Fire Safety of Wood Construction

An Online Continuing Education Course for Engineers

Course Number: S-2014

Credit: 2 Hours / 2 PDH / 2 CPD

Fire Safety of Wood Construction

John Galinski, P.E.

Introduction

Fire safety is an important concern in all types of construction. The high level of national concern for fire safety is reflected in limitations and design requirements in building codes. These code requirements and related fire performance data are discussed in the context of fire safety design and evaluation in the initial section of this course. Because basic data on fire behavior of wood products are needed to evaluate fire safety for wood construction, the second major section of this course provides additional information on fire behavior and fire performance characteristics of wood products. The course concludes with a discussion of fire-retardant treatments that can be used to reduce the combustibility of wood.

Fire Safety Design and Evaluation

Fire safety involves prevention, detection, evacuation, containment, and extinguishment. Fire prevention basically means preventing the sustained ignition of combustible materials by controlling either the source of heat or the combustible materials. This involves proper design, installation or construction, and maintenance of the building and its contents. Proper fire safety measures depend upon the occupancy or processes taking place in the building. Smoke and heat detectors can be installed to provide early detection of a fire. Early detection is essential for ensuring adequate time for egress. Egress, or the ability to escape from a fire, often is a critical factor in life safety. Statutory requirements pertaining to fire safety are specified in building codes or fire codes. Design deficiencies are often responsible for spread of heat and smoke in a fire. Spread of a fire can be prevented with designs that limit fire growth and spread within a compartment and contain fire to the compartment of origin. Sprinklers provide improved capabilities to extinguish a fire in its initial stages. These requirements fall into two broad categories: material requirements and building requirements. Material requirements include such things as combustibility, flame spread, and fire resistance. Building requirements include area and height limitations, firestops and draftstops, doors and other exits, automatic sprinklers, and fire detectors.

Adherence to codes will result in improved fire safety. Code officials should be consulted early in the design of a building because the codes offer alternatives. For example, floor areas can be increased if automatic sprinkler systems are added. Code officials have the option to approve alternative materials and methods of construction and to modify provisions of the codes when equivalent fire protection and structural integrity are documented.

Most current building codes in the United States are based on the model building code produced by the International Code Council (ICC) (*International Building Code*® (IBC)) and related *International Code*® (I-Codes®) documents). In addition to the documents of the ICC, the National Fire Protection Association's (NFPA's) Life Safety Code (NFPA 101) provides guidelines for life safety from fire in buildings and structures. NFPA also has a model building code known as NFPA 5000. The provisions of the ICC and NFPA documents become statutory requirements when adopted by local or state authorities having jurisdiction.

Information on fire ratings for different products and assemblies can be obtained from industry literature, evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES) and other organizations, and listings published by testing laboratories or quality assurance agencies. Products listed by Underwriters Laboratories, Inc. (UL), Intertek, and other such organizations are stamped with the rating information.

The field of fire safety engineering is undergoing rapid changes because of the development of more engineering and scientific approaches to fire safety. This development is evidenced by the publication of the fourth edition of *The Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering*. Steady advances are being made in the fields of fire dynamics, fire hazard calculations, fire design calculations, and fire risk analysis. Such efforts support the worldwide trend to develop alternative building codes based on performance criteria rather than prescriptive requirements. Additional information on fire protection can be found in various publications of the NFPA and SFPE.

In the following sections, various aspects of building code provisions pertaining to fire safety of building materials are discussed under the broad categories of (a) types of construction, (b) ignition, (c) fire growth within compartment, (d) containment to compartment of origin, and (e) exterior fires. These are largely requirements for materials. Information on prevention and building requirements not related to materials (for example, detection) can be found in NFPA publications.

Types of Construction

A central aspect of the fire safety provisions of building codes is the classification of buildings by types of construction and use or occupancy. Based on classifications of building type and occupancy, the codes set limits on areas and heights of buildings. Building codes generally recognize five classifications of construction based on types of materials and required fire resistance ratings. The two classifications known as Type I (fire-resistant construction) and Type II (noncombustible construction) basically restrict the building elements to noncombustible materials. Wood is permitted to be used more liberally in the other three classifications, which are Type III (ordinary), Type IV (heavy timber), and Type V (light-frame). Type III construction allows smaller wood members to be used for interior walls, floors, and roofs including wood studs, joists, trusses, and I-joists. For Type IV (heavy timber) construction, interior wood columns, beams, floors, and roofs are required to satisfy certain minimum dimensions and no concealed spaces are permitted. In both Types III and IV construction, exterior walls must be of noncombustible materials, except that fire-retardant-treated (FRT) wood is permitted within exterior wall assemblies of Type III construction when the requirements for fire resistance ratings are 2-h or less. In Type V construction, walls, floors, and roofs may be of any dimension lumber and the exterior walls may be of combustible materials. Types I, II, III, and V constructions are further subdivided into two parts—A (protected) and B (unprotected), depending on the required fire resistance ratings. In Type V-A (protected light-frame) construction, most of the structural elements have a 1-h fire resistance rating. No general fire resistance requirements are specified for buildings of Type V-B (unprotected light-frame) construction. The required fire resistance ratings for exterior walls also depend on the fire separation distance from the lot line, centerline of the street, or another building. Such property line setback requirements are intended to mitigate the risk of exterior fire exposure.

Based on their performance in the ASTM E 136, both untreated and FRT wood are combustible materials. However, building codes permit substitution of FRT wood for noncombustible materials in some specific applications otherwise limited to noncombustible materials. Specific performance and treatment requirements are defined for FRT wood used in such applications.

In addition to type of construction, height and area limitations also depend on the use or occupancy of a structure. Fire safety is improved by automatic sprinklers, property line setbacks, or more fire-resistant construction. Building codes recognize the improved fire safety resulting from application of these factors by increasing allowable areas and heights beyond that designated for a particular type of construction and occupancy. Thus, proper site planning and building design may result in a desired building area classification being achieved with wood construction.

Ignition

The most effective ways to improve fire safety are preventive actions that will reduce or eliminate the risks of ignition. Some code provisions, such as those in electrical codes, are designed to address this issue. Other such provisions are those pertaining to separations between heated pipes, stoves, and similar items and any combustible material. In situations of prolonged exposures and confined spaces, wood has been known to ignite at temperatures much lower than the temperatures normally associated with wood ignition. To address this concern, a safe margin of fire safety from ignition even in cases of prolonged exposures can be obtained if surface temperatures of heated wood are maintained below about 80 °C, which avoids the incipient wood degradation associated with reduction in the ignition temperature.

Other examples of regulations addressing ignition are requirements for the proper installation and treatment of cellulosic installation. Proper chemical treatments of cellulosic insulation are required to reduce its tendency for smoldering combustion and to reduce flame spread. Cellulosic insulation is regulated by a product safety standard of the U.S. Consumer Product Safety Commission. One of the required tests is a smoldering combustion test. Proper installation around recessed light fixtures and other electrical devices is necessary.

Exterior Fire Exposure in the Wildland–Urban Interface

In areas subjected to wildfires, actions to remove ignition sources around the home or other structures and prevent easy fire penetration into such buildings can significantly improve the chances that a structure will survive a wildfire. This includes appropriate landscaping to create a defensible space around the structure. Particular attention should be paid to the removal of vegetation and other combustible exterior items (such as firewood, fence, landscape mulch) that are close to openings (vents, windows, and doors), combustible surfaces of the building, and soffits. Openings in building exteriors can allow the fire to penetrate into the building and cause interior ignitions. Building design and maintenance should be done to limit the accumulation of combustible debris that could be ignited by firebrands that originate from burning trees and buildings, with particular attention paid to nooks and crannies that allow accumulation of debris.

The firebrands' distribution is such that they can cause destruction of unprotected structures that are some distance from the actual flames of the wildfire. Regardless of the type of material used for the exterior membrane, the type and placement of the joints of the membrane can affect the likelihood that a fire will penetrate the exterior membrane. For example, bird stops should be installed at the ends of clay tile barrel roof coverings to prevent firebrands from igniting the underlining substrate.

Rated roof covering materials are designated Class A, B, or C according to their performance in the tests described in ASTM E 108, Fire Tests of Roof Coverings. This test standard includes intermittent flame exposure, spread of flame, burning brand, flying brand, and rain tests. Each of the three classes has a different version of the pass–fail test. The Class A test is the most severe, Class C the least. In the case of the burning brand tests, the brand for the Class B test is larger than that for the Class C test. FRT wood shingles and shakes are available that carry a Class B or C fire rating. A Class A rated wood roof system can be achieved by using Class B wood shingles with specified roof deck and underlayment.

For other exterior applications, FRT wood is tested in accordance with ASTM E 84. An exterior treatment is required to have no increase in the listed flame spread index after being subjected to the rain test of ASTM D 2898. At the present time, a commercial treated-wood product for exterior applications is either treated to improve fire retardancy or treated to improve resistance to decay and insects, not both.

Various websites (such as www.firewise.org) provide additional information addressing the protection of homes in the wildland–urban interface. The national Firewise Communities program is a multiagency effort designed to reach beyond the fire service by involving homeowners, community leaders, planners, developers, and others in the effort to protect people, property, and natural resources from the risk of wildland fire, before a fire starts. The Firewise Communities approach emphasizes community responsibility for planning in the design of a safe community and effective emergency response, along with individual responsibility for safer home construction and design, landscaping, and maintenance.

The ICC's International Wildland–Urban Interface Code provides model code regulations that specifically address structures and related land use in areas subjected to wild- fires. NFPA 1144 is a standard that focuses on individual structure hazards from wildland fires. In response to losses due to wildfires, the California State Fire Marshal's Office (www.fire.ca.gov) has implemented ignition-resistant construction standards for structures in the wildland–urban interface. These test requirements intended to address ignitability of the structure are based on tests developed at the University of California for exterior wall siding and sheathing, exterior windows, under eave, and exterior decking.

Fire Growth within Compartment

Flame Spread

Important provisions in the building codes are those that regulate the exposed interior surface of walls, floors, and ceilings (that is, the interior finish). Codes typically exclude trim and incidental finish, as well as decorations and furnishings that are not affixed to the structure, from the more rigid requirements for walls and ceilings. For regulatory purposes, interior finish materials are classified according to their flame spread index. Thus, flame spread is one of the most tested fire performance properties of a material. Numerous flame spread tests are used, but the one cited by building codes is ASTM E 84 (also known as NFPA 255 and UL 723), the "25-ft tunnel" test. In this test method, the 508-mm-wide, 7.32-m-long specimen completes the top of the tunnel furnace. Flames from a burner at one end of the tunnel provide the fire exposure, which includes forced draft conditions. The furnace operator records the flame front position as a function of time and the time of maximum flame front travel during a 10-min period.

Table 1. ASTM 84 flame spread indexes for 19-mm-thick solid lumber of various wood species as reported in the literature[a]

Species[b]	Flame spread index[c]	Smoke developed index[c]	Source[d]
Softwoods			
Yellow-cedar (Pacific Coast yellow cedar)	78	90	CWC
Baldcypress (cypress)	145-150	---	UL
Douglas-fir	70-100	---	UL
Fir, Pacific silver	69	58	CWC
Hemlock, western (West Coast)	60-75	---	UL
Pine, eastern white (eastern white, northern white)	85, 120-215[f]	122, ---	CWC, UL
Pine, lodgepole	93	210	CWC
Pine, ponderosa	105-230[e]	---	UL
Pine, red	142	229	CWC
Pine, Southern (southern)	130-195[f]	---	UL
Pine, western white	75[f]	---	UL
Redcedar, western	70	213	HPVA
Redwood	70	---	UL
Spruce, eastern (northern, white)	65	---	UL, CWC
Spruce, Sitka (western, Sitka)	100, 74	---, 74	UL, CWC
Hardwoods			
Birch, yellow	105-110	---	UL
Cottonwood	115	---	UL
Maple (maple flooring)	104	---	CWC
Oak (red, white)	100	100	UL
Sweetgum (gum, red)	140-155	---	UL
Walnut	130-140	---	UL
Yellow-popular	170-185	---	UL

[a]Additional data for domestic solid-sawn and panel products are provided in the AF&PA–AWC DCA No. 1, "Flame Spread Performance of Wood Products."

[b]In cases where the name given in the source did not conform to the official nomenclature of the Forest Service, the probable official nomenclature name is given and the name given by the source is given in parentheses.

[c]Data are as reported in the literature (dash where data do not exist). Changes in the ASTM E 84 test method have occurred over the years. However, data indicate that the changes have not significantly changed earlier data reported in this table. The change in the calculation procedure has usually resulted in slightly lower flame spread results for untreated wood. Smoke developed index is not known to exceed 450, the limiting value often cited in the building codes.

[d]CWC, Canadian Wood Council (CWC 1996); HPVA, Hardwood Plywood Manufacturers Association (Tests) (now Hardwood Plywood & Veneer Assoc.); UL, Underwriters Laboratories, Inc. (Wood-fire hazard classification. Card Data Service, Serial No. UL 527, 1971).

[e]Footnote of UL: In 18 tests of ponderosa pine, three had values over 200 and the average of all tests is 154.

[f]Footnote of UL: Due to wide variations in the different species of the pine family and local connotations of their popular names, exact identification of the types of pine tested was not possible. The effects of differing climatic and soil conditions on the burning characteristics of given species have not been determined.

The standard prescribes a formula to convert these data to a flame spread index (FSI), which is a measure of the overall rate of flame spreading in the direction of air flow. In the building codes, the classes for flame spread index are A (FSI of 0 to 25), B (FSI of 26 to 75), and C (FSI of 76 to 200). Generally, codes specify FSI for interior finish based on building occupancy, location within the building, and availability of automatic sprinkler protection. The more restrictive classes, Classes A and B, are generally prescribed for stairways and corridors that provide access to exits. In general, the more flammable classification (Class C) is permitted for the interior finish of other areas of the building that are not considered exit ways or where the area in question is protected by automatic sprinklers. In other areas, no flammability restrictions are specified on the interior finish, and unclassified materials (that is, more than 200 FSI) can be used. The classification labels of I, II, and III hav... of A, B, and C.

The FSI for most do... 1). Thus, unfinished lumber, 10 mm or thi... lications requiring a Class C rating. Fire-retarda... pread index is required for a wood product. S... flame spread index without treatment. Oth... upper limit of 200 for Class C. All available ... high-density imported hardwood species have... solid-sawn and panel products are provided i... &PA)–American Wood Council (AWC) design ... PA–The Engineered Wood Association (APA... on plywood panels.

Code provisions pertaini... on the critical radiant flux test (ASTM ... t of the radiant panel is such that the radiant he... tensity down the length of the horizontal s... the end of high heat flux (or intensity) to the o... the heat flux is not sufficient for further propagation. T... ical radiant flux (CRF). Thus, low CRF reflects materials with high flamma...