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Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

Earlier Digests (**CBD 85**, **CBD 86**) have dealt with the relation of the basic properties of wood to its effective use as a construction material. Those who are not specialists in timber design but who, from time to time, work with wood as an engineering material will also find it useful to familiarize themselves with current practices in its design and specification. These practices, based on continuing developments in wood technology, are reflected in various codes, standards and design handbooks on timber listed at the end of this Digest.

One of the more important references is that of the Canadian Standards Association: CSA 086, "Code of Recommended Practice for Engineering Design in Timber"[1] on which the Wood Section[2] of the *National Building Code of Canada* is based. These documents, together with reference manuals published by the Forest Products Laboratories of the Department of Forestry and Rural Development[3] and by such organizations as the Canadian Institute of Timber Construction[4], Canadian Wood Council and Plywood Manufacturers Association of British Columbia, provide a comprehensive set of wood design aids. It is the aim of this Digest to consider the implications of these design aids in the safe and efficient use of wood in construction.

Lumber Classification

If lumber is to be specified correctly a commonly accepted terminology must be used; CSA 0141, "Softwood Lumber"[5] fills a valuable need in this regard. It covers the principal size and trade classifications of softwood lumber for yard, structural and shop use, and provides a common basis of understanding of softwood lumber terminology. It has done much to encourage and promote the adoption of uniform methods in the grading, measurement and description of softwood lumber in Canada.

CSA 0141 classifies lumber according to end-use designations, which are further related to the size of the piece. The two main types of concern to the designer are 'Yard Lumber', which is intended for ordinary construction and general building purposes, and 'Structural Lumber', which is intended for use where working stresses are required. Lumber is classified by nominal size into boards (less than 2 inches thick and 2 or more inches wide); dimension lumber (at least 2 inches but less than 5 inches thick and 2 inches or more wide); and timbers (at least 5 inches or more in least dimension). Lumber used for structural purposes may be further designated on the basis of end use as 'joists and planks,' 'beams and stringers,' and 'posts and timbers.'

It is customary to specify lumber by nominal size, although the actual or dressed size may be as much as ½ inch less in both thickness and width. Minimum dressed sizes corresponding to accepted nominal sizes have been established by CSA 0141 and must be used in all design computations. One limitation of the present size standards for dressed lumber is the omission of any reference to moisture content at the time of dressing. This will be remedied if revisions currently under discussion in Canada and the United States are adopted. The revisions will establish new size standards at 19 per cent moisture content and provide shrinkage allowances for lumber dressed at other moisture contents.

The grading of lumber is difficult and complex, but essential if wood is to be used safely and economically in construction. Individual pieces of lumber as they come from the saw exhibit a wide range in quality and appearance with respect to knots, slope of grain, shakes and other natural characteristics, and hence vary considerably in strength, utility and value. The establishment of grades standardizes the quality of lumber at different levels and is an important prerequisite to the proper use of the material.

Factors affecting appearance and strength, as well as others determining suitability for specific end uses, must be considered in grading. The rules specify the minimum quality board permitted in each grade. The grading operation is inevitably subject to some variation because it is based on visual assessment and judgment. Grading rules, however, are intended to be explicit enough to establish a maximum of 5 per cent below grade as a reasonable variation.

Grade Marking

A significant development in the grading of lumber in Canada[6] is the mandatory grade marking of lumber used in housing constructed under the National Housing Act. This has been in effect since 1962, following the inclusion of a requirement for grade-marked lumber in Supplement No. 5 to the National Building Code (i.e. *Residential Standards*); and it is now the practice of the major lumber manufacturers to grade mark all dimension lumber.

Grading is carried out by authorized agencies in accordance with grading rules prepared by major Canadian industry associations. The grade marks identify the species, the grade and the rules by which it is graded. The grade marking procedure is controlled by the Canadian Lumber Standards Administrative Board, a division of the Canadian Standards Association responsible for maintaining a satisfactory standard of grade marking in Canada. Through this Board grading agencies are controlled, grading rules approved, and grading licences granted. The board has also established a check grading service to verify the work of the graders periodically and ensure that the agencies are maintaining standards.

Lumber satisfying the provisions of CSA 0141 and graded under recognized rules by agencies approved by the Board is designated as CLS (Canadian Lumber Standards) lumber. This provides a basis for controlling lumber quality and when used in association with the table of Minimum Lumber Grades for Specific End Uses included in*Residential Standards 1965* can do much to ensure the safe and economical use of wood in construction.

Strength Groups

To simplify design procedures and thus facilitate the structural use of wood, Canadian wood species are divided into four main strength groups so that species having similar strength and stiffness properties are grouped together (Table 1). Group I, which contains the stronger species commonly used for engineering purposes, has been further subdivided to permit greater efficiency in wood utilization.

Table 1. Strength Groups

Group	Species
I	(a) Douglas Fir (dense)
	(b) Douglas Fir, Western Larch
	(c) Pacific Coast Hemlock
II	Pacific Coast Yellow Cedar
	Eastern Larch (Tamarack)
	Jack Pine
III	Fir (Amabilis and Grandis)
	Balsam Fir
	Eastern Hemlock
	Lodgepole Pine
	Ponderosa Pine
	Spruce (all species)
IV	Western Red Cedar
	Red Pine
	Pine (Western and Eastern White
	Poplar (Aspen, Largetooth Aspen, and Balsam Poplar)

Structurally-Graded Lumber

In designing for sawn lumber it is important to note the difference between structurally-graded and non-structurally-graded material. The former grades are intended to meet engineering requirements and are therefore much more precise than non-structural grades in the control of knots, checks, splits, slope of grain and other strength-reducing characteristics. Requirements for these grades have been established by the CSA 043 "Specification for Structural Timber".[7]

The factors that affect lumber strengths differ according to the kind of stress involved; it is therefore important that stress-graded lumber be specified by intended use as well as by species and grade. All rectangular members such as joists, planks, beams and stringers are graded for strength in bending. Posts and timbers, being square or nearly square and intended for use as columns, are graded for strength in compression. If a rectangular timber is to be used as a column it is important that it be graded under post and timber grading rules to establish its strength in compression rather than in bending.

Allowable Unit Stresses

The allowable unit stresses for lumber used structurally are determined by strength values obtained from extensive tests of small clear specimens, making allowances for the natural variability of wood, the duration of load, and the effect of factors such as knots and other strength reducing defects. Basic principles of structural grading have been established that permit the evaluation of any timber in terms of 'strength ratio,'[8]which is the ratio of the strength of a structural timber to that established for clear timbers of the same species with no strength-reducing defects. Thus timber with a strength ratio of 75 per cent would have 75 per cent of the basic unit stress established for the clear timber. This is the basis on which the allowable unit stresses for structurally graded sawn lumber have been established.

These stresses are specified for the usual conditions of service, that is, normal duration of full design load and dry service conditions. Most codes require that these should be further adjusted to allow for a different duration of loading or moisture condition. Normal load application is one in which the structure is subjected to the full design load only occasionally, as generally occurs in assembly, residential, institutional and commercial occupancies. When the load is of longer duration, as in most storage occupancies, the allowable stresses are decreased by 10 per cent; for loadings of shorter duration, such as those due to wind, a 33 per cent increase in allowable stress is permitted. The unit stress may also be increased by 10 per cent when used in a load-sharing system in which three or more essentially parallel members spaced at not more than 24-inch centres are so arranged or connected that they mutually support the load.

Similarly, when the average moisture content of wood over a year is 15 per cent or less, as in most protected locations, the wood is considered to be in a dry service condition. If it is used in other than dry service condition, the working stresses must be reduced by specified amounts.

As structurally graded lumber is not always readily available, the National Building Code and CSA 086 also include provisions to permit assignment of working stresses to some types of non-structurally graded material. Control of strength-reducing defects such as knots and slope of grain is less exact in these non-structural grades and the working stresses are therefore reduced accordingly. In addition, working stresses may be assigned only to certain grades, and their application is limited to lumber used in a load-sharing system. In lumber used singly as post, beam or tension members, working stresses may be assigned to non-structural grades only when the lumber has been regraded, with certain limitations placed on slope of grain.

Lumber for Residential Construction

The assignment of working stresses to non-structural grades of lumber is of particular importance in the residential field. Structural grades are more suited to buildings with heavy loads and wide spacing and it is seldom economical to use them as load bearing members in housing. In recognition of this, the Ottawa Forest Products Laboratory has prepared a set of tables showing the size and span relations for a wide range of yard grades of dimension lumber for use as joists and rafters in housing.[9] These tables give the maximum span as the smaller of the spans determined by stress or deflection limitations. In the lower grades the spans are usually governed by bending stress. There is a certain point, however, in the higher grades for each particular species where the spans are governed by deflection, and further improvements in grade do not justify an increase. In such grades, although appearance may be improved, factors unrelated to appearance control the span. These tables facilitate compliance with the *Residential Standards* and assist the house builder in selecting the most economical grade for a particular use.

The builder has been similarly aided in the use of wood roof trusses in residential buildings. Following a detailed research program on the strength of roofs, conducted jointly by DBR/NRC and the Ottawa Forest Products Laboratory, performance criteria acceptable to CMHC were developed for wood trusses and later incorporated in*Residential Standards*. These criteria require that "lumber roof trusses shall be capable of withstanding a load equal to the ceiling load plus 2-2/3 times the design roof snow load (but not less than 60 psf) for 24 hours. Such trusses shall not deflect more than 1/360 of the span after being loaded with the ceiling load plus 1-1/3 the design roof snow load (but not less than 30 psf) after one hour."

These criteria permit the suitability of wood trusses to be determined by test and provide the basis for acceptance of most of the wood trusses for residential construction currently in use in Canada. These include designs using nailed plywood gusset plate connectors embracing a wide range of slope, span and load conditions developed jointly by the Ottawa FPL and DBR and made available through the Builders Bulletin series of CMHC[10].

Glued-Laminated Timber

Developments concerning the use of glued-laminated timber in construction deserve special mention.

The designer of such assemblies has a comprehensive materials specification available in the form of CSA 0122: "Specification for Glued-Laminated Softwood Structural Timber."[11] This gives detailed requirements for adhesives, laminating grades and other items governing the proper manufacture of such products. In addition, the CSA has established a separate Administrative Board similar to the one concerned with lumber grading to implement its "Qualification Code for Manufacturers of Structural Glued-Laminated Timber" known as CSA 0177[12]. This standard was first developed by the Canadian Institute of Timber Construction and was operated by that association as a voluntary standard until its adoption by CSA in 1965.

The qualification code requires each laminating plant to have certain equipment and personnel and to carry out manufacturing and quality control procedures. Inspections are made initially and at selected intervals by an independent examiner. Providing the structural laminator remains qualified, he may attach a suitable label to his product and provide a certificate attesting that the product is manufactured in accordance with the material specification CSA 0122 and the quality requirements of CSA 0177. The National Building Code now requires that all fabricators of glued-laminated timber be qualified in accordance with this latter standard.

Conclusion

As should be evident from the foregoing discussion, developments in wood technology have greatly facilitated the use of wood as an engineering material in construction despite the varied nature of the product in its natural form. Current classification and grading practices permit the specification of lumber properties within certain desired limits and provide the designer with assurance that an acceptable product will be obtained.

This broad review of design and specification practices only introduces the subject; for more detailed information the reader is referred to the various design aids cited in this Digest. In addition to the references listed much other useful information is available in publications of organizations such as the Canadian Wood Council, the Canadian Institute of Timber Construction and the Plywood Manufacturers Association of British Columbia.

The Division of Building Research also has several papers available dealing with the application of wood in various types of construction. These range from Housing Notes on conventional wall, floor and roof framing practices to more specialized studies of trusses, prefabricated systems, shop manufacturing processes and stressed skin panels. A list is available on request. In all of its work involving wood the Division maintains close liaison with the Forest Products Laboratories of the Department of Forestry and Rural Development, the organization responsible for preparing most of the available data on the properties of Canadian woods and for developing much of the information used in establishing criteria for timber design.

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