Until recently, light-frame construction has made only limited use of analytical engineering procedures. "Rules of thumb" were generally the easiest to apply to the many design situations faced by the architect or builder. Even today, designers of light-frame wood structures should realize that many practices and customs, not necessarily of an engineering nature, still play an important role. The presence of many pieces of framing, inter-connected with sheathing materials and fasteners, can make a light-frame wood structure more complicated to analyze than a 10-story office building! Consequently, designers often use a mixture of rules of thumb and analytic methods.

In current practice, there is a mixture of sophisticated engineered structural components with what is commonly referred to as conventional or stick-built construction. For instance, long-span, computer-analyzed floor trusses, carefully designed and fabricated, are often set on wall plates that have not been designed to

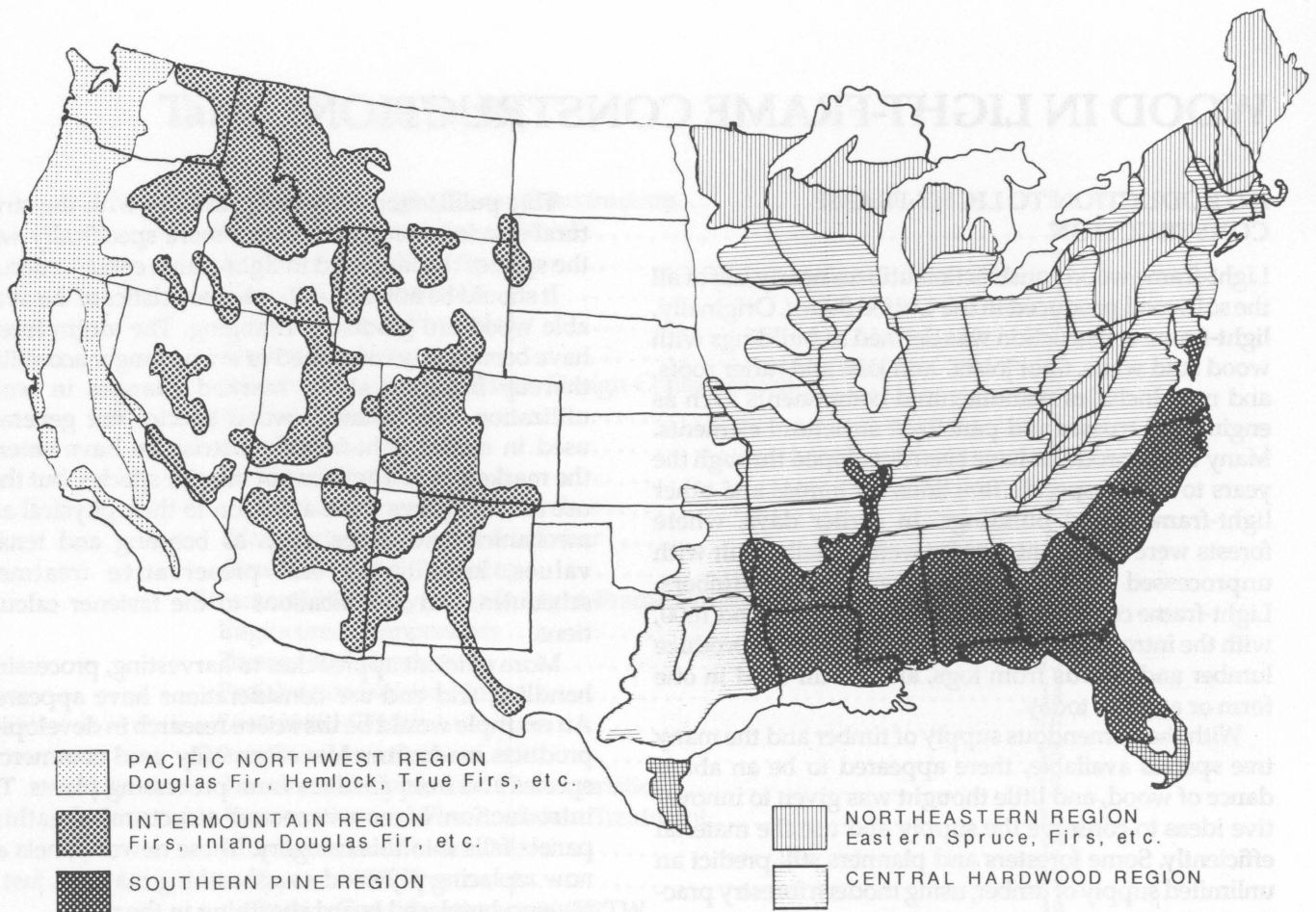


Figure 1. Forest regions of the United States.

meet the bearing forces created by the trusses. A typical 2x4 Engelmann spruce wall stud would not meet the standard design requirements for supporting the end of a 40-foot, clear-span roof truss with a design load of 50 pounds per square foot, but is often used for that purpose. Another example is an engineered garage door header, designed to carry one end of eight of these 40-foot roof trusses, which is supported at the ends by a doubled 2x4 column made with standard grade lumber. The reason for this inconsistency is that, in practice, a stud does not typically fail when assembled in a frame wall even though it may have a low compression value.

This practice of combining engineering with custom has evolved because "everyone knows it works," and it has performed well. However, designers must remember that this process only functions when designing buildings that fit the shorter-span experience-base of light wood framing. Otherwise "real" engineering is required.

Special Characteristics of Wood

Many wood products have characteristics which fit well in homes and other light-frame structures. These

products include lumber, sheathing, wall paneling, trim, flooring, siding, and decorative hardwood veneers, to name a few.

Wood has a number of desirable properties: 1) it is a good insulator of electricity, sound, and heat; 2) it is easily cut and machined; 3) it can be assembled into large laminated beams and columns with adhesives; 4) it is easily fastened with nails, screws, bolts, and pressed-in metal truss plates; 5) it is paintable and will not rust or corrode; 6) it exhibits varying degrees of resistance to chemicals such as strong acids and alkalis; and 7) its durability can be extended with wood preservatives and fire-retardants. In addition, wood has a remarkable strength-to-weight ratio and is particularly efficient for horizontal structural members. Most important for the future, the supply of wood can be unlimited with correct forest management and planning.

Wood does have some limitations. Everyone knows that wood will burn, but attention to construction methods and other considerations can lower the risks of fire damage. For instance, the installation of fire stops, covering the framing with gypsum drywall, and separating the wood from high heat sources such as fur-

naces, wood burning stoves, and fireplaces can lower the potential hazard. Additionally, large dimensioned beams and timbers have a good record in fires. The outer surfaces become charred, which insulates the remainder of the section from the heat of the fire.

Another important limitation is the characteristic ability of wood to absorb moisture from or lose moisture to its environment. This is known as hygroscopicity. At high moisture levels, spores of wood-destroying fungi become active and attack the wood. By maintaining lower humidity levels, decay spores cannot become active. The use of preservative chemicals can protect wood from decay in high-moisture environments.

Various types of insects, such as carpenter ants, powder post beetles, old house borers, and termites can attack wood, but in various degrees. Termites are of special concern because they consume the major component of the wood structure—the cellulose. Familiarity with the habits and characteristics of these insects can assist the designer and builder in reducing the probability of attack. Using proper construction practices and approved termite control procedures definitely improves the long-term performance of wood structures.

Differences in Wood Species

Since the introduction of engineering principles to light-frame construction, designers, engineers, and builders are challenged to learn more about the differences in wood species, which includes the physical and mechanical properties. This would seem to be an unnecessary task, but in light of the current blame-assigning legal environment, it is necessary for designers to know the technology of the products and materials they are specifying.

Wood grows in an almost unlimited number of species with an extensive variation of physical, mechanical, and chemical properties, and with different strength, stiffness, and chemical treatment characteristics. This large selection of species with varying properties places an additional responsibility on the designer of engineered wood construction. The designer must select the most efficient materials to match the end-use and long-term service requirements with the physical and mechanical properties. This requires an understanding of the variations between species, as well as within any given species, to provide satisfactory results.

For instance, to build a satisfactory residential floor at a competitive price, one cannot merely go to a building material supplier and order a number of 2x8 floor joists to build a moderately long-span floor. The designer must consider the strength and stiffness properties of the wood species, the span of the floor between supports, the building code requirements for the loads that might be expected on the floor, the type and support

spacing specifications of the subflooring and flooring materials, and the environmental conditions where the joists are to be used. All of these factors are important for a satisfactory floor.

The common structural softwood species used to manufacture floor joists are: Douglas fir, Western hemlock, Southern pine, mixtures of spruces, pines and firs, and mixtures of Douglas fir and larch. In some areas of the country, mixed hardwoods, such as the oaks, yellow poplar, etc., are used to a minor degree.

Growth Characteristics

All species grow by adding wood in the form of rings just under the bark layers. This growing ring of cells divides and adds wood cells toward the inside. Each year the tree adds a complete ring, consisting of the portion grown in the spring or early part of the growing season and a portion grown in the summer or early fall. The spring or early growth portions grow faster and contain less wood substance than the summer or late wood growth. This can readily be seen by examining the end-grain of a piece of lumber. The darker, more dense part of the ring was grown in the later stages. Figure 2 shows a piece of wood with several labeled parts: the pith or center of the tree; the growth rings, showing the early and late wood; the heartwood; the sapwood or outer rings of the stem; and the longitudinal, tangential, and radial orientation directions, which are important to the mechanical properties of the wood.

Some of these characteristics become important to such people as the grader of structural lumber, the manufacturer of radially cut wood siding, or the preservative wood treater. The number of rings per inch and proportion of early wood to late wood enter into

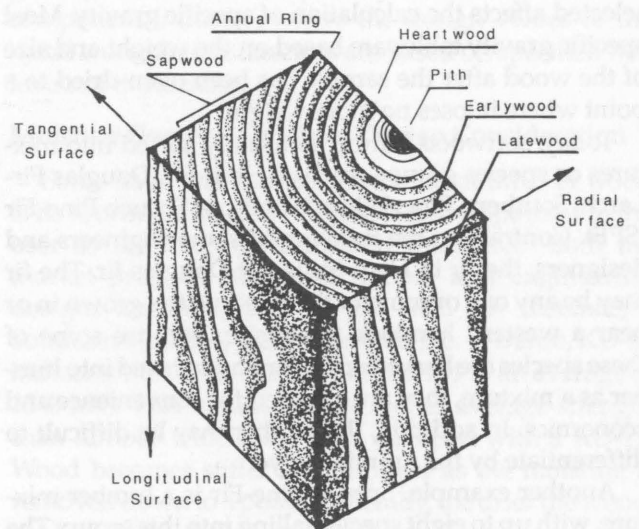


Figure 2. Block of wood showing some of the more easily recognizable features.

the grading rules of structural lumbers. Radially sawn siding has been preferred because it is less susceptible to splitting and cracking. For the wood treater, the amount of heartwood is considered in the specifications for lumber going into preservative-treated wood foundations. Heartwood in some species is very difficult or impossible to treat properly because the heartwood portion consists of wood cells which are filled with extractives, resins, and other types of deposits during growth.

Other physical properties important to the end use of the material, but which cannot be shown in the sketch, are moisture content, density, and specific gravity (sp.gr.). Variations between species (and even variation within a species) have a strong influence on the mechanical properties. Growth characteristics, such as grain slope, checks, knots, knot-holes, the orientation of the grain around a knot, and decay, are considered as strength-reducing characteristics and are part of the grading rules.

Textbooks and articles pertaining to the strength of wood will often refer to density and specific gravity, which are two characteristics used to indicate the amount of wood substance present in a sample. Generally, the higher the specific gravity, the stronger the wood. For example, a sample of longleaf pine may have a specific gravity of 0.54 while white spruce may be 0.35. This indicates the longleaf pine has more density or more wood substance than the white spruce. The cells in the pine sample are thicker and contain a larger proportion of summer wood than might be found in the white spruce.

The specific gravity of a sample of wood can be determined by dividing the weight of a specified volume of wood by the weight of an equal volume of water. The moisture content of the wood at the time the sample was selected affects the calculation of specific gravity. Most specific gravity tables are based on the weight and size of the wood after the sample has been oven-dried to a point where it loses no more weight.

Today, softwood lumber is usually sorted into mixtures or species groups, such as Hem-Fir, Douglas Fir-Larch, Southern Pine, White Woods, or Spruce-Pine-Fir (SPF). Contrary to the thinking of some engineers and designers, the fir in Hem-Fir is not Douglas fir. The fir may be any one or more of the five true firs grown in or near a western hemlock forest site. Because some of these species are harvested and manufactured into lumber as a mixture, they are grouped for convenience and economics. In addition, the lumber may be difficult to differentiate by the untrained eye.

Another example, Spruce-Pine-Fir is a lumber mixture, with up to eight species falling into this group. The mechanical and physical properties of these species will vary. For instance, some species are very difficult to treat

with preservatives and fire-retardants. Consequently, when a truss fabricator sends an order of truss lumber to be treated, having a knowledge of the treatability of each species would be recommended for satisfactory results. Single species, such as western hemlock in the mix Hem-Fir or lodgepole pine in the species mix SPF, can be purchased separately, but the process will increase the cost. A beam laminator, for example, might require a certain tension value for his beams and therefore choose western hemlock for that particular property. However, when this western hemlock is sold as Hem-Fir, the tension value for this combination of species carries the slightly lower values of the true firs which make up part of this mixture.

Each wood-producing area of the country will be concerned with the species differences in various ways. Wood or wood products as we know them, come from a large number of species. Some are of more commercial importance than others and have found their way into the marketplace because of a particular physical or mechanical property. Douglas fir and Southern Pine, for example, are valued for their structural capabilities; black walnut and hard maple for furniture and paneling; and aspen for manufacture of structural panels. Demand for any particular species has strongly influenced the forestry practices in most wood-producing regions.

The western part of the country will be concerned primarily with Douglas fir, larch, western hemlock, the true firs, spruces, western pine, etc.; the northeastern region with the eastern species of firs, hemlock, etc., and the southern portion with the Southern Pines, of which there are four important species, longleaf, loblolly, slash, and shortleaf. These four species are grouped and designated Southern Pine, similar to the grouping of Hem-Fir and SPF. It should be pointed out that longleaf pine, which may come from Alabama, will often have different properties than shortleaf pine grown in Arkansas. The grading procedures usually take care of these differences; however, the designer should realize that the differences in species and where the trees are grown can have an effect on the average physical and mechanical properties.

Wood-Moisture Physiology

Because wood is a natural organic material, it is sensitive to moisture vapor and water in its environment. It shrinks when exposed to a dry environment and swells when exposed to high humidities or water. The relationship between wood and moisture has been known since wood was first used in construction, but because of the persistent number of problems reported, a brief review of moisture content (MC) is appropriate.

As the tree grows, it stores water brought up from the root system. The cells of the wood, which are more or

less cube-shaped units, absorb the water in the cellulose portion and into the cavities of the cells. This cavity water is known as free water. When the tree is cut, the sapwood of some species may be as high as 200% MC. Others may exhibit a MC in the range of 40% to 80%. All are known as "green" wood (not to be confused with the preservative-treated, green-colored wood now commonly used for outside porches, decks, and wood foundations).

As the wood dries, the free water is the first to migrate to the outer surfaces and the surrounding atmosphere. This process is gradual, with the water passing from one cell to another toward the surface. Obviously, the outer surfaces lose water faster than the center portions which are still wet. Wood technologists refer to this MC variation as a gradient. Eventually, under recommended drying conditions, the MC reaches an equal level throughout the piece.

Drying procedures have been developed (for most species) to remove the water with the least amount of shrinkage and stress damage. Most "conditioned" wood is processed in drying kilns to practical levels of moisture content, or to some specified average, as the marketplace dictates. Wood can be dried to a point that the only water left is the water retained as part of the chemical makeup of the material (known as water of constitution). In practice, wood is not dried to this extent. Structural lumber is rarely dried to an average moisture content of less than 8-12%. Even when dried to this low level, when the lumber is removed from the drying kiln it will eventually stabilize at an equilibrium MC with the surrounding atmosphere.

It is common practice to relate the MC of a sample of wood at the time it was obtained to the weight of that sample after it has been dried until there is no further weight loss. This is an expression of the ratio of its original weight to its weight after drying. The drying process is done in an oven at about 212°F, for about 48 hours or until the sample no longer loses weight. This method is used primarily for precise laboratory calculations and is rarely found in commercial processes:

$$MC = \frac{\text{original weight} - \text{oven-dry weight}}{\text{oven-dry weight}} \times 100$$

Commercial drying operations will generally use sample pieces scattered throughout the kiln and weighed periodically to monitor the changing moisture content as the drying process continues.

MC can also be measured with electric-resistance moisture meters for quicker determination. The accuracy is nearly equal to the oven-drying method—at least within one percentage point of the true value. For most construction applications, the moisture meter is satisfactory. The temperature of the wood and the species will have some effect, but most meters include tables to make adjustments. The moisture meter is used

by wood products manufacturers to sample incoming lumber or panel products. Certain manufactured wood products require carefully controlled moisture content of the wood being used to produce a quality end product.

Drying Considerations

Reducing the moisture in wood is best achieved by kiln-drying—an important process which has evolved to meet the more specific requirements of various wood-using industries. The manufacturers of high quality pianos or hardwood flooring cannot produce quality products without carefully kiln-dried wood. In construction, most lumber is kiln-dried to reduce the transportation weight, to reduce shrinkage problems once the structure has been completed, and to take advantage of the increased allowable stress values given to drier material. It is interesting to note that wood does not begin to shrink until the MC has been reduced to about 30%. From this level on down, shrinkage occurs as a straight line function; that is, a fixed percentage of shrinkage with each percentage loss in MC. Today, most construction lumber is kiln-dried to levels between 15% and 19%. There may be a moisture content designation in the grade stamp on lumber, such as: *MC-15*, *KD-15*, or *KD-19* (kiln-dried to 15% or 19%), or *S-dry* or *dry-19* (kiln-dried to 19%). These indicate the level of MC as the lumber is removed from the kiln. There are still areas of the country, mostly in the extreme western parts, where "green" lumber is preferred by the carpenters for one reason or another. In this case, the grade stamp would have the notation of *S-grn*, meaning the lumber had been dressed or run through the planer in the "green" MC range; that is over 19%. This practice is gradually changing due to the increasing use of engineered construction, especially in the structural wood component industry, where the design values of the metal truss plate connectors are based on specified MC levels of the lumber.

Moisture Content—A Major Design Consideration

Some have said the moisture content (MC) of wood is its fourth dimension because it is as important to the user as the length, width, and thickness. Both the market price of structural lumber and engineering designs are influenced by the MC. For instance, a Southern Pine 2x4, grade-stamped No. 1, Dense, KD-15 indicates the wood has been kiln dried to an average of 15% MC. This would have a higher average strength than lumber which had been stamped with a KD-19. Wood becomes stiffer and stronger as the moisture is removed down to a point. Generally, the drier the wood, the higher the design stress values.

Moisture content becomes important when fasteners are put into wood with a high MC and then the com-

pleted component used in a dry environment. Shrinkage occurs in the dry atmosphere and can cause loosening of the fasteners. On the other hand, when dry wood is used in an environment of high humidity, the MC rises and can reach levels where decay spores become active.

It is not uncommon to find moisture-related problems when the builder has neglected to install a ground cover in a crawl-space house. In housing locations where the crawl-space foundation is popular, and where there is a high amount of ground moisture present, improper design can cause the humidity in the crawl-space to reach levels sufficiently high to affect the wood floor joists or trusses and the subflooring. This moisture can also pass on up into the house and even affect the roof-framing and sheathing. Understanding the wood moisture relationship can reduce the vulnerability of the floor framing and subfloor to swelling, shrinkage, and decay problems. Building the house at safe levels above the ground line, providing good drainage patterns, and installing a ground cover in the crawl space are three provisions of construction which lower the risks of problems.

SPECIFIC PRODUCTS

Lumber

More than half of all the trees harvested come to the marketplace as lumber for construction. Because of the trend toward structural components, engineered light-frame structures, and end-use performance, this discussion will deal mainly with dimension lumber. Dimension lumber is material in the thickness range of 2 inches (nominal) up to, but not including, 5 inches in thickness. The other two broad categories of lumber size include boards (up to 2 inches in thickness), and timber, (5 inches or more in thickness). A length of 2x6, kiln-dried and planed (surfaced) at a MC of 15%, for example, will have an actual size of $1\frac{1}{2}$ inches x $5\frac{1}{2}$ inches; a 2x4, kiln-dried and planed at a MC of 19%, will have an actual size of $1\frac{1}{2}$ inches x $3\frac{1}{2}$ inches; and a 2x10, kiln-dried and planed at 17% MC will have an actual size of $1\frac{1}{2}$ inches x $9\frac{1}{4}$ inches. The fact that actual lumber sizes do not match their size names may seem to be a conflict of terminology to those unfamiliar with the lumber industry, so grade rule books emphasize the term nominal size.

Historically, dimension lumber was originally produced in actual sizes of around 2" x 4" and 2" x 6", etc.; therefore, these common terms became established. Because lumber wholesalers handled material from more than one producer, uniformity in sizes became important. This demand for standardized sizes brought about changes in lumber manufacturing to achieve smoother surfaces and a more uniform product. In ad-

dition, a nominal 2x4 may be found in the marketplace as rough sawn in the "green" or high MC condition or surfaced in the "dry" condition. Each will have a different size, but will be called a 2x4. As a point of interest, people in some countries using metric measurements use the term 2x4. It is more convenient to call a metric 8-foot stud a 2x4 stud, than a 38mm x 89mm x 2.44 meter piece of lumber.

Lumber standardization became significant in 1924 with the organization of the American Lumber Standards Committee, authorized by the United States Department of Commerce. This committee deals with lumber sizes and grading and reevaluates specifications as new research information and market requirements enter the picture. The committee is made up of members representing manufacturers, distributors, and users of lumber. From the work of this committee, grading specifications are developed by the separate lumber associations representing producers. These associations have cooperated in developing the National Grading

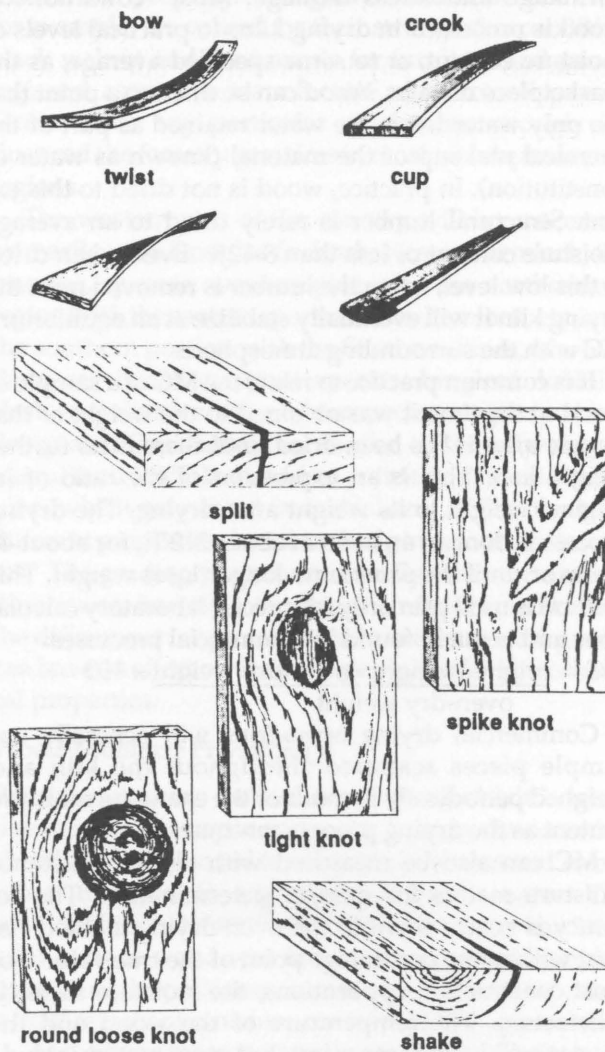


Figure 3. Various types of warping and wood defects.

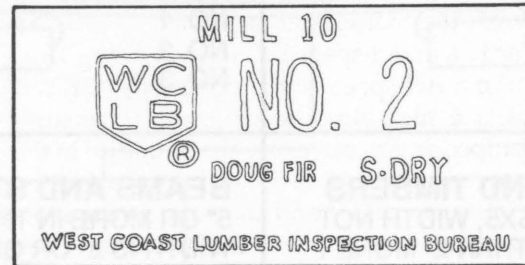
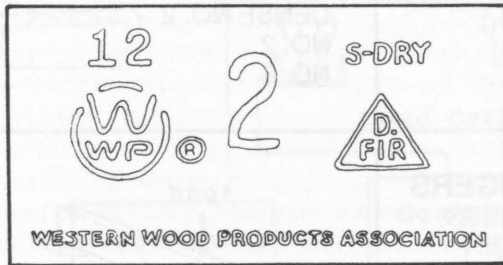
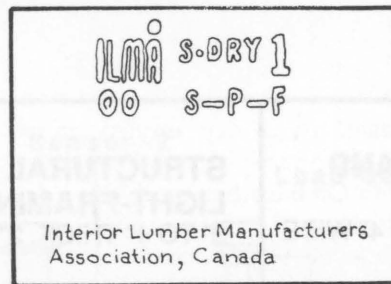
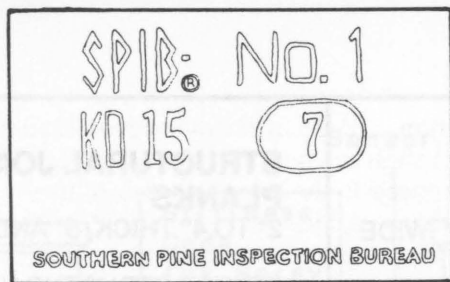


Figure 4. Samples of visual grading stamps used on lumber.

Rule for Softwood Dimension Lumber: Product Standard 20-70. This rule incorporates a common classification for grades, terminology, sizes, and moisture content. The rules are similar for all graded lumber, regardless of the physical properties, but each region then uses stress and stiffness ratings in their grade book for the species within their jurisdiction.

Lumber is graded today by two methods: visual inspection and machine stress rating (MSR). Most structural lumber is graded by visual inspection, but with the growing emphasis on engineered structures, MSR has entered the marketplace, especially for glue-laminated beams, light-frame wood trusses, and prefabricated wood I joists.

Visual Grading

Visual grading separates the lumber into the various grades by using the grade book limitations on defects and natural growth characteristics which may limit strength and stiffness. Several manufacturing characteristics are also limited by the grade rules. The grading specifications have evolved through knowledge of past performance of lumber and research on lumber properties. Certain strength- and stiffness-reducing characteristics, such as knot sizes, knot location, splits and checks, bowing and warping from the drying process, and wane are some of the things the grader considers. Figure 3 shows a few sample defects and warping types.

Lumber graders are certified by the various grading agencies. They are periodically checked by the agencies as well as up-dated and instructed on changes in the grading rules. Visual grading rules incorporate specifications which allow separating lumber into three broad categories: shop/factory lumber, yard lumber, and structural lumber. Factory lumber is usually remanufactured for other wood products such as ladder stock, window and cabinet parts, etc. Yard lumber

is intended for general construction purposes, such as exterior walls and partitions, framing around rough wall openings, wall plates, etc. It does not necessarily meet the requirements for stress-rated structural lumber, but has performed satisfactorily for years in wood-frame structures. Structural lumber, on the other hand, is sorted and graded for engineered construction and structural components. These grades carry specific design values. Examples would be lumber grade-stamped with *No. 1, D. fir-Larch, S-Dry*, or *No. 2, Dn, KD, SP* (see Figure 4).

The procedures for determining the design values are developed through Committee D-7, Wood, of the American Society for Testing and Materials (ASTM), and are contained in standards D-245 and D-2555. This information is then incorporated in the National Design Specification for Wood Construction (NDS), and its supplement. NDS is under the jurisdiction of the National Forest Products Association. The supplement lists the allowable design values for the important commercial wood species as developed by the various lumber-grading associations.

Industry grading associations have assigned names to the various sizes of lumber in the following divisions: 1) Light-framing and Studs, 2) Structural Light-framing, 3) Structural Joists and Planks, 4) Beams and Stringers, and 5) Posts and Timbers. The division on Light-framing includes 2x4 and 4x4 lumber, which is sorted into several grades, depending on the defects present in the pieces. The grade names *Construction, Standard, Utility, Economy, and Stud* are found in this group. The division on Structural Light-framing also includes 2x4's and 4x4's, but they are stress-rated and stamped either *Select Structural, No. 1, No. 2, or No. 3*. MSR lumber will be identified with a stamp indicating the allowable bending stress and the stiffness value, such as *MSR, 1650f-1.5E*. The division of Structural Joists and Planks

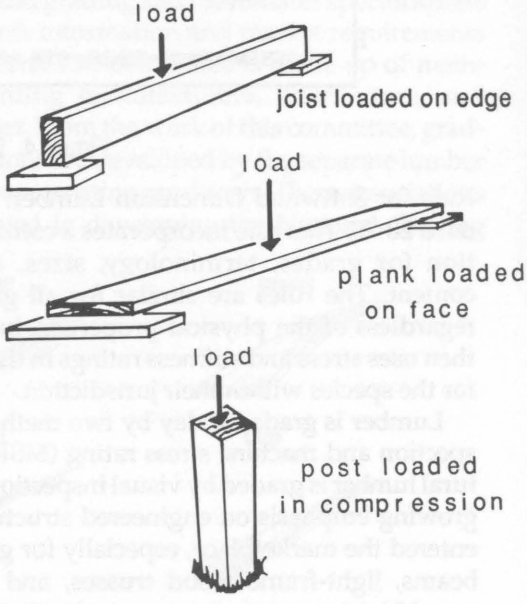
<p>LIGHT-FRAMING AND STUDS 2" TO 4" THICK, 2" TO 4" WIDE</p> <p>CONSTRUCTION STANDARD UTILITY ECONOMY STUD</p>	<p>STRUCTURAL LIGHT-FRAMING 2" TO 4" THICK, 2" TO 4" WIDE</p> <p>SELECT STRUCTURAL DENSE NO. 1 NO. 1 NO. 2 NO. 3</p>	<p>STRUCTURAL JOISTS AND PLANKS 2" TO 4" THICK, 5" AND WIDER</p> <p>SELECT STRUCTURAL NO. 1 DENSE NO. 2 NO. 2 NO. 3</p>
<p>POSTS AND TIMBERS AT LEAST 5X5, WIDTH NOT GREATER THAN 2" MORE THAN THE THICKNESS</p> <p>SELECT STRUCTURAL NO. 1 NO. 2 NO. 3</p>	<p>BEAMS AND STRINGERS 5" OR MORE IN THICKNESS, WIDTH IS 2" OR GREATER THAN THE THICKNESS</p> <p>SELECT STRUCTURAL NO. 1 NO. 2 NO. 3</p>	 <p>load joist loaded on edge</p> <p>load plank loaded on face</p> <p>load post loaded in compression</p>
<p>SOME IMPORTANT ENGINEERING PROPERTIES</p> <p>MOR - Modulus Of Rupture MOE - Modulus Of Elasticity F_t - Tension parallel to the grain F_v - Horizontal shear F_c - Compression parallel to the grain $F_{c\perp}$ - Compression perpendicular to the grain F_b - Extreme fiber in bending</p>		

Table 1. A sampling of softwood lumber grade designations

includes lumber 2 inches in thickness by 5 inches and wider, such as 2x8 and 2x10. Another division, Beams and Stringers, is classified as members 5 inches or more in thickness with the width more than 2 inches greater than the thickness, such as a 6x10. Post and Timbers are classified as members 5 inches x 5 inches and larger, with the width not more than 2 inches greater than the thickness, such as an 8x8 or 8x10. A sampling of grades for the various groups is shown in Table 1. Additional grades may be found in the various grade rules.

Machine-Stress-Rated Lumber

Structural lumber is also sorted by machine, (MSR), which measures the elastic or stiffness characteristics of the lumber. Because there is a known relationship between the stiffness and strength properties of wood, lumber can be evaluated for strength by measuring the stiffness. The machine is a valuable tool in the grading process because it permits more efficient use of lumber by classifying the material more precisely within each

grade designation—a more refined grading system.

There are several machine types in use today: the Continuous Lumber Tester (CLT), the Stress-O-Matic (SOM), the Computermatic (CM), etc. Using the CLT to illustrate the process (see Figure 5), the piece of lumber is passed through the machine, where a deflection is imposed on the wide face and the load causing the deflection is measured. The computer in the machine records the average and minimum elasticity values of that piece. As it leaves the machine, an identification mark is put on the lumber to indicate to the visual grader the stiffness of that piece. The grader then visually inspects the piece for strength-reducing characteristics and stamps it with the appropriate grade. The result is lumber that is grouped more closely to the average stiffness with a more uniform distribution within each designated grade. This becomes important in the design and end-use of structural components, especially for floor trusses where the stiffness characteristics between adjoining trusses should be similar.

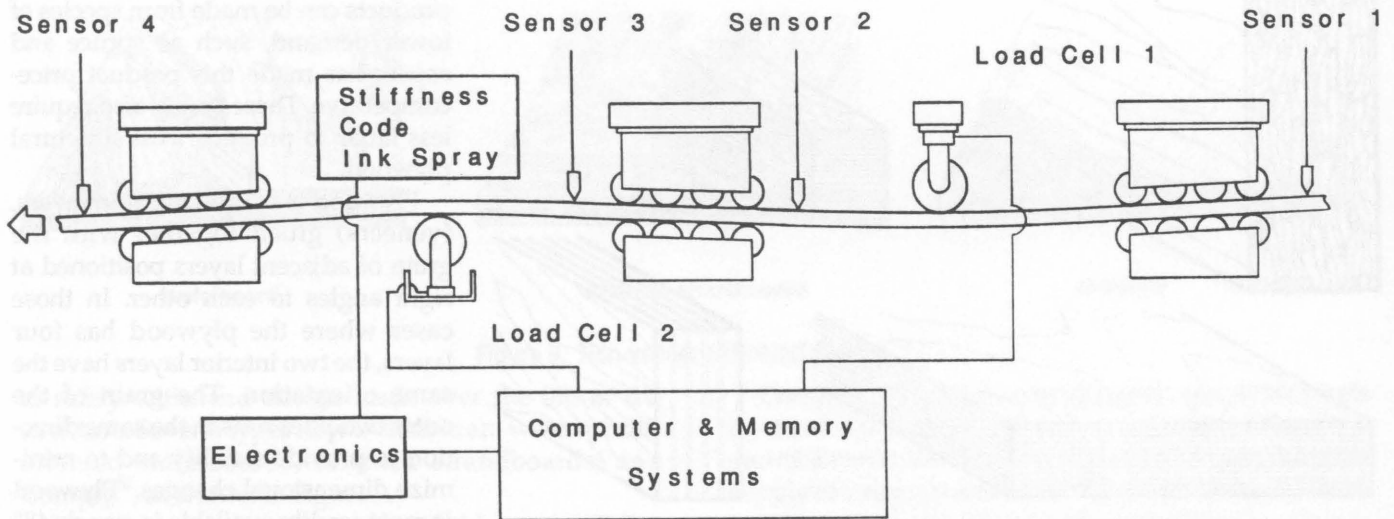


Figure 5. Diagrammatic representation of one of the more popular machine stress-rating systems used in North America.

The design engineer or architect can specify the bending stress (F_b) and modulus of elasticity (E) which are included in the grade stamp of MSR lumber. Each grading agency has developed combinations of F_b and E for the species under their jurisdiction. For instance, the combination 1500 f-1.3E can be found only in the Southern Pine grade book. However, the combination 1650 f-1.5E can be found in all four of the grade books: NLGA of Canada, WCLIB, SPIB, and WWPA. The f-E combinations common to all of the grade specifications for MSR lumber are:

1200 f - 1.2E	2100 f - 1.8E
1500 f - 1.4E	2250 f - 1.9E
1650 f - 1.5E	2400 f - 2.0E
1800 f - 1.6E	2700 f - 2.2E

Other grade designations can be found in Table 4B of the National Design Specification Supplement. These other combinations have been developed to more effi-

ciently fit the lumber produced in a given area or forest site. The use of MSR lumber will increase to meet the evolving changes in engineered structures and to meet the increasing demand for certification and quality control of products in the marketplace. Figure 6 shows a sampling of MSR grade stamps.

Manufactured Structural Lumber

Also entering the marketplace are lumber-type products such as parallel-strand lumber and laminated veneer lumber (LVL) (also called structural composite lumber), a structural material laminated from veneer or pieces of veneer, to form planks or panels which can be sawn to standard dimensions. These products have shown high strength and stiffness properties because the defects in the veneer are randomly distributed during the lay-up of the material. The development of these products evolved to supplement the diminishing

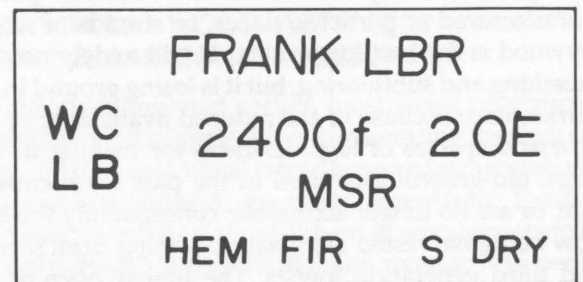
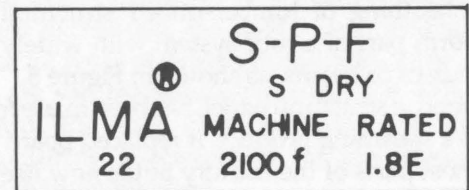
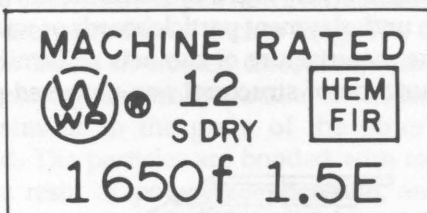


Figure 6. Samples of Machine Stress Rating (MSR) stamps used on lumber.

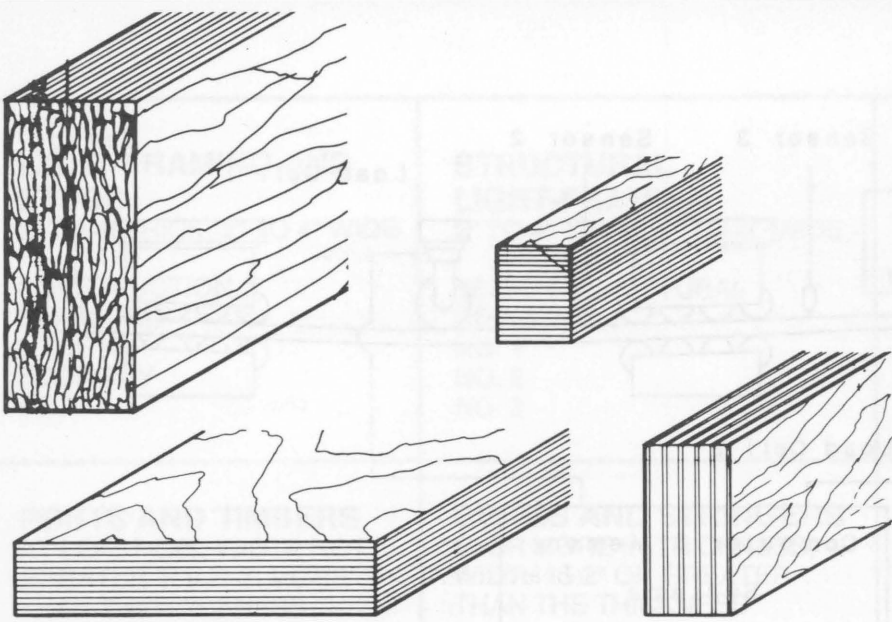


Figure 7. Laminated veneer and parallel-strand lumber.

olome of high-quality raw lumber and the supply of long lengths.

To date, LVL is being used as flanges of plywood web "T" beams, ridge beam girders, engineered scaffolding planks, and other structural products. As the demand grows for more certification of structural components and engineered structures, these "man-made" lumber products will increase in use. Several types of LVL are shown in Figure 7.

Structural Panel Products

Although structural lumber may be the major load carrying component in light-frame construction, structural panels are an integral part of the construction. Structural panels cover at least two groups of products—plywood and structural non-veneered panels. These products are used primarily for sheathing roofs, walls, and floors in light-frame construction. An increasing amount is being used in light-commercial construction as the sheathing of lumber-ribbed structural panels which form part of a roof system with widely spaced wood trusses or beams, as shown in Figure 8.

Plywood, a structural panel, has been in use for many years as a sheathing product. It replaced board sheathing in most parts of the country but is now itself being slowly replaced by structural non-veneered panels manufactured of particles, flakes, or strands of wood. Plywood is the best known and is still widely used as sheathing and subflooring, but it is losing ground in the marketplace because of the reduced availability of the type and species of logs desirable for making it. The large, old-growth logs used in the past are becoming rare, or are no longer accessible; consequently the logs now being harvested are smaller, coming from second and third generation forests. The higher price of the desirable logs, plus the fact that structural panel

products can be made from species of lower demand, such as spruce and aspen, has made this product price-competitive. These panels also require less labor to produce than structural plywood.

Plywood is made with thin layers, (veneers) glued together with the grain of adjacent layers positioned at right angles to each other. In those cases where the plywood has four layers, the two interior layers have the same orientation. The grain of the outer two plies runs in the same direction to provide stability and to minimize dimensional changes. Plywood is most readily available in panels 48" wide and 96" long and is produced in thicknesses from $\frac{1}{4}$ to $\frac{1}{8}$ inches. For $\frac{1}{2}$ -inch, $\frac{5}{8}$ -inch, and $\frac{3}{4}$ -inch panels, the actual thickness can now be $\frac{1}{32}$ -inch less than the nominal thickness. Plywood *type* refers to the durability of the adhesive used to bond the veneers; exterior type for exposures to excessive moisture and free water, and interior type for protected areas. There are four types: Exterior; Exposure I; Exposure II; and Interior. Exterior type is manufactured with phenolic or resorcinol adhesives, which are insoluble in water, and interior type with any one of the water-soluble adhesives. (The major differences refer to the bond durability among the types).

Plywood is also graded to indicate the presence or absence of defects in the surface veneers. Structural grades are usually identified by the veneer grades used in the face and back, or more recently, by the end-use or performance rating for that panel.

The new structural non-veneered panels are entering the sheathing market. These products are not to be confused with underlayment particleboards or with panels used in the manufacture of cabinets or furniture. The primary function of structural non-veneered panels is

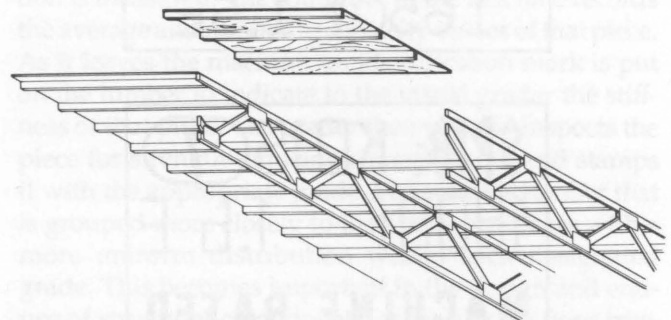
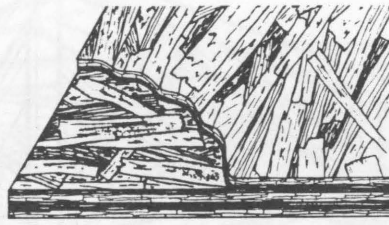


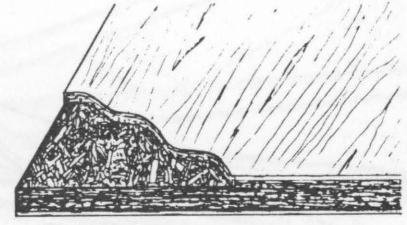
Figure 8. Plywood and purlin roof panels supported by parallel-chord trusses.



waferboard



oriented strand board



comply®

Figure 9. Non-veneer structural panels.

to safely withstand design loads over the life of the structure. Several types now available are waferboards, oriented waferboards, oriented strandboards, and Comply®, as shown in Figure 9.

Waferboard is usually made of thin aspen flakes ranging in size from $1\frac{1}{8}$ inches to 3 inches and having essentially rectangular shapes. The flakes are either randomly positioned or specifically oriented and are bonded with powdered phenolic resins. The assembly is then formed in hot presses to achieve the desired thickness. Panels can be manufactured in sizes up to 16 by 24 feet, and with or without tongue-and-grooved edges. At present, it is produced in thicknesses from $\frac{1}{4}$ -inch to $\frac{3}{4}$ -inch. Some panels have roughened surfaces for increased traction for working on sloped roofs. Waferboard has lower bending strength and stiffness than plywood, but is being widely used in the United States and Canada as a sheathing material, with $\frac{7}{16}$ -inch material being substituted for $\frac{3}{8}$ -inch plywood.

Oriented strandboard (OSB) has been recently developed to increase the strength and stiffness properties of the structural panel products. Elements used to make these panels are long and narrow and are produced in a manner similar to waferboard. The flakes or strands range from $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch in width and from 2 to 3 inches in length; however, at some plants the strands are more than 3 inches long. The strands are placed in layers in crossed directions, with the outer layers running essentially parallel to the length of the panel, similar to the grain of the outer layers in plywood. The particles are bonded with either liquid phenolic resin or powdered phenolics, and are hot-pressed to form the panels. The alignment of strands in a given layer increases the strength, stiffness, and dimensional stability in the direction of the orientation. OSB panels are currently made in thicknesses from $\frac{1}{4}$ -inch to $1\frac{1}{4}$ inches and sizes up to 8 feet by 24 feet. The strength and stiffness properties are nearly the same as plywood for similar thicknesses.

Recently, some waferboard manufacturers have aligned specialized wafers, resulting in an oriented strandboard composition. Such products are marketed as oriented waferboard.

Comply® is also a structural panel made with single layers of veneer, resin-bonded to the outer surfaces of a particleboard core. It has the advantage of stretching the supply of veneer in areas where plywood is made. There are at least two ways to manufacture Comply; one is to produce the particleboard core in one operation and bond the veneer faces to it separately. The other process produces the panel by placing the resin-coated particles on the bottom veneer, covering them with the top veneer and hot-pressing the complete panel in one operation.

As of mid to late 1988, general overall specifications of allowable stresses for structural panels were not available. Acceptance by the various code bodies has been on a company-by-company or proprietary basis. This requires the user to specify the correct product for a particular use and has led to the performance standard concept as promoted by the American Plywood Association (APA). Each product is rated for a particular performance. These rated sheathing specifications are based on the National Evaluation Service, NRB Report No. 108. The APA has developed this end-use performance standard to qualify wood-based panels for the major market applications of roof and wall sheathing and subflooring. As the standard is now written, the levels of performance for each end-use category and, with few exceptions, the methods of testing, are the same for all types of panels. In addition, some plywood panels are still manufactured under the APA Product Standard, PS 1-83. This prescribes the minimum manufacturing requirements for the production of many grades of plywood.

STRUCTURAL WOOD SYSTEMS IN LIGHT-FRAME CONSTRUCTION

As briefly mentioned earlier, most wood construction has evolved from generation to generation through custom, with an occasional introduction of structural components designed to meet specified loading requirements. The state-of-the-art in wood construction has progressed from specification standards to performance standards, or mixtures thereof. For example, specification standards required the use of a specific

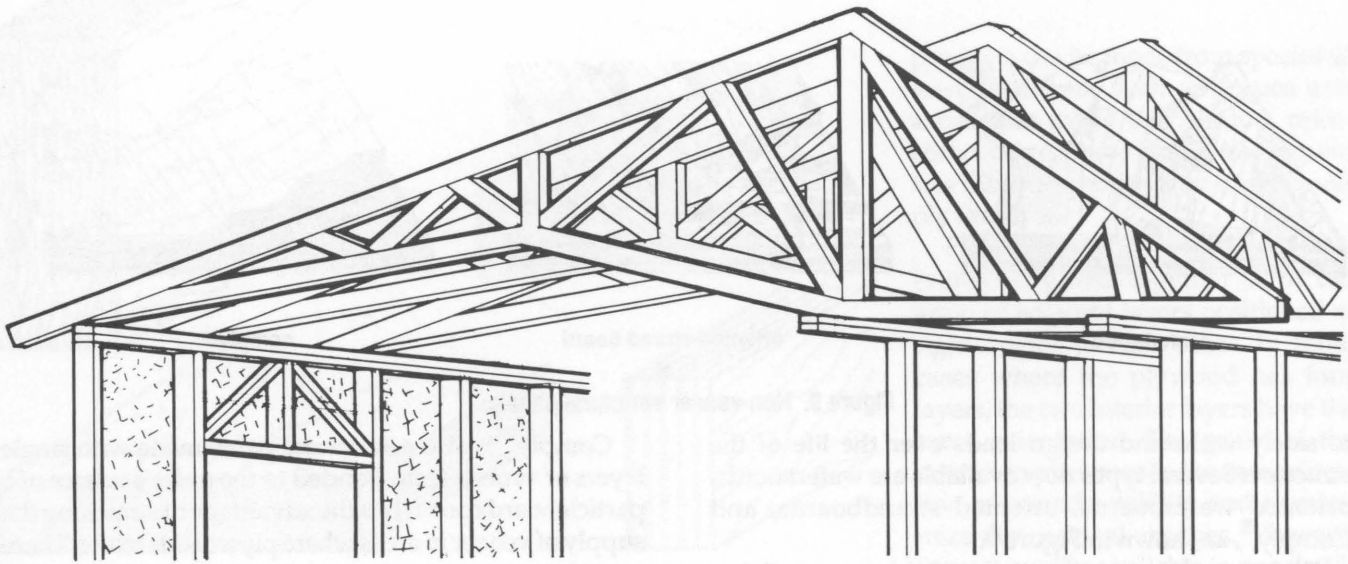


Figure 10. Trussed window lintels and special roof trusses.

size and spacing of floor joists or roof rafters for a given span, the spacing of the studs, or the size of a lintel or header for windows. The sheathing and subfloor coverings were specified by thickness for given spacings of the support framing. By contrast, the performance standards concept entails the design of a system or section of the structure performing as a unit to meet the code requirements.

Engineered Components

Many innovations have been tried, but relatively few have survived. The survivors have done so because they have either cut the overall in-place costs of construction or they have provided methods of spanning greater distances than previously possible. One of the

more popular structural components, the roof truss, has replaced joist-and-rafter construction to such an extent that trusses are now considered by many as the conventional method of roof framing. There are several other engineered components in the light-frame market today: parallel-chord floor and roof trusses, wood "I" beams for floors and roofs, engineered window and garage door headers, laminated ridge beams for post-and-beam construction, engineered wall sections, structural panels designed for specific support spacings, structural lumber substitutes such as LVL, and pressure-treated wood foundations. In addition, preservative-treated poles and posts are used for foundations and structural framing, especially in certain types of light-commercial and farm-building construction.

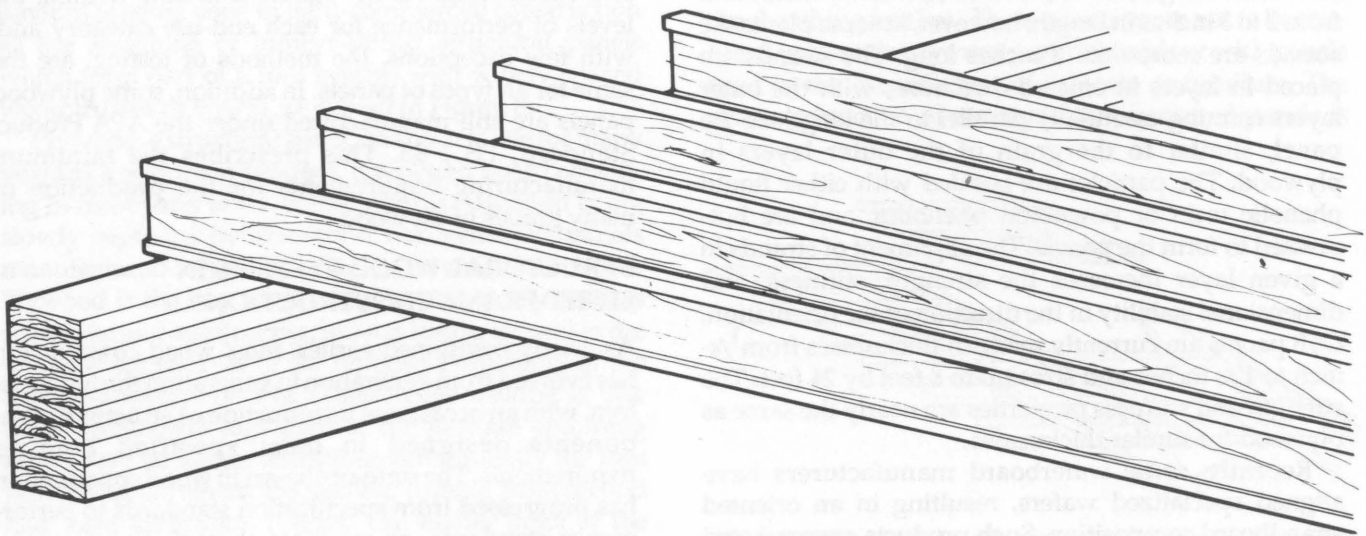


Figure 11. I-joists supported on a laminated girder.

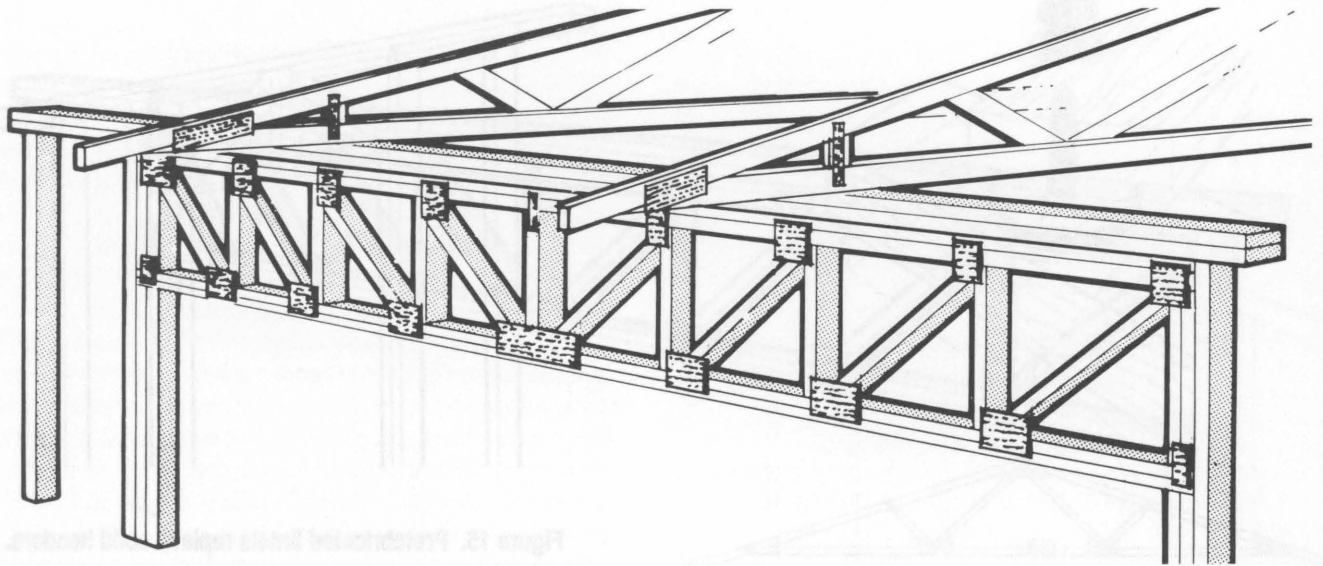


Figure 12. Roof trusses supported on a garage header.

Figures 10-13 show a few examples of structural wood components now found in the marketplace. The development of structural adhesives, innovative fasteners, and modern wood engineering analysis has opened the door to the design and use of very sophisticated structural systems.

Trusses and Headers

A variety of truss forms have been used for many years, including larger timbers connected by bolts and split-ring connectors and dimension-lumber trusses with nails and spikes. Most of these heavy trusses were used in larger buildings and structures not necessarily considered light-framing. Many reasons can be cited, but the wood truss as we know it today generally came

about because of the high demand for housing in the late 1940's. There was a logical progression of light-frame truss connectors from nails to split-ring connectors, to nailed and glued plywood gussets, to the present widespread use of structurally designed toothed metal connector plates, as shown in Figure 14.

Without question, the now-common metal-plate-connected roof truss has made the greatest impact in light-frame construction. It is estimated that roof truss systems are used in at least 80% of today's light-frame construction. This is primarily because less material is used, erection time and field labor are reduced, code design specifications can be met, and long clear spans are possible.

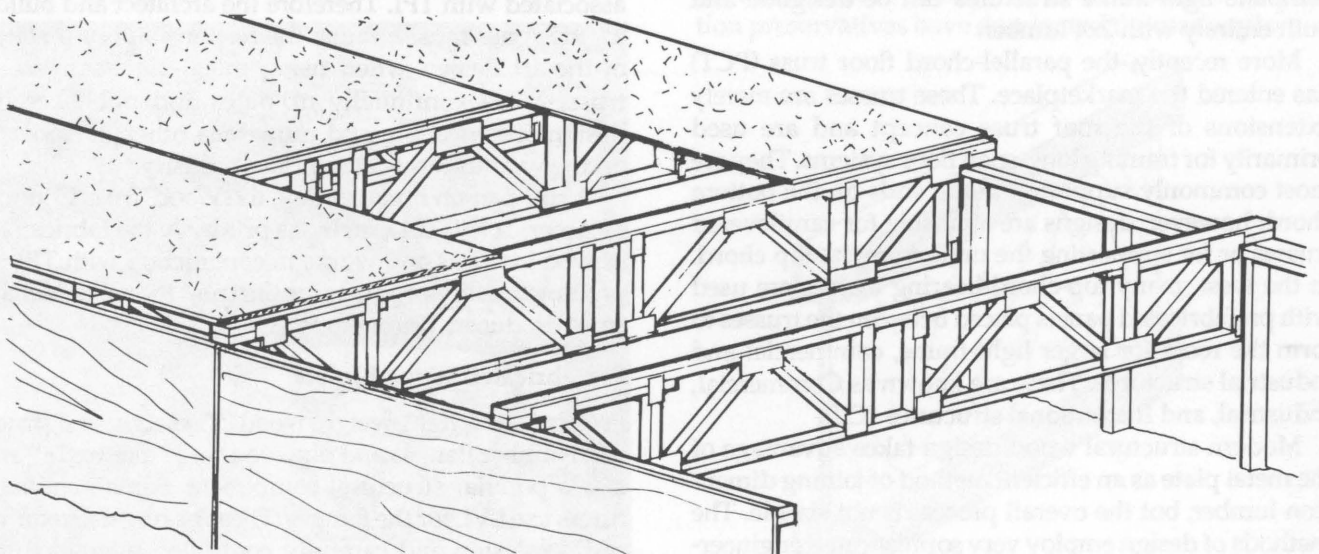


Figure 13. Treated wood foundations, floor trusses, and non-veneered subfloor panels are typical manufactured components.

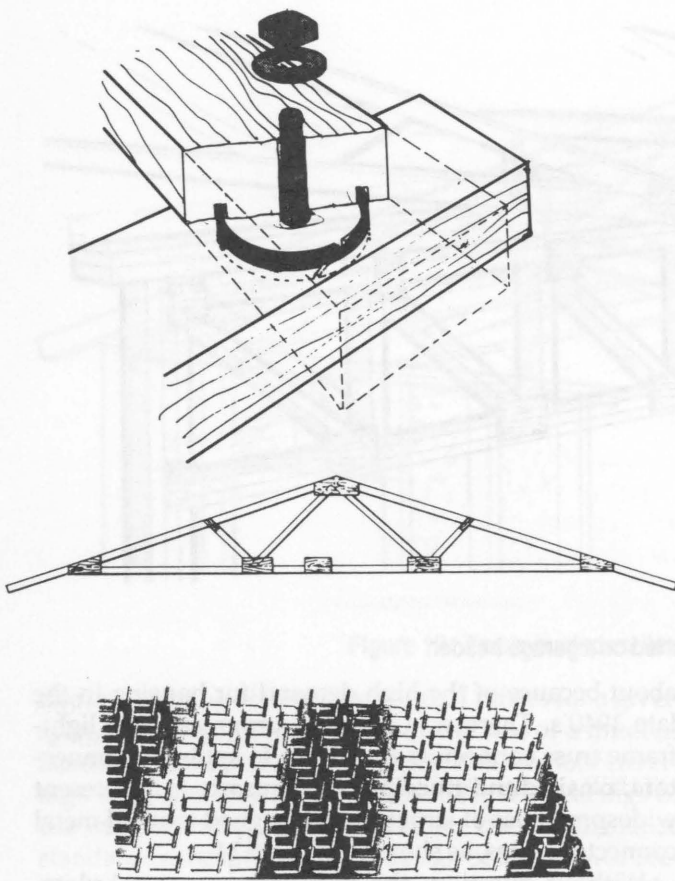


Figure 14. Truss connectors have evolved from split-rings to nail-glued plywood gussets to metal connector plates.

Various other forms of metal-plate-connected components, such as garage door headers, are also used. Some firms use metal connectors to fabricate wall sections with the window and door lintels built into the wall (Figures 15-16). Using this method of connection, complete light-frame structures can be designed and built entirely with 2x4 lumber.

More recently, the parallel-chord floor truss (PCT) has entered the marketplace. These trusses are merely extensions of the roof truss concept and are used primarily for framing long-span floor systems. They are most commonly supported at the ends on the bottom chord; however, designs are available for cantilevered trusses or for supporting the units from the top chord. In the west, many top-chord-bearing trusses are used with prefabricated panels placed between the trusses to form the roofs for larger light-frame, commercial and industrial structures. These are known as Commercial, Industrial, and Institutional structures (CII).

Modern structural wood design takes advantage of the metal plate as an efficient method of joining dimension lumber, but the overall process is not simple. The methods of design employ very sophisticated engineering analysis, with the computer as a necessary tool to manage the many designs.

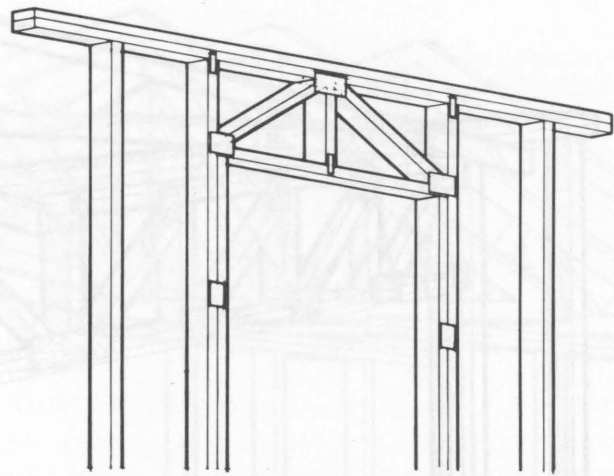


Figure 15. Prefabricated lintels replace solid headers.

The engineer must first consider the selection of lumber grades to fit the design requirements, the design and joint testing of the metal connector plates, and full-scale testing of units to verify performance. Then the means of truss fabrication, material handling and processing, plate attachment, transportation, site erection, and bracing must be considered. Further complicating the process is the variation in connector plates. There are about a dozen firms producing plate connectors, with some also providing engineering services to the light-frame construction industry. Each company develops their own plate designs and engineering processes. A few of these plate firms sponsor research to meet changing conditions, code specifications, and user requirements. A collection of plate types is shown in Figure 17.

The truss plate engineering firms are organized as the Truss Plate Institute (TPI). It should be pointed out that there are a few additional plate manufacturers not associated with TPI. Therefore the architect and building designer must assume the responsibility for state-of-the-art design when using metal-plate-connected trusses. TPI continually up-dates and publishes its design specification, and numerous other documents on the various facets of the truss industry.

A companion organization, the Wood Truss Council of America (WTCA), includes primarily the fabricators of wood trusses and works in conjunction with TPI to promote quality products for the truss industry. Not all truss producers belong to WTCA.

Prefabricated Wood I Joists

Prefabricated, light-weight wood "I" joists, using structural lumber flanges and plywood webs (Figure 18), are also a popular structural component. Some manufacturers use LVL for the flanges. These beams also require precise design and carefully controlled manufacture. They are competitive with the metal-plate-connected parallel-chord truss.

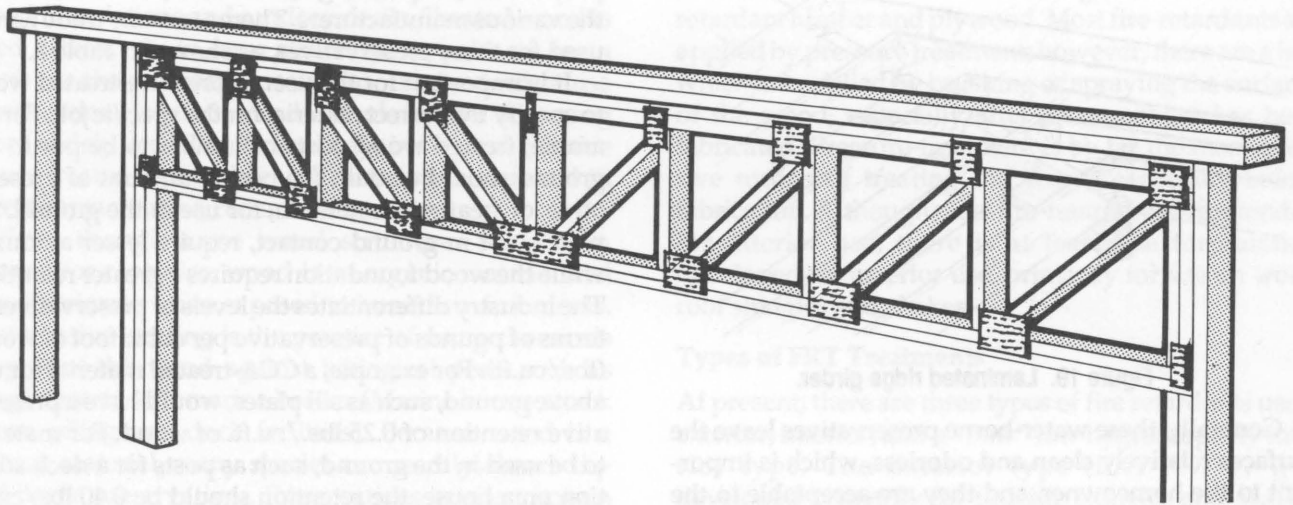


Fig. 16. Plate-connected long-span garage door headers replace steel or heavy wood beams.

Laminated Girders

Laminated girders (glu-lam) are also used in specific applications of light-frame construction. Floor girders (to support "T" joists, parallel-chord trusses, or common floor joists) and ridge beams (Figure 19) are two common uses of laminated girders. However, the greatest proportion of glu-lam is used in long-span applications such as arenas, churches, and other commercial buildings.

Without question, innovations will continue to appear in the area of light-frame construction. But, as mentioned earlier, they will be engineered as part of a system, working in conjunction with the adjoining elements to form the structure. However, for new methods to be accepted in the marketplace, they will have to

show lower in-place costs or provide special functions not possible with the present methods of construction.

OTHER CONSIDERATIONS

Preservative Types and Characteristics

There are several types of wood preservatives which have evolved over time, usually to satisfy some particular requirement of the user. For instance, coal-tar and creosote were developed to treat railroad cross ties, transmission and utility poles, and piling for marine and waterfront construction. Another popular preservative, pentachlorophenol, was developed for use around farm structures, but has been removed from over-the-counter markets because of environmental concerns. More recently, water-borne oxide formulation preservatives have dominated the marketplace.

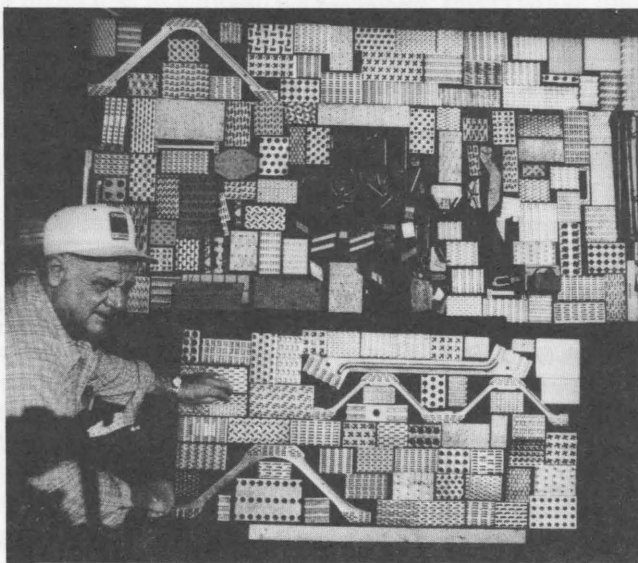


Figure 17. A collection of metal-plate connectors.

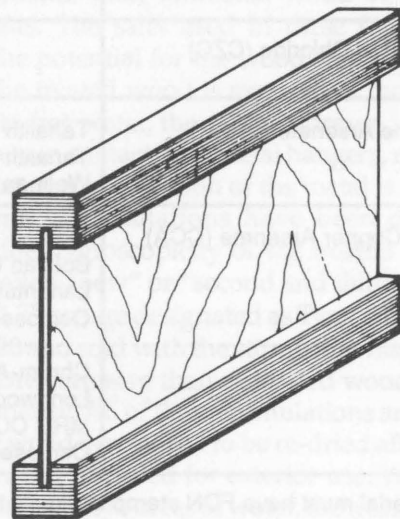


Figure 18. Prefabricated wood I-joist.

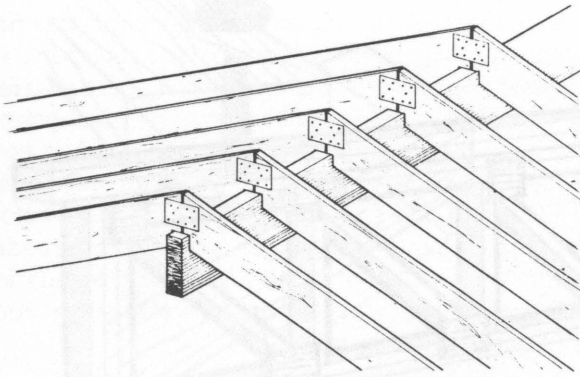


Figure 19. Laminated ridge girder.

Generally, these water-borne preservatives leave the surfaces relatively clean and odorless, which is important to the homeowner, and they are acceptable in the building codes for light-frame construction. The present "Permanent wood foundation system" includes two of these preservatives: Ammoniacal Copper Arsenate (ACA) and Chromated Copper Arsenate (CCA). The ACA formulation was developed primarily to treat Douglas fir and some of the other refractory or difficult-to-treat wood species. There are now two types of CCA, each containing the same chemicals but in different

proportions, depending on the formulations used by the various manufacturers. There are many trade names used for these preservatives, as shown in Table 2.

It is important for the user of pressure-treated wood to specify the correct material for the specific job. For example, treated wood posts or lumber to be put in the ground should contain the proper amount of preservative, or treatment retention, for use in the ground. Sill plates, not in ground contact, require lesser amounts, while the wood foundation requires a greater retention. The industry differentiates the levels of preservatives in terms of pounds of preservative per cubic foot of wood, (lbs/cu.ft). For example, a CCA-treated material for use above ground, such as sill plates, would have a preservative retention of 0.25 lbs./cu.ft. of wood. For material to be used in the ground, such as posts for a deck addition on a house, the retention should be 0.40 lbs/cu.ft. For a treated wood foundation, the retention must equal 0.60 lbs/cu.ft.

Preservative and Fire-Retardant Treatment

A discussion of wood and wood construction would not be complete without covering preservative and fire-retardant treatments. Treated products, especially lumber and plywood, are widely used throughout the

- I. Creosote Type: Used primarily for railroad ties, naval installations, wharfs, piers, retaining walls, poles, etc. (As of 1988, not available to public.)
- II. Pentachlorophenol (Penta): Used primarily for farm structures, utility poles, retaining walls, etc. (As of 1988, not available to public.)
- III. Water-borne Oxides: Clean, odorless, paintable surfaces, specified for wood foundations and patio and porch construction.

Details on Water-borne Preservatives:

CHEMICAL NAMES	TRADE NAMES	TREATMENT RETENTIONS	LBS/CU/FT	
1. Ammoniacal Copper Arsenate (ACA)	Chemonite	Above ground use Ground contact	0.25 0.40	
2. Acid Copper Chromate (ACC)	Celcure	Above ground use Ground contact	0.25 0.50	
3. Chromated Zinc Chloride (CZC)		Above ground use	0.45	
4. Fluor Chrome Arsenate (FCAP)	Tanalith Tanalith U Wolman Salts (FMP)	Above ground use	0.25	
5. Chromated Copper Arsenate (CCA) Type B	Bolidan CCA Lahontuho-K-33 Osmose-K-33	TACO-CCA Tanalith-NCA Tanalith Oxide-B	Above ground use Ground contact	0.25 0.40
Type C	Chrom-AsCU (CAC) Longwood MRC CCA Type C Osmose-K-33C	Tanolith CCA-C Tanolith Oxide-C Wolman-CCA Wolmanac-CCA	Above ground use Ground contact	0.25 0.40
* Treated material must have FDN stamp to signify that the treated material meets the specifications for use in wood foundations.		Special retention for treated wood foundations *	All CCA types ACA type	0.60 0.60

Table 2. Wood preservatives, uses, and retention specifications

building industry. Growing in popularity are treated wood foundations and outdoor decks. Treated wood is used extensively in farm structures as poles or sawn posts for the supporting columns. In standard house construction, treated wood sill plates are becoming more widely used, but it has always been good practice to use treated wood plates when the plate is placed in direct contact with a concrete foundation.

Even though some wood structures have been around for centuries, wood is an organic material and can deteriorate when exposed to humid environments. Preservative-treating is the practice of using chemicals to protect the wood against biological pests such as fungi, insects, and marine borers. (Marine borers attack ocean piling and dock facilities). Because wood is a porous material, many species can readily absorb liquid-borne preservatives. Preservatives in effect poison the food supply for the wood destroying organisms. In addition to the wood as a food supply, fungi require moisture, a suitable temperature, and the oxygen to grow. Therefore, a practical approach is to treat wood with a preservative when it is to be used in moist environments, such as a deck or a wood foundation.

Under most circumstances, merely keeping the wood dry will prevent the growth of decay spores. It is advisable to design and build light-frame structures to avoid trapping water and to prevent high relative humidities. There are, however, certain construction systems that can take advantage of treated wood, such as barns and larger commercial structures, houses built on treated lumber and plywood framing, overhanging porches for two-story houses and apartment buildings, outdoor decks, fences, etc.

The most effective method of treating wood is by pressure treatment. There are several processes in commercial use. In general, they force the preservative into the cell structure and cavities of the wood. One process, called "full-cell," continues the treatment until the wood can no longer accept more preservative. Another uses a vacuum process after treatment, to withdraw the excessive preservative from the cell cavities and surfaces. There are also combinations of each. The end-use of the products usually dictates the method of treatment.

Fire-Retardant-Treated Wood

Some building codes and local building authorities require fire-retardant-treated wood (FRTW) to be used in certain types of light-frame construction. FRTW has historically been thought of in terms of resistance to flame spread and, more recently, FRTW is being used in engineered construction and structural applications. This requires the designer to acquire a more thorough knowledge of the properties of the treated material. The truss industry has been one of the principal motivators in this respect by introducing engineered wood units

into structures where the building code dictates fire-retardant lumber and plywood. Most fire-retardants are applied by pressure treatment; however, there are a few which are applied by brushing or spraying the surfaces of the wood, especially after a component has been fabricated. Pressure-treatment is by far the most effective means of treating the wood, especially before fabrication. Although most fire-retardants are intended for interior use, there is at least one formulation developed for exterior use, primarily for use on wood roof shingles and shakes.

Types of FRT Treatments

At present, there are three types of fire retardants used: exterior, interior, and a "new" low hygroscopicity interior type. The Exterior type (EXT-FRTW) was developed primarily for treating shingles and shakes, but occasionally has been used on lumber and plywood for outdoor or exterior exposures. Some material specifiers would use this type where there is a good possibility of exposure to rain or high humidities. The exterior types, after exposure to the standard rain test, ASTM-D2898 (method A), must not show an increase in its flame spread classification. The exterior types are proprietary, but generally consist of water-soluble monomers or phenolic resin, which, when polymerized to an insoluble resin, becomes insoluble in water. After pressure treatment, the wood is re-dried to remove the water and set the chemicals.

The oldest of the fire-retardant formulations are interior, type B (AWPA-C20). These formulations were composed of mineral or inorganic water-soluble salts, such as ammonium sulfate, monoammonium phosphate, diammonium phosphate, zinc chloride, and boric acid. Generally, these "older interior" types were very hygroscopic; that is, higher in moisture absorption characteristics than untreated wood or exterior-type treatments. The salts used in these formulations increase the potential for the wood to pick up moisture. When the treated wood is exposed to humidities over 80% or to free water, the salts are drawn to the surface, and, when in contact with metal hangers, nails, conduit, truss plates, etc., corrosion of the metal is possible.

Recently, formulations have been developed to reduce the hygroscopicity of the treated wood. These are so-called "new" or "second and third generation interiors." These are designated as Type A in AWPA Standard-C20 and sold with the stipulation that the material is no more corrosive than untreated wood at 95% relative humidity. All of these formulations are proprietary and the wood is required to be re-dried after treatment. They are not intended for exterior use. When exposed to rain and other sources of water, the treated wood may not meet the ASTM flame spread tests.

Most of the older formulations have been removed from the marketplace, but caution should be exercised, since some are still available. If a structure was built prior to 1982, it is likely that the fire-retardant treatment was with one of the older interior formulations. Periodic inspections of the truss plates and other metal parts in contact with fire-retardant-treated wood should be a part of a maintenance plan. Just recently, a new organization was formed to work with FRT products, the Fire Retardant Treatment Chemical Manufacturers Council

Design Considerations with FRTW

Until recently, the National Design Specification (NDS) contained specifications for a 10% reduction in all design values for lumber treated with fire-retardants. With the introduction of the newer "low hygroscopic formulations," a change has been made in the NDS specification. NDS states, "the effects of fire-retardant chemical treatments on strength shall be considered. Design values, including fastener design loads, for lumber and structural glued laminated timber pressure impregnated with fire-retardant chemicals shall be obtained from the company providing the treating and drying service." It should be pointed out that NDS does specify a reduction if the seller of the treated material follows the NDS protocol of third party inspection and the material is identified by the quality mark of an approved inspection agency which maintains continuing supervision, testing, and inspection over the quality of the treated product. The NDS adjustment factors for fire retardant treated wood are 20% reduction for tension parallel to the grain, 15% for extreme fiber stress in bending, and 10% for all other properties.

Organizations in Wood Preservation

The major organizations in the treating industry are: the American Wood Preservers Association (AWPA); the American Wood Preservers Institute (AWPI); the American Wood Preservers Bureau (AWPB); and The Society of American Wood Preservers (SAWP). AWPA is the technical, research, and standards-writing organization. The AWPA handbook of standards contains sections on commodity standards, treatment specifications, preservatives, quality control, and inspection specifications. AWPI is the publication and promotional arm of the wood preserving industry. AWPB is an organization operating a voluntary industry quality control program which supervises the issuing of stamps certifying quality standards and specifications. They also publish specifications on preservatives, processes, and requirements for certifying pressure-treated wood products. SAWP deals solely with water-borne oxide formulation preservatives.

ENVIRONMENTAL CONSIDERATIONS

Included in the previous discussion of wood in engineered light-frame construction, occasional reference has been made to the fact that wood, being an organic product of nature, can deteriorate when exposed to severe environmental conditions. These conditions can sometimes be found inside crawl-spaces, attics, and wall cavities. This can be in the form of water condensation or high humidity.

Deterioration can usually be prevented through good design and attention to details during construction. Without exception, books, articles, and research reports on wood include cautions about the relationship of water or high humidity and wood. Unfortunately, not all of the cautions and recommendations reach those using wood products in the field. Providing good drainage and detailing to prevent entrapment of water, controlling water vapor, and keeping the wood dry, ensures that the great majority of wood structures will "outlast the mortgage." Aside from the spectacular effects of fire, decay and insect damage are by far the most prevalent agents of wood deterioration. Other natural agents can deteriorate wood but at a much slower pace; chemical or oxidation stains, blue stains, and weathering are examples. By controlling liquid water and water vapor through recommended construction practices, the probability of decay attack can be reduced. This means maintaining proper distances between wood members and the soil, providing proper drainage away from the structure, providing proper drainage with sloping surfaces on the exterior trim, and providing vapor control and adequate ventilation for enclosed areas.

Decay of wood members begins in the incipient or early stages on the wood surfaces when the MC reaches 20% and higher. As the MC increases, decay increases in activity, especially with higher temperatures. However, when the wood MC is maintained below this level, the decay spores become dormant or die in time. Advanced stages are easily detectable by the presence of fruiting bodies on the wood, or as dark, punky, depressed areas in the member. As the decay progresses, the important properties of strength and stiffness decrease. Repair and replacement costs can easily exceed the initial savings of inattention to detailing, skimpy construction practices, and poor or non-existent maintenance programs.

RECOMMENDED CONSTRUCTION PRACTICES

Most authorities in wood use and construction would agree on the following recommendations to reduce the probability of decay problems:

- Use proper design and detailing to prevent trapping water. This would include designing the trim

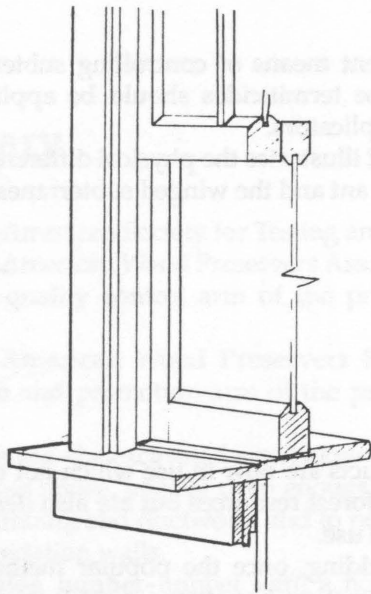


Figure 20. Flat surfaces hold water, increasing the chances of wood decay.

around windows and doors to slope away from the structure for quick rainwater run-off. Flat surfaces and details that trap water (Figure 20) are sources of problems. Porches, wooden steps, and decks built with improper drainage provisions are well-known sources of deterioration.

- Don't use untreated wood below the ground line. Putting untreated wood at or below the ground line or in contact with concrete foundations can raise the MC to dangerous levels. Contemporary light-frame design often places the structure only slightly above the ground line, thereby putting the siding, sill-plates, floor girders, and substructure members in close proximity to the sources of moisture. A common practice of placing a concrete porch slab next to the band joist can allow water to be trapped along this juncture. Good practice would be to provide flashing between the concrete and the wood members (Figure 21). Also recommended is the use of treated sill-plates (or sill-plates containing the heartwood of one of the "durable species").
- Provide good ventilation and vapor control measures. Many crawl-space-type foundations have been built without thought to ventilation and control of ground vapor. Vapor migrating from the soil inside the crawl space can condense to water and be absorbed by the floor members and sub-flooring, causing them to reach a high MC. This vapor can also migrate up through the structure, even to the attic. Controlling this vapor with a ground cover can prevent this migration. Installing vent openings in the foundation walls can allow air movement to reduce excessive water vapor that has migrated through the concrete or

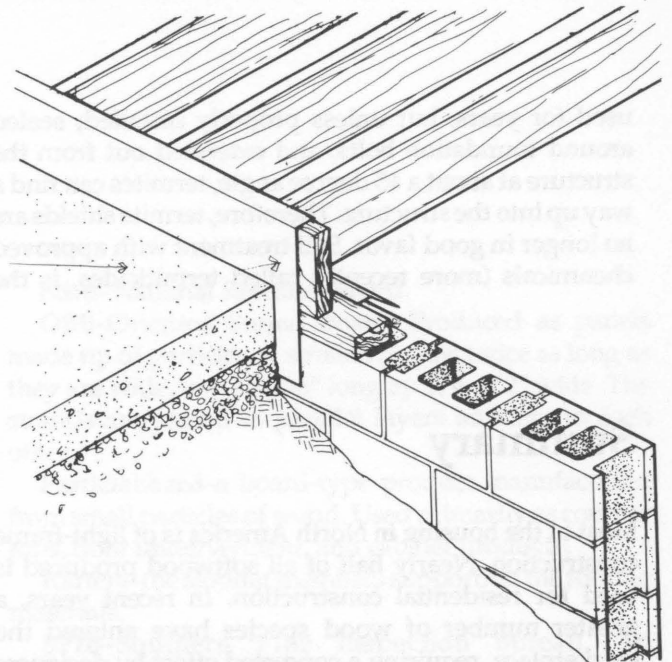


Figure 21. Flashing is recommended where a concrete slab adjoins wood framing.

through breaks in the ground cover.

- Have a regular inspection program to check for roof and plumbing leaks. Common areas of water damage occur near and under plumbing lines, not only from leaks, but also from condensation on the water lines. This occurs most frequently in bathrooms and can cause deterioration of the sub-floor. Roof leaks from shingles being blown off can cause water to run under the remaining shingles and deteriorate the roof sheathing. Improperly flashed chimneys are also a source of water getting to the roof sheathing and framing.

TERMITE CONTROL

One should not leave the subject of wood deterioration without covering termite control. As previously stated, using preservative-treated sill-plates is good practice for reducing the chances of decay, and the termites will not consume the wood. However, it should be pointed out that termites will build tunnels over treated wood and attack untreated wood. Termite shields have been

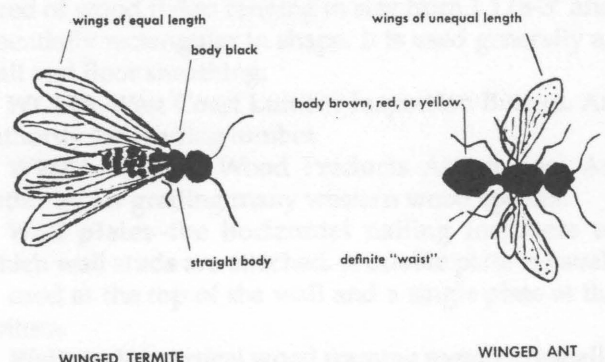


Figure 22. Many people mistake winged ants for the winged phase of subterranean termites. Note the physical differences.

used for years, but unless properly installed, sealed around foundation bolts, and extended out from the structure at about a 45 degree angle, termites can find a way up into the structure. Therefore, termite shields are no longer in good favor. Soil treatment with approved chemicals (more recently called termiticides, is the

most efficient means of controlling subterranean termites. These termiticides should be applied only by licensed applicators.

Figure 22 illustrates the physical differences between the winged ant and the winged subterranean termite.

Summary

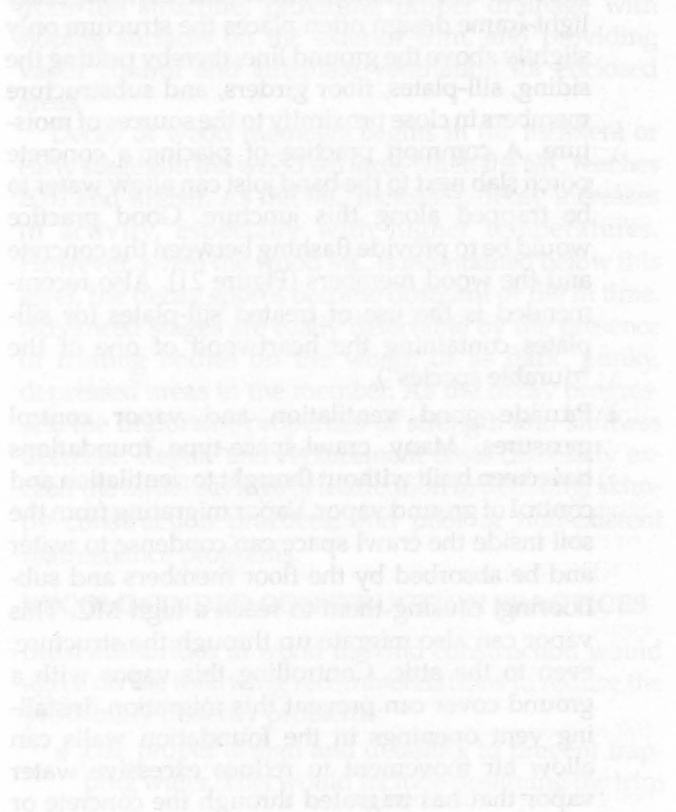
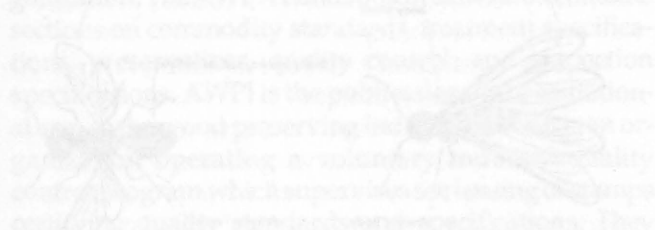
Most of the housing in North America is of light-frame construction. Nearly half of all softwood produced is used for residential construction. In recent years, a greater number of wood species have entered the marketplace, requiring a concerted effort by designers and end-users to familiarize themselves with the varied characteristics of the materials.

More sophisticated analytical design procedures are being used in light-frame commercial and residential construction. These recent developments bring into focus more precise knowledge of lumber moisture content relationships and grading for specific structural applications. There is more emphasis on engineered design to use the materials more economically. In addition, some of the so-called "man-made" lumber products are increasing in use, and they have the benefit of less variable design values. Engineered structural

panel products are now in use which not only help to extend the forest resources but are also designed for a specific end use.

Stick building, once the popular method of light-frame construction, has given way to factory-fabricated structural components. Factory fabrication can provide greater quality control, protect the materials before erection, and increase control of production costs. The most popular of the structural wood components is the truss, in one form or another, for roofs and floors.

This industry has taken advantage of the up-dated design methods and changing technology to bring about extensive involvement by many organizations and material producers. A "flow chart" showing the interaction of people, materials, and organizations involved in building is included on the last page.



Glossary

ASTM—American Society for Testing and Materials

AWPA—American Wood Preservers Association. The voluntary quality control arm of the preserving industry.

AWPB—American Wood Preservers Bureau. The publication and promotion arm of the preserving industry.

Crawl space—the excavated area below the floor of a basementless house, usually deep enough to allow access to plumbing and ductwork, and to permit inspection of foundation walls.

Dimension lumber—lumber with a nominal thickness of 2 to 5 inches.

Extractives—deposits of chemicals or extraneous materials in the cell cavities which can be removed by solvents which do not degrade the wood structure.

Grade book—a book of instructions and definitions pertaining to the grading of lumber. Each of the major grading associations maintain their own set of rules for the species graded under their authority.

Ground cover—a material used to reduce the evaporation of moisture or movement of water vapor from the soil in a crawl space.

Hygroscopicity—a characteristic of wood allowing it to absorb moisture from or lose moisture to the surrounding environment.

Joists—long horizontal members making up the framing of the floor or ceiling in stick-built light-frame construction.

Kiln-drying—a method of removing moisture from freshly cut lumber or wood through control of heat and humidity.

Ladder stock—wood parts sorted or graded for manufacturing ladders.

LVL—Laminated Veneer Lumber. Material produced from glued veneer panels and used as lumber.

M.C.—(abbreviation for moisture content) The amount of water contained in wood, expressed as a percentage of the weight of the wood after it is oven-dried.

Metal connector plate—pronged or toothed light-gauge metal plates used to assemble structural components such as roof or floor trusses.

NDS—National Design Specification. Contains design values for lumber and fasteners, published by NFPA.

NES—National Evaluation Service.

NFPA—National Forest Products Association. Publishes the design values for lumber.

NLGA—National Lumber Grading Authority. A lumber grading association in Canada.

NRB—National Research Board.

OSB—Oriented Strand Board. Produced as panels made up of particles or strands at least twice as long as they are wide, usually 2-3" long by 1/4-1/2" wide. The strands are placed in parallel layers adjacent to each other.

Particleboard—a board-type product manufactured from small particles of wood. Used primarily as counter tops, floor underlayment, and cabinet products.

Rafters—the sloping members supporting the roofing materials.

SPIB—Southern Pine Inspection Bureau. An authority for grading lumber grown in the southern region of the United States.

Slope of grain—a deviation of wood fibers from the parallel orientation to the face or edges of a piece of wood or lumber.

Sheathing—the material used to cover the floor, wall, or roof framing and support the finish material.

SAWP—Society of American Wood Preservers. An association dealing solely with salt-based preservatives, such as CCA, ACA, etc.

Stick-building—a form of light-frame construction in which the structure is assembled piece-by-piece on site.

Stress-rated lumber—lumber which has been graded and identified for structural uses. The various grades are characterized by specific allowable properties for engineering purposes.

Sub-floor—the elements below the flooring, including the joists, girders, floor trusses, floor sheathing, etc., that make up the floor structure.

Sub-flooring—the sheathing covering the floor framing and supporting the flooring or underlayment.

Veneer—a thin layer of wood peeled or sliced from a log, to be glued to other layers to form plywood.

Waferboard—A structural panel product manufactured of wood flakes ranging in size from 1 1/8-3" and essentially rectangular in shape. It is used generally as wall and floor sheathing.

WCLIB—West Coast Lumber Inspection Bureau. An authority for grading lumber.

WWPA—Western Wood Products Association. An authority for grading many western wood species.

Wall plates—the horizontal nailing members to which wall studs are attached. A double plate is usually used at the top of the wall and a single plate at the bottom.

Wall stud—a vertical wood framing member, usually a 2x4 or 2x6, which is used to frame the wall and support the roof framing.

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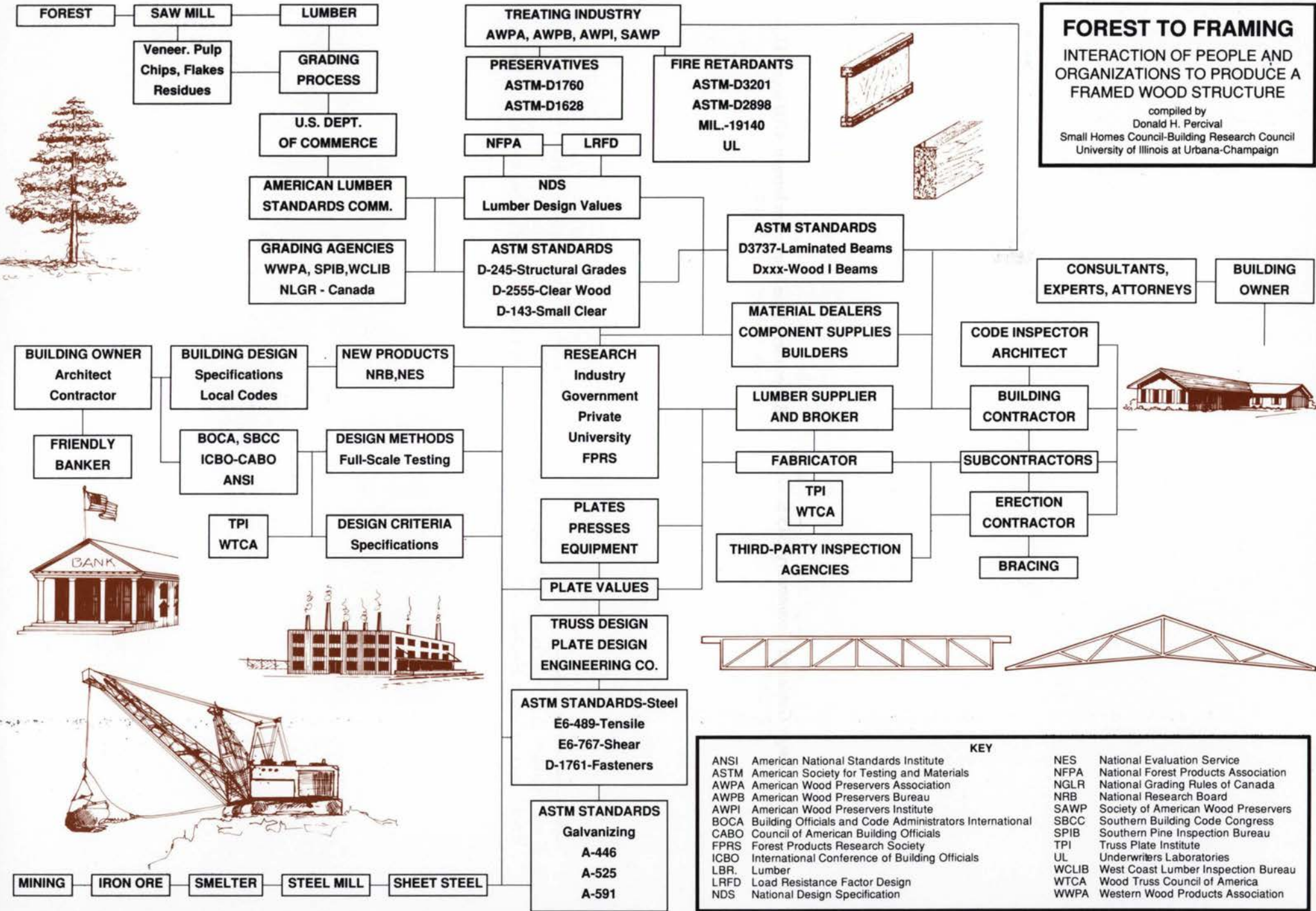
Wood residues—materials such as sawdust, bark, planer shavings, etc., usually associated with wood

processing plants.

Wood technology—the field of science involving the many characteristics of wood, such as the physical and mechanical properties, as they relate to use.

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FOREST TO FRAMING
 INTERACTION OF PEOPLE AND ORGANIZATIONS TO PRODUCE A FRAMED WOOD STRUCTURE
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KEY

ANSI	American National Standards Institute	NES	National Evaluation Service
ASTM	American Society for Testing and Materials	NFPA	National Forest Products Association
AWPA	American Wood Preservers Association	NGLR	National Grading Rules of Canada
AWPB	American Wood Preservers Bureau	NRB	National Research Board
AWPI	American Wood Preservers Institute	SAWP	Society of American Wood Preservers
BOCA	Building Officials and Code Administrators International	SBCC	Southern Building Code Congress
CABO	Council of American Building Officials	SPIB	Southern Pine Inspection Bureau
FPRS	Forest Products Research Society	TPI	Truss Plate Institute
ICBO	International Conference of Building Officials	UL	Underwriters Laboratories
LBR.	Lumber	WCLIB	West Coast Lumber Inspection Bureau
LRFD	Load Resistance Factor Design	WTCA	Wood Truss Council of America
NDS	National Design Specification	WWPA	Western Wood Products Association