Status of wood products use in nonresidential construction

Henry Spelter
Robert Maeglin
Susan LeVan

Abstract

This paper discusses some results of a survey of wood use in nonresidential construction. Nonresidential construction is a large market for building materials, including lumber, laminated beams, plywood, and other panel products. The survey showed that over 2.1 billion board feet (BBF) of lumber, 1.7 billion square feet (ft.^{2}) of plywood, and 41 million ft.^{2} of nonveneered structural panels were purchased for nonresidential building projects in 1982. An additional 0.5 BBF of lumber and 0.4 billion ft.^{2} of plywood were purchased for other nonresidential construction (but excluding farm-related construction and maintenance of existing nonresidential structures). While these quantities are large, and larger than the estimates made in the late 1960s, the survey showed wood construction generally remained smaller than nonwood construction. Contractor and builder responses indicate that many perceive wood construction as more expensive than alternatives, wood products as less consistent in quality than other materials, and building codes as limiting the use of wood. This paper examines same aspects of these concerns.

Economic conditions have recently improved for forest products manufacturers. But the current improvement underscores the continued strong dependence of the solid wood products industry on housing construction. During much of the past decade, when in the West, for example, almost one mill in five was reported closed (4), many in the industry felt cultivating nonhousing markets was one way to restore profitability in the long run (1). One area of particular interest was nonresidential construction. Increased wood use in this area could contribute to more stable demand, while reducing dependence on new housing. This paper discusses some findings of a recent survey of wood use in nonresidential construction (16,171.

The nonresidential markets surveyed include construction of new buildings, additions to existing buildings, and remodeling of structures. Among other nonresidential construction categories were streets and highways, conservation and development, sewers, water facilities, public utility construction, and miscellaneous nonbuilding construction. Farm buildings and repair and maintenance of existing structures were excluded. Construction projects undertaken by the military and construction of highrise residential buildings also were not part of the survey.

In 1983 the Wood Product Promotion Council and the Forest Service extensively surveyed nonresidential projects constructed in 1982 to discover the characteristics of the nonresidential market, and to determine how widely wood products are used there. Over 800 contractors and managers were contacted, either on the telephone by interviewers, or in person by industry field representatives. Information was gathered on the type of construction activity, project characteristics such as the size and value of the project, and materials used. Total wood use estimates and market shares were made from these data and from data obtained from the F. W. Dodge Company and the U.S. Department of Commerce (20). The complete results of the study, including a description of the methodology, and estimates of the statistical variability of the study findings are published elsewhere (16, 17). This paper presents a summary of the survey and a discussion of some constraints on the use of wood in nonresidential construction.

Survey highlights

Two areas of nonresidential construction were considered. The first consisted of buildings, including hotels and other nonhousekeeping structures which, though residential, are regulated by building codes more similar to nonresidential than residential construction. The second area consisted of general construction such as highways, dams, tunnels, pipelines etc., which hereafter will be referred to as nonbuildings.

Wood use is more important in the building than in the nonbuilding category. The estimates of wood use for constructing buildings in 1982 were 2.1 billion board feet (BBF) of lumber (including those in laminated

The authors are, respectively, Economist, Supervisory Research Forest Products Technologist, and Chemcal Engineer, USDA Forest Serv., Forest Prod. Lab., Madison, WI 53705. This paper was received for publication in November 1985.

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TABLE 1. – *Nonresidential buildings surveyed, by number of stories and superstructure framing, 1982.*

Number of stories	Framing type			
	Wood	Metal	Masonry	Concrete
	(%)			
1	27	23	39	11
2	40	27	25	8
3	26	32	24	18
4+	0	47	10	43

TABLE 2. – *Building size and superstructure framing of one-and two-story buildings surveyed in 1982.*

Building size	Framing type			
	Wood	Metal	Masonry	Concrete
(ft.²)	(%)			
One story				
5,000 or less	48	11	38	3
5 to 10,000	21	16	51	12
10 to 50,000	18	37	33	13
50,000 or more	10	33	33	24
Two story				
5,000 or less	61	11	26	2
5 to 10,000	38	33	20	10
10 to 50,000	29	43	25	4
50,000 or more	26	26	30	17

beams and trusses), 1.7 billion square feet (ft.^{2}) of plywood (3/8-inch basis), and 41 million ft.^{2} of nonveneered structural panels (also 3/8-inch basis).

Wood construction was predominantly employed in lowrise buildings (Table 1) containing less than 10,000 ft.^{2} of floor area (Table 2). Such buildings made up an estimated one-third of the 1.8 billion ft.^{2} of buildings constructed in 1982 (17).

Total building component surfaces (roofs, walls, partitions, floors) were estimated at 5.1 billion ft.^{2}. Wood construction made up 22 percent of this total (Fig. 1). Wood's share ranged from 36 percent for roofs and partitions to 8 percent for floors. Over 80 percent of the lumber went into framing these components, with the rest used for concrete forming, scaffolding, millwork, and miscellaneous uses. Seventy-four percent of the plywood went into decking, sheathing, or cladding these surfaces, while the bulk of the remainder went into concrete forming and millwork.

For every $1,000 of construction, the average wood use was 26 board feet (BF) of lumber, 21 ft.^{2} of plywood, and 1/2 ft.^{2} of nonveneered structural panels.

Consumption of wood products in nonbuilding construction was substantially less. An estimated 0.5 BBF of lumber and 0.4 billion ft.^{2} of plywood were used in 1982 (16). These translate to use factors of 7 BF of lumber and 5 ft.^{2} of plywood per $1,000 of construction. About two-thirds of the lumber and 85 percent of the plywood were used for concrete forming or form supports. Most of the rest was used for facilitating purposes such as shoring, scaffolding, signs, and temporary structures. Except for special structures such as piers,

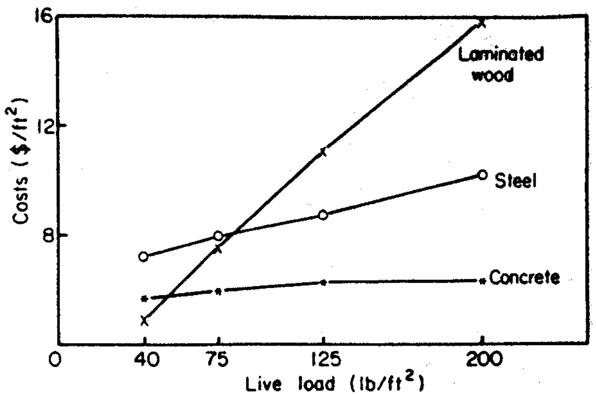

Figure 1. – The share of wood in nonresidential construction.

bulkheads, and amusement rides, relatively few projects actually used wood as integral parts of the structure; most of the wood was used as temporary facilitating or forming material.

While consideration of constraints on the use of wood was not the aim of the survey, a large number of user opinions were compiled regarding different building products, and these comments can help identify such constraints.

Builders, in general, appreciated wood products for their ease of use. Good insulating characteristics, ample availability of workers familiar with wood construction, and the ready availability of lumber and plywood were often cited as factors favorable to wood use. However, many builders perceived wood buildings as being more costly in some cases than alternatives; they frequently mentioned problems with warp and surface size variability; finally, many viewed building codes as a major impediment to more widespread use of wood. In the following sections, we examine these concerns.

Wood building costs

Many contractors who regarded wood unfavorably expressed the belief that wood construction was more costly than alternatives, primarily steel. However, it was apparent in many cases that wood had not been considered as an alternative. Some contractors just preferred to work with steel or other noncombustible materials. In cases where the contractors were constrained to use wood because of owner preference, they often expressed surprise at the competitiveness of the wood system.

A comparison of costs published in a recent edition of a widely used construction-estimating manual does not support the view that wood is a relatively more costly method of construction (13). While the cost of partitions (nonload-bearing walls) was about 10 percent lower using steel, the cost of load-bearing exterior walls of similar characteristics was about 20 percent higher using steel (Table 3). For floors, a design using laminated wood beams and lumber purlins is less costly than steel or concrete at a low load level of 40 lb/ft.^{2}, but becomes more expensive at higher loads (Fig. 2). However, this does not allow for the effect of the lower weight associated with wood, which reduces the load on other building components, thereby enabling cost savings elsewhere in a building's design.

Table 4, in which square foot costs of two systems are compared, illustrates the advantage stemming from the lower weight of wood in a three-story building with 9,600 ft.^{2} per floor. System A is an all-concrete structure consisting of 7-1/2-inch cast-in-place concrete floors and roof, and 20-inch round cast-in-place concrete columns. The total load on the foundation is approximately 200 thousand pounds per footing. System B assumes a building of similar size but with laminated beam floors and roof and 12 by 12 precast concrete columns with base plates for floor member supports. The transmitted load to the foundation is approximately 105 thousand pounds.

As Table 4 shows, the all-concrete structure has a $1.22 per ft.^{2} advantage over wood in floor and roof components. But, because of the lighter load advantage, this is substantially eroded by a $0.30 per ft.^{2} disadvantage in the columns, and a $0.27 per ft.^{2} deficit in the foundation. This example does not explore all the possible cost ramifications of using alternative materials, but it indicates the extent to which total system costs affect the competitiveness of a particular product in a building component.

Preengineered steel buildings also compete with wood structures in medium-sized, lowrise, light commercial buildings. In recent decades, there has been a documented increase in one- and two-story structures of 150,000 ft.^{2} and less being built of these steel systems (10). The minimum economical area for such buildings is about 3,000 ft.^{2}, and they become increasingly economical with increasing eave heights and floor areas (13). The relatively lower cost for larger sizes has made this type of construction popular for factories and warehouses. Increasingly, they have been used also for offices and other buildings occupied by humans (21). The survey showed that this type of steel construction predominated among industrial buildings.

TABLE 3. – ***Comparison of in-place costs of various building components built with wood and alternative materials.***[a]

Component type	Materials	Installation	Total
	($/ft.2)		
Partitions, 5/8-inch drywall, both sides			
Wood studs, 2 by 4, 16-inch spacing	$0.85	$1.42	$ 2.27
Metal studs, 1-5/8-inch, 24-inch spacing	.64	1.40	2.04
Walls, 1/2-inch CDX sheathing, fiberglass batts			
Wood studs, 2 by 4.16-inch spacing	1.00	1.18	2.18
Metal studs, 16 gage, 3-5/8inch, 24-inch spacing	1.39	1.18	2.57
Floors, superimposed load = 40 lb./ft.^{2}. 20- by 20-foot bay			
Laminated wood beams and joists	4.01	1.88	5.89
Wide flange steel beams and deck	4.28	2.92	7.20
Cast-in-place concrete	2.11	3.59	5.70
Floors, superimposed load = 125 lb./ft.^{2} 20- by 20-foot bay			
Laminated wood beams and joists	8.05	3.04	11.09
Wide flange steel beams and deck	5.35	3.40	8.75
Cat-in-place concrete	2.53	3.75	6.28

[a]Source: (13) Partitions, pages 213,214; walls. pages 159,161; floors, page 410.

Wood construction is generally viewed as most cost-effective in small residential-sized structures, and its use there is widespread. In intermediate, lowrise structures, where codes are still not restrictive, wood is often regarded as more costly than alternatives. Industrial engineering studies are needed to compare material and labor costa among various building designs in order to establish the actual cost-competitiveness of wood construction and pinpoint designs where wood systems have an advantage.

Lumber quality

A number of contractors reported that some lumber purchased for nonresidential building construction suffers from warp and instability. They indicated that they use alternative materials because they require straight, stable building products. Some users suggested that better and more consistent lumber must be produced to maintain or increase wood's portion of the construction market.

The decline in quality of wood raw material stems from a gradual change in available resources. When lumber was king in construction, the raw material was primarily old-growth timber. Today, most of that resource is gone. Across the United States, the standard resource is second-growth timber, composed of smaller diameter trees which contain a larger proportion of juvenile wood and less clear wood than mature timber (14). Although much of the present resource is not large

TABLE 4. – ***Effect of wood floor system on total superstructure costs of a three-stow. 29,000 ft^2 building.***

System A	Cost	System B	Cost
	($/ft.^{2})		($/ft.^{2})
Concrete floor and roof	5.88	Wood floor and roof[b]	7.00
Concrete columns	1.57	Concrete columns	1.27
Footings	.46	Footings	.19
Total	7.91	Total	8.46

[a]Total load (live and dead). 231 lb./ft.^{2}.
[b]Total load (live and dead). 148 lb./ft.^{2}.
Source: (13).

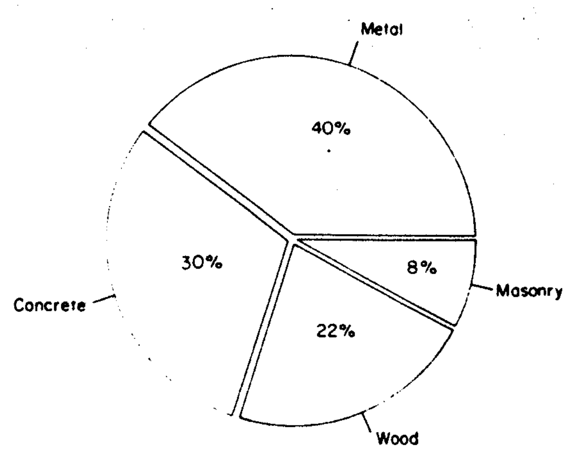

Figure 2. – Costs of three floor systems as a function of the live load.

TABLE 5. – *Occupancy classifications from Uniform Building Code.*

Subgroup	Description
	ASSEMBLY (A)
A-1	Occupant load > 1,000, stage
A-2	Occupant load < 1,000, stage
A-3	Occupant load < 300, no stage
A-4	Stadiums
	BUSINESS (B)
B-1	Gasoline service stations
B-2	Offices, mercantile buildings
B-3	Aircraft hangers
B-4	Industrial
	EDUCATIONAL (E)
E-1	Through 12th grade, > 50 persons
E-2	Through 12th grade, < 50 persons
E-3	Day care
	HAZARDOUS (H)
H-1	Highly flammable material storage
H-2	Less flammable material storage
H-3	Combustible dust generating activity
H-4	Repair garages not in B-1
H-5	Aircraft repair hangers
	INSTITUTIONAL (I)
I-1	Nurseries, hospitals
I-2	Nursing homes
I-3	Jails

old growth, it is possible to manufacture straight and stable lumber from second-growth timber by proper processing and quality control. Wholesalers and retailers who sell lumber graded at or above 19 percent moisture content sometimes get complaints about lumber being below grade on the job. Most of the degrade occurs because the wood has dried out, shrunk, and warped after leaving the mill (2, 9). Manufacturers of some species believe that, if they dried to 15 percent or less, the degrade would occur in the mill and their costs would escalate (3). However, this would not necessarily occur if proper sawing, drying, and quality control procedures were used. In fact, it is possible to manufacture good lumber that the manufacturer can stand behind and promote on the basis of quality and reliability.

A major problem in some second-growth timber is excessive growth stress. Improved sawing techniques are required to relieve the stresses without warping the lumber. One such technique is Saw-Dry-Rip (SDR), developed by the U.S. Forest Products Laboratory to process low- to medium-density hardwoods into high quality structural lumber (5-7). The SDR technique has been tested and found to work well with softwoods such as second-growth ponderosa pine (8) and second-growth southern pine.

Using existing methods and techniques, mills can still upgrade their products by rigorously following proper maintenance and operational procedures and quality control.

Building and fire code restrictions

Wood is a traditional construction material, but building codes restrict its use in nonresidential buildings. Building codes are complicated legal documents intended to protect lives and limit liability. Three model building codes in the United States serve as guides for communities in various regions. Local authorities, however, may alter elements to suit local needs and preferences. As a result, designers must contend not only with the complexity of the codes, but with variability from community to community. A number of contractors cited difficulties with building codes as a factor that favors the use of noncombustible materials instead of wood.

Even with the restrictions on wood use in nonresidential construction, there are numerous ways to use wood within the building codes. In the remaining discussion we focus on these.

Structural wood use

The process of selecting the structural material begins with determining the occupancy classification of a building. Although the terminology differs among the three model codes, the basic groupings are the same, and we will use the Uniform Building Code (predominant in the West) to illustrate the various groups. Table 5 lists five general groupings that cover most nonresidential buildings. These general categories are further subdivided according to various criteria affecting occupant risk.

The occupancy classification and the size of a prospective structure are critical because they determine the materials that may be used in the building (Table 6). Structural elements of Types I and II construction are generally required to be of noncombustible materials such as steel, concrete, or masonry. Type III construction is defined as having exterior walls of noncombustible materials (fire-retardant-treated wood framing may sometimes be allowed) with floors, roofs, interior walls, and partitions of wood frame. Type IV construction is defined as having exterior walls of noncombustible materials with columns, floors, roof, or interior partitions constructed of wood members of a certain minimum size. Type V construction is defined as having exterior walls, load-bearing walls, partitions, floors, and roofs of conventional wood stud and joist framing. For a one-story A-1 occupancy building, for example, only Type I and Type II fire-resistive construction is allowed, regardless of building size.

As Table 6 shows, even if the use of combustible materials is permitted, the permission extends only within specified size limits. Nevertheless, wood can be used beyond these limits if the erector is willing to implement various changes in the building's design. For illustrative purposes we discuss two of these changes. (For more specific details we refer the reader to the National Forest Products Association (11).)

Increases in allowable heights and areas.—In addition to the area limitations of Table 6, building codes also restrict a structure's height. Both limits are generally more severe with wood than with nonwood structures. But basic floor areas for different types of wood construction can be increased if "open space" exists on a specified amount of the exterior of the building, or if automatic sprinkler systems are used. The open space criterion is especially important as more buildings are located in suburban areas where parking requirements ensure considerable separation between structures.

TABLE 6. – *Allowable floor area for one-story buildings from Uniform Building Code.*

	Type of construction								
	I	II			III		IV	V	
Occupancy classification	Fire resistive	Fire resistive	Protected 1 hour	Unprotected	Protected 1 hour	Unprotected	Heavy timber (glulam)	Protected 1 hour	Unprotected
	(ft.^{2})								
A-1	Unlimited	29,900							
A-2	Unlimited	29,900	13,500		13,500		13,500	10,500	
A-3.4	Unlimited	29,900	13,500	9,100	13,500	9,100	13,500	10,500	6,000
B-1,2,3	Unlimited	39,900	18,000	12,000	18,000	12,000	18,000	14,000	8,000
B-4	Unlimited	59,900	27,000	18,000	27,000	18,000	27,000	21,000	12,000
E-1.2.3	Unlimited	45,200	20,200	13,500	20,200	13,500	20,200	15.700	9,100
H-1,2	15,000	12,400	5,600	3.700	5,600	3,700	5,800	4,400	2,500
H-3,4,5	Unlimited	24,800	11,200	7,500	11,200	7,500	11,200	8,800	5,100
1-1,2	Unlimited	15,100	6.800		6,800		6,800	5,200	
	Unlimited	15,100							

TABLE 7. – *Increased allowable floor areas in one-story B-2 occupancy buildings due to open spaces and sprinklers, in Uniform Building Code.*

		Type of construction					
		III		IV	V		
Sprinklers	Open space (no. of sides)	Protected 1 hour	Unprotected	Heavy timber	Protected 1 hour	Unprotected	Remarks
		(ft.^{2})					
No	1	18,000	12,000	18,000	14,000	8,000	Basic allowable floor area from Table 5
No	2	27,000	18,000	27,000	21,000	12,000	Increased floor area allowed with open space on one additional side
No	3	36,000	24,000	36,000	28,000	16,000	Increased floor area allowed with open space on two additional sides
Yes	1	54,000	36,000	56,000	42,000	24,000	Increased floor area allowed with installation of sprinklers
Yes	2	81,000	54,000	81,000	63,000	36,000	Increased floor area allowed with installation of sprinklers and open space on one additional side
Yes	3	108,000	72,000	108,000	84,000	48,000	Increased floor area allowed with installation of sprinklers and open space on two additional sides

Even if open space is lacking, the effective allowable area can be increased by installing a wall with a minimum 2-hour fire-resistive capacity. The code treats the separated areas as individual buildings, thus permitting the increase.

As an illustrative example, consider the case of an architect wanting to build a one-story B-2 occupancy office building. For B-2, the Uniform Building Code permits floor area increases to be determined as follows:

> Where streets, public space, or yards more than 20 feet in width extend along and adjoin two sides of the building, basic floor areas may be increased as much as 50 percent by a rate of 1.25 percent for each foot by which the minimum width exceeds 20 feet, as much as 100 percent by a rate of 2.5 percent for each foot by which the minimum width exceeds 20 feet on three sides, and as much as 100 percent by a rate of 5 percent for each foot by which the minimum width exceeds 20 feet on four sides.

Automatic sprinkler systems allow floor areas to be tripled in one-story buildings and doubled in buildings more than one story in height. Table 7 shows how these increases affect allowable floor areas in a one-story B-2 occupancy with or without sprinklers. Fire-resistive ratings in Table 6 are based on the number of hours an assembly is able to maintain its structural integrity while subjected to a fire on one side. Ratings can be improved by protecting the member or assembly from high temperatures. This can be done with various types of thermal barriers such as gypsum wall boards (15).

Fire-resistive coatings which intumesce (swell and insulate the substrate) are typically used on steel and concrete. Recent evidence indicates they can also be used effectively on wood (18,19).

Wood roof structures.—Various codes allow for wood roofs in Type I and Type II buildings, provided the wood has been fire-retardant treated or consists of heavy timbers (specified by minimum dimensions). As with all applications using wood, the allowance depends on the type of occupancy and the particular building code.

Fire-retardant-treated wood

The survey revealed that the amount of fire-retardant-treated wood in nonresidential construction is small, only about 2-1/4 percent of the lumber and 1-3/4 percent of the plywood used. Although some codes allow the use of fire-retardant-treated wood roof structures, and in certain cases partition framing, some contractors complained about the performance and/or cost of fire-retardant-treated wood.

Most fire-retardant-treated wood is impregnated with inorganic, water-soluble chemical formulations. Some problems have been reported in high-humidity areas because the hygroscopicity (ability to absorb moisture in a humid environment) of "old" types of treatments caused fasteners to corrode and wood to weaken in the vicinity of nails or metal plates. However, within the past several years, new formulations that are nonhygroscopic have been put on the market and can be used in wood exposed to the weather and in wood used under high-humidity conditions. The newer, nonhygroscopic formulations have yet to establish a reliable product performance record to overcome an unfavorable reputation stemming from past problems.

Fire-retardant treatment is expensive. It involves the cost of the chemical, its application, and the redrying of the wood. This can add $200 per 1,000 BF to the cost of wood, about doubling its original cost. Less expensive chemical formulations can be used but only at the expense of imparting undesirable properties such as higher hygroscopicity and lower strength. Many contractors reported that the unfavorable cost comparison between fire-retardant-treated wood and metal roof systems had led them to choose metal. If greater use of fire-retardant-treated wood is to be achieved, the overall cost-effectiveness of wood-based systems relative to nonwood alternatives needs to be demonstrated.

Conclusion

Wood buildings in general occupy a minority position in the nonresidential construction market as measured by floor area, but seem to be maintaining their share. Comparison to a 1969 building survey (12) shows lumber use per square foot to be slightly higher and plywood use to be significantly higher in 1982.

The potential of wood buildings and wood systems is limited in this market by codes that regulate building practices. However, it appears that a much greater percentage of nonresidential buildings could be constructed of wood frame. The survey indicated that a significant portion of lowrise buildings were constructed from alternative materials such as pre-engineered steel, concrete, and masonry. These are the buildings for which wood is most cost-effective and building codes are least restrictive. Wood could increase its share of this market if wood manufacturers can demonstrate the effectiveness of wood in this application.

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