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Wood use in Type I and II (noncombustible) construction

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ABSTRACT: As with many products, the building code regulates the use of wood in construction. Two broad categories separate materials: combustible and noncombustible. Codes limit the application of combustible materials on the basis of fire and life safety. The question then is, "Are there options available in the 2009 International Building Code for using wood in structural applications in lieu of noncombustible materials?" Fire Retardant Treated Wood (FRTW) provides that option. The 2009 IBC recognize FRTW for many applications where a noncombustible material is mandated. A few applications allow FRTW in lieu of 1-hour ratings.

1 INTERNATIONAL BUILDING CODE

In 1994 the three existing national building code organizations created the Internal Code Council (ICC), a nonprofit organization dedicated to developing a single set of comprehensive and coordinated national model construction codes. The goal of the ICC was to have a family of national codes available by the year 2000, and ICC met that goal. In 1996 work began on the creation of the International Building Code (IBC). It was developed primarily from the provisions of the three nationally recognized model building codes: the National Building Code (NBC), Standard Building Code (SBC), and Uniform Building Code (UBC).

The IBC is a comprehensive code and is the coordinating document for the suite of International codes. In certain instances, the IBC provisions are identical to those of the three model codes. In other instances, the provisions are a modification of requirements from one or more of the three regional codes. Some provisions are entirely new and unique to the IBC.

2 FIRE SAFETY

Fire safety is the reduction of the potential for harm to life as a result of fire in buildings. Although the potential for being killed or injured in a fire cannot be completely eliminated, fire safety in a building can be achieved through proven building design features intended to minimize the risk of harm to people from fire to the greatest extent possible.

Designing a building to ensure minimal risk or to meet a prescribed level of safety from fire is more complex than just the simple consideration of what building materials will be used in construction of the building. Many factors must be considered including the use of the building, the number of occupants, how easily they can exit the building in case of a fire and how a fire can be contained.

The IBC only regulates those elements which are part of the building construction. The building contents found in any building are typically not regulated by the IBC but in some cases are regulated by the fire codes. The classification of buildings or parts of buildings according to their intended use accounts for:

– the quantity and type of combustible materials likely to be present (potential fire load);
– the number of persons likely to be exposed to the threat of fire;
– the area of the building;
– the height of the building.

This classification is the starting point in determining which fire safety requirements apply to a particular building. Classification dictates:

– the type of building construction;
– the level of fire protection;
– the degree of structural protection against fire spread between parts of a building that are used for different purposes.

Even materials that do not sustain fire do not guarantee the safety of a structure. Steel, for instance, quickly loses its strength when heated and its yield point decreases significantly as it absorbs heat, endangering the stability of the structure. An unprotected, conventional steel joist system will fail in less than 10 minutes under standard laboratory fire exposure test methods, while a conventional wood joist floor system can last up to 15 minutes.

Even reinforced concrete is not immune to fire. Though concrete structures have rarely collapsed, concrete will spall under elevated temperatures, exposing the steel reinforcement and weakening structural members.

It is generally recognized then, that there is really no such thing as a fireproof building. Fires can occur in any type of structure. The severity of a fire, however, is contingent on the ability of a construction to:

- confine the fire;
- limit its effects on the supporting structure;
- control the spread of smoke and gases.

To varying degrees, any type of construction can be designed as a system, that is, a combination of construction assemblies, to limit the effects of fire. This allows occupants sufficient time to escape the building and for firefighters to safely reach the seat of the fire.

Occupant safety also depends on other parameters such as detection and exit paths, and the use of automatic fire suppression systems such as sprinklers. These concepts form the basis of the IBC.

3 FIRE RETARDANT TREATED WOOD

Wood loses its strength in a different way than metals. In the early stages of a fire, wood's strength is increased because of a reduction in moisture content. Wood is a good insulator and does not transfer the heat on its surfaces to its core very quickly. While it may be burning or charring on its surface, its interior will be relatively cool for a long time. All this increases the length of time wood and fire retardant treated wood will retain its integrity—time to get the people out of the building, time to get the firemen to the building, and time to extinguish the fire. Fire retardant treated wood has the added advantage of maintaining structural integrity even longer because it chars at a slower rate than untreated wood is consumed. In addition, fire retardant treated wood will not spread the fire from one portion of a building to another, and it will extinguish itself once the ignition source is removed.

Wood is principally composed of cellulose, hemicellulose, and lignin, all of which change their physical and chemical characteristics by oxidation and chemical decomposition. This phenomenon is called combustion or burning. It destroys the structure of the wood so it will not support a load by reducing it to a small amount (1% or less) of a mineral substance called ash.

The kindling temperature of wood (500°F) is the temperature above which the wood will ignite spontaneously. At this point, as a result of chemical decomposition, the wood contributes a heat of its own, and the temperature rises even higher. Combustible gases and smoke are given off, and the wood begins to char. Because wood in itself is a good insulator, the high temperature at the surface is not readily transmitted to its interior. This insulating quality and the moisture always present in the wood results in a slow destruction, especially of large timbers. How quickly the material burns, depends on its size, shape, the air circulation, and the control of radiation. Therefore, if the conduction of heat in the wood can be controlled to prevent the temperature of the wood from exceeding its kindling temperature, its rate of destruction can be greatly reduced. This is the key to Fire Retardant Pressure Treated Wood.

Research has shown that certain ingredients, when added to the wood, are able to insulate its surfaces so that its temperature remains below the kindling temperature for an extended period of time no matter how hot the heat source might become. Among the ingredients used for this purpose are the acid salts of sulfates and phosphates, borates, and boric acid.

All fire retardant treatments are water-soluble so water is used as the vehicle for carrying the treatments into the wood. The only effective method of application is by the Pressure Treatment Process. After pressure impregnation, most of the moisture is removed until the treated wood has a moisture content of no more than 19% for lumber and 15% for plywood.

Fire retardant treatments do not necessarily prevent wood from being destroyed by fire, but they are the necessary ingredient that, when added to wood, slow down the decomposition to such an extent that the wood structurally out performs most other building materials during actual fire conditions.

When temperatures reach a point slightly below the kindling point, the chemicals react with each other. Nonflammable gases and water vapor are formed and released at a slow persistent rate which envelope the wood fibers insulating them from temperatures that cause the wood to decompose. The inflammable gases and tars are reduced and an insulating char forms on the surface of the wood, further slowing down the process of decomposition.

Because of the greatly reduced rate of decomposition or burning, the structural integrity of the wood is preserved for a long period of time, smoke and toxic fumes are greatly reduced, and when the heat source is removed, the wood ceases to decompose and the spread of fire by the wood is eliminated.

In Section 2303.2, the IBC defines fire-retardant-treated wood as "any wood product which, when impregnated with chemicals by a pressure process or other means during manufacture, shall have, when tested in accordance with ASTM E 84, a listed flame spread index of 25 or less and show no evidence of significant progressive combustion when the test is continued for an additional 20-minute period. In addition, the flame front shall not progress more than 10.5 feet (3200 mm) beyond the centerline of the burners at any time during the test."

This definition is a performance specification. Unlike the specifications for wood preservatives, fire retardant treated wood is specified on the basis of performance and not retention. The "Flame Spread" index is a measure of the surface burning characteristics of a building material when compared to the relative surface burning characteristics of cement board (rated at 0) and untreated select red oak flooring (rated at 100). The index is determined by relative performance in a 25-foot long fire test tunnel furnace under controlled conditions of draft and temperature.

In the ASTM E-84 tunnel test, a gas jet is located near one end of the tunnel. Without a test specimen present in the tunnel, the ignition flame from the gas jet extends down the tunnel for a distance of 4½ feet from the burners. After a test specimen is placed in the tunnel and exposed to the ignition flame for a period of 10 minutes, the spread of the flame is measured from the fire end of the tunnel.

Keep in mind that the standard flame spread test is only for 10 minutes. The opinion of researchers was that this method only demonstrated delayed ignition and gave little indication of non-combustibility. To remedy this, the test period for fire retardant treated wood was extended another 20 minutes to 30 minutes duration. If the specimen shows no evidence of additional spread of flame beyond the limit attained in 10 minutes, then the specimen could be said to show no significant progressive combustion. Fire retardant treated wood must meet this additional test standard to be used for structural applications.

4 TYPES OF CONSTRUCTION

Similar to the previous codes, construction type provisions are set out in Chapter 6 of the IBC. The type of construction is determined by two factors: 1) whether the materials used in the structural frame are combustible or noncombustible, and 2) the fire resistance of building elements. Noncombustible materials can have very little fire resistance (for instance, steel framing when subjected to a hot fire can fail quickly), and so combustibility and fire resistance are separate determining factors in type of construction.

In the IBC there are five types of construction, and they are summarized in Table 1. Types III through V are primarily wood frame construction; Type III is wood frame with noncombustible or fire-retardant treated wood exterior walls, Type IV is heavy timber, and Type V is generally thought of as wood frame. The "A" designation in these construction types means the building elements for the most part are required to be of one-hour rated construction. The "B" designation means that no fire resistance rating is required (referred to as "unprotected" wood frame construction).

Even in the noncombustible construction types (Types I and II), many nonstructural elements of the building, such as floor coverings, windows and doors, and interior finishes, can be wood. Permitted combustible building elements in noncombustible buildings are conveniently listed in Section 603 of the IBC. This list includes structural elements that are constructed of fire retardant treated wood (FRTW). FRTW is not considered noncombustible, but can often be used in place of noncombustible materials. For instance, FRTW can be used in place of noncombustible materials in exterior walls of Type III and IV buildings, and in roof structures of low-rise buildings of Types I and II construction. Table 2 summarizes where fire-retardant treated wood is permitted to be used in lieu of noncombustible materials.

In Section 602.3, the IBC defines Type III Construction as being "that type in which the exterior walls are of noncombustible materials and the interior building elements are of any material permitted by the code." The section goes on to say that fire-retardant treated wood is permitted in exterior wall assemblies in lieu of noncombustible materials when the rating of the wall is required to be 2-hours or less. Therefore, for many of the most common occupancies, buildings constructed entirely of wood can be just as large and as high as noncombustible buildings. Table 3 shows that buildings of IBC Type IIIB in many occupancies, may be just as large as buildings of Type IIB (noncombustible unprotected). Buildings of Type IIIB, for the occupancies shown, may be entirely of wood if FRTW is used in the exterior walls.

Table 1. Types of construction in the IBC.

Type	IBC description
Noncombustible	Type I (A & B) Type II (A) Type II (B)
Mixed noncombustible and combustible including frame and heavy timber (HT)	Type III (A) Type III (B) Type IV (HT)
Combustible—traditional wood frame	Type V (A) Type V (B)

Table 2. Allowable uses of FRTW in the IBC.

Type	Building assembly
I and II	Nonbearing partitions where the required fire-resistance rating is 2 hours or less (Section 603.1.25.1) Nonbearing exterior walls where no fire rating is required (Section 603.1.25.2) Roof construction including girders, trusses, framing and decking (Section 603.1.25.3)
III and IV	Permitted within exterior wall assemblies of a 2-hour rating or less (Sections 602.3 and 602.4)
V	Use of FRTW is unrestricted

Table 3. Comparison of IBC Type IIB and IIIB construction.

IBC Occupancy	IBC Table 503 allowable area (sq ft)		IBC Table 503 allowable height (stories/feet)	
	Type IIB	Type IIIB	Type IIB	Type IIIB
A-3	9,500	9,500	2/55	2/55
B	23,000	19,000	3/55	3/55
E	14,500	14,500	2/55	2/55
M	12,500	12,500	2/55	2/55
R-1	16,000	16,000	4/55	4/55
R-2	16,000	16,000	4/55	4/55
S-2	26,000	26,000	3/55	3/55

The IBC permits sprinklered buildings with National Fire Protection Association NFPA 13 systems to contain one additional story and be increased in height 20 feet. Residential buildings with NFPA 13R systems may be increased one story and 20 feet in height and are not subject to the total building area limit of a three story building (13R is only appropriate up to four stories above grade plane).

In the IBC, a rated wall in accordance with Table 602 can be used to separate a building into two smaller areas, neither of which exceeds threshold values that require installation of sprinklers. This is not considered a fire wall separating buildings. It is a fire separation assembly, separating the building into fire areas.

5 FIRE RESISTANCE

Fire retardant treated wood has a surface burning classification and, by itself, does not have a resistance rating in hours any greater than untreated wood. Fire ratings in hours are assigned to wall, floor, and roof deck assemblies, following testing in accordance with ASTM E 119. References such as the Underwriters Laboratories "Fire Resistance Directory" specifically point out that FRT wood may be substituted for untreated wood in any related assembly. FRTW can be used as a component of such assemblies in structures where the code does not permit the use of untreated wood.

Descriptions of fire resistance rated assemblies incorporating structural lumber are listed in IBC Table 720.1(2) as well several publications referenced by the IBC including:

- Fire Resistance Directory, published by Underwriters Laboratories;
- Fire Resistance Design Manual, published by the Gypsum Association.

As way of example, the Gypsum Association's "Fire Resistance Design Manual" contains a one hour wall or partition assembly (WP 3605) that has wood studs covered by 5/8″ Type X gypsum board with specified nailing and positioning of the panels. This assembly could be used for interior, non-bearing partitions, requiring a one hour rating in a noncombustible structure if the studs were FRTW. In a similar manner, by substituting FRTW for untreated wood, other one and two hour wall and ceiling assemblies can be used in noncombustible type buildings. The IBC also permit use of ceiling assemblies with the top membrane omitted where only unused attic space is above.

The IBC permits asymmetric testing for fire resistance rating (testing from the inside only) where the distance to the property line is at least 5 feet.

If sprinklering is not used for H&A increases, it is permitted to reduce fire resistive requirements by one hour for all construction elements except exterior walls.

6 CASE STUDIES

Figure 1 shows a 1.2 million square foot warehouse that was developed for multiple tenants and features a hybrid panelized roof system utilizing fire retardant treated wood. The hybrid roof system consists of 4 ft × 8 ft fire retardant treated plywood on 2x and 3x fire retardant treated sawn lumber subpurlins. The primary framing consists of steel bar joist spaced 8 ft on center with steel girder trusses as the main structural members. This system uses panelized units assembled on the ground and then lifted into position at the roof level, where the steel bar joists are welded or bolted to the primary steel girder trusses. The free edge of the wood decking for each panelized unit is nailed to the framing edge of the previously placed unit. Pre-framed panel ends attached to the main steel trusses complete the assembly.

In a fire retardant treated wood roof system, the panelized wood sections speed the erection process

Figure 1. FRTW panelized roof system.

Figure 2. Apartment complex utilizing FRTW studs.

Figure 3. The Orchard shopping mall.

and add strength, dimensional stability, and high diaphragm capacity to the roof. The ability to pre-frame large roof panelized units reduce cost, cuts construction time, and enhances job site safety since fewer man-hours are spent on the roof. Panelized roof systems are one of the safest systems to erect because most of the work is accomplished on the ground during the fabrication of the large pre-framed roof panels. Once the large panels are lifted into position at the proper roof elevation, only one or two workers are required on the roof to complete the final purlin attachments and diaphragm nailing.

Another advantage to the hybrid panelized roof system is the speed at which it can be constructed. In this case, the entire 1,200,000 square-foot roof was erected in only 5 weeks with minimal overtime required. An experienced 4 man crew can erect 25,000 square feet of roof per day.

The apartment complex in Figure 2 contains 500,000 square feet of residential space, 40,000 square feet of retail space, and a 350,000 square foot parking garage. The exterior bearing walls are constructed with fire retardant treated wood studs. The interior framing is untreated wood.

The two story parking garage consists of a one-story enclosed parking garage and a one-story open garage. The parking garages are not considered in determining the maximum number of stories allowed in the building under the IBC when constructed of Type I construction and a three hour occupancy separation is maintained between the parking garage and the residential occupancy.

The IBC allows the base area to be doubled and a one-story height increase when a NFPA 13 sprinkler system is installed.

Figure 3 is The Orchard at Westminster, designed to be reminiscent of the Main Streets of small towns in the first half of the 20th century. It is an open-air, entertainment and lifestyle center that comprises a million square feet of exclusive, outdoor, fashion-oriented retail including big boxes, department stores and smaller, upscale retailers. The development also includes 500 housing units and office space. The name was selected to reflect the rich agricultural heritage of the area, which was home to some of the largest apple orchards in Colorado.

It was designed under the IBC to be a Type II noncombustible structure of concrete and steel. The IBC allows fire retardant treated to be used in the roofs and nonbearing walls of noncombustible types of construction. Fire retardant treated plywood was used as roof sheathing over light gauge steel roof trusses providing an easy to nail surface for the 3-dimensional architectural composite shingles.

REFERENCE

2009 International Building Code. International Code Council, Inc. Country Club Hills, IL.