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CBD 141

Flammability of Lining and Insulating Materials

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Please note

In 1963, shortly after detailed flame-spread requirements were introduced into the National Building Code of Canada, **CBD 45**, "Flame Spread," was issued. The discussion in that Digest concerning the influence of the flammability of interior lining materials on the rate of fire development within a compartment, flame-spread requirements, tests and ratings provides a useful background for this present Digest. For example, the concept that the surface flammability of lining materials is usually one of the major factors in the development of fire within a compartment and consequently should be regulated continues to be widely accepted, as evidenced by the additional flame-spread requirements which were included in the 1965 and 1970 editions of the National Building Code of Canada.

Flame-Spread Requirements

In 1965 several flame-spread requirements for residential occupancies were introduced into the Code, the most significant changes being; (1) imposition of a maximum flame-spread rating of 150 (ASTM E84 method) for any wall or ceiling finish in any room or space or in any exit, or corridor leading to an exit, even if sprinklered; (2) a maximum flame-spread rating of 25 for 90 per cent of the area of an unsprinklered exit ceiling; (3) a maximum flame-spread rating of 75 for 90 per cent of the wall surface of an unsprinklered exit, or an alternative third clause, a maximum flame-spread rating of 25 for 90 per cent of the upper half of the wall surface of an unsprinklered exit (with presumably a maximum of 150 on the lower half).

In 1968 "residential occupancy" was extended to include single-family dwellings, and corresponding restrictions on interior finishes were imposed.

Additional flame-spread requirements have been introduced in the 1970 edition of the NBC. These in the main have consisted of the addition of requirements concerning the flame-spread of lining materials, including floor coverings, in high-rise buildings, with restrictions on "smoke developed" as well as flame-spread, for floor coverings, stairwells, service spaces, building services, and lighting elements.

Flame-Spread Tests

ASTM E84-70, Test for Surface Burning Characteristics of Building Materials

Several amendments have been made to this Standard since **CBD 45** was issued. A fourth method of calculating flame-spread classification was added in 1965, which is as follows. For those cases where the flame front fails to reach the end of the tunnel (19.5 ft net advance) but advances beyond 13.5 ft, the flame-spread classification is calculated on the basis of FSC = 50 + 1.41 d, where d = net flame-spread in feet. For net flame-spreads of 13.5 ft or less, FSC = 5.128 d, as in the past.

This change was introduced to eliminate the anomaly of materials of obviously different flammabilities receiving the same FSC by the earlier methods of calculation.

The most recent amendments to the Standard, now designated as ASTM E84-70, involve recommendations on methods of mounting or supporting such materials as 12- by 12-in. ceiling tile; loose fill, batt or blanket insulation; and plastics in the form of films, membranes, grids or foams, assuring some degree of uniformity in procedure among testing agencies. A minor editorial change in Section 1, "Scope," of ASTM E84-70 states that while fuel contributed (FC) and smoke developed (SD) are recorded as well as flame-spread classification (FSC), "there is not necessarily a relationship among these three measurements."

Although there are those who still question the validity of the ASTM E84 tunnel test in the evaluation of flame spread, the cumulative evidence confirms the usefulness of the flame-spread classification determined by it. Full-scale studies of fire propagation in corridors by the Illinois Institute of Technology Research Institute (IITRI)(1); and National Research Council of Canada(2) have substantiated the opinions of those who believe that the tunnel test, despite its cost and limitations, remains the most reliable source of information on the relative fire hazard characteristics of most lining materials. Both the IITRI and NRC studies indicate that propagation along a corridor of a fire originating in an abutting room is probable if the FSC of the vertical surfaces of the corridor is over 35.

ASTM E162-67, Test for Surface Flammability of Materials Using a Radiant Heat Energy Source

Although this test is intended essentially for research and development studies, it is used in the United States for evaluating the flame-spread index (I_s) of aircraft and marine lining materials. It has distinct limitations, however, when used for the testing of certain plastics, composites and painted wood products, seldom giving satisfactory agreement with results of the E84 tunnel test.

ASTM E286-69, Test for Surface Flammability of Building Materials Using an 8-ft Tunnel Furnace

This test has continued to be used extensively as a research tool in the wood products field. With the trend toward composites and thinner materials, the correlation between the 8-ft and 25-ft tunnels may be expected to become poorer in the 50 to 150 FSC range. Even greater disparities occur in the determination of smoke developed, in spite of the use of red oak flooring as the calibration material in both methods.

Miscellaneous Small-Scale Tests

Because of the cost and scale of the E84 test, many small-scale tests have been suggested for research and plant control. Among these are the Pittsburgh Corning 30/30, the Monsanto and Miller 2-ft tunnels (the latter specifically designed for testing fire-retardant paints), and several variations on each of these basic designs. Extensive experience at the Division of Building Research with the Pittsburgh Corning apparatus in the original 30-in. model and the later 36-in. version has shown that, although it furnishes useful information in the preliminary study of thicker wood-based products, it has distinct limitations in the evaluation of thin plywoods, plastics and textiles. Industrial research organizations have generally modified these small tunnels to suit specific products and markets.

Great care should be exercised in using the results from small-scale tests, particularly of plastics, if they are to be related to ASTM E84 results.

Flame-Spread Ratings

Since the publication of **CBD 45** many new interior lining materials of unpredictable flammability have become available. In addition, a number of lining materials that have been on the market for some time have been progressively modified in recent years. For example, conventional materials such as plywood and hardboard are now being marketed in the form of much thinner panelling with a consequent increase in flame-spread unless some form of fire retardant is employed.

It should be pointed out that while many fire-retardant additives and paints are reasonably effective in reducing flame-spread, the use of some of these retardants increases smoke production. This is an important consideration because requirements concerning smoke production from lining materials have been introduced into the NBC 1970 when such materials are used in high rise buildings, as already mentioned.

Flammability of Conventional Lining Materials

Up to the end of the last decade, flame-spread classifications of materials listed by Underwriters' Laboratories of Canada and Underwriters' Laboratories Incorporated (U.S.A.) were usually limited to the 0 to 75 range. The 75 to 150 range has become of greater interest with the increasing number of restrictions in the NBC. A maximum FSC of 150 for interior linings is also called for in CSA Preliminary Standard Z240.2-1970; "Structural Requirements for Mobile Housing," and the same maximum rating (with a limit of 300 for smoke developed) is specified in recent directives of the Office of the Dominion Fire Commissioner covering movable screens for open-plan office landscaping.

Because, until very recently, the number of E84 ratings in the 75 to 200 range in the relevant literature and UL listings was limited, particularly on Canadian products, it has been the objective of the Division to produce and publish information on conventional lining and coating materials as rapidly as possible.[3,4]

Low Density Fibreboards

Fibreboard ceiling tiles and panelling, whether factory-finished or painted on site, have often been considered almost explosively flammable, because of their involvement in many fatal fires in the past. European research has certainly suggested that painted fibreboard linings contribute to early flashover because of their ready ignitability and their insulating properties.

ASTM E84 tunnel tests on factory-finished Canadian fibreboard ceiling tiles and panelling (7/16 to 5/8 in. in thickness, 15 to 18 lb/cu ft density) have given FSC values of 50 to 100, with samples mounted in the manner recommended in Appendix A.1 of ASTM E84-70. Similar values have been obtained even when a semi-gloss enamel (alkyd-type) is applied over the usual latex factory finish or a conventional latex primer-sealer. The FSC of a factory-finished ceiling tile, even of the perforated acoustical type, may be reduced as much as 50 per cent by application of a modern, UL-listed fire-retardant latex paint of the intumescent type at a coverage of 300 sq ft per gal.

Hardboards

Hardboards (50 to 65 lb/cu ft) are produced from many different cellulosic materials by several different processes in many parts of the world. A substantial tonnage of foreign hardboard is imported into Canada for subsequent finishing or use in furniture manufacture.

The drab hardboards of the immediate post-war years, which were often shipped to specialty finishers and furniture manufacturers for coating, are now being given a great variety of in-plant decorative treatments - printed paper overlays, lithographed woodgrain patterns, and surface textures produced during hot pressing of the wet pulp, followed by appropriate finishing.

With the broad variety of prefinished 3/16- and 1/4-in. hardboards available it is obviously impossible to generalize on the basis of the few tested in the DBR tunnel furnace. Typical 1/4-in. unfinished hardboards have given FSC's of 130 to 150, with 10 to 25 per cent higher values for 3/16-in. board.

Because of competitive pressures from both domestic and imported thin plywoods, most of the decorative hardboards are 3/16-in. thick, although some 1/4-in. types are available. The decorative treatment, whether by means of multicolour lithographing, a hot-pressed printed paper overlay or a polyvinyl-chloride film, usually increases the FSC significantly over that of the raw board, values of 180 to 210 being common for 3/16-in. and 150 to 190 for 1/4-in. boards.

Application of conventional flat or semi-gloss alkyd paints at normal coverages usually increases the FSC of 1/4-in. hardboards by 25 to 50 percent. Little information is available on the effect of latex paints or primers.

Particleboards

Particleboards, like hardboards, are produced in a wide variety of types, densities and thicknesses, from many different raw materials, virgin or by-product, and for distinctly different markets. Boards of homogeneous and graduated construction have been produced for furniture, subflooring, decorative panelling, sheathing and plywood core stock.

Down to about 1/4 in., thickness appears to have less influence on the FSC in a given type of board than density, raw material mix, adhesive content and other process variables. Unfinished boards from several sources tested by DBR have given FSC values of 130 to 275 on 1/2- to 3/4-in. thicknesses, with a variation from 130 to 180 from lot to lot for 1/2-in. board of one type and 220 to 275 for 5/8-in. board of another.

Conventional flat or semi-gloss alkyd paints over a suitable primer (or factory-applied primer or filler coat) usually reduce the FSC slightly (10-20 per cent) but, in the case of one of the more flammable types, the FSC actually increased when a two-coat alkyd paint system was applied.

Plywoods

The fire hazard classifications of the more common structural plywoods have been adequately covered in the literature.

With the increasing use of 4-mm (0.150-in.) prefinished plywoods, both domestic and imported, for residential and mobile housing applications, one of the limitations of the E84 tunnel furnace has become more obvious. Lack of uniformity of contact between the thin plywood and the massive cover of the furnace, indeterminate effects of the exposed joints, and inherent variability in the plywood itself have resulted in poor agreement between runs on supposedly identical panels. This is particularly true in the case of 4- mm lauan ("Philippine mahogany") which is imported in very large quantities for finishing in Canada. Evaluation of such plywoods which have been coated with opaque fire-retardant paints in an attempt to reach an FSC of 150 has proved to be difficult. U.S. experience in the 150 to 200 range confirms the findings of DBR//NRC.

Fire-Retardant Coatings

In the typical UL listings of fire-retardant paints and varnishes for use on interior combustible surfaces, the standard substrates are nominal 1- by 4-in. tongue-and-groove Douglas fir lumber (FSC of 70 to 95), and factory-finished 1/2-in. fibreboard tile (FSC of 50 to 90) over an incombustible base.

Frequently the assumption is made that these listed coatings, applied at the recommended coverages, would reduce the FSC of any material to the 10 to 35 range obtained with fir lumber and fibreboard tile. In general, the final FSC with clear fire-retardant varnishes on reasonably thick (3/16 in. and over) hardboards, particleboards and plywoods is dependent on the initial FSC of the board, with a significant increase in smoke developed in most cases. Even these flame-spread reductions are obtained only with the very heavy coverages (150 to 200 sq f/gal) recommended and hence at sometimes excessive cost for low-priced boards and structures.

The intumescent latex paints now on the market are much superior to those available five or ten years ago. Active fire-retardants in modern paints are less water-soluble than the typical salts, such as monoammonium phosphate, used in the past. This leads to improved washability as well as higher durability under high-humidity conditions.

Foamed Plastic Insulation

In the National Building Code of Canada 1970 it is required that: "Combustible insulation having a flame-spread rating of not more than 75 may be used in assemblies required to be of noncombustible construction provided that such insulation is sandwiched between two layers of noncombustible material without an intervening air space. Where insulation in such noncombustible construction is not installed in this manner, it shall have a flame-spread rating of not more than 25."

With restrictions of this nature and the growing use of foamed plastics in construction, an increase in the number of requests for E84 tests and UL listings is to be expected.

In the U.S.A., a large number of UL listings in the 10 to 85 range of polystyrene foams up to 1 in. and polyurethane foams up to 4 in. in thickness have been published. In Canada, no listings of either type have been issued to date.

The testing of fire-retardant grades of polystyrene foam in the E84 furnace presents certain problems. Very soon after the start of the test the foam melts and collects in small puddles on the floor of the furnace. Depending on the thickness and density of the sample, propagation of fire along the tunnel, with heavy evolution of smoke, occurs after the fire-retardant additive in the foam has been driven off by the burner flames. Obscuration of the windows makes estimation of the flame travel difficult and FSC values above 25 are approximations, at best.

Rigid polyurethane and chemically related foams of both the sprayed-in-place and continuously-produced types are now available in fire-retardant and untreated grades. The former may have FSC values as low as 5 to 30 depending on thickness and composition; the latter may have FSC values of 300 to 500. Both these classes, however, may be rated SE (self-extinguishing) by ASTM D1692-68, "Flammability of Plastic Sheeting and Cellular Plastics" which is a widely-accepted small-scale test for foamed plastics, frequently quoted in research work as well as in specifications.

Evaluation of the real hazard of foams of different FSC's in various fire situations is obviously required.

Smoke

The problems of smoke evolution and its measurement in the E84 test have been almost ignored in the foregoing discussion. The equipment and instrumentation required for smoke measurement have not been standardized by furnace operators. The validity of the method, particularly for high smoke levels, has been questioned both on theoretical and practical grounds, and close agreement between laboratories is not in general to be expected at high "smoke developed."

The development of the new National Bureau of Standards smoke chamber holds some promise of the future availability of smoke ratings independent of flame-spread measurements, and using small samples.

Conclusion

The proliferation of new lining materials and composite structural products, modification of established products which lead to higher flammabilities and greater difficulties in testing, and application of the ASTM E84 test to materials for which it was never intended, have presented tunnel furnace operators with serious problems.

In the case of thin plywoods and other semi-rigid lining materials (self-supporting across the width of the furnace), new methods of mounting may be required to assure both good reproducibility of results and a realistic appraisal of the behaviour of the material in an actual fire. In some cases it may be necessary, in spite of the increased cost and inconvenience, to test such materials as part of a structure or assembly.

The choice of 150 as a maximum FSC for lining materials in many occupancies has led to the use of integral and surface fire-retardant treatments to upgrade many conventional materials. This is often achieved at the expense of higher "smoke developed."

In summary, ASTM E84 has probably not attained its final and immutable form. More research work on methods of mounting, more testing to assure good agreement between laboratories, particularly in the measurement of smoke, and a keener appreciation on the part of regulatory authorities of its limitations may be expected in the future.

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