# HISTORICAL CONSIDERATIONS IN EVALUATING TIMBER STRUCTURES

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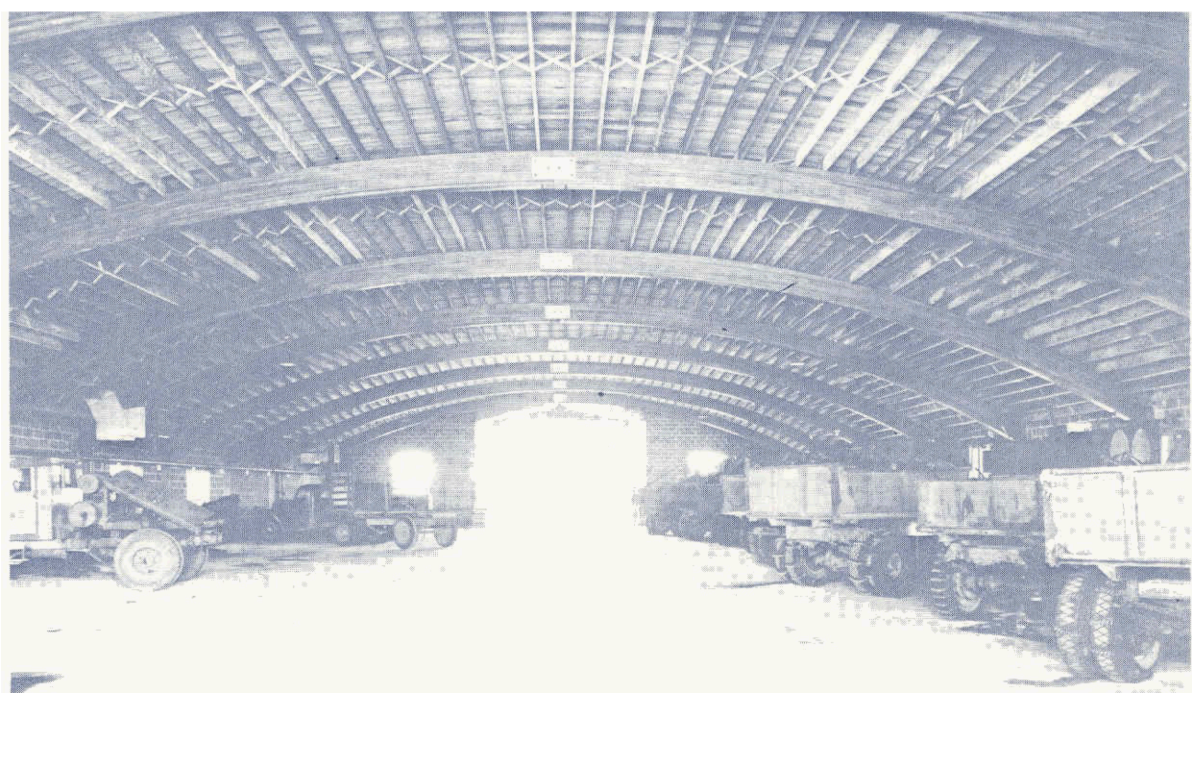

# HISTORICAL CONSIDERATIONS IN EVALUATING TIMBER STRUCTURES[1]

**By**

**R. L. TUOMI and R. C. MOODY,** ***Engineers***

*Forest Products Laboratory*

*Forest Service*

*U.S. Department of Agriculture*

## Abstract

Evaluation, maintenance, and upgrading of timber structures is an area where little printed reference material exists. This paper covers the state-of-the-art on design, material properties, and construction procedures on older buildings. Some guidelines are presented on rehabilitating and upgrading timber structures, along with significant references.

A key point in evaluating existing timber structures is to understand some of the historical elements that influenced their design and construction. This is a consideration in the overall process of evaluation, maintenance, and upgrading of timber structures, a broad area where practically no printed reference material is available. This is not to say that expertise and technology is not available, but the information has never been systematically compiled or documented.

For example, the U.S. Forest Products Laboratory (FPL) has long been considered a source for information on wood. FPL receives, during an average year, about 21,000 requests for information. ,About 11,000 inquiries can be answered rather routinely with available publications, most of which are free upon request. The other 10,000 questions generally require some research on the subject, and the response often provides a list of references.

Unfortunately, when the question relates to "Evaluation, Maintenance, and Upgrading of Timber Structures," we draw a near blank. We have been able to locate only a few articles on the subject, most of which appeared in journals over 20 years ago. Most publications containing valuable information either require interpretation or are not readily available to those who need the information.

The ASCE Committee on Wood and FPL have recognized this problem and formed a subcommittee to develop a manual on "Evaluation, Maintenance, and Upgrading Timber Structures." If anyone has expertise or interest in this undertaking, please contact us.

## Why Rehabilitate?

The first question is, "Why bother to recycle or upgrade existing older structures?" There are many good reasons (6). From a national viewpoint, extending the life of structures conserves a valuable resource. Recycling an existing building saves an equiva-

[1] Presented at the American Society of Civil Engineers National Convention, October 20, 1978, Chicago, III.

lent amount of new timber. Advantages to the owner include lower costs and continued or earlier occupancy. The cost of renovation is far less than the cost of new construction. Demolition is minimized, and the building can be ready for use in far less time. There are also other reasons–such as value to the surrounding neighborhood (particularly downtown areas), prestige, and historical considerations. Perhaps I can best illustrate this with a couple of examples.

The old Boston City Hall, a landmark, was rehabilitated for office space. The owners, seeking a new company headquarters, had the option of constructing a new building out in the suburbs or rehabilitating city hall. They learned that rehabbing would cost half as much, and that they could have access to the building in 9 months rather than 18.

The Butler Square Building in Minneapolis is another example, a very unique one (2). The building was designed in 1906 and served as a warehouse until 1968. The 8-story building is 170 feet wide by 230 feet long and contains approximately $^{1}/_{2}$ million square feet of floor area. The interior columns, all solid timber, started 24 inches square at the bottom and decreased in 2-inch increments per floor to 8 inches square at the top.

In rehabbing, the interior wood structure was sandblasted and left exposed. A large open atrium was provided as a center core to highlight the timber framing. One half of the building was converted to office rental and retail space. The remaining half is being converted for hotel and restaurant use. The total cost of reconstruction was $17.54 per square foot. The building was given an honor award by the Minnesota Society of Architects and is listed in the "National Register of Historical Buildings."

## Evaluation

Once you have convinced yourself that the economics of rehabilitation are sound, then comes the evaluation process.

Probably the three most important factors in structural evaluation are species, grade, and condition of the wood.

The strength of wood, as you all know, varies considerably with species. The first step is to get positive identification of the wood. This is not as easy as it might sound, because many woods look alike once they have been cut into lumber or timber. Personally, I can venture a reasonable guess only if I can find a grade stamp. Consult a wood technologist if there is any doubt! Identification can be made from small pieces shaved from the structural members.

One myth that must be dismissed is the misconception that, because wood is old, it is no longer sound (7). Timber in a favorable environment can last almost indefinitely. The tomb of Egypt's Tutankhamen, who ruled in the fourteenth century before Christ, contained wood objects which were in perfect condition when recovered in the twentieth century. There are Japanese temples constructed with wood that date back thirteen centuries. A covered bridge built in 1440 at Lucerne, Switzerland was still in service at last report. In the United States, some 950 covered bridges built during the nineteenth century still remain.

This is not to imply that wood will not deteriorate. We all know that the service life of wood is affected by many things including decay, insect attack, and high temperature. However, many factors can be controlled or minimized with proper design and maintenance. The main point is, when evaluating timber structures, age alone should not be the deciding factor. It is the condition of the wood at the time of inspection that counts!

One of the most frequently asked questions by engineers evaluating older structures is, "What was the design stress for the timber when the building was constructed?" Maybe a better question would be, "What is the allowable design stress today?" A brief discussion on the history of grading rules may help.

The need for a standardized procedure for assigning working stresses to timber was recognized in the early 1900's. At that time, there was considerable debate on how to test wood for mechanical properties. One side advocated testing small clear specimens, and the other promoted tests of structural-size material. The "small clear" side won out.

The Forest Service, in concert with universities, lumber producers, and design engineers, participated in the development of building codes, wood design procedures, and procedures for assessment of domestic U.S. species. One result was ASTM D 143, "Testing Small Clear Specimens of Timber." Technical bulletins issue by the Forest Service provided the data upon which properties of commodity products (Lumber) were based. ASTM D 245, "Establishing Structural Grades and Related Allowable Properties Based on Concepts of Visual Grading,'' was first published in 1927.

Many thousands of small clear specimens have been tested following a comprehensive sampling plan to classify clear wood strength by species. Results of these tests currently are summarized in ASTM D 2555, "Establishing Clear Wood Strength Values."

An estimate of near-minimum strength, the fifth percentile, has for many years been the starting point for developing the design stresses. Adjustments were next made to account for seasoning, size, shape, and duration of load, etc. The resulting value is essentially the allowable property for clear, full-sized material.

The grading rules then went on to adjust this allowable property to account for defects. Knots, cross grain, and checks were (and still are) the primary strength-reducing characteristics; strength ratios were developed to account for each. A particular lumber grade of a species with an average clear wood modulus of rupture of 10,000 pounds per square inch might well end up with an allowable property for design of only 1,000 pounds per square inch, for example. This procedure has provided the backbone of successful wood design for over 50 years, but in terms of today's design concepts, we are not sure of its degree of precision. With the move toward probabilistic-based design, there is renewed interest in evaluating the performance of full-sized lumber. We hope this will serve to calibrate the existing procedures.

The important point is–the existing procedures have served well, and the principles behind those procedures can be applied directly, in place, to existing structural members.

## Wartime Construction

Many of the problem structures that we hear about at FPL were built during World War II. This was a critical period when wood was used to the extent possible to conserve "critical steel" for the war effort. The demand for wood soared to 36 billion board feet in 1942. Military housing, bridges, industrial plants, warehouses, and shipyard facilities used wood wherever possible.

Some of these structures were among the largest ever built. The LTA or blimp hangars were 1,000 feet long and 176 feet high at the crown, with a clear span width of 298 feet at ground level. A single hangar required 3 million board feet of lumber. The Army alone estimated that it had $1^1/_4$ billion square feet of timber buildings. This was equivalent to a 92-foot-wide building extending from New York to San Francisco.

These buildings were built on a "crash" program as temporary structures with an anticipated life of not over 5 years. It is interesting that *now*–36 years later–many of these buildings are experiencing problems. And these problems are caused mostly by changes in use and occupancy of the structure, which impose different loadings than originally intended.

Frank Hanrahan (1) documented many of the unique circumstances attending wartime construction. Government agencies concerned with material shortages took drastic action to accomplish national objectives. Some general examples are:

(1) Designs of roofs were based upon 15 pounds per square foot live load throughout the country. This was done even in areas where building codes called for 20, 30, or more pounds per square foot:

(2) All designs were based on 1,200 pounds per square inch stress-grade lumber. However, design stresses were increased from 1,200 to 1,800 pounds per square inch.

(3) There was not enough stress-graded lumber available. Lower grades never before considered "structural" and nonstructural lumber often had to be substituted.

(4) Unseasoned lumber had to be used. In some cases, wood went from tree to structure in only 3 days.

(5) Design errors were made. In some

cases, in the haste to get the job done, personnel with little or no experience in design, fabrication, and erection of wood structures had to be used.

There was also a shortage of qualified journeymen for construction. Hanrahan visited a construction site where a carpenter crew was nailing on roof sheathing. One workman, evidently a rank amateur, was wearing a long overcoat. He was swinging his hammer at a great rate, having considerable trouble hitting the nails, but nevertheless doing his best to keep up with his fellow workmen. When he started to move to a new position, he had nailed his overcoat to the roof.

Hanrahan provided a number of other examples such as parallel chord trusses being installed upside down, leaving out split-ring connectors to speed erection, and using the wrong size lumber.

Where are the World War II structures today? Many are still out there if you can identify them. We ran across an office memo the other day, written in 1947. Because of overcrowded classrooms, a "temporary" military warehouse from Sangamon Ordinance in Illinois was dismantled, shipped, and re-erected as a "temporary" classroom at the University of Wisconsin. Out of curiosity, we called an engineering professor to learn the fate of the "temporary" building. "It's still there," he said. "It houses the classrooms where the engineering drafting courses are taught." He added, "nothing on campus is more permanent than a 'temporary' building."

In 1954, Mike Salgo (5) wrote a paper on examples of timber structure failures, which dealt primarily with World War II military structures. Mike designed many of the large Navy structures during World War II when he was with the Bureau of Yards and Docks. Incidentally, Mike is the chairman of the Research Council on the Performance of Structures.

On World War II timber structures Salgo, stated, "It is significance to note that relatively few major structural failures occurred with this tremendous construction program in spite of the pioneering nature of many of the designs. But failures did occur, and it is from these that certain lessons can be learned." He went on to present some excellent examples of structural failures. They ranged from hurricanes in the "Act of God" classification to design deficiencies.

His experience indicated that most failures in timber structures occurred in individual truss members and did not result in the failure or collapse of the structure.

On one example, he noted, "The failure was actually caused by deficiencies in design, construction, and maintenance. Everything went wrong. However, on the basis of reanalysis, repairs are being accomplished. This building with an estimated present value of about $1,000,000 will be rehabilitated for less than $40,000."

## Considerations Today

In closing, we would like to cite two of Salgo's conclusions from his 1954 paper:

> (1) Most of the difficulties experienced with timber structures can be attributed to incomplete designs, the use of unseasoned and lower grades of lumber, and lack of periodic maintenance. Timber structures properly designed, constructed, and maintained have taken their place as major components in our present-day construction.
>
> (2) Maintenance and construction standards have been well established. There does exist an educational problem. There is a need for more widespread knowledge of this information. Such articles as "Are Timber Checks and Splits Serious?" (4) and "Timber Maintenance Methods" (3) are doing a great deal of good. These articles are designed for reading by engineers and artisans who are actually building and maintaining timber structures. More such articles are needed.

These statements made 24 years ago, are still true today particularly as they relate to maintenance and the need for educational information.



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## Literature Cited


1. Hanrahan, F. J.
   1945. Performance of wartime wood buildings—and its postwar application. So. Lumberman. 171(2142):57-64 (July 1).

2. Horner, F.
   1976. Hi-rise in wood. Preprint 2798, 1976 Amer. Soc. Civil Eng. Annual Convention. ASCE, New York, N.Y.

3. Ketchum, V.
   1945. Timber maintenance methods. Western Construction News (Jan.).

4. Ketchum, V., T. K. May, and F. J. Hanrahan.
   1944. Are timber checks and splits serious? Engineering News Record 133(4):90-93 (July 27).

5. Salgo, M.N.
   1954. Examples of timber structure failures. Proceedings Vol. 80, Separate No. 544. Amer. Soc. Civil Eng., Str. Div. (Nov.).

6. Sherwood, G. E.
   1975. New Life for old dwellings: Appraisal and rehabilitation. U.S. Dep. Agric. Handb. 481.

7. Wood, L. W.
   1954. Structural values in old lumber. So. Lumberman 189(2369):158160 (Dec. 15).

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