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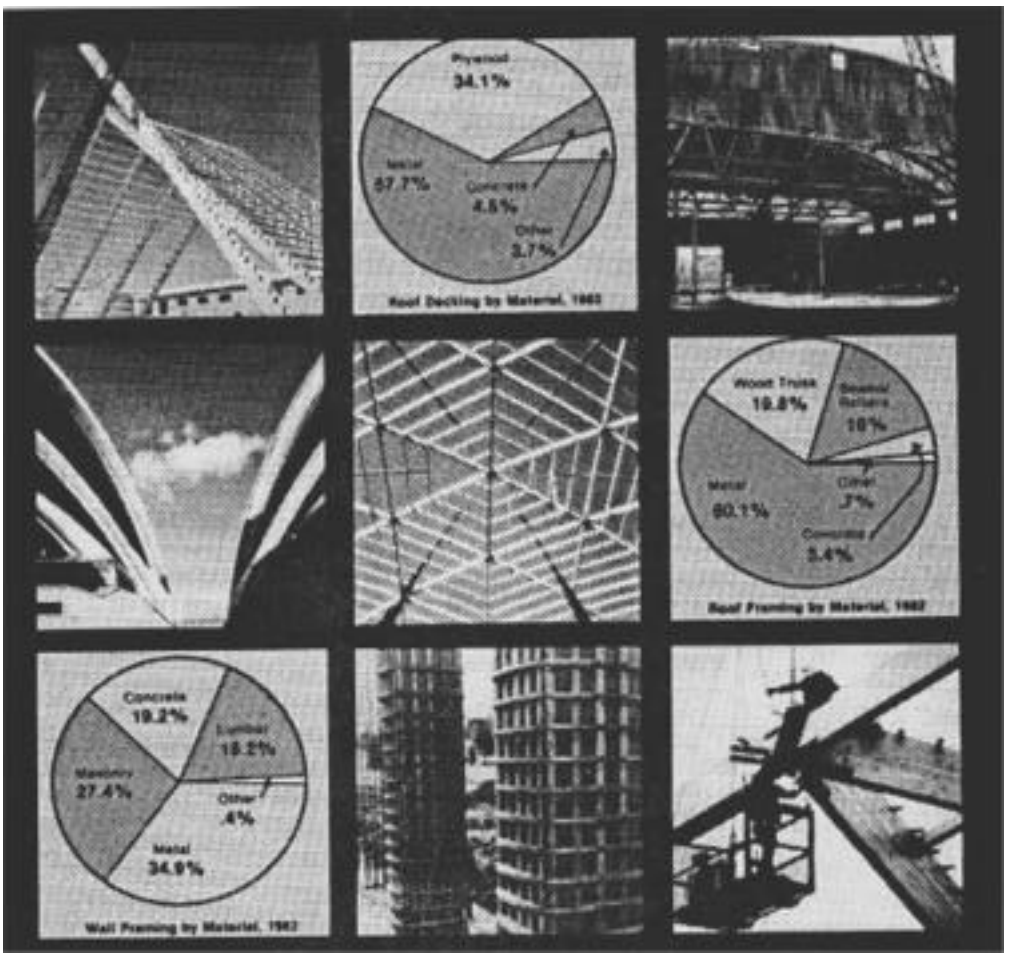
A Profile of Wood Use in Nonresidential Building Construction

Henry Spelter
Robert G. Anderson



Abstract

This report presents estimates of the amounts of lumber, glued-laminated lumber, trusses, plywood, particleboard, hardboard, and wood shingles used in new nonresidential building construction in the United States. Use of wood products is shown for several building types, project sizes, and building components. The estimates are based on a survey of 489 projects under construction in 1982-84. Lumber and plywood used per $1,000 of construction were 26 board feet and 21 square feet, respectively. These figures represent an increase over levels reported in 1969.

Keywords: Nonresidential construction markets, wood use, lumber, plywood, particleboard.

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Clarification
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Definitions

The components of the nonresidential market studied in Resource Bulletin FPL 15 were as follows:

- *New Buildings
- *Building Additions
- *Alterations or Conversions of Existing Space

The following components of the nonresidental sector were not covered:

- *Farm-Related Construction
- *Repair and Maintenance of Existing Structures
- *Nonbuilding Construction of Structures such as Dams, Highways, Sewers, etc.
- *Military Construction

Military structures were listed in FPL 15 as one of the building types included in "Public and miscellaneous" buildings (page 21, Appendix C). This is an error. Military structures were not part of this category.

Limitations of the Data

Data from the nonresidential building survey, like data from all surveys, are subject to many sources of sampling error, nonsampling error, and bias. Sampling error is a measure of the variability in the data because only a subset of buildings were canvassed rather than the entire population. Estimates of this variability are contained on page 20 of the report. Nonsampling error and bias can result from respondent error and bias, interviewer error and bias, and imputation procedures. The wording and format of the survey questionnaires, the selection of the interviewers, and the quality control built into the data collection and processing were all designed to minimize these sources of error (for further details, see Appendix A of the report).

In two areas, however, some identifiable bias occurred that may have led to undercounting of wood use. These involved (1) material use in shell buildings (buildings built speculatively without predetermined occupants) and (2) transformation of the sample to the population.

In about an eighth of the buildings, only shells were constructed, leaving interiors unpartitioned pending final building occupancy. The amount of materials used in partitions, therefore, was understated in the report. We estimate this understatement to be between 30 and 50 million board feet for lumber.

A greater source of bias might have occurred in using size classes to transform the sample to the population. Although the large building class makes up a great part of total square footage, there are relatively few large buildings. To insure selection of a meaningful number of large buildings, this class was oversampled in the survey. To compensate, the three size classes were assigned weights reflecting the underlying importance of each stratum. The implicit assumption was that the incidence of use within strata were equal. In general, this assumption did not hold, most particularly for the critical small-building category (less than 10,000 square feet). Ideally, many more strata should have been used, but such a step would have required more data--which available funds did not allow. We estimate the potential undercount at between 250 million and 350 million board feet of lumber and between 150 million and 300 million square feet of plywood.

The total potential undercount caused by these factors may be equivalent to between 13 and 19 percent of the reported estimate for lumber, and between 9 and 19 percent of the reported estimate for plywood.

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Contents

Research Highlights

In 1982, about $82.5 billion were spent for new nonresidential building construction put in place in the United States.[1] New construction consists of (1) new buildings, (2) additions, and (3) alterations. The $82.5 billion figure excludes architects' and engineering fees, about 2 percent of the total. Farm buildings are also excluded. This contrasts with about $73 billion spent for new residential buildings. Despite the higher expenditures, builders of non-residential buildings purchased much less wood than builders of residential buildings. The amounts of lumber and plywood were only one-sixth to one-fourth of the amounts estimated for residential construction. Estimated consumption of wood products based on the findings of this survey and reported 1982 construction activity were as follows:

- Lumber, 2.1 billion board feet
- Plywood, 1.7 billion square feet (3/8 in. basis)
- Structural particleboard (SPB), 41 million square feet (3/8 in. basis)
- Particleboard, 41 million square feet (3/4 in. basis)
- Hardboard, 50 million square feet (1/8 in. basis)
- Shingles, 870,000 squares (1 square = 100 ft^2)

Of the 2.1 billion board feet of lumber approximately 160 million board feet were in laminated members, 430 million were in trusses, and the remaining 1.5 billion in boards, dimension, and timbers. Of the 1.7 billion square feet of plywood, about 30 million were used as webbing in wood I-beams. Most of the remainder was used in panel form for sheathing, siding, and concrete forming. Almost 50 million board feet of the lumber and 30 million square feet of the plywood were treated with fire retardants.

Wood use varied sharply among different building size classes. Small structures (less than 10,000 ft^2) used the most. Although representing only a third of the total construction value, they accounted for over one-half of the lumber, plywood, and particleboard, and about three-quarters of the structural particleboard, hardboard, and wood shingle consumption. Medium size projects (10,000-50,000 ft^2), which accounted for a fifth of total construction, and large projects (more than 50,000 ft^2), which accounted for nearly a half of expenditures, used wood much more sparingly as illustrated by market shares of various building components. For example, in roof framing, lumber market shares in small, medium, and large projects were 45, 36, and 23 percent, respectively. Similarly, in exterior wall framing, the proportions using lumber were 27, 16, and 9 percent. In interior walls, these shares were 60, 34, and 12 percent. In roof sheathing, the largest use for plywood, market shares by project size, were 44, 36, and 20 percent.

Measured per square foot of floor area, lumber use was 1.18 board feet while plywood was 0.95 square foot. Structural particleboard use was a relatively minor 0.02 square foot, or between 2 and 3 percent of plywood's level.

Wood use is generally highest in the West and lowest in the South. Lumber used per $1,000 of construction in 1982 was 40 board feet in the West, 25 in the North, and 18 in the South. Similarly, plywood used per $1,000 of construction was 33 square feet in the West, 17 in the North, and 17 in the South. Structural particleboard use was almost totally confined to the North, being 1.3 square feet per $1,000 of construction there, near zero elsewhere.

Four trends relevant to future wood products consumption emerged from the survey responses. First, structural particleboard use is becoming a factor in the structural panel markets serving mostly as wall sheathing in small buildings. While not widely used in the survey projects, those who have tried it overwhelmingly feel that its use will increase.

Second, the use of engineered wood products, such as trusses and composite lumber/plywood I-beams, is rising. This is occurring both at the expense of nonwood materials and dimension lumber. To the extent that lumber is displaced, a net decrease in lumber use occurs because trussed and composite components are capable of supporting a given load with less wood than freestanding lumber.

Third, wood siding materials, primarily lumber and plywood, appear to be replacing some brick siding. Wood sidings cost less to install, and many feel they give a more desirable appearance, considerations which offset higher maintenance costs.

Fourth, noncombustible materials are replacing some lumber framing. Steel framing is the primary beneficiary, as its in-place costs are more competitive than masonry construction and fire-retardant-treated wood framing.

Comparison of the results of this survey with the previous 1969 survey shows that the use of wood products has increased. The use of lumber per square foot of floor area was 15 percent higher in 1982. For plywood, the gain was a much higher 55 percent. Structural particleboard was not used in any significant volume prior to the mid-seventies.

'U.S. Department of Commerce, Bureau of the Census. Value of new construction put in place. Construction Reports (30-83-11); 1983.

A Profile of Wood Use in Nonresidential Building Construction

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Introduction

The new nonresidential building construction market, consisting of commercial, industrial, institutional, and nonhousekeeping structures, represents a major market for producers of building materials. About $82.5 billion worth of contracts for such construction were awarded in 1982, an amount exceeding the value of new residential construction. Although considerable quantities of wood products are purchased for such construction, the actual share of wood products in this activity has traditionally been small.[2,3] With many well-established nonwood materials available as alternatives to wood, even this share cannot be taken for granted.

This report contains information on the recent status of wood-based building materials in nonresidential building construction and highlights some of the problems and opportunities wood manufacturers face. The first section covers information from our survey about characteristics of new nonresidential and nonhousekeeping building construction, such as floor area, regional distribution, and type of construction. The second provides detailed information on estimated wood use. The third presents estimates of wood use per dollar of construction and per square foot of floor space (use factors). The fourth describes the materials used in various building components. The paper concludes with a discussion of the findings in this study. Appendix A contains a description of the survey methods and Appendix B a discussion of statistical method and the extrapolations made to obtain the information reported. Definition of terms used in this survey for building types, construction measures, and products is provided in Appendix C.

[2]Rieid, Willlam H.; Wright, Maurice G. Wood products use in the construction of nonresidential and nonhousekeeping buildings-United States, 1969. Stat. Bull. 534. Washington, DC: USDA, Forest Service; 1974. 70 p.

[3]Anderson, Robert G. Softwood plywood use in nonresidential construction. Market Res. Rep. R41. Tacoma, WA: American Plywood Association: 1978.

Nine categories of buildings were defined for the purposes of this study; offices, stores, industrial, schools, hospitals, religious. recreational, non-housekeeping, and public (see Appendix C for definitions). For projects in each category, data were gathered on: area of flat and pitched roofs, area of exterior and interior walls (net of openings for doors and windows), and area of ground and upper story floors. In addition, the dollar value of construction was obtained. From these sample characteristics the characteristics of the industry, as defined by F. W. Dodge contract awards, were estimated using conversion factors based on the ratio of Dodge construction values to sample construction values. Dodge. however, misses a portion of construction, particularly in the smaller size categories. A second conversion was made, therefore, to account for these omissions (for specifics see Appendix B). On the basis of the above procedure, we estimated the following characteristics of nonresidential building construction for which *contracts were awarded in 1982.*

Value of Construction

- The total value of building construction as measured by contract awards was $82.5 billion (table 1) distributed between different building types as shown in figure 1.
- Small projects represented 33 percent of the value, medium 22 percent, while 45 percent were in large projects (table 1).
- Thirty-six percent were located in the northern census regions (Northeast and North Central), 41 percent in the South. and 23 percent in the West (table 1).

Roof Area

- Total roof area was 1.38 billion square feet (table 2) or 27 percent of building component surfaces (fig. 2).
- Sixty-five percent was flat (table 2).
- On the average, for each square foot of floor area there was 0.77 square foot of roof area (table 2). This ranged from 1.13 for schools to 0.47 for offices.

Exterior Wall Area

- Total exterior wall area was 1.06 billion square feet (table 2) or 21 percent of building component surfaces (fig. 2).
- On the average, for each square foot of floor area there was 0.59 square foot of exterior wall surface (table 2). This ranged from 0.74 for industrial projects to 0.50 for stores.

Interior Wall Area

- Total interior wall area was 0.86 billion square feet (table 2) or 17 percent of building component surfaces (fig. 2).
- On the average, for each square foot of exterior wall area, there was 0.81 square foot of interior wall surface (table 2). This ranged from 1.90 for hospitals to 0.58 for religious buildings.

Floor Area

- Total floor area was 1.79 billion square feet (table 2) or 35.2 percent of building component surfaces (fig. 2).
- Twenty-eight percent was in upper stories (table 2).
- On the average, building costs per square foot of floor area were $46 (table 2). The cost varied from $63 a square foot for public projects to $33 for stores.

Number of Floors

- Fifty-five percent of the floor area was in single-story structures (table 2). Two-story buildings accounted for 23 percent, while buildings three stories or higher made up 22 percent.

Table 1.—Estimated value of new nonresidential building activity based on 1982 contract awards, by building type, size, and region

Building type	Project size[1]			Region			Total
	Small	Medium	Large	North	South	West	
	Billion dollars						
Offices	5.1	3.3	11.7	5.9	8.5	5.8	20.1
Stores	5.2	3.4	5.5	4.1	6.3	3.7	14.2
Industrial	6.5	3.0	8.6	8.4	7.0	2.8	18.2
Schools	2.8	2.2	2.7	2.8	3.1	1.8	7.7
Hospitals	2.2	2.3	4.3	4.2	3.0	1.6	8.8
Religious	.9	7	.0	.5	.7	.3	1.6
Recreation	1.5	1.0	.8	1.0	1.4	.8	3.2
Hotels	1.4	1.1	1.8	1.4	1.8	1.0	4.3
Public and miscel-laneous	1.7	1.0	1.6	1.5	1.5	1.3	4.3
Total	27.3	18.1	37.1	29.9	33.4	19.2	82.5

[1]Small = <10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

To summarize, building characteristics dictate the amount of materials used. The purposes for which buildings are intended are a prime influence in this regard. Building size and number of stories are other factors.

Structures intended for general public use, such as churches, stores, and manufacturing facilities, typically have large unpartitioned interiors with fewer than average inside walls. More restricted-use buildings such as offices and hotels are more subdivided. Hospitals, where many functions do not require natural light, are the most partitioned structures and have the greatest area of inside walls relative to floor space.

Roof area relative to floor space is governed by the number of floors and pitch of roof. Industrial buildings, schools, churches, and recreatronal facilities tend to be one-story structures and their roof/floor ratios are close to one. Offices, hospitals. and hotels tend to be multistoried and have less roof area relative to floors.

Exterior wall area relative to floor area is the least variable ratio across building types. The ratio declines as structures increase in size and as the number of stories increase.

The absence of basements is another characteristic of most nonresidential buildings. Unlike residential buildings, where almost half the structures have a basement, nonresidential buildings are typically built on a slab at ground level.

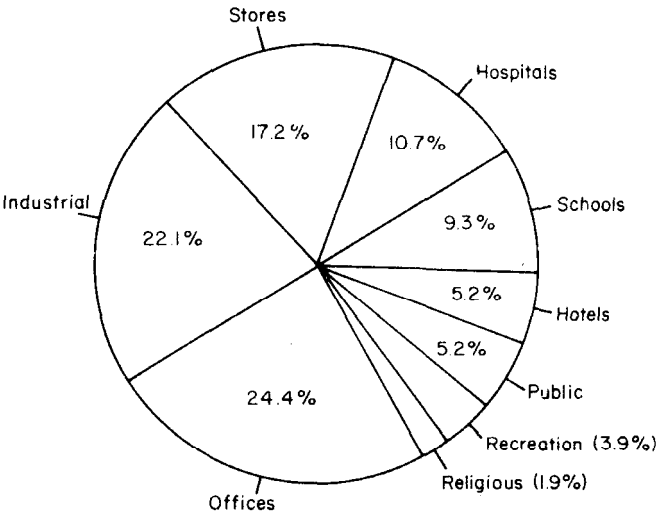

Figure 1.—Construction value by building type, 1982. Total 82.5 billion dollars. (ML84 5634)

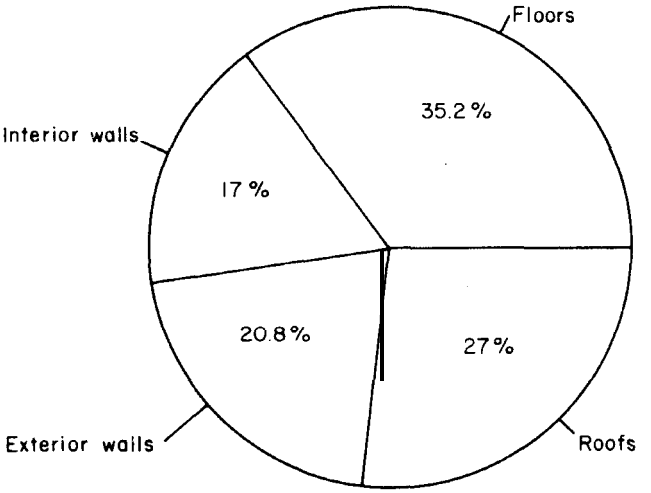

Figure 2.—Building component surfaces, by component, 1982. Total 5.09 billion square feet. (ML84 5635)

Table 2.—Characteristics of new nonresidential buildings based on 1982 contract awards[1]

Building type	Roof area	Percent flat	Exterior wall area	Interior wall area	Ratio of interior/ exterior walls	Floor area	Percent upper floors	Ratio of roofs to floors	Ratio of exterior walls to floors	Dollar cost per square foot
Offices	174	67	195	194	1.00	368	57	0.47	0.53	55
Stores	372	69	219	133	.61	435	16	.86	.50	33
industrial	359	79	306	113	0.37	414	13	.87	.74	44
Schools	170	58	84	101	1.20	150	10	1.13	.56	51
Hospitals	100	43	87	165	1.90	164	44	.61	.53	54
Religious	31	24	20	12	.58	29	11	1.08	.69	55
Recreation	63	71	44	35	.81	69	13	.91	.63	47
Hotels	56	21	61	69	1.12	97	44	.58	.64	44
Public and miscellaneous	52	60	45	42	.95	69	29	.75	.64	63
Number of floors										
1	1,034	65	701	413	0.59	992	0	1.04	0.71	40
2	258	56	194	239	1.23	404	43	.64	.48	45
3	46	81	59	79	1.35	134	66	.35	.44	52
4 or 5	24	97	38	39	1.03	93	77	.26	.41	63
6 or more	14	99	69	94	1.35	171	93	.08	.41	70
Project size										
Small	566	53	487	322	.66	592	9	.96	.82	46
Medium	388	59	271	210	.78	468	20	.83	.58	39
Large	422	87	303	332	1.10	733	48	.58	.41	51
Overall	1,376	65	1,061	864	.81	1,794	28	.77	.59	46

'Characteristics were inferred from the sample of 489 projects, Areas are in million ft^2.

Table 3.—Wood products in new nonresidential buildings, based on 1982 awards, by building type

Building type	Lumber		Plywood (3/8-in. basis)		Other products			
	Total	Fire-retardant treated	Total	Fire-retardant treated	Structural particle. board (3/8-in. basis)	Particle board (3/4-in. basis)	Hardboard (1/8-in. basis	Shingles
	Million board feet		*Million ft^2*					*Thousand squares*
Offices	421	8	323	2	16	7	21	313
Stores	535	12	440	14	7	5	7	75
Industrial	215	5	166	1	11	3	17	137
Schools	223	14	179	8	2	3	0	43
Hospitals	296	7	236	2	1	4	2	229
Religious	88	1	65	1	0	1	0	16
Recreation	110	1	75	1	0	0	0	7
Hotels	152	2	146	2	4	14	0	7
Public and miscellaneous	85	0	72	1	0	4	2	44
Total	2,125	49	1,701	31	41	41	50	872

Wood Products Used in Building Construction

Wood product use was estimated by building type and component. The following are included:

- Lumber (board, dimension, timbers, trussed, laminated, fire-retardant-treated)
- Plywood (panel form, beam members, fire-retardant-treated)
- Structural particleboard
- Particleboard
- Hardboard
- Wood shingles

Estimates of waste and loss are included in the amounts shown in tables 3 to 6. They are 10 percent for lumber and 5 percent for panels.

Lumber

Total lumber use for 1982 was estimated at 2.13 billion board feet (table 3). Stores account for the largest fraction (25 pct), followed by offices (20 pct), hospitals and clinics (14 pct), and schools (11 pct). The remaining 30 percent is scattered among the five other building types.

Roof framing is by far the largest use of lumber (fig. 3, table 4). Building codes in general require greater fire resistance in walls, partitions, and floors than in roofs. Hence, it is not uncommon to see a wood-framed roof on a structure with masonry or other noncombustible exterior walls. This drives up wood use in roofs relative to other components. For all buildings, 40 percent of the lumber is used in roofs, principally as trusses, but also as beams, rafters, joists, and decking. Another 15 percent is used for framing interior walls and partitions and 13 percent for exterior walls. Floor framing accounts for only 10 percent while use of lumber for facilitating purposes, such as concrete forming, scaffolds, and shoring, accounts for 8 percent. This latter figure excludes (1) reused materials and (2) volumes that were ultimately used elsewhere in a building after initial use as facilitating material. A variety of other uses, such as millwork, siding, flooring, landscaping, fencing, and privacy screening account for the remaining volumes (fig. 3).

About 8 percent of the lumber or 163 million board feet is laminated (fig. 4). This includes both conventional glued-laminated timbers (glulam) and lumber in glued wood-plywood members of built-up cross sections (wood I-beams). Greatest concentrations of use are in stores where 58 million board feet are used (11 pct of all lumber use in that building type), industrial (24 million fbm, 11 pct of total), offices (18 million fbm, 4 pct of total), and religious (16 million fbm, 19 pct of total). Laminated timbers are used primarily in roofs while glued wood-plywood beams tend to be used in floors.

Trusses account for more than one-fifth of lumber use or 430 million board feet (fig. 4). Greatest use is in stores and offices (108 and 95 million fbm, respectively) with schools third (70 million fbm). Most of the volume goes into roofs, but floor truss use in upper stories is also widespread.

Little fire-retardant-treated lumber is used–49 million board feet (table 3). Schools and stores use the most. Fire-retardant-treated lumber is used most for partitions but can also be found in a host of other uses such as roof blocking, top and bottom plates, wall furring, doors, trusses, and so on.

Plywood

Over 1.7 billion square feet (3/8-in. basis) of plywood were used in construction of nonresidential and nonhousekeeping buildings during 1982 (table 5).

As with lumber, the largest volume of the product goes into roofs (fig. 5, table 5). Roof sheathing or decking accounts for 48 percent of the total volume. Subflooring and floor underlayment are second with 17 percent, followed by concrete forming (14 pct) and wall sheathing (7 pct). The remaining 14 percent goes into a variety of uses, including soffits, siding, millwork, glued wood-plywood joists, and miscellaneous uses.

The amount of fire-retardant-treated plywood is just 31 million square feet. Uses range from decking entire roofs and floors to minor uses such as backing for telephone equipment, cabinetry, and doors.

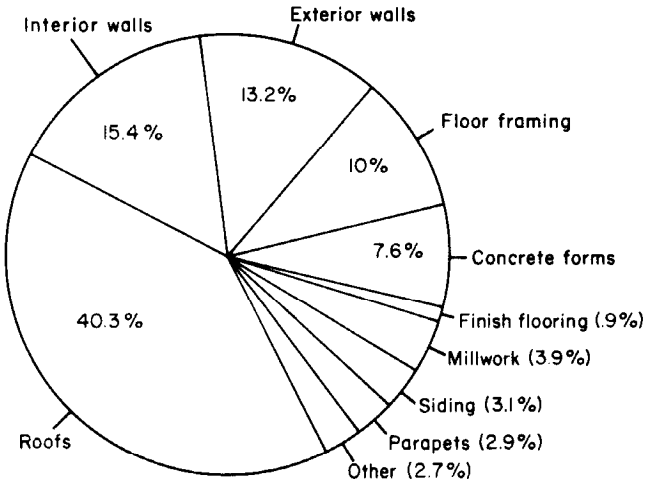

Figure 3.—Lumber used in nonresidential construction by building component, 1982. Total 2.13 billion board feet. (ML84 5636)

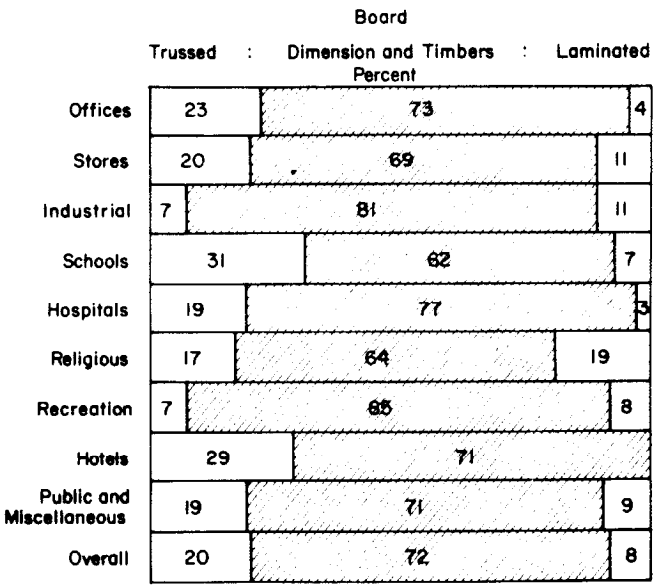

Figure 4.—Percentages of trussed, board dimension and timbers, and laminated lumber used for different types of nonresidential buildings, based on 1982 awards. (ML84 5638)

Table 4.—Lumber used in new nonresidential buildings based on 1982 contract awards, by building type

Building type	Roof framing	Exterior wall framing	Interior wall framing	Floor framing	Concrete forms and scaffolds	Parapets, canopies, and facias	Siding and trim	Mill-work	Finish flooring	Other and not specified	Total lumber
	Million board feet										
Offices	124	64	55	72	42	18	16	14	3	13	421
Stores	268	59	72	22	44	21	10	28	4	7	535
Industrial	72	41	26	16	35	4	8	8	0	6	215
Schools	110	27	36	14	10	6	4	11	2	4	223
Hospitals	133	42	63	29	4	3	14	7	0	2	296
Religious	46	12	8	6	2	1	4	5	0	4	88
Recreation	32	11	15	9	8	3	3	5	11	13	110
Hotels	43	15	43	35	4	1	4	4	0	4	152
Public and miscell-aneous	28	10	10	8	13	5	5	2	0	4	85
Total	856	280	327	212	162	62	66	83	20	57	2,125

Table 5.—Plywood used in new nonresidential buildings based on 1982 contract awards, by building type

Building type	Roof sheathing	Soffits	Sub-flooring and under layment	Siding	Wall sheathing	Mill-work	Concrete forming	I-beams	Other	Total plywood
	Million ft² (3/8-in, basis)									
Offices	135	11	75	14	31	3	43	5	7	323
Stores	247	17	34	9	30	8	67	4	24	440
Industrial	77	4	10	1	4	3	56	5	6	166
Schools	109	7	23	4	15	2	15	3	1	179
Hospitals	99	9	75	3	20	4	16	8	1	236
Religious	40	2	10	3	4	1	3	1	2	65
Recreation	29	1	12	0	10	1	8	4	10	75
Hotels	59	4	35	0	6	35	3	1	2	146
Public and miscellaneous	19	2	7	2	6	2	30	1	4	72
Total	814	57	280	37	125	58	242	31	57	1,701

Table 6.—Panel products used in new nonresidential buildings based on 1982 contract awards, by building type

Building type	Structural particleboard (3/8-in. basis)					Particleboard, (3/4-in. basis)				Hard. board (1/8-in. basis)
	Roof sheathing	Exterior wall sheathing	Floor sheathing	Interior and other	Total	Under-layment	Mill-work	Other	Total	Total
	Million ft²									
Offices	11.8	3.7	0.0	0.4	15.9	1.3	5.3	0.5	7.0	21.5
Stores	.0	1.3	.0	5.7	6.9	1.3	2.8	.5	4.6	6.7
Industrial	.0	10.7	.0	.3	10.9	.5	1.7	.3	2.5	17.4
Schools	.5	.0	.3	.9	1.7	.7	2.3	.0	3.0	.3
Hospitals	.0	.9	.0	.0	.9	2.7	1.5	.0	4.3	1.6
Religious	.0	.0	.0	.0	.0	.5	.0	.0	.5	.3
Recreation	.0	.0	.0	.0	.0	.1	.0	.1	.1	.4
Hotels	1.9	.0	2.5	.0	4.4	13.0	1.5	.0	14.5	.0
Public and miscellaneous	.0	.0	.0	.1	.1	.0	4.3	.0	4.4	1.8
Total	14.2	16.5	2.8	7.3	40.8	20.1	19.4	1.4	40.9	49.9

Structural Particleboard (Nonveneered Structural Panels)

Structural particleboard consumption was 41 million square feet during 1982 (3/8-in. basis, table 6). Most is used for roof and wall sheathing (40 and 35 pct, respectively) (fig. 6, table 6). Interior uses, such as accent paneling, backing for inside wall finishes, stair treads, etc., are the third highest end use and account for 18 percent of the total. Floor sheathing takes 7 percent.

Particleboard (Nonstructural)

Total nonstructural particleboard use was 41 million square feet (3/4-in. basis, table 6). This represents the portion which was used in its unprocessed form at the building site. The volumes which are used as parts of other products, such as cabinets, vanities, or doors, are not included but are covered in the survey of manufacturing industries.[4]

Flooring underlayment represents half the volume used (table 6), millwork most of the other half. Miscellaneous uses account for 3 percent.

Hardboard

Total hardboard use was calculated at 50 million square feet (1/8-in. basis, table 6). Hardboard use, like particleboard use, includes only that portion used by the contractor on the job. Hardboard used in cabinets, millwork, and doors manufactured off site is included in a separate report.[4] Most of the identified product is used for millwork, with scattered reports of use for interior walls, floors, and sidings.

Shingles

Total use of wood shingles is 872,000 squares (a square equals 100 ft^2). Offices and hospitals account for over 62 percent of total use (table 3). Most is used in roofs and mansards, with some additional use as siding.

[4]McKeever. David B.: Martens, David G. Wood used in U.S. manufacturing Industries. 1088/ Res. Bull. FPL-12. Madison. WI. U.S. Department of Agriculture, Forest Service. Forest Products Laboratory: 1983

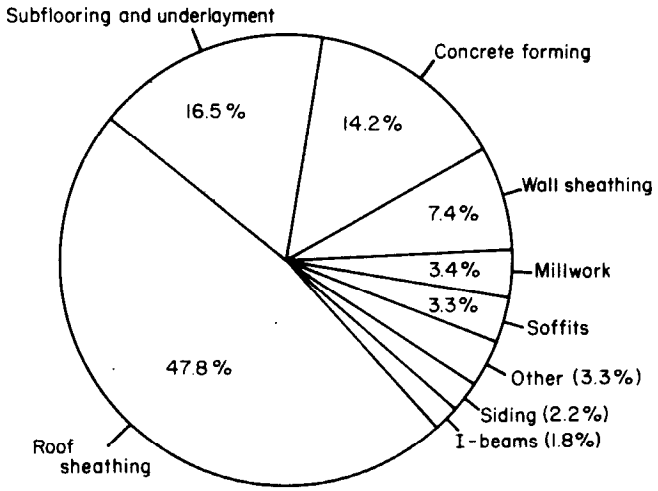

Figure 5.—Plywood used in nonresidential construction by building component, 1982. Total 1.7 billion square feet (3/8-in. basis). (ML84 5637)

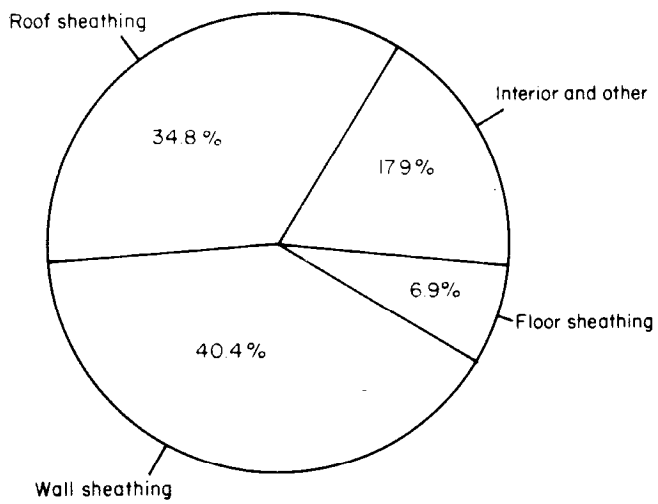

Figure 6.—SPB used in nonresidential construction by building component, 1982. Total 41 million square feet (3/8-in. basis). (ML84 5639)

Wood Use Factors

It is helpful to compare consumption of wood per dollar of construction or per square foot of floor space for different building categories. Such measures indicate intensity of wood use and provide a link between a given level of construction and total wood use. Wood use per thousand dollars of construction was calculated by each building type, region, and project size (table 7). Wood use per square foot of floor area was also calculated by building type and by number of stories (table 8).

Lumber

Lumber use per $1,000 of construction averages 25.8 board feet (table 7, fig. 7). The factor is highest for religious buildings where the popularity of vaulted, exposed ceilings leads to wide use of laminated timber beams and lumber roof decking. It is lowest in industrial buildings (only 11.8 fbm per $1,000), due to fewer interior walls, more flat roofs, and higher incidence of preengineered steel or structural steel buildings.

Use factor is highest in the West, lowest in the South. and near average in the North (table 7, fig. 8). The use factor is over twice as high in the West as in the South. By project size, the use factor for smallest buildings is over four times that for large.

On the average. 1.18 board foot of lumber is used per square foot of floor area (table 8). The range is from a high of 3.03 board feet for religious structures to 0.52 for industrial.

Plywood

The amount of plywood used per $1,000 of construction averages 20.6 square feet (3/8-in. basis, table 7, fig. 9). As with lumber, the highest intensity of use is in religious buildings and the lowest is in industrial projects. Further parallels to lumber use exist in relation to region and project size (table 7, fig. 10). Use intensity is highest in the West and in small projects, lowest in the South and in large projects.

Use of plywood averages 0.95 square foot per square foot of floor area (table 8) and ranges from 2.23 for religious structures to 0.40 for industrial projects.

Structural Particleboard (Nonveneered Structural Panels)

The amount of structural particleboard used per $1.000 of construction is 0.50 square foot (3/8-in. basis, table 7). The highest use factors are in hotels and offices while several building types reported little or no structural particleboard use.

Almost all structural particleboard is used in the North (table 7). Most plants are located in this region or in adjacent Canadian provinces. The northern use factor of 1.32 square feet per $1,000 of construction dwarfs the 0.01 in the South and the 0.06 in the West. The use factor by project size follows the expected pattern with the highest level reported in small projects.

On a per square foot basis, the use factor is slightly larger than 0.02 square foot.

Particleboard (Nonstructural) and Hardboard

The amount of nonstructural particleboard used per $1,000 of construction is 0.50 square foot (3/4-in. basis). Hardboard use is a slightly higher 0.60 square foot (1/8-in. basis).

On a regional basis, nonstructural particleboard use is highest in the West, and lowest in the North. Hardboard use, by contrast, is highest in the South and lowest in the West. Use by project size follows the expected pattern of decline as projects get bigger.

Wood Shingles

For every million dollars of construction, 10.6 squares of shingles are used. Use is highest in hospitals and offices, lowest in recreation and hotel structures. The highest rate of use is found in the North, the lowest in the West.

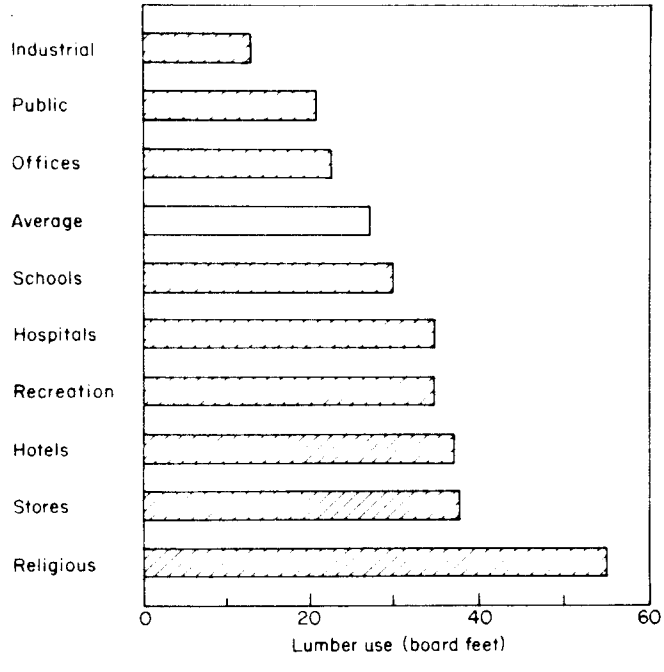

Figure 7.—Lumber use per 1,000 1982 dollars. by building type. (ML84 5629)

Table 7.—Wood products used per $1,000 of construction in new nonresidential buildings, based on 1982 contract awards

Building type	Lumber	Plywood (3/8-in. basis)	Structural particle. board (3/8-in. basis)	Particle-board (3/4-in. basis)	Hardboard (1/8-in. basis)	Shingles
	Board feet		*Ft²*			*Thousand squares*[1]
Offices	20.9	16.0	0.79	.35	1.07	15.6
Stores	37.7	31.0	.49	.33	.47	5.3
industrial	11.8	9.1	.60	.14	.96	7.6
Schools	28.9	23.2	.22	.39	.04	5.6
Hospitals	33.6	26.8	.10	.49	.18	26.1
Religious	55.0	40.4	.00	.31	.17	9.7
Recreation	34.0	23.1	.00	.05	.11	2.0
Hotels	35.8	34.2	1.04	3.40	.00	1.7
Public and miscellaneous	19.6	16.5	.02	1.00	.41	10.2
Average	25.8	20.6	.50	.50	.60	10.6
Region						
North	24.7	17.3	1.32	0.31	0.61	19.6
South	18.3	16.6	.01	.55	.89	7.0
West	40.3	32.8	.06	.68	.11	2.6
Average	25.8	20.6	.50	.50	.60	10.6
Project size[2]						
Small	44.1	32.1	1.05	0.88	1.40	25.0
Medium	29.8	25.1	.54	.43	.62	8.7
Large	10.3	9.9	.07	.24	.02	.8
Average	25.8	20.6	0.50	0.50	.60	10.6

[1]Per billion dollars.

[2]Small = <10,000 ft², medium = 10,000-50,000 ft², large = >50,000 ft².

NOTE: To convert factors to constant (1977) dollar basis, multiply by 1.56.

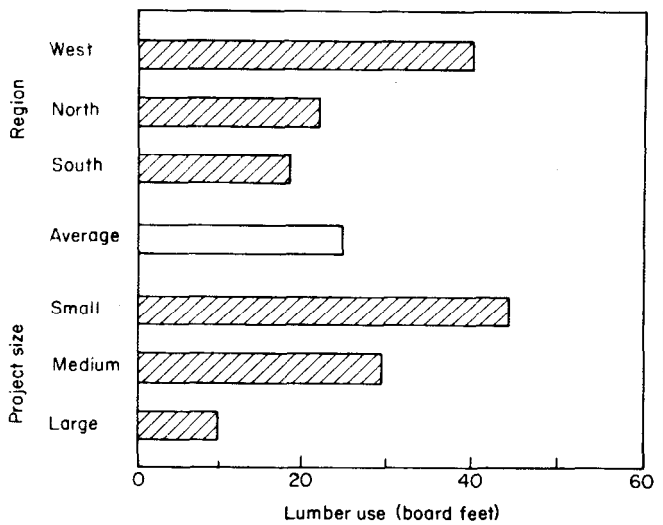

Figure 8.—Lumber use per 1,000 1982 dollars, by region and size class. (ML84 5630)

Table 8.—Wood products used per square foot of new nonresidential building construction based on 1982 contract awards

Building type	Lumber	Plywood (3/8-in. basis)	Structural particle-board (3/8-in. basis)	Particle board (3/4-in. basis)	Hardboard (1/8-in. basis)	Shingles
	Board feet			*Ft²*		*Thousand squares*[1]
Offices	1.14	0.88	0.04	0.02	0.06	0.85
Stores	1.23	1.01	.02	.01	.02	.17
Industrial	.52	.40	.03	.01	.04	.33
Schools	1.49	1.20	.01	.02	.00	.29
Hospitals	1.80	1.43	.01	.03	.01	1.40
Religious	3.03	2.23	.00	.02	.01	.53
Recreation	1.59	1.08	.00	.00	.01	.10
Hotels	1.58	1.51	.05	.15	.00	.07
Public and miscellaneous	1.23	1.04	.00	.06	.03	.64
Average	1.18	.95	.02	.02	.03	.49
Number of floors						
1	1.29	1.01	0.01	0.03	0.03	0.56
2	1.56	1.12	.07	.02	.04	.56
3	1.20	1.17	.00	.01	.03	.66
4 or 5	.23	.63	.00	.00	.00	.00
6 or more	.18	.17	.00	.02	.00	.00
Average	1.18	.95	.02	.02	.03	.49

[1]Per million square feet.

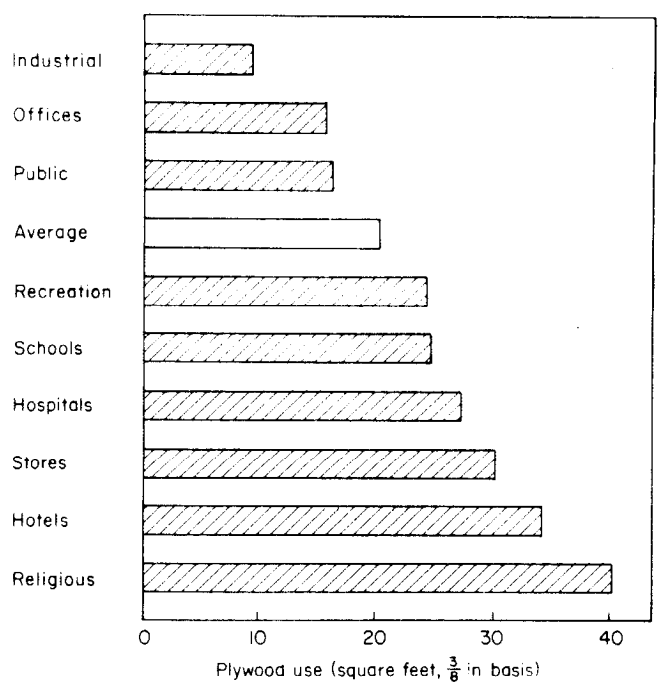

Figure 9.—Plywood use per 1,000 1982 dollars, by building type. (ML84 5631)

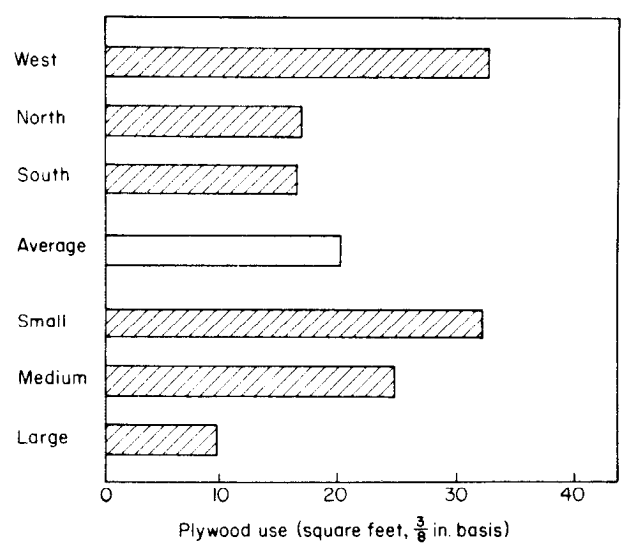

Figure 10.—Plywood use per 1,000 1982 dollars, by region and size class. (ML84 5632)

Materials Used in Building Components

In this section, we compare wood use to use of competing construction materials. First we describe the distribution of materials in the framing of components, then in the decking, sheathing, and siding elements.

Roof Framing

Metal is the most widely used material in framing for roofs, primarily in the form of steel beams or steel bar joists in flat roofs and steel trusses in pitched roofs (table 9). Overall, 60 percent of roofs are framed with metal, ranging from 50 percent for small projects to 72 percent for large.

Wood truss framing is used for 20 percent of roofs. The smaller a building, the more likely it is to be framed with wood trusses. Roofs of small projects are 29 percent wood truss framed, medium projects are 20 percent, and large projects are 6 percent.

Laminated wood beam or rafter-joist framing is used on 16 percent of roofs. Use is fairly evenly distributed between size classes.

Concrete roofs are used for only 3 percent of total roof area.

Wall Framing

Noncombustible materials dominate exterior wall framing (table 10). Structural steel and load-bearing steel studs account for 35 percent of the market, masonry 27 percent, and concrete 19 percent. Lumber is fourth with 18 percent. The lumber share is a moderately high 27 percent in small structures, but drops to 16 percent in medium and 7 percent in large structures.

Interior Wall Framing

Metal studs also dominate the interior wall market with 52 percent of the total area (table 10). Lumber studs are second, however, with 35 percent. Lumber framing dominates the small size class with 60 percent of the total but drops to 34 percent in medium and 12 percent in large structures while metal framing rises from 26 percent in small projects to 77 percent in large. Masonry construction represents about 11 percent of the total and concrete less than 2 percent.

Ground Floor Framing

As most nonresidential buildings lack a basement, the dominant structural floor material is concrete slab (table 11). Almost 92 percent of the total is concrete. Concrete over metal framing accounts for 2.5 percent and wood for about 4 percent.

Table 9.—Roof framing in new nonresidential buildings based on 1982 contract awards, by project size and material

Project size	Metal	Concrete	Wood truss	Laminated beams or rafters	Other
			pct		
Small	50.3	3.2	29.4	16.0	1.0
Medium	61.5	2.0	20.4	15.2	.9
Large	72.1	4.9	6.2	16.8	.0
Average	60.1	3.4	19.8	16.0	.7

[1]Small = <10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

Table 10.—Wall structure of new nonresidential buildings based on 1982 contract awards, by project size and material

Project size[1]	Metal	Concrete	Masonry	Lumber	Other
			Pct		
Exterior					
Small	28.8	10.6	33.8	26.7	.0
Medium	46.4	14.7	23.0	15.6	.3
Large	34.4	36.9	21.0	6.7	1.0
Average	34.9	19.2	27.4	18.2	.4
Interior					
Small	25.5	0.7	13.5	59.8	.0
Medium	51.2	2.8	11.0	33.6	1.4
Large	77.1	1.6	9.5	11.8	.0
Average	51.6	1.6	11.4	35.0	0.3

[1]Small = <10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

Upper Floor Framing

Concrete over metal framing or reinforced concrete dominates flooring in large-sized structures where most multistoried buildings are found (table 11). In smaller and medium structures wood framing has significant portions of the total with 76 and 35 percent, respectively. But the wood proportion overall is only 18 percent.

Roof Decking

Metal and plywood are the two most widely used decking materials (table 12). Metal decking accounts for 58 percent of roof surfaces, plywood for 34 percent. Concrete accounts for an additional 4.5 percent while other materials, chiefly fiberboard, structural particleboard and lumber. cover 3.7 percent. Paralleling wood framing, plywood IS used more in small than in large projects.

Wall Siding

A great variety of siding products are used in nonresidential buildings (fig. 11. table 13). Masonry is most frequent with 39 percent of walls. This is followed by metal siding and concrete with 19 and 17 percent. respectively. Stucco or stuccolike products. glass, stone, plywood and lumber account for most of the rest.

Wall Sheathing

Three-quarters of walls are not sheathed as either the siding is put directly over the framing or the structural material is left uncovered (table 14). Plywood sheathing accounts for 8 percent of total wall surfaces. followed by gypsum board (6 pct). Styrofoam (6 pct), fiberboard (4 pct), and other materials (2 pct). These figures exceed 100 percent slightly because in some **instances double-layer sheathing is used, primarily plywood or gypsum over foam-based sheathing.**

Table 11.—Floor structure of new nonresidential buildings based on 1982 contract awards, by project size and material

Project size[1]	Metal	Concrete	Concrete and metal	Wood
		Pct		
Ground floor				
Small	1.0	89.7	0.3	6.9
Medium	.6	95.0	1.5	2.8
Large	.0	91.7	6.7	.6
Average	.6	91.8	2.5	3.8
Upper floors				
Small	.0	9.8	9.8	76.2
Medium	2.7	12.8	48.7	35.0
Large	4.0	16.4	75.1	4.4
Average	3.4	15.0	63.3	17.7

[1]Small = <10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

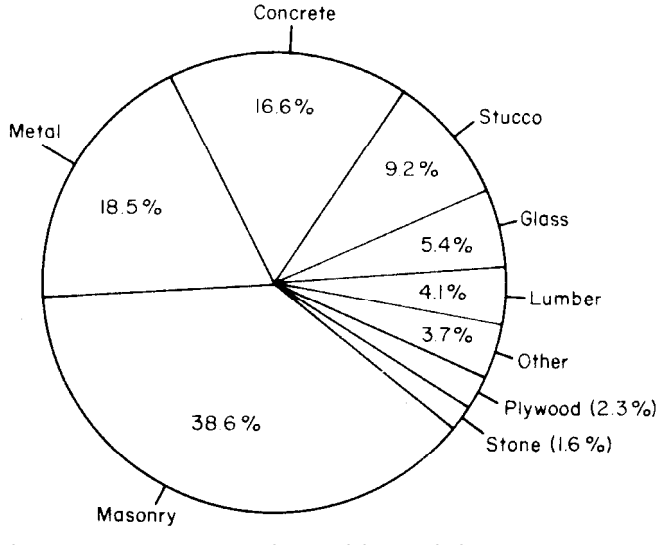

Figure 11.—Percentages of materials used for exterior siding. by area of exterior walls. (ML84 5633)

Table 12.—Roof decking of new nonresidential buildings based on 1982 contract awards, by project size and material

Project size[1]	Metal	Concrete	Plywood	Other
		Pct		
Small	47.6	3.5	43.5	5.4
Medium	58.6	3.4	35.6	2.0
Large	70.0	7.0	19.9	3.1
Average	57.6	4.5	34.1	3.7

[1]Small = ≤10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

Table 13.—Wall siding of new nonresidential buildings based on 1982 contract awards, by project size and material

Project size'	Metal	Concrete	Masonry	Glass	stucco	Stone	Plywood	Lumber	Other
					Pct				
Small	17.9	7.4	44.8	1.9	11.3	1.0	3.0	7.1	5.7
Medium	32.6	11.6	37.3	2.2	9.5	.1	2.8	2.3	1.5
Large	7.0	35.7	29.7	13.9	5.6	3.9	.8	1.0	2.4
Average	18.5	16.6	38.6	5.4	9.2	1.6	2.3	4.1	3.7

[1]Small = <10,000 ft^2, medium = 10,000-50.000 ft^2, large = >50,000 ft^2.

Table 14.—Wall sheathing of new nonresidential buildings based on 1982 contract awards, by project size and material

Project size[1]	Ply wood	Fiber board	Styro-foam	Gyp sum	Other	None
			Pct			
Small	11.0	5.3	7.0	3.4	3.6	69.8
Medium	6.6	2.6	5.4	11.0	2.3	72.3
Large	3.1	1.8	3.4	7.5	0	84.6
Average	7.6	3.6	5.5	6.5	2.2	74.7

[1]Small = ≤10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

Discussion

The survey results show a high frequency of wood use in small buildings. As the size of structure increases, the amount of wood declines per square foot of floor area. This condition covers all building types but is not as prevalent in the West, where wood construction systems have broader general usage. While the survey did not fully account for factors governing choice of materials, it did identify a number of factors and attitudes which may help explain the variations in wood use.

First. nonresidential construction covers a wide range of building sizes and occupancies. Buildings are physically larger and usually have fewer partitions than residential units. This means spans can be longer, loads heavier, and stresses greater than in residential work. Designers typically look to steel and masonry to meet more demanding requirements for this type of larger building, although perfectly acceptable wood systems may be available. Standard light framing methods fit small structures well, and builders of such structures are familiar with them. However, larger structures, which would use laminated beams or structural timbers, in many cases are not not designed with wood because the architects are not familiar with nor trained in design and engineering for such wood use.

Second, and related to the lack of training and experience with wood design, is the fire safety issue. Most localities base their codes on one of the three model codes used in the United States and modify it according to local requirements.

A common feature of all codes is that a category of noncombustible construction exists where wood is not permitted even if it has been treated with fire retardant. Generally, the buildings in this category are five or more stories in height or have unique occupancy and/or site location. More often than not the buildings are large.

There are nevertheless many situations in which wood construction systems could be used, but a lack of familiarity with codes keep wood from consideration. With a better knowledge of the code, wood buildings could in most cases be successfully erected.

Contractors' attitudes toward wood are also influential. In interviews conducted in the course of this survey, three aspects of wood as building material received particular comment-cost, durability, and quality.

In connection with cost, many building contractors believe that wood construction may be more costly than nonwood despite a lower price per piece, and perceive systems, particularly in metal, as having some inherent value. The preengineered metal building industry has capitalized on these perceptions, offering a turnkey quote method, while most wood systems are pretty much sold by the piece. Several building contractors commented that the wood industry could benefit by offering a complete building package rather than forcing the contractor to go to a number of sources to get the parts for assembly on the job. Such packaging, they suggested, would not only make the job easier for builders but would increase efficiency with potential cost savings.

In connection with durability, respondents in hot humid southern areas referred to termites and rot as restricting wood use. Although treatment is available which enables wood products to withstand these problems, the possibility of infestation is still viewed as giving wood less permanence than steel or concrete.

The third area of comment related to product quality. Crooked and warped lumber is a common irritant to builders. Poor quality was the reason most frequently given by respondents who said they would use less wood in the future.

Interviewers tried to elicit information about trends that might affect future wood use, given the current level of costs, durability, and quality. The contractors and architects in our survey were asked to comment on whether they anticipated using the same or different amounts of wood products in future projects. The majority said there would be no change or had no opinion. This indicates that the pace of any change is slow. From those respondents anticipating change (see table 15) we found:

1. About as many indicated they would use more lumber in the future as indicated they would use less. However, about twice as many thought they would use more steel as thought they would use less. Most who expressed an opinion expected concrete use to rise and concrete block and brick use to fall.

2. Among wood products, the number of positive answers significantly exceeded negatives for wood siding, wood trusses, glued-laminated timbers, I-beams, structural particleboard, and fire-retardant-treated wood. Plywood received about as many positive as negative mentions, as did lumber.

These responses indicate a slight declining trend in overall lumber use. However, comparing the 1982 results with those from an earlier 1969 survey by Reid and Wright (cited above) we find that wood use per square foot is higher in the more recent period (Table 16). The 15 percent increase in lumber is too small to be statistically significant but the 55 percent gain in plywood is statistically significant. The gain exceeds the 20 percent increase reported in plywood production between the two periods, indicating strong growth for plywood in nonresidential construction. It is not possible to determine from the previous survey, however, which other product's growth has suffered by plywood's gain. The growth of the structural particleboard industry will undoubtedly slow future plywood gains, although potential plywood gains remain in roof and floor sheathing.

In summary, wood products have to hurdle institutional as well as economic barriers to gain wider use in the nonresidential building market. Despite the problems, comparison with the previous survey shows wood products are retaining and even expanding their share of this segment of the construction industry.

Table 15.—Nonresidential contractor responses indicating change in materials use

Product	Number of mentions indicating		
	Increase	Decrease	Total
Lumber	40	42	82
Steel	38	20	58
Plywood	17	14	31
Concrete block	10	13	23
Brick	8	14	22
Wood siding	14	4	18
Concrete	13	4	17
Wood trusses	12	1	13
Structural particleboard	11	1	12
Glulam/I-beams	7	3	10
stucco	6	1	7
Fire-retardant wood	6	1	7

Table 16.—Comparison of lumber and plywood results with a previous study

Study	Consumption		Floor area of new construction	Board feet used per square foot	
	Lumber	Plywood		Lumber	Plywood
	Billion board foot		*Billion square foot*		
Reid and Wright (1969)	1.64	0.98	1.61	1.02	0.61
Current (1982)	2.12	1.70	1.79	1.18	.95

Acknowledgments

This project resulted from the joint efforts of five trade associations and the U.S. Forest Service. Forty-two field representatives gathered much of the raw data on which the report is based:

American Plywood Association

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Southern Forest Products Association

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Joseph Harding
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Western Wood Products Association

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Richard Geary
Doug Ketchum
Craig Larsen
William Moore
Frank Stewart
Don Wallace
Dave Wilson

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Within the Forest Products Laboratory, Cherilyn Hatfield, Statistical Assistant, and David McKeever, Research Forester, prepared computer programs to calculate lumber volumes in various truss configurations; Ronald Wolfe and Russell Moody, Research General Engineers, provided engineering data on trusses; Ronald Reeves, Volunteer, prepared and verified data; Florence Schwartz, Data Transcriber, keypunched data; Kenneth Skog, Research Forester. Irene Watterson, Forester, and Robert Kempen, Statistical Clerk, helped in computer programming and data analysis; and James Evans, Mathematical Statistician, provided statistical support.

Over 500 architects, contractors, and estimators provided the detailed information contained in this report. Their cooperation is greatly appreciated.

Appendix A
Survey Procedure

Two surveys were used to gather data. One survey was conducted by trade association field representatives who arranged personal interviews with contractors (see Acknowledgements). The second was conducted by professional telephone interviewers. The reason for undertaking the expensive personal interview part of the study was to obtain the most accurate data possible on materials use by using interviewers with professional knowledge about materials. From these data, use coefficients were derived for various building components. These coefficients were used to compute values in about a quarter of the phone surveys where respondents indicated using a given material but were unable or unwilling to specify the amount. The assumption underlying this procedure was that although the frequency of wood use might vary from region to region in a particular building type, the amount of wood used per unit of a component, when wood use was indicated, did not vary appreciably.

In the personal interview portion of the study, each field representative was assigned a specific geographic area of the country in which to find projects, together with a quota of building types to be located. The quotas were stratified so that the representation of each building type in the sample was approximately proportional to its share in the dollar value of construction as determined from U.S. Department of Commerce data (table Al). Exceptions to this were the two less frequent building categories, religious and recreation, which were oversampled to obtain the minimum number of projects deemed to be representative. The relatively low wood-using industrial category was under-sampled to permit projects from more important types to be included.

To identify projects, each interviewer was asked to follow a random selection procedure. This consisted of taking the numerical value of the month of the interviewer's birth and starting with that entry under contractors in the yellow pages telephone book. Thereafter every fifth name was selected. Repeat cycles were made through the list, if needed, to fill the quota of project types. Interviewers asked contractors about their current project or most recent project in 1982.

In the telephone survey, each interviewer was given a list of randomly selected contractors obtained from a commercial listing. From each respondent, the interviewers identified the type of the current or most recent project and obtained the required information about the project.

In all, 253 projects were surveyed in person and about 350 by telephone. Of the latter, data on 236 were of sufficient quality to be usable in the analysis. A total of 489 projects constituted the sample.

In order to expand our project data to represent all U.S. projects, we stratified them into 9 building types, 3 project sizes and 3 regions, for a total of 81 cells. A weighting factor was computed for each cell by dividing the dollar value of the sample projects in the cell into the corresponding dollar value reported by Dodge for 1982. A second set of weighting factors, based on data obtained from the U.S. Department of Commerce, was used to boost the Dodge data to Commerce equivalents. These weights are given in table A2. The combined conversion factors were then applied to the 489 projects to obtain the results reported in this study.

Table A1.—Distribution of total United States construction and sample projects by building type, 1982

Building type	Value of construction put-in-place	Number of projects in personal interviews	Number of projects in telephone interviews	Number of projects in total sample
	Pct			
Offices	27	26	17	22
Stores	17	22	22	22
Industrial	22	8	14	11
Schools	9	7	9	8
Hospitals	9	9	9	9
Religious	2	6	9	7
Recreation	2	8	5	6
Hotels	5	7	2	5
Public and miscellaneous	7	7	13	10
Total	100	100	100	100

Table A2.—Weights used to adjust F. W. Dodge data to U.S. Department of Commerce levels

Building type	Project size[1]		
	Small	Medium	Large
Offices	1.31	1.18	1.07
Stores	1.45	1.31	1.18
Industrial	2.09	1.95	1.81
Schools	1.39	1.25	1.13
Hospitals	1.26	1.14	1.03
Religious	1.32	1.18	1.18
Recreation	1.24	1.12	1.01
Hotels	1.26	1.14	1.03
Public and miscellaneous	1.24	1.12	1.01

[1]Small = ≤10,000 ft^2, medium = 10,000-50,000 ft^2, large = >50,000 ft^2.

Appendix B
Relative Standard Errors of Survey Estimates

Because uneven weighting of individual observations was required to reflect the original population, relative standard errors would have been difficult to compute using parametric techniques. As an alternative, we chose a nonparametric technique, called a bootstrap procedure, used by Skog and Watterson[5] based on a method given by Efron.[6]

The bootstrap procedure involves taking repeated samples with replacement of the survey data to represent many more surveys. A total of 75 such samples was taken of our survey sample. Each of the 75 was made up of 483 projects, selected at random from the sample of projects. As each of the 489 was selected. it was returned to the sample. Estimates of 3 data items were made for each of these 75 samples, and the standard deviation of these estimates was calculated. This calculated standard deviation of the means is an estimate of the standard error of the estimate for the survey sample. The relative standard error for each data item is calculated by dividing the standard error by the mean.

Table B1 shows the relative standard errors for lumber, plywood, and structural particleboard. These figures indicate that if the survey were repeated many times with an identical sample design, then 67 percent of the repeated estimates would be within one standard error of the sample estimates.

For total lumber and plywood use, the estimated relative standard errors are 8 percent. For structural particleboard, they are a much greater 38 percent, indicating greater uncertainty about the value of this estimate.

Another indication of the survey's accuracy may be gained from comparisons of portions of the survey results with equivalent trade association data. information on fire-retardant-treated wood, laminated beams, and metal buildings was available.

Survey-estimated amounts of fire-retardant-treated lumber and plywood in nonresidential buildings were 49 and 31 million board and square feet, respectively. Data from the American Wood-Preservers' Association[7] for 1981 showed 53 million board feet of lumber and 35 million square feet of plywood were treated with fire retardants by those reporting to the association.

Table B2 shows estimates of glulam consumption in eight building types obtained from the American Institute for Timber Construction (AITC) and from the survey. The survey total of 127 million board feet corresponds closely to the 121 million board feet estimated by the association. Deviations within individual building types are large, but the total is within 5 percent indicating that the deviations largely cancel out.

Finally, 1982 orders for low-rise metal building systems were reported by the Metal Building Manufacturers Association at 231 million square feet.[8] With the association's membership accounting for approximately 90 percent of industry sales, this translates to an estimate of 257 million square feet.

The survey estimate for low-rise metal buildings is 369 million square feet, but this figure includes conventional steel framed buildings as well, so that a somewhat larger value is to be expected.

[5]Skog. Kenneth E.; Watterson, Irene. Residential fuelwood use in the United States, 1980 -91. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1983.

[6]Efron, Bradley. The jacknife, bootstrap and other resampling plans. Philadelphia, PA Society for Industrial and Applied Mathematics; 1982.

[7]American Wood-Preservers' Association. Wood preservation statistics. Proceedings of annual meeting; 1982.

[8]Metal Building Manufacturers Association Fact book. Cleveland, OH: 1984.

Table B1.—Lumber, plywood, and structural particleboard use in nonresidential building construction in 1982 with estimates of standard errors

Material	Consumption	Standard error of estimate
		Pct
Lumber	2.13 billion board feet	8
Plywood	1.70 billion square feet'	8
Structural particleboard	41 million square feet[1]	38

[1]3/8-in. basis.

Table B2.—Glulam consumption compared for seven building types, 1982

Building type	American Institute for Timber Construction	Survey	Difference
	--- Million board feet ---		*pct*
Off ices and stores	56.9	65.3	+ 15
Industrial	33.8	17.0	– 50
Schools	6.4	14.1	+ 121
Hospitals	.9	5.1	+ 466
Religious	13.0	13.0	+ 0
Recreation	7.2	6.0	– 17
Public and miscellaneous	2.8	7.2	+ 157
Total	121.0	127.7	+ 5

Appendix C
Definitions

Building Types

Office	Office and professional buildings used primarily for office space. Excludes office structures at industrial sites.
Stores	Buildings for use by wholesale, retail, or service trade establishments such as shopping centers, department stores, banks and financial institutions, drug stores, and parking garages. Also warehouse and storage buildings, trade schools, and auto repair garages.
industrial	Buildings of manufacturing establishments.
Educational	Schools and associated structures except dormitories and other housing. Also includes museums and art galleries.
Hospital	Hospitals, clinics, sanatoria, convalescent homes, nursing homes, and similar establishments for prolonged institutional care.
Religious	Churches, religious training centers, and auxiliary structures.
Recreation	Gyms, fieldhouses, auditoriums, clubs. community buildings, theatres.
Hotels	Hotels, motels, and other nonhousekeeping buildings such as dormitories, barracks, fraternity and sorority houses.
Public and miscellaneous	Government administration buildings, post offices, jail and detention facilities, police and fire stations, military structures, airline terminals, animal hospitals, freight terminals, radio and television stations.

Regions

North	Northeast and North Central census regions.
South	Southern census region.
West	Western census region.

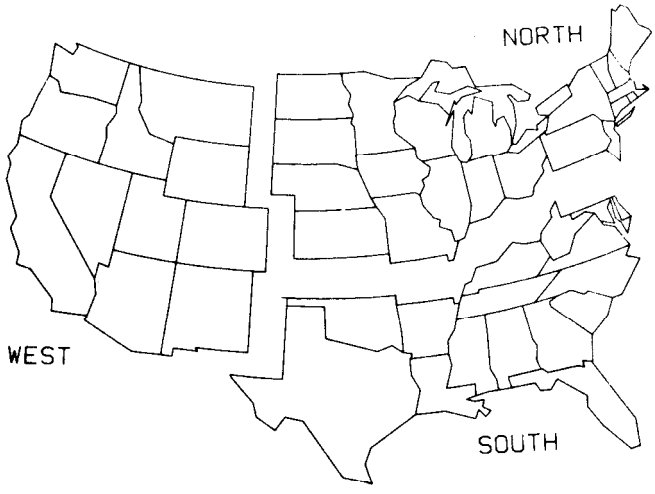

Figure C-1.—Regions used in survey. (ML84 5640)

Nonresidential Building Construction Measures

Contract awards — The dollar value of buildings at the time contracts have been awarded. Includes the costs of labor, material, contractor's profit, and site preparation, but excludes land costs and architect's and engineer's fees.

Floor area — Area measured from the outside of exterior walls and including all enclosed, usable floor space.

Products

Hardboard — A panel manufactured primarily from interfelted lignocellulosic fiber (usually wood) consolidated under heat and pressure in a hot press to a density of 31 pounds per cubic foot (lb/ft^3) or greater.

Laminated timber — Two or more layers of lumber glued together, with the grain of all the laminations parallel. Includes small volumes of parallel laminated veneer (PLV), used as structural members in lieu of lumber and for flanges of wood I-beams.

Lumber — Sawn timber.

Particleboard (nonstructural) — Small particles of wood that are glued together with a thermosetting synthetic resin, usually urea-formaldehyde. These boards are usually water resistant but not waterproof.

Plywood — A glued wood panel made up of relatively thin layers, or plies, with the grain of adjacent layers at an angle, usually 90°. For exterior applications a waterproof binder, usually phenol-formaldehyde, is used. For interior uses a water-resistant binder, usually urea-formaldehyde, is used.

Structural particleboard (nonveneered structural panels) — A family of panel products made of wood particles glued together with a waterproof, thermosetting resin (usually phenol-formaldehyde). The wood particles range from specially cut flakes an inch or more in length to strands of wood laid down in discrete layers with the orientation of the strands in adjacent layers at right angles to one another.

Wood I-beams — Glued wood-plywood members of lumber flanges and plywood webs.

Wood shingles — Shingles are sawn rectangular pieces of wood of up to 24 inches in length. A related product, shakes, are handsplit.

Wood trusses — Engineered structures consisting of separate lumber members fastened together with metal plates so as to form a rigid framework. All members are interconnected to form triangles.

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