IMPACT OF FIRE RESEARCH ON BUILDING PRODUCT ACCEPTANCE

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SUMMARY

Recent advances in fire science are paving the way for new approaches for delivering fire safety in buildings. A new generation of fire tests offers improved insight into the fire performance of building products and furnishings. Computer fire models predicting the development of hazardous conditions in a burning building and the resulting loss of life are available. One can envision the day when building codes move away from current prescriptive requirements to performance requirements based on this emerging technology. This presentation will show how such changes in building regulations could affect markets for fire-retardant treated wood products.

INTRODUCTION

Building designers usually assure a design is fire-safe by demonstrating compliance with building code requirements. It is estimated that 75% of the National Building Code of Canada (NBC) (1) addresses fire safety concerns. Code requirements have evolved over the years based on the judgement of experts in fire safety. In writing the code, these experts have had only past fire experience, limited fire research and "seat-of-the-pants" fire test methods to draw on. As a consequence, fire safety requirements are generally cumbersome and prescriptive (i.e., they are followed much like recipes in a cook book). Although there is little doubt that NBC fire safety requirements are effective, it is generally not possible to quantify the level of safety (or inversely the probability of failure) they provide. Recent advances in fire science and computer technology are leading to new approaches for delivering fire safety. A new generation of fire tests offers improved insight into the fire performance of building products and furnishings. Data generated in such tests provides input for computer fire models to predict the development of hazardous conditions in a building on fire and the expected loss of life. One can envision the day when designers abandon the cook book practice in favour of computer fire models to design buildings which comply with performance-based code requirements. This would introduce increased flexibility and cost-effectiveness into building design without compromising fire safety.

The paper begins with a review of current codes and standards, particularly as they relate to fire-retardant treated wood. Then an overview of how emerging technology may change fire safety regulations is presented. Finally, the impact of these changes on markets for fire-retardant treated wood is addressed.

CURRENT CODES AND STANDARDS

COMBUSTIBILITY

A building material is classified as either combustible or noncombustible in the NBC. It is noncombustible if it passes the noncombustibility test, CAN4-S114 (2). The test measures the ability of a material to resist ignition and burning when subjected to an arbitrary temperature of 750 C for 15 minutes. Not surprisingly, wood products, fire-retardant treated or not, are found to be combustible. In fact, even gypsum wallboard, which exhibits desirable fire performance, is combustible.

In addition to distinguishing between combustible and noncombustible materials, the NBC distinguishes between combustible and noncombustible construction. In an attempt to limit the contribution of building elements to fire loads, particularly in high or large-area buildings, and to inhibit fire spread through buildings, the NBC requires such buildings be of noncombustible construction. This means that assemblies in these buildings must be constructed of noncombustible materials. For practical reasons, some combustible elements considered not to represent an undue hazard in limited amounts and specially listed in the NBC are permitted (i.e., materials deemed combustible by CAN4-S114 may exhibit good fire performance). For example, gypsum wallboard is permitted. There are also many permitted uses of wood products (fire retardant-treated or not). So the NBC is in the awkward position of permitting combustible building elements in buildings it requires to be of noncombustible construction.

FLAME-SPREAD RATINGS

Combustible building materials are assessed flame-spread and smoke-developed ratings employing the "25 foot" tunnel test, CAN4-S102 (3). In the test, 7.2 m specimens are placed in the ceiling (or floor, CAN4-S102.2 (4)) of the tunnel and exposed to a 1.37 m flame. The advance of flames along the specimen and the evolution of smoke are monitored to determine flame-spread and smoke-developed ratings. Some typical ratings for building materials are listed in Table 1 (5). Notice that 6 mm Douglas fir plywood (and, in fact, all untreated dimensional lumber) is considered to have a flame-spread rating not exceeding 150. In Sentence 3.1.4.4.(1) of the NBC, fire-retardant treated wood is defined as being pressure impregnated with fire-retardant chemicals and having a flame-spread rating not exceeding 25.

TABLE 1

FLAME-SPREAD RATINGS OF BUILDING MATERIALS

Building Material	Flame-Spread Rating
Gypsum Wallboard	< 25
Fire-Retardant Treated Wood	< 25
Red Oak Flooring	100
6 mm Douglas Fir Plywood	< 150

In an attempt to reduce the contribution of building materials to fire growth, the NBC has minimum requirements for flame- spread ratings of interior finish materials. For example, in many areas of high risk to occupants, such as exits, flame-spread ratings of walls and ceilings are not to exceed 25. In practice, any material which performs as well as or better than gypsum wallboard (e.g. fire-retardant treated wood) is permitted.

As another example, interior finish materials used on walls of residential rooms are required to have a flame-spread rating not exceeding 150. In practice, any lining material which performs as well as or better than 6 mm Douglas fir plywood is permitted.

FIRE-RESISTANCE RATINGS

Building assemblies (walls, floors, etc.) are assessed fire-resistance ratings employing CAN4-S101 (6). In this test, the assembly is exposed in a furnace to a standard fire following a prescribed temperature-time curve. The fire resistance rating is the length of time the assembly can prevent the passage of flame and transmission of heat (for fire separations) and/or supports its load (for load-bearing elements).

Fire-resistance ratings of wood construction assemblies are well known. The effect of fire-retardant treatment on fire resistance depends on the treatment. As fire retardants are designed to reduce flame-spread, they may slightly increase the time until ignition. However, some fire retardants reduce flammability by lowering the temperature at which charring occurs. This may increase the charring rate and decrease fire resistance. A few fire retardants and a number of coatings have been found to improve charring resistance and hence fire resistance.

To inhibit the spread of fire through buildings and to safeguard exits, the NBC requires that buildings be subdivided into fire compartments isolated from one another by fire separations with prescribed fire resistance ratings. To prevent the premature collapse of a building or components thereof, the NBC requires that structural elements have prescribed fire resistance ratings.

ROOF DECK ASSEMBLIES

Special consideration is given to fire-retardant treated wood in the construction of roof deck assemblies in some buildings. In office, mercantile, and some public assembly buildings not exceeding one storey and specified areas, roof assemblies must have a fire resistance rating from below of 45 minutes. This requirement can be waived if the roof assembly is of noncombustible construction or is constructed as a fire-retardant treated roof system meeting the requirements of CAN/ULC-S126 (7).

ROOF COVERINGS

Another common application of fire-retardant treated wood is for roof coverings. To prevent the spread of fire from building to building via roofs, the NBC requires that roof coverings have a Class A, B or C rating when tested in accordance with CAN/ULC-S107 (8). To meet these requirements, wood shakes and shingles must be fire-retardant treated.

The city of Los Angeles recently banned the use of fire-retardant treated shakes and shingles. Although there are no obvious moves afoot in Canada to do the same, it would be prudent for the industry to continue to monitor developments in this area.

IMPACT ON MARKETS FOR FIRE-RETARDANT TREATED WOOD

The traditional fire tests cited in the NBC to establish minimum levels of safety, provide rudimentary methods for modelling the fire performance of building products. Limiting the use and flame-spread ratings of combustible building materials inhibits fire growth. Intercompartmental fire spread is inhibited by the use of fire resistance ratings. These measures aid in extending the time available for occupants to escape to a safe area within or outside a burning building.

NBC requirements infer the use of wood products, fire-retardant treated or not, for many applications is in keeping with fire-safety objectives. Yet, in practice buildings are often built of noncombustible construction when combustible construction is permitted, and, in buildings of noncombustible construction, wood products are not employed as liberally as NBC requirements would permit. The question arises as to why this should be the case.

Construction costs cannot be regarded as the complete answer. It is true, for example, that gypsum wallboard is often employed where fire-retardant treated panelling is permitted because of cost. Yet, on the whole, it is cheaper to build of combustible construction than of noncombustible construction. Forintek has recently constructed its new Western Laboratory from wood and has realized a savings of $50 per square meter ($5 per sq. ft.) over what it would have cost to build with structural steel.

The answer, I feel, lies in a perceived fire hazard associated with the use of wood. The NBC requirements notwithstanding, many insurance companies, building officials, owners and builders appear to harbour prejudices against wood. In essence, this implies that not everyone "trusts the code". Why may that be? There is little doubt that most code provisions are an asset to fire safety. The question is to what degree? Unfortunately, there is no existing method for quantifying the level of safety implied by provisions taken individually or in tandem. We cannot predict on the basis of flame-spread and fire resistance ratings whether or not there is sufficient time for occupants to escape in the event of fire. We cannot predict the expected loss to life over the life time of a building as a result of fire, or any other parameter that might give us a measure of the **performance** of NBC provisions.

The surest way to combat the prejudice against wood products would be to say, " I've calculated the impact on fire safety resulting from the use of this wood product and find that it is consistent with code requirements". That is we need to express fire safety design criteria in performance language as is done for structural design in Part 4 of the NBC. The designer could then use any material he chooses as long as his design meets the performance requirements of the code.

Fortunately, emerging fire technology will enable designers and building officials to address fire safety design in a quantitative fashion.

EMERGING FIRE STANDARDS

ROOM-FIRE TEST

To better understand the contribution of combustible walls and ceilings to fire growth, a room-fire test method is under development by ASTM (9) and ISO (10). Tests are conducted in a room with floor dimensions of 2.4 x 3.6 m, and a ceiling height of 2.4 m. The walls and/or ceiling are lined with the interior finish to be tested and the experiment is started with a small fire source in one corner of the room. During the experiment the rates of release of heat, smoke and toxic gases, and the rate of spread of flames are measured as well as the time to flashover (full-room involvement) should it occur.

Much experience has been gained with room fire testing. In Table 2 approximate times to flashover are listed for several wall and ceiling linings exposed to a 100 kW ignition source (equivalent to a fire involving a small upholstered chair) (11).

TABLE 2

ROOM FIRE TEST RESULTS

Room Lining Material	(CAN4-S102) Flame-Spread Rating	Time to Flashover
Gypsum Wallboard	<25	-
Fire-Retardant Treated Wood	<25	-
6 mm Douglas Fir Plywood	<150	3 min
Polyurethane Insulation A	500	13 sec

When the room is lined with gypsum wallboard or fire-retardant treated panelling, flashover does not occur so occupants have a great deal of time to escape. In a room lined with 6 mm Douglas fir plywood, the time to flashover is about 3 minutes so that the time to escape has been greatly reduced. Finally, in a room lined with polyurethane foam insulation (flame-spread rating of 500) the time to flashover is as low as 13 seconds; there is almost no time for escape. Incidentally, this is the reason the NBC requires a thermal barrier cover such insulation.

Room-fire testing offers several advantages over current small-scale fire tests. To begin with, because of its obvious correspondence with real-world fires, it can reliably predict the time available for escape from a room given an ignition source. One can compare directly the relative contributions of different lining materials and also furnishings to fire growth. Finally data generated in room-fire tests has proven useful in validating fire models about which more will be said shortly. Although costly to conduct, room fire tests are being considered as the fundamental method for product acceptance of room lining materials in Europe, perhaps as early as 1992.

CONE CALORIMETER

Research in fire dynamics has determined that the heat released when materials burn is the most important driving force in fire growth. Combustible materials with low rates of heat release contribute little to fire growth; whereas those with high rates of heat release contribute significantly.

In appreciation of this finding, much effort has been expended on developing test methods for determining the rate of heat release of materials and products. The cone calorimeter (ASTM E1354 (12) or ISO DIS 5660 (13)) has emerged as the most widely accepted test method for this purpose. Employing oxygen consumption calorimetry, the test determines the rate of heat (and smoke) release of specimens (100 x 100 mm with a thickness up to 50 mm) exposed to a radiant heat flux typical of a fire scenario.

The method is being considered by Underwriters' Laboratories of Canada to establish degrees of combustibilty of building materials based on their rates of heat release. Referencing the test method, the NBC plans to replace the old combustible / non-combustible classification system with a new one based on degrees of combustibility. Although firm guidelines are not in place yet, it is likey that products with low rates of heat release, such as gypsum wallboard and fire-retardant treated wood, would be classified as being of limited combustibility and would receive preferential treatment over more combustible materials.

The European community may employ the cone calorimeter in its building regulations as early as 1992. Although the room-fire test is likely to be the preferred test, consideration is being given to referencing the cheaper cone calorimeter test as an alternative.

One of the most striking features of this "new generation" test method is that it may find value as both a tool for regulations, as outlined above, and also as a tool for developing input data for fire models, as will be outlined below.

LIFT (Lateral Ignition and Flame Travel)

Another "new generation" fire test, ASTM E1321 (14), referred to as the LIFT test, has been developed to determine material properties related to piloted ignition and lateral flame spread on a vertical surface exposed to an external radiant heat flux.

Mathematical models employing data generated using the LIFT apparatus predict rather well the results of room-fire tests. As a consequence, the LIFT test may eventually replace the "25 foot" tunnel test in the NBC. In fact, the European community is considering referencing the LIFT test as a cheap alternative to the room fire test in its building regulations as early as 1992. A related test method is already referenced by the International Maritime Organization to regulate combustible linings in ships.

Once again this new generation test is valuable both as a tool for regulations and for developing input data for fire models.

TOXICITY

It is estimated that 80% of all fire fatalities result from the inhalation of smoke and toxic products of combustion rather than from burns. For this reason, much effort is being expended to develop test standards assessing the toxic potency of the products of combustion of burning materials. Although several test methods have been developed, neither ASTM or ISO have adopted any concensus toxic potency standards.

It is not clear if toxic potency standards will ever be referenced in the NBC. The State of New York requires building products be tested employing the University of Pittsburgh (UPitt) test and the results be registered with the state. No products are banned by the state. However, in the City of New York, materials more toxic than wood, as assessed using the UPitt test, are not permitted. As fire-retardants and preservatives inhibit combustion (enhancing carbon monoxide production), and produce addition toxic gases, they may increase combustion gas toxicity. There is reason for concern here for your industry.

However, due to complexities related to the prediction of the production and migration of combustion products in buildings, the fire research community is not pushing for inclusion of toxicity requirements in building codes. The problem is complicated by the fact that furnishings may contribute more to combustion gas toxicity than building elements. As a consequence, the preferred approach appears to be to employ toxic potency tests to develop data for computer models in which a more equitable treatment of the development of hazardous conditions is possible.

EXTERIOR WALL TEST

Combustible cladding on the exterior walls of buildings can spread fire from one storey to another and between buildings by ignition of the cladding, followed by flame spread over the facade. For this reason, the 1985 version of the NBC excluded the use of combustible claddings on most large buildings.

Research conducted at the National Research Council (NRC) has demonstrated that some combustible claddings, including several incorporating fire-retardant treated wood, do not support vertical flame propagation. As a result, the 1990 NBC permits combustible cladding on some buildings required to be of noncombustible construction. Combustible cladding is limited to buildings up to 3 storeys high if not sprinklered, and up to 6 storeys if sprinklered, provided the cladding has performed satisfactorily in a full-scale test developed by NRC. This may provide a market for fire-retardant treated claddings.

COMPUTER FIRE MODELLING

In recent years, a great deal of effort has been devoted to development of computer fire models. Models have been developed to predict the course of a growing fire, the severity of a fully developed fire, the structural response of building elements subjected to fire, the movement of fire and smoke through a building, the actuation of sprinkler or fire alarm systems, the evacuation of occupants, and so on. Many of these models are undergoing validation to determine their accuracy.

One of the more widely publicized of these computer models is HAZARD I. HAZARD I is made up of a series of procedures which can assess the relative contribution of specific products (building elements or furnishings) to the hazards of fire and smoke in single-family residences. The model can calculate the following phenomena associated with a fire:

* the production of heat, smoke and gases by burning objects in one room, based on small- or large-scale measurements,
* the transport of heat, smoke and gases throughout the building,
* the temperatures, smoke optical densities and gas concentrations throughout the building,
* the actuation of fire alarm systems,
* the evacuation of occupants accounting for delays in notification, decision making, behavioural interactions, and inherent capabilities, and
* the impact of the exposure of these occupants to the predicted room environments as they move through the building, in terms of the expected fatalities.

A fire risk-cost assessment model is under development at NRC to determine the cost-effectiveness of fire safety provisions in Canadian apartment buildings. The model predicts the dynamic interaction between fire growth and spread, and occupant evacuation. Fire statistics are used to describe phenomena such as the likelihood of a fire starting in a room or the reliability of an alarm system. Mathematical models are used to describe phenomena such as the development of a fire in a room or the spread of smoke through the building.

The performance of any building design is given by the model in terms of the expected risk-to-life and fire cost expectation. The expected risk-to-life is the predicted annual per capita death rate and the fire cost expectation is the expected direct costs and losses divided by the total cost of the building.

Models such as these predict the level of safety inherent in a design in terms of an expected loss to life. What is of particular interest to the fire-retardant industry and to the wood industry is that these models have no built in prejudice against wood products. The input data for the models is either determined in a small-scale test or from a statistical data base. This assures an equitable treatment of all materials, products and designs.

FUTURE DIRECTIONS

This new technology based on new generation fire tests providing data for computer fire modelling will not receive universal acceptance over night. Nonetheless, one can envision several ways this technology may assist in delivering fire safety.

Setting minimum levels of safety in building codes is not easy. For this reason code writers have expressed interest in employing computer fire models (and new generation fire tests) during their deliberations. It is to be expected that submissions for code changes will be increasingly supported by and analyzed with computer fire models. To a limited extent, fire modelling is already one of the tools employed by code writers.

A second example of how computer fire models may be used in design is in demonsrating equivalency. From time to time, during the design of a new building or the renovation of an existing building, it is found that building code requirements are inconsistent with the spirit of the design. In such situations the designer may wish to propose alternative designs. Computer fire models can be used to demonstrate whether or not the proposed design provides a level of protection equivalent to that intended by the NBC. This is already being done in the field.

Finally, computer fire models could be used to replace current prescriptive building code requirements. Design procedures could be based on properties of real fires, the performance of materials as predicted in new generation tests, and well-defined performance criteria. For example, if the performance criteria demanded that the expected risk-to-life not exceed a set level, computer fire models could be used to assure a design satisfies these criteria without direct reference to prescriptive code requirements. This latter approach is not likely to be realized for quite some time to come.

Outside the realm of building regulations computer fire modelling is finding applications in fire litigation analyses and in insurance underwriting.

In summary, the current NBC permits a much broader use of wood and fire-retardant treated wood than current markets reflect. This is particularily true in industrial buildings. One of the biggest stumbling blocks to the use of wood and fire-retardant treated wood is not the NBC but perceived notions as to the fire hazards associated with their use. Fire research has, however, developed test methods and computer fire models which permit equitable treatment of all materials, products and designs. This may well lead to the safe use of fire-retardant treated wood in expanded markets in the future.

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