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THE ROLE OF FIRE-RETARDANT TREATED WOOD IN THE PROTECTION OF LIFE AND PROPERTY[1]

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ABSTRACT

Fire-retardant treated wood is discussed with two approaches to fire protection offered: fire hazard and fire resistance. Descriptive terms used by testing and regulatory agencies are defined. Several of the more commonly accepted test methods used to determine efficiency of fire-retardant treatments in retarding flame spread or resisting burn-through are examined. The roles played by two major impregnated fire-retardant treatments in this accomplishment are described. Sources of information for more detailed study are provided.

Keywords: Fire hazard; fire protection; fire resistance; fire-retardant treatment; test methods; pressure impregnation; water-borne retardants.

INTRODUCTION

Wood can be chemically treated, either by pressure impregnation or by various coatings, to render it less vulnerable to rapid pyrolysis. As the title of this paper indicates, some of the terms used by the various testing and regulatory agencies will be introduced and defined in a way that will relate the type of protection required to the methods by which fire-retardant treatments provide that protection. By so doing, the reader should be more qualified to select the proper material to satisfy the requirement and also be in a position to make the decision whether or not fire-retardant treated wood can qualify for that end use, rather than eliminate use of fire-retardant treated wood because one doesn't know how to make use of it. I will recommend sources of information that can be disseminated to contractors, architects, design engineers and, eventually, the general public.

The National Building Code defines fire-retardant treated wood as "lumber and plywood that have been treated by an approved pressure impregnation process, or by other means, during manufacture, and has a flame spread rating not higher than the equivalent of 25 with no evidence of significant progressive combustion when tested for 30-min duration under standard test methods, such as UL-723, NFPA-255 or ASTM E84" (Am. Insur. Assoc. 1976).

The International Conference of Building Officials uses much the same definition but adds the weathering test of Uniform Building Code Standard No. 32-7, and the additional requirement for inspection of materials at the factory by the testing agency (Int. Conf. Build. Off. 1976). The Building Officials and Code Administrators International and Southern Building Code Congress have similar definitions. A few authorities, such as the State of Michigan, Housing and Urban Development, and the General Services Administration, also make use of fuel and smoke ratings. The Council of American Building Officials is currently in the process of trying to unify major model codes to clarify definitions.

TWO APPROACHES TO PROTECTION OF LIFE AND PROPERTY

There are basically two ways that we can approach the problem of protection of life and property. First, we can reduce fire hazard and second, we can increase fire

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resistance. Before I go into the details of how fire-retardant treated wood can satisfy both of these approaches, I would like to define both terms. Let us discuss fire hazard first. To me, fire hazard is not a general term and I want to convince others that it should not be used as such. ASTM defines fire hazard as "the degree of risk that a fire will occur, and the potential for harm to life and damage to property resulting from its occurrence" (ASTM 1976a). Independent testing laboratories, such as Underwriters Laboratories, Factory Mutual, etc., rate building materials as to fire hazard in a different way, using very definite terms. The most widely accepted method is to limit flame spread, fuel contributed, and smoke developed. In most cases, limits are placed on flame spread for the product to be eligible for classification. Some agencies also place limits on smoke developed. These ratings are usually determined by testing the material in a 25-ft tunnel. The test method is designated ASTM E84 or UL-723 (ASTM 1976b).

In the ASTM E84 test method, material to be evaluated for flame spread is made part of the ceiling of the 25-ft-long tunnel. In cross section the tunnel is approximately 18 inches wide and 12 inches high. Observation windows are provided in the side for observing the progress of flame from the ignition end to the flue. A controlled flame is ignited and progress of the flame is noted during the normal 10-min test period. This is compared to untreated red oak, which has been assigned a rating of 100 and asbestos cement board, which has been assigned the rating of 0. To be listed in the Underwriters Building Materials Directory, the flame spread may not not exceed 70 in the 10-min test (Underwrit. Lab. 1977a). Most well-treated lumber will not exceed a rating of 25 in the 10-min test. Building code regulators use this 10-min test to classify the flame spread characteristics of a material without reference to whether the material can or cannot be used for structural purposes.

During the course of establishing the various parameters for building materials, the question was asked: Does a 10-min test truly represent the performance in actual fire exposure? In other words, how will it perform structurally? The test therefore was extended another 20 min. If, in a test of 20 min duration, the flame spread, fuel contributed, and smoke developed do not exceed the equivalent of 25 and there is no evidence of significant progressive combustion, a rating of FR-S is established (Underwrit. Lab. 1977b). Temperature is recorded by a thermocouple at the vent end of the chamber to establish the fuel-contributed rating, and a photoelectric cell looks vertically down through the horizontal stack to gain information to establish the smoke-developed rating. This 30-min test is used not only to evaluate the flame-spread characteristics but also to determine if a material can be used for structural purposes. Here the building code regulator will be using this test to define if a material can or cannot be used as an alternative to noncombustible materials.

I have briefly given the technical description of fire hazard, which is clearly defined by ASTM specifications. What do they really mean? Let's fall back on the old waste-basket-in-the-corner illustration. Someone tosses a cigarette into the waste basket and walks out of the room. The paper catches fire, the flame reaches the wall and begins to climb. If there is enough fuel in the basket to keep it going for 10 or 20 s, the wall ignites. If the wall is combustible the flame goes up to the ceiling, across the ceiling and within a few minutes flashover occurs, and everything in the room is on fire.

Where does fire-retardant treated wood come into the picture? First of all, fire-retardant treated wood will retard the flame spread. How does it do this? Whenever a flame from an ignition source reaches the surface of fire-retardant treated wood, the heat from the flame begins to heat the surface of the treated wood. If the heat source is below the ignition temperature of the treated wood surface, charring will begin at a temperature somewhat below the temperature at which untreated wood begins to char. The effect of the fire-retardant treatment is to reduce the average heat of combustion for the volatile pyrolysis products released at the early stages of pyrolysis below the value associated with untreated wood (Browne and Brenden 1964). If the heat is from a radiant source rather than a flame, wood will continue to char more deeply and could slowly char to destruction without ever flaming. I know of an example where a salamander used to dry out the plaster in a utility building produced enough heat on the treated wood floor to slowly char the floor to destruction, and the salamander fell through to the crawl space below. No flaming occurred. The floor was repaired and work went on. Untreated wood would have flamed and the building would have been lost.

Results of testing by independent laboratories have shown that the rate of heat release from fire-retardant treated wood is only one-third that of untreated wood. The total heat released is one-half that released by untreated wood, depending on species (Fact. Mut. Res. 1976). However, total fuel contribution is not as important as rate of heat release. You can't compare a 12 × 12 timber with a barrel of gasoline.

What if the heat source is flaming? If the flame impinges directly on the fire-retardant treated wood surface, in a few minutes that surface will flame. However, only that portion of the surface where the ignition flame impinges will flame. The area adjacent to it or, as in our waste basket illustration, the wall above the basket will be heated by the flame and begin to char. The heat from the flame begins to change the fire-retardant chemicals to noncombustible gases, which mix with the volatile gases coming from the heated wood, diluting them and rendering them nonflammable. This retards flaming pyrolysis and progressive combustion. There are other theories on exactly how and why pyrolysis takes place in a piece of wood (Eichner 1962). It is not the purpose of this paper to take issue with any of them. I am interested in the consequences of pyrolytic action. If the fuel source is large enough and the ignition flame continues, the char becomes deeper and more widespread. The pressure impregnation has forced the fire-retardant chemicals deep into the wood providing enough chemicals to allow the wood in the ignition flame to be completely charred through without progressive flame spread. As a result, when the ignition fuel source is depleted, the progressive char stops and all flaming ceases. So in effect, what have we actually done? We have confined the flame, less heat has been released, and fewer volatiles have been produced, reducing the chance of flashover. Less wood has been burned, reducing the amount of smoke produced, which in turn means that fewer toxic gases have been produced. In confining the flame: we have retained structural integrity; we have greatly reduced the chances of involving combustible interior furnishings; and we have gained that all-important time interval for someone, or some device, to detect the fact that a fire has occurred or is occurring.

I have briefly described how fire hazard is rated and what that rating means in a practical application. There are, however, other methods of rating: the so-called 8-ft tunnel test, designated ASTM E286 (ASTM 1976c); the 2-ft tunnel test, the roof-deck test, designated ASTM E108; which evaluates both hazard and resistance in roof-deck construction (ASTM 1976d); the full-scale room, corner, and corridor test (Fact. Mutual Res. 1972); etc. These are all described by various testing and rating associations.

The second approach to protection of life and property is by increasing fire resistance. When a fire does start, from whatever ignition source that may be present, and combustibles in the vicinity of the ignition flame ignite and continue to burn, it is necessary to contain the fire long enough for fire fighters to arrive and extinguish it. Assume the fire has been contained, as in our first approach, and life safety is no longer a factor. The ignition source, instead of a waste basket, is now a fuel source capable of sustaining an ignition flame for an hour or more if left unchecked. We must now have a type of construction capable of containing the fire and preventing it from burning through walls, doors, ceilings, or floors for a period long enough, depending upon the type of occupancy, to permit fire fighters to begin fighting the fire. At this time, fire resistance ratings become important. How long will a particular type of construction (combination of components) withstand a fire of a known intensity before it fails and permits the flame to reach untouched materials? In the previous sentence we have three terms to define: 1) type of construction, 2) fire of a known intensity, and 3) failure.

For the first item, "type of construction," it would be difficult to give an example of an individual component that has a fire resistance rating. In the case of most building construction materials, it is a combination of materials that carry the rating; that is, a stud wall with a layer of gypsum board on each side, or two layers on each side, might have a 1-h rating. A dropped ceiling with a specific kind of insulation, a specified method of hanging, etc. might have a 1½-h rating. A fire door with a mineral core, fire-retardant treated stiles, rails and cross bands, and an untreated face veneer, in an approved metal frame with labeled hardware, might have a 1½-h rating. In other words, the individually approved components when used in conjunction with other approved components to make an approved assembly will actually carry a label with the resistance rating upon it.

Item 2, "fire of a known intensity," and item 3, "failure," can be combined into one example. No two actual fires are alike. So how can this be taken into account? Over the years ASTM has established a method for testing assemblies (such as we have been discussing) and designated it ASTM E119 (ASTM 1976e) for structures such as floors, roofs, walls, etc., and ASTM E152 (ASTM 1976f) for fire doors. Briefly, the construction to be evaluated is made a part of the test furnace, and a controlled ignition flame establishes a controlled temperature, which rises with time along a designated curve over a specific time period. In the case of a door or wall assembly, a hose stream is played upon the structure at the end of a given time period. The test assembly must withstand the fire and the hose test without developing openings anywhere through the assembly. There is more to the determination of fire resistance, but this description briefly explains the procedure.

There are many other types of fire tests that are currently used to evaluate fire performance. Some are rather exotic, some are strictly laboratory tools, some are quality control measures, and some are exercises in theory.

I purposely omitted from this discussion detailed descriptions of some of the many more exotic fire test methods because most code groups do not refer to them in their current specifications. This is not to say that they are of any less value. As far as this paper is concerned, the value of a test is determined by how well the test method is understood by the majority of the people involved in building design and construction, and how widely the test is accepted by the people writing the codes. The value of the test method as a research tool is not in question. However, the local building inspector determines the acceptability of construction methods. He cannot know all things about all building materials; therefore, he must be guided by building codes. In many municipalities, a uniform code is accepted intact and it is the architect, designer, or building contractor who must prove that the materials desired conform to the code. Whenever the material is not included in the code or is considered unacceptable, you must request a waiver for the use of unlisted products. If no backup data are provided and you have no idea where these data are available, you lose a customer. Many times the design engineer or architect will be unfamiliar with the terms used in the code or unaware that fire-retardant treated wood will qualify as a noncombustible material under one of several definitions. As a result, alternate raw materials will be used as a substitute because of lack of information.

ASTM has published a two-part series on standardization basics. In the first part the idea was to promote a basic understanding of the dynamic world of standards: what they are, why they are necessary, who writes them, and how they are developed. In the first paragraph, the author said that standards are an essential and all-pervasive element of society; yet most people, from the man on the street to the highest officer of the community, understand precious little about standards. Understanding code requirements and being able to intelligently select the esthetic material to satisfy those requirements are the first steps in designing a structure (ASTM 1977).

TYPES OF FIRE-RETARDANT TREATMENT

I want to discuss briefly two general types of fire-retardant treatment that will satisfy most code requirements. There are others; however, they are limited in use. I receive many phone calls from architects, engineers, and contractors that demonstrate a lack of knowledge about proper fire-retardant application or end use. I am limiting this discussion to pressure impregnation only. There are many fine, accepted and listed fire-retardant coatings and finishes on the market (Underwrit. Lab. 1977b). For the two approaches to protection of life and property that I outlined above, I will discuss only pressure impregnation.

Of the two types of fire-retardant treatment available, one is rather hygroscopic; that is, at high relative humidities, the treated wood tends to absorb moisture in greater quantities than untreated wood. In addition, as moisture moves in and out of the wood, it carries some of the fire-retardant chemicals with it, gradually depleting the wood of the fire protection qualities we desire. If used in the wrong application (in a hostile environment) the movement of moisture will discolor paint and cause a failure of the coating. This product, in one of several forms, has been on the market for more than 15 yr and has done, and is still doing, an excellent job of protecting life and property. It is only when its known limitations are exceeded that it does not perform as anticipated. It is therefore important that you understand these limitations before writing it into a particular specification. This fire-retardant consists of several proprietary combinations of phosphorus, boron, and other chemicals with known fire-retardant qualities dissolved in water and pressure impregnated into the wood. After impregnation of the measured quantities, the water is removed in a dry kiln (Am. Wood-Preserv. Assoc. 1976).

The second type of fire-retardant is a water-borne amino resin combined with a phosphate and is also pressure impregnated into the wood. The difference is that the amino resin enters the wood as a monomer and is polymerized during the kiln drying process. The resin remains in the wood as a long-chain polymer and is not influenced by movement of water into and out of the wood. The resulting treatment is nonhygroscopic and, when exposed to a high temperature and high relative humidity, the treated wood will have an equilibrium moisture content the same as, or slightly lower than, the untreated wood. It can be glued or painted and will not interfere with bonding or ability of a paint film to adhere.

RELATED SOURCES OF INFORMATION

The information contained in this paper only briefly describes how fire-retardant treated wood can be used to protect life and property. There are many other sources of information available to broaden knowledge of pressure impregnated wood, how it functions, where and how it should be used, where it can be obtained, etc. Attached to this paper, as Appendix A, is a list of organizations, associations, testing laboratories, and education institutions that are directly involved in the dissemination of information. They can offer suggestions or make available data to permit you to make responsible decisions with regard to fire-retardant treatment. In addition to providing information on fire-retardant treatment, many of these references will also provide information regarding the treatment of wood-based materials for prevention of rot and decay, provide dimensional stability, or impart other qualities. Their facilities are also available to help in engineering problems related to the use of fire-retardant treated wood.

SUMMARY

Two approaches to fire protection have been discussed: fire hazard and fire resistance. Some of the terms used by both testing and regulatory agencies have been defined. The role played by two major types of fire-retardant treatment in preventing flame spread and resisting burn-through were discussed. The test methods used to determine the degree of protection offered by fire-retardant treatment were described. Sources of information for more detailed study are provided.

REFERENCES

American Insurance Association. 1976. National Building Code. New York, NY.

American Society for Testing and Materials. 1976a. ASTM designation E535-75, standard recommended practices for preparation of fire test standards. Part 18. Annual Book of ASTM Standards. Philadelphia, PA.

———. 1976b. ASTM designation E84, standard test method for surface burning characteristics of building materials. Part 18. Annual Book of ASTM Standards. Philadelphia, PA.

———. 1976c. ASTM designation E286-69, standard test method for surface flammability of building materials using an 8-foot (2.44-m) tunnel furnace. Part 18. Annual Book of ASTM Standards. Philadelphia, PA.

———. 1976d. ASTM designation E108-75, standard methods of fire tests of roof coverings. Part 18. Annual Book of ASTM Standards. Philadelphia, PA.

———. 1976e. ASTM designation E119-76, standard methods of fire tests of building construction and materials. Part 18. Annual Book of ASTM Stanards. Philadelphia, PA.

———. 1976f. ASTM designation E152-76, standard methods of fire tests of door assemblies. Part 18. Annual Book of ASTM Standards. Philadelphia, PA.

———. 1977. Standardization basics: Part 1. The what and why of standards. ASTM Stand. News. 5(2):24–27.

American Wood-Preservers' Association. 1976. Book of Standards. Washington, D.C.

Browne, F. L., and J. S. Brenden. 1964. Heat of combustion of the volatile pyrolysis products of fire-retardant-treated ponderosa pine. USFS research paper FPL19. Forest Products Laboratory, Madison, WI.

Eichner, H. W. 1962. Basic research on pyrolysis and combustion of wood. For. Prod. J. 12 (4):194–199.

Factory Mutual Research. August 1976. Comparative fire tests of treated and untreated lumber. Reprint Serial #2467901. Norwood, MA.

———. June 1972. Factory Mutual building-corner fire test procedures. Norwood, MA.

International Conference of Building Officials. 1976. Uniform Building Code. Whittier, CA.

Underwriters Laboratories, Inc. 1977a. Building Materials Directory. Northbrook, IL.

———. 1977b. Building Materials Directory. Northbrook, IL.

APPENDIX

List of Organizations and Associations that Can Supply Information on Wood Products, Treated and Untreated

American Board Products Association
205 West Touhy Avenue
Parkridge, IL 60068
312-692-5178

American Institute of Timber Construction
333 West Hampden Avenue
Englewood, Colorado 80110
303-761-3212

American Plywood Association
1119 A Street
Tacoma, Washington 98401
206-272-2283

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103
215-299-5474 (information center)

American Wood-Preservers Association
1625 I Street, N.W.
Washington, D.C. 20036
202-331-1382

American Wood Preservers Institute
1651 Old Meadow Road
McLean, Virginia 22101
703-893-4005

Committee on Fire Research
National Research Council
2101 Constitution Avenue
Washington, D.C. 20418
202-393-8100

Factory Mutual Research Corporation
1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062
617-762-4300

Flammability Research Center
Dept. of Materials Science and Engineering
The University of Utah
Salt Lake City, Utah 84100
801-581-8431

Forest Products Laboratory
U.S. Dept. of Agriculture
P.O. Box 5130
Madison, Wisconsin 53705
608-257-2211

Forest Products Research Society
2801 Marshall Court
Madison, Wisconsin 53705
608-231-1361

Hardwood Plywood Mfgs. Association
P.O. Box 6246
Arlington, Virginia 22206
703-671-6262

Koppers Company, Inc.
Forest Products Division
Technical Services Group
P.O. Box 107
Orrville, Ohio 44667
216-682-3080

National Bureau of Standards
Center for Fire Research
Building 225—Room B 142
Gaithersburg, Maryland 20760
301-921-1000

National Fire Protection Association
470 Atlanta Avenue
Boston, Massachusetts 02210
617-482-8755

National Forest Products Association
1619 Massachusetts Avenue, N.W.
Washington, D.C. 20036
202-332-1050

National Lumber Mfg. Association
Technical Services Division
1619 Massachusetts Avenue, N.W.
Washington, D.C. 20000
202-332-1050

National Paint and Coatings Association
1500 Rhode Island Avenue, N.W.
Washington, D.C. 20005
202-462-6272

National Particleboard Association
2306 Perkins Place
Silver Springs, Maryland 20910
301-587-2204

National Woodwork Mfgs. Assoc., Inc.
400 West Madison Street
Chicago, Illinois 60606
312-782-6232

Plywood Research Foundation
1119 A Street
Tacoma, Washington 98401
206-383-3488

Red Cedar Shingle and Handsplit Shake Bureau
515 116th Ave. NE, Ste. 275
Bellevue, Washington 98004
206-442-0111

Southern Forest Products Association
P.O. Box 52468
New Orleans, Louisiana 70152
504-525-7381

Underwriters Laboratories of Canada
7 Crouse Road
Scarborough, Ontario
416-757-3611

Underwriters Laboratories, Inc.
Fire Protection Department
333 Pfingsten Road
Northbrook, Illinois 60062
312-272-8800

Western Wood Preservers Institute
Yeon Building
Portland, Oregon 97204
503-224-7877