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# Teaching Aids for Timber Engineering Design

**Lawrence A. Soltis[1], Member, ASCE**

## Abstract

Structural engineering curricula and courses are often based on the premise that steel and concrete are the primary construction materials and timber and masonry are secondary. The objective of this paper is to encourage teaching of timber engineering and to describe the teaching materials that are available. Data are presented on where and how each material is used in the construction industry. Trends in timber engineering indicate that the wood industry has targeted nonresidential building and bridge construction as potential expanding markets. One factor opposing this trend is the lack of engineers trained in timber design. Information is presented on available textbooks and on the Clark Heritage Memorial Series of educational modules to help engineering faculty prepare and teach timber engineering.

## Introduction

The objective of this paper is to encourage teaching of timber engineering and to describe the teaching materials that are available. In addition, this information may help educators to plan the engineering curriculum and coursework.

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[1]Supervisory General Engineer, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398. The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin. 

Structural engineering education is currently based on the premise that steel and concrete are the primary construction materials and timber and masonry are the secondary materials. A closer look at how and where construction materials are used indicates that a specific material may be either primary or secondary, depending on the type of construction project and the structural system within a project.

Wood has traditionally been used for residential construction. In the past several years, the wood industry has increased its effort to use wood in nonresidential building and bridge construction. If properly designed, wood is equally durable and usually more economical than competing materials. One problem with the increased use of wood in engineered structures is the lack of undergraduate training in timber design. A 1984 survey (Wadlin 1984) found that over 75 percent of the curricula leading to a bachelor's degree in civil engineering required a course in either steel or concrete design, but only 13 percent required a course in timber design.

**Materials and Uses**

Data on how and where different materials are used should be considered for curriculum and course content. Census data (U.S. Department of Commerce 1989) for new construction in 1987 are given in Table 1. Residential construction accounted for about half (US$171 billion) the total 1987 construction (US$349 billion). Wood is the primary material used in residential construction. Nonresidential building construction (public and private) accounted for US$99 billion. Information on nonresidential building size (Table 2) for 1982 (Spelter and Anderson 1985) indicates 78 percent of the floor area was in one- or two-story buildings. Wood is often very cost competitive in low-rise nonresidential construction. This explains the timber industry's effort to gain a larger share of the 78 percent of this US$99 billion industry.

Data from a 1982 survey (Spelter and Anderson 1985) on primary and secondary materials used for various components of nonresidential buildings are given in Table 3. Wood was used in over one-third of the roof and interior wall systems. The use of wood in roof systems was split between truss and glued-laminated beam systems. Wood was also used for a significant share of the upper floor systems. Concrete was the primary material for the ground floor systems (no data were given for foundation systems), metal (steel) the primary material for roof systems, and a composite of steel and concrete the primary material for upper floor systems. All materials were used for exterior wall systems.

Data on how and where different materials are used in bridge construction are not available, although several wood systems for short-span bridge construction are used.

In summary, Tables 1, 2, and 3 can be used as tools for structural engineering curriculum and course planning. Timber structures or components are often either the primary material in construction or have the potential to be used for an increased share of structural systems.

## Trends in Timber Engineering

Wood is an anisotropic material with highly variable and time-dependent material properties. It shrinks and swells with changing moisture content, and it is susceptible to decay and fire. Many of these properties are unique to wood construction and, therefore, they are not well understood by students schooled in steel and concrete design.

The wood industry produces composite products (such as I-beams and laminated-veneer lumber) that reduce variability: preservatives exist to prevent decay, and fire-rated construction is possible. The wood industry has targeted a larger share of the nonresidential building construction and the short-span bridge market as potential expanding markets. They are currently developing a Load and Resistance Factor Design (LRFD) manual that will parallel the steel and concrete LRFD manuals. Engineers trained in timber engineering can design reliable timber structures.

## Timber Engineering Education

Wadlin (1984) found that only 13 percent of the civil engineering curricula required a timber design course for a bachelor's degree, whereas more than three-fourths of the curricula required either a steel or concrete design course. Moody and Freas (1987) discussed the present timber engineering education for undergraduates. They suggested increasing student exposure to timber design either by combining timber design with a steel design course or by developing a timber design project for senior students.

Several reasons exist for the shortage of timber design course requirements. First, timber is thought of as a secondary material (discussed previously). Second, only a limited number of courses can be taught within a curriculum. Third, many engineering faculty are not well-schooled in timber engineering. The remainder of this paper focuses on the third issue.

One problem perceived by engineering faculty is the lack of comprehensive technical information. Several excellent recently published textbooks are available (Breyer 1988; Faherty and Williamson 1989: Hoyle and Woeste 1979: Stalnacker and Harris 1989) as well as various design specifications (American Institute of Timber Construction 1985; National Forest Products Association (NFPA) 1986) and product literature. The NFPA specification will be updated shortly and a Load and Resistance Factor Design Manual is in preparation.

To complement these books, four volumes of educational materials have been developed based on a series of workshops sponsored by the USDA Forest Service, Forest Products Laboratory (FPL), in cooperation with the University of Wisconsin (Clark Heritage Memorial Series 1981, 1982, 1983, 1986). Each volume is divided into modules suitable for developing course material: each module contains an objective statement, technical material including sample problems, and self-test questions and answers. Each module has also been published separately in the *Journal of Materials Education* and its predecessor, the *Journal of Educational Modules for Materials Science and Engineering*.

Volume I of the Clark Heritage Memorial Series, *Wood, Its Structure and Properties*, concentrates on the physical characteristics of wood. Volume II, *Wood as a Structural Material*, is directed at the use of wood in structures. Volume III, *Adhesive Bonding of Wood and Other Structural Materials*, looks at the bonding necessary for many wood products. Volume IV, *Wood Engineering Design Concepts*, is directly applicable to structural engineering design. This volume covers the design of beams (solid, laminated, and composite), columns, connections, trusses, diaphragms, and curved members including arches and domes.

In addition to developing these four volumes, the FPL, in cooperation with Marquette University, sponsored a workshop in 1988 to educate university faculty in timber engineering. Thirty participants were selected from about 120 applications. One product resulting from the workshop was a "class notes" style teaching manual (Faherty 1988) to complement Volume IV of the (Wood Engineering Design Concepts) Clark Heritage Memorial Series.

## Concluding Remarks

Economics favor the use of wood in many nonresidential applications, but improved education is necessary to bring about expanded wood use. Engineering education in timber design is currently not proportional to the actual or potential use of wood in nonresidential construction. The Clark Heritage Memorial Series of teaching modules are designed to help the educator integrate timber engineering into the university curriculum and to overcome the perceived lack of comprehensive technical data on wood.

Table 1--New construction in 1987[a]

| Type of construction | | cost (billion US$) |
|---|---|---|
| Private | | |
| Residential | | 171 |
| Nonresidential | | 78 |
| Farm | | 2 |
| Public utilities | | 30 |
| Miscellaneous | | 2 |
| | Subtotal | 283 |
| Public | | |
| Buildings | | 21 |
| Highways | | 20 |
| Military facilities | | 4 |
| Conservation and development | | 5 |
| Sewer and water | | 12 |
| Miscellaneous | | 4 |
| | Subtotal | 66 |
| | Total | 349 |

[a]U.S. Department of Commerce 1989.

Table 2--Distribution of non-residential building sizes by relative floor area[a]

| Nonresidential building size | Percent |
|---|---|
| One story | 55 |
| Two story | 23 |
| Three or more stories | 22 |
| Total | 100 |

[a]Spelter and Anderson 1985.

Table 3--Materials used in nonresidential buildings[a]

| Building component | Material (percent) | | | | |
|---|---|---|---|---|---|
| | Wood | Metal | Concrete | Concrete and metal | Masonry |
| Roof | 36[b] | 60 | 3 | -- | -- |
| Exterior wall | 18 | 35 | 19 | __ | 27 |
| Interior wall | 35 | 52 | 2 | __ | 11 |
| Ground floor | 4 | __ | 92 | 4 | __ |
| Upper floor | 18 | 3 | 15 | 63 | -- |

[a]Office, store, industrial, school, hospital, religious, recreational, and public buildings (Spelter and Anderson 1985).

[b]Wood: 20 percent trusses, 16 percent glue-laminated beams.

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