

TRENDS IN REGULATION OF WOOD CONSTRUCTION AND PRODUCTS: AN INSURANCE COMPANY VIEWPOINT¹

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ABSTRACT

The historical development of fire insurance companies was discussed with emphasis on their negative attitude towards wood construction. The fire-safety advantages of heavy timber over joisted flooring were examined. Various types of conventional nineteenth-century pitched roof constructions displayed fire-safety disadvantages, such as large unprotected loft volumes and large numbers of framing members. With the invention of the automatic sprinkler system, either heavy timber or joisted construction was feasible. This was confirmed by Factory Mutual loss analysis studies. Unless special protection was provided, tests proved wood superior to both steel framing and plastics. Compared to other industries, the fire loss history of the woodworking industry has been high.

Keywords: Heavy timber construction, joisted construction, fire safety, hazards, mill construction, automatic sprinkler systems, steel framing, plastics, reinforced concrete, woodworking industry.

HISTORICAL BACKGROUND

The attitude of fire insurance companies toward wood as a construction material is as old as the companies themselves. These companies were organized following the Great Fire of London in 1666, which destroyed more than 13,300 buildings.

The Fire Office, a company to insure homes against fire, was established in London in 1667, setting premium rates for frame houses at twice that of brick homes. A second London company, the Friendly Society, was founded in 1683. As with Fire Office, premium rates on homes were based on whether the construction was frame or brick. A third English company, Hand in Hand, also charged twice the rate for frame as for brick dwellings. (Established in 1696, this company is currently known as the Commercial Union Assurance Co.)

In 1752, the Philadelphia Contributorship became the first incorporated fire insurance company in this country, with Benjamin Franklin as one of the directors. The com-

pany insured only dwellings of brick or stone. The Green Tree Society, which was organized in Philadelphia in 1784, also insured only masonry houses.

Therefore, attitudes of early fire insurance companies toward wood construction were negative. The first English companies charged much higher rates for frame houses, while the first American companies did not even insure wooden homes.

Although the attitudes of early American insurance companies toward wood dwellings were negative, one group of companies favored wood in mill construction. Their positive attitude was based on the following conditions:

1. that the wood members be massive,
2. that the wood assemblies be tight and solid,
3. that the combustible surface area be minimal.

EARLY NINETEENTH-CENTURY FACTORY CONSTRUCTION

Cotton and woolen mills were very common in New England during the early nineteenth century. These mills were so common in New England that the term manufactory, which later became factory,

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was understood to be a cotton or woolen mill. Early textile mills were quite vulnerable to fire caused by metallic particles in the fiber being processed, spontaneous combustion of oily waste, and hot journals. Once ignited, fire would rapidly spread over accumulations of lint and dust. Most of these mills were constructed of wood. Moreover, fire insurance could only be obtained for textile mills at a high premium rate since insurance companies viewed factories as a fire hazard.

A NEW ATTITUDE TOWARD WOOD CONSTRUCTION

In 1822, a woolen mill was built near Providence, RI, equipped with the most contemporary fire-safety design. Floors of the four-story structure were constructed of extra-thick wood plank. Other fire-safety features included a mortar base for the roof shingles, fire pumps, and an unusual quantity of hydrants, pipe, and hose.

The mill owner appealed to his insurer for a preferential rate. The matter was referred to the directors of the insurance company, who stated ". . . although it seems unjust, the Board has decided that a fire risk is a fire risk, and we can make no reduction." The mill owner, Zachariah Allen, was so incensed with this attitude that he founded a mutual insurance company for factories, which later became known as the first of the Factory Mutual companies.

Until the Civil War, the Factory Mutual companies concentrated on insuring textile and textile machinery plants in the northeastern United States. Only preferred risks were accepted, which generally meant that the building was constructed of heavy timbers or planks-on-timber.

What qualified as heavy timber construction was three-inch (75-mm)-thick plank floors supported by massive timber beams 8–10 ft (2.5–3.0 m) apart. The beams were in turn supported by posts of either wood or cast iron. Frequently, there was a 1-inch (25-mm) wood overlay on the plank floors.

Nineteenth-century beams were monolithic. If heavy timber construction was

built today, the beams might be laminated instead. Laminated beams simulate monolithic beams of the same size in fire tests and are equally acceptable in heavy timber construction.

HEAVY TIMBER VS. JOISTED CONSTRUCTION

Heavy timber construction of textile mills was an American development. English textile mills of 1840 (and many American mills outside of the Factory Mutual System) normally had board-on-joist floor construction. This flooring could be as thin as 1 inch (25 mm) over joists of 2–3-inch (50–75 mm) stock spaced on 16-inch (400 mm) centers. Heavy timber construction resulted in a firmer working surface than boards on joists. However, the main reason for its use was fire safety.

Heavy timber construction has an advantage over joisted construction from both a fire hazard and a fire resistance standpoint. The lower surface of joisted construction presents nearly double the exposed area to a potential fire that heavy timber construction does, because there are up to five times as many supporting members in joisted construction. If bridging was used between the joists, the fire-safety advantage of heavy timber construction would be even greater compared to joisted construction.

Joisted construction lends itself to the creation of concealed spaces. A ceiling can be fastened to the bottom of the joists. If fire should break through the ceiling, it could spread undetected, shielded from attempts at extinguishment. On the contrary, heavy timber construction does not lend itself to the creation of concealed spaces, which is superior from a fire hazard standpoint.

Floors of joisted construction can burn through in 15 minutes when exposed by an ASTM E119-type fire. This is a standard fire used in laboratory testing, which develops ceiling temperatures of 1000 F (538 C) at five minutes and 1700 F (926 C) at one hour. Heavy timber floors, on the other hand, will resist burn-through for 45 minutes from the same fire. The fire resistance

of heavy timber floors is thus greater than that of joisted floors.

ROOF CONSTRUCTION IN THE 1800's

While the typical mill insured by Factory Mutual had solid flooring well arranged for fire safety, the same could not be said for roof construction during the first half of the 19th century. There were several types of mill roofs in vogue, such as the factory roofs of steep pitch, square or pitched barn roofs, Mansard roofs with a double pitch, and flat joisted roofs.

All of these types of roofs had fire-safety disadvantages, such as pitched roofs which created troublesome loft areas. Since pitched roofs did not offer the ideal working environment, they inevitably were used for storage and were often combustible. Furthermore, combustible textile fibers tended to accumulate in the lofts. This occupancy hazard became even more serious since the lofts were hard to enter and made fire fighting very difficult.

Fire fighting was also made difficult by the Mansard roof due to the excessive number of framing members needed to create it. Their popularity diminished after the great Boston fire of 1872. (The recent emergence from obscurity of Mansard roofs fortunately seems confined to retail establishments and homes.)

Flat joisted roofs had the same disadvantages described above for joisted floors. Finally, someone realized that a flat roof could be constructed in the same way as a floor—3-inch (75-mm) planking on heavy timber supports. An asphaltic built-up roof could be installed over the planking, preferably with a 1-inch (25-mm) board overlay placed first. Although the idea of a plank-on-timber roof was promoted actively by Factory Mutual, the first such building was not constructed until 1862.

The concept of heavy timber construction appears to have predated Factory Mutual. (Extending this concept to include the roof *was* a Factory Mutual idea, however.) Continued emphasis on the merits of flat-roofed, heavy timber mill buildings, and

granting them lower insurance rates made such buildings the prevailing type of industrial construction well into the 20th century.

The president of one of the early Factory Mutual companies was described by Bainbridge (1952) as an especially tireless advocate of heavy-timber construction. He prepared a concise and modern paper, "Mill or Slow-Burning Construction, What It Is; What It Is Not" for *American Architect*. He chided architects for their lack of attention to fire safety. He even wrote a 10,000-word article on the merits of mill construction and persuaded the editors of *The Century*, a magazine similar to today's *Atlantic Monthly*, to publish it. His advocacy was not confined to mill buildings, but also included public and mercantile buildings and hotels. He claimed that America was burning 12 hotels a week, and the wise guest would provide himself a knotted rope for escape.

INVENTION OF THE AUTOMATIC SPRINKLER

Invention of the automatic sprinkler in the late nineteenth century greatly improved the possible fire safety of all types of buildings. Since 1852, certain mill owners had sought a way to deliver water to a fire through pipes instead of hand-held hoses. Perforated pipes with hand-operated valves were installed, along with systems relying on the burning of cords or melting of wax to achieve a flow of water. Though unreliable, the early sprinkler systems achieved partial success.

In 1874, Henry Parmalee, a Connecticut piano manufacturer, felt that his fire insurance rate was too high. Like Zachariah Allan a half-century earlier, he attempted to obtain a lower rate. He invented the first practical automatic sprinkler and installed sprinklers of improved design in his factory.

Interest in automatic sprinklers was strong at the turn of the 20th century. Between 1872 and 1914, more than 450 patents on sprinklers were obtained. By 1911, over 100,000 buildings were protected by

automatic sprinklers manufactured by the Grinnell Company alone.

As long as a building is protected by automatic sprinklers, it does not matter whether a building is of fire-resistive, non-combustible, heavy-timber or joisted construction. Factory Mutual loss analysis emphasizes this point. An unpublished 1968 study of 42,000 losses occurring between 1957-1966 contains the following conclusions:

"Plank-on-timber construction shows the highest overall fire loss of any type. But when catastrophic fire losses (mostly shut-valve disasters) are deducted, it shows one of the lowest.

"Board-on-joist construction shows lower fire and wind losses than plank on timber . . ."

In addition to loss analysis, Factory Mutual has test experience to support its contention that full sprinkler protection provides a far greater fire-safety factor than the type of construction. Test work was done because of a change in sprinkler deflector design about 25 years ago. Whereas the earlier type of sprinkler discharged about 60% of its water spray up against the ceiling, the new type discharged none against it. Fire-protection engineers were concerned whether the new type of sprinkler would control a fire in a joisted ceiling. At first, the sprinkler installation rules penalized the new type of sprinkler when installed under joisted construction.

Eight full-scale fire tests were conducted: two with the old type and six with the new type of sprinkler head. The new design was found to be superior to the old one, despite the fact that it discharged no water upward under non-fire conditions. The point stated in the conclusion of the test report is that ". . . it follows that board-on-joist construction need not be assumed a determinant in limiting the protection area of standard (new) sprinklers."

From a fire-safety viewpoint, whether the construction is heavy timber or joisted is not important in buildings fully equipped with sprinkler systems. Also, fire-safety differences between combustible and non-combustible construction are not as important in these buildings.

WOOD VS. STEEL FRAMING OVER HIGH-HAZARD OCCUPANCIES

Factory Mutual has long advocated that complete automatic sprinkler protection be installed where combustible construction or combustible occupancy is present. If both construction and occupancy were combustible, no additional sprinkler protection would be required than if the occupancy alone were combustible. It was assumed that adequate protection for the occupancy would also suffice for the construction. However, developments within the past two decades have shown that this assumption is not always valid.

If a heavy timber or joisted building contains an occupancy requiring sprinkler protection, it will be protected by whatever level of sprinkler protection the particular occupancy requires. However, if a non-combustible (steel deck on steel frame) building contains (1) high roll-paper, (2) high idle pallets, or (3) high plastic storage, the level of sprinkler protection for the occupancy will not necessarily protect the building. The steel members that support the roof or floor above usually require additional protection.

Reasons for extra protection needed for steel roof or floor members over the above three high-hazard occupancies include:

1. Structural steel deforms and loses its strength at temperatures above 1,000 F (538 C).
2. Ceiling temperatures over fires in high-hazard occupancies can exceed 1,000 F (538 C) for a few minutes, despite sprinkler operation.
3. Since steel roof and floor members support the sprinkler systems, their loss would deprive the building of fire protection.

The additional protection required for roof or floor steel framing may be provided by either thermal insulation or extra sprinklers. Neither solution is simple, especially for existing buildings. Installing more sprinklers capable of discharging at high pressure frequently means installing an-

other fire pump. Providing a coating on open-web steel joists often requires cleaning the steel first, and then protecting the occupancy from the inevitable overspray.

However, no additional protection is required for buildings of heavy timber construction, even though they may contain high roll-paper or plastic storage, because no structural failure is expected to occur in the few minutes that ceiling temperatures would exceed 1,000 F (538 C) during an occupancy fire. Although temporarily bathed in fire, the sprinkler system would eventually establish control. Thus, for framing above high heat-release occupancies, wood construction enjoys a fire-safety advantage over steel.

COMPARING WOOD AND PLASTIC

Since plastics are not yet widely used in industry as structural replacements for wood, the two materials will be compared as an interior finish. (Reinforced plastics are widely used as a structural material in ducts, stacks, and translucent panels; wood is not.) Wood interior finish materials are normally evaluated for fire hazard by one of two test methods. The more popular method is ASTM E-84, the tunnel test. Products are evaluated for flame spread, fuel contributed, and smoke developed. Woods that receive a flame spread rating of less than 25 (red oak has a flame spread of 100) are considered Class A materials by many building codes. Class A materials may, for example, be used for corridor wall finish without automatic sprinkler protection.

The other test method for establishing the fire hazard of interior finish materials is the Factory Mutual Construction Materials Calorimeter Test. In this test, a furnace measures the calorific value of the material. Products having a low rate of heat release, measured in Btu/sq ft/min, are considered Class I for use in noncombustible occupancies without automatic sprinkler protection.

Both test methods are quite satisfactory for evaluating cellulosic materials such as wood. Neither test method is satisfactory,

however, for evaluating plastics. When installed on interior walls and/or ceilings, plastic materials with flame spread ratings below 25 (Class A materials) have performed badly in fires. Also, several such materials have failed in the full-scale Building Corner Test. This test is a simulation of an industrial building. A 25-ft (7.6-m) high corner is formed by walls that extend out 38 ft (11.6 m) and 50 ft (15.2 m), respectively, with a rectangular ceiling. A 750-lb (328-kg) crib of wood pallets in the corner provides the fire exposure.

Even when protected by automatic sprinklers, some plastic finish materials with fire-retardant additives and low flame-spread ratings have performed poorly in the Corner Test. A few plastic finishes have passed without sprinkler protection. However, conventional tests for fire hazard, especially ASTM E-84, have proven an unreliable indicator of the actual fire hazard of plastics.

Because of the known fire hazard of plastics, especially when expanded into a foam, a thermal barrier of ½ inch (12 mm) or more thickness is usually recommended for their exposed surfaces. This precaution is necessary even in sprinklered areas, because of the ease with which many plastics ignite. Room temperatures can briefly exceed their ignition point prior to sprinkler operation. Once ignited, plastic surfaces can propagate fire despite sprinkler discharge.

With cellulosic finish materials such as wood, the recognized tests can reliably measure fire hazard. No larger-scale test is necessary. Materials found to be of low hazard usually require no sprinkler protection. (Cellulosic materials do not require a thermal barrier even when their fire hazard is high.)

REINFORCED CONCRETE CONSTRUCTION

Few people might expect that wood construction could outperform reinforced concrete in a fire performance test, but consider the following example:

A multi-story, reinforced concrete ware-

house in an eastern city experienced a complete burnout of its contents. Because the fire burned for more than 8 hours, structural damage occurred, and the building was no longer usable. The owner considered demolishing the remains of the warehouse, but found it cheaper to abandon it to the city.

If the building had been of heavy timber or joisted construction, the demolition and cleanup of its remains would have been a simple matter. Unfortunately, ease of demolition is not reflected in premiums charged for wooden construction. As stated above, premiums charged for fully sprinklered buildings are not greatly affected by type of construction.

PROTECTION FOR THE WOODWORKING INDUSTRY

Until now, only wood has been considered as a construction material. However, Factory Mutual's interest in wood is not confined to its use as a construction material. The System insures companies that produce wood products such as plywood and furniture, and companies that store such products as furniture and idle pallets. All of these companies exhibit special fire protection problems.

Factory Mutual loss prevention guides are available to the woodworking and wood-using industries. They include:

- Data Sheet 7-10—Particleboard Plants
- Data Sheet 7-12—Protection of Plywood Plants
- Data Sheet 7-25—Protection for Sawmills
- Data Sheet 7-90—Factory-Constructed Housing and Recreational Vehicle Plants
- Data Sheet 8-24—Idle Pallet Storage
- Data Sheet 8-27—Outdoor Storage of Wood Chips

Much of what could be stated about loss prevention in the above industries is contained in the above loss prevention guides.

Anyone interested in obtaining copies can write to or call the Factory Mutual Engineering Corporation, Resource Center for Loss Control Management, Box 688, Norwood, MA 02062.

The favorable Factory Mutual attitude toward wood in sprinklered heavy timber construction does not, however, apply to the woodworking industry. The loss experience in this industry has not been favorable. In fact, a 1976 study by Factory Mutual loss analysis includes this statement:

A recent study of losses vs. premium income for all individual occupancy classes over a ten-year period indicates that woodworking ranks 98th out of 104 classes in the probability of its having a favorable loss ratio . . . The principal reason for the unfavorable loss experience is a high frequency of large fire losses.

SUMMARY—FUTURE RESEARCH

Early insurance company attitudes toward wood dwellings were negative and this carried over into factory buildings. The Factory Mutual companies, however, promoted using wood in massive quantities for mill construction. Following development of the automatic sprinkler, premium rates for fully sprinklered properties of all types of construction tended to equalize.

Currently, wood framing is superior to steel framing for fire safety in sprinklered storage of certain high heat-release materials, unless the overhead steel is specially protected. Wood finish materials of low fire hazard are superior to many plastic finish materials of low fire hazard, unless the plastic materials are covered with a thermal barrier. The woodworking industry has an unfavorable fire loss record and needs better loss prevention efforts.

No paper such as this would be complete without a plea for more research. One problem that has not been investigated is the fire hazard of high untreated wooden walls. As long as ceiling heights remain low, sprinkler protection of modest density (0.15–0.20 gpm/sq ft) (6–8 mm/min) will protect both wooden walls and the occupancy. However, it is not certain that ordinary ceiling sprinklers would protect the

wood-paneled walls of the lobby of a modern office building or hotel that extend upwards for two or more floors.

For a noncharring fuel, the velocity of upward spread on a vertical surface is proportional to the height of the surface already burning. Upward flame velocity thus accelerates with height. However, wood surfaces form a char when burning.

A massive exposing fire may be necessary to produce an accelerating vertical fire spread on a wood surface. Full-scale fire tests would be a great help in studying the fire hazard of untreated wooden walls.

REFERENCE

- BAINBRIDGE, JOHN. 1952. *Biography of an idea*. Doubleday.