Evaluation of Exterior Insulation and Finish System Fire Hazard for Commercial Applications

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ABSTRACT: To judge existing fire test methods in use or those planned/proposed for use with exterior insulation and finish system (EIFS) products, a critical commercial/industrial accident scenario has been identified that involves storage adjacent to a building exterior having a 90° corner. The heat flux environment expected in the assumed accident scenario, as determined from the FM Approvals 50-ft. (15.25-m) Corner Test, is not reproduced by existing EIFS test methods, since these mostly involve flames issuing from a window opening. In the current study, the experience gained from testing two EIFS products in the 50-ft. corner has allowed practical procedures for the categorization of EIFS products to be recommended.

KEY WORDS: building facade, EIFS, fire scenario, fire test, heat-flux profile.

INTRODUCTION

EXTERIOR INSULATION AND Finish System (EIFS) products are becoming widely used for the finished outer surface (or facade) of shopping mall stores, hotels, gaming establishments and many other commercial operations. EIFS products begin with a 50–100-mm thickness of expanded polystyrene (EPS) foam insulation (density about 16 kg/m^3) adhered to, or fastened over, gypsum sheathing on the exterior of a building. Covering the EPS in successive thin layers totaling 3 mm in thickness are polymer/cement adhesive, a fiberglass mesh and an outer coating consisting of a weather-resistant polymer/cement/colorant mixture. The resultant product represents a flammability hazard that could lead to extensive

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exterior building damage, as well as interior damage should there be unprotected openings. This hazard was initially recognized by the building code community [1,2] in 1988–1990.

The objective of this research is to determine the suitability of widely accepted fire tests for evaluating the EIFS flammability hazard in important commercial (including hotels) and industrial scenarios. Because of the complexity of the EIFS product (e.g., melting of EPS) and the possibility of the fiberglass mesh/coating delaminating in a fire, small-scale or even intermediate-scale tests will probably not be suitable until there is sufficient experience with a number of different EIFS products.

In this paper, a reasonable accident scenario is discussed first, followed by a review of existing methods to test EIFS materials for this scenario. Experience with use of the FM Approvals 50-ft Corner Test [3] for two EIFS materials is then presented. Practical procedures to categorize EIFS products, based on the experience gained from these full-scale tests, are described in the last section.

THE EIFS ACCIDENT SCENARIO

A reasonable accident scenario for initiation of a building exterior fire begins with outdoor, combustible storage adjacent to an EIFS building facade. Such temporary storage of waste or products close to the building (especially at rear receiving and waste-handling areas) is very common because the building facade has the appearance of solid concrete or stucco, not a foamed plastic surface. Ignition of the temporary combustible storage can lead to extensive property damage, since: (a) upward fire propagation on the EIFS product can be initiated by tall flames from the storage (especially for burning waste or pallets left over from received goods) followed by lateral fire spread, with the consequence that (b) there is extensive damage to the facade, especially for high-rise buildings and/or (c) there is interior damage to the building due to flame penetration through window/vent openings on multiple levels. As is frequently the case, the building may include one or more 90° corners as part of the exterior facade. Then, the preceding accident scenario is even more likely, since the corner provides radiant reinforcement to promote upward fire propagation. Another type of accident scenario can involve flames from a fully involved portion of the building interior breaking out through a window opening to expose the EIFS, but this is more likely for residential occupancies lacking sprinkler protection than for highly protected commercial/industrial buildings.

A test method for EIFS products must reproduce the heat flux environment expected in the preceding accident scenario. The exposure used for several decades to simulate an isolated combustible hazard inside an otherwise noncombustible, unsprinklered occupancy by FM Approvals [3] is a 1.5-m high stack of moisture conditioned wood pallets. Based on previous measurements [4] for burning stacks of pallets of various sizes, the heat release rate of this fire source is about 4 MW. Extensive testing of interior panel materials in a corner adjacent to this fire source over the past thirty years has shown that such an exposure tends to differentiate among good and poorly performing joint systems in metal sandwich and other fire-hardened panels. Joint systems that perform well with this fire source tend to maintain their integrity while poorly performing joint systems allow the core material to be exposed. Since the performance of EIFS products in a fire depends critically on the performance of the thin covering in adhering to the underlying EPS fuel and protecting it from the fire exposure, this same fire source should be a useful prototype for the EIFS accident scenario. Note that storage outside a building may be restricted much less by building regulations than interior storage, leading to the possibility of actual fire sources from adjacent storage being considerably more severe than the 1.5-m high pallet stack. For example, storage consisting of a 1-m square by 1.5-m high stack of glass-fiber-reinforced plastic letter trays, in which mainly the paper contents are consumed, results [4] in a heat release rate of about 8.5 MW, compared to 4 MW for the pallet stack.

HEAT FLUX ENVIRONMENT IN THE EIFS ACCIDENT SCENARIO

The heat flux environment from a burning, 1.5-m high pallet stack adjacent to a 90° wall-corner must be characterized for an exterior surface sufficiently high to eliminate any ceiling effects. To accomplish this, an instrumented 50-ft Corner Test [3] is performed with its standard fire source, the 1.5-m high pallet stack, and an inert wall lining. This lining, which is fiberglass-faced gypsum board with an overall density of 680 kg/m^3, is applied to the full wall height but only out to a distance of 2.44-m from the corner. The ceiling used to brace the wall of the structure is unprotected steel deck, similar to the walls of the facility beyond the inert lining. Figure 1 is a schematic of the instrumented corner test facility and Figure 2 is a photograph of such an instrumented test in progress.

During the inert-wall test, total heat flux to the wall surface and gas temperature 25 mm from the wall surface is measured at seven different elevations above the base of the pallet stack: 0.75, 1.5, 2.25, 3, 4.5, 6 and 7.5 m, versus a total ceiling height of 15 m. Measurements are obtained using Gardon-type heat flux gauges (19- or 25-mm diameter housings) and bare-bead thermocouples (fabricated from 0.81-mm diameter wire) located along

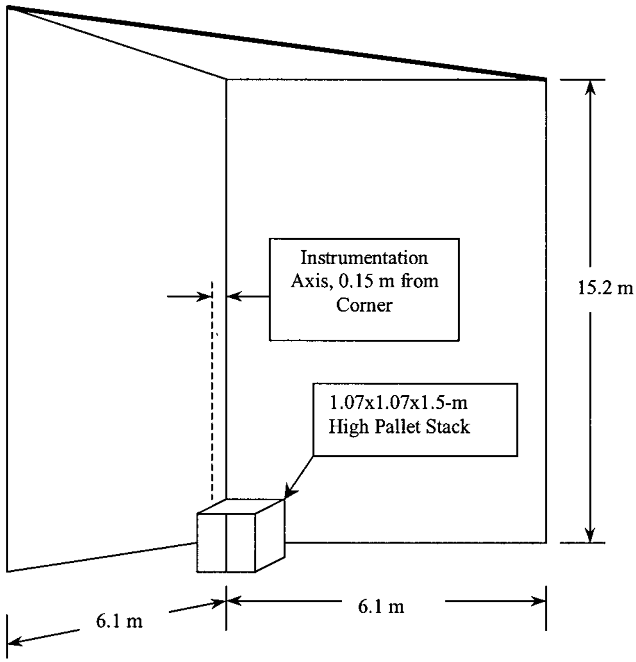

Figure 1. *Schematic of 50-ft Corner Test facility.*

one wall of the facility, 0.15 m from the corner. As shown in Figures 1 and 2, the location of this vertical instrument axis is the midpoint of the 0.305-m space between each wall and the pallet stack. Each heat flux gauge is calibrated before the test and then mounted so that the foil sensor is flush with the surface of the gypsum board. To minimize condensation effects, the gauges are cooled with water maintained at about 50°C.

The 1.5-m high pallet stack fire source for the heat flux characterization is composed of about 340 kg of 1.07 × 1.07 m oak-wood pallets. Ignition of the pallets is by means of two cotton rolls, each of which has absorbed 0.24 L of gasoline. For this test, the pallets are conditioned to a moisture content of 5.6%, which is within the range (5–7%) specified for 50-ft and 25-ft Corner Tests [3].

Profiles of gas temperature and total heat flux to the surface 0.15 m from the corner are shown in Figures 3 and 4, respectively, as a function of time after initiation of the pallet fire and evaluation above the base of the pallets. Each symbol in these profiles represents a 50-s average of data originally recorded every second. At measurement positions not blocked by the pallet stack, temperatures and heat fluxes peak at a test time of about 650 s, just as

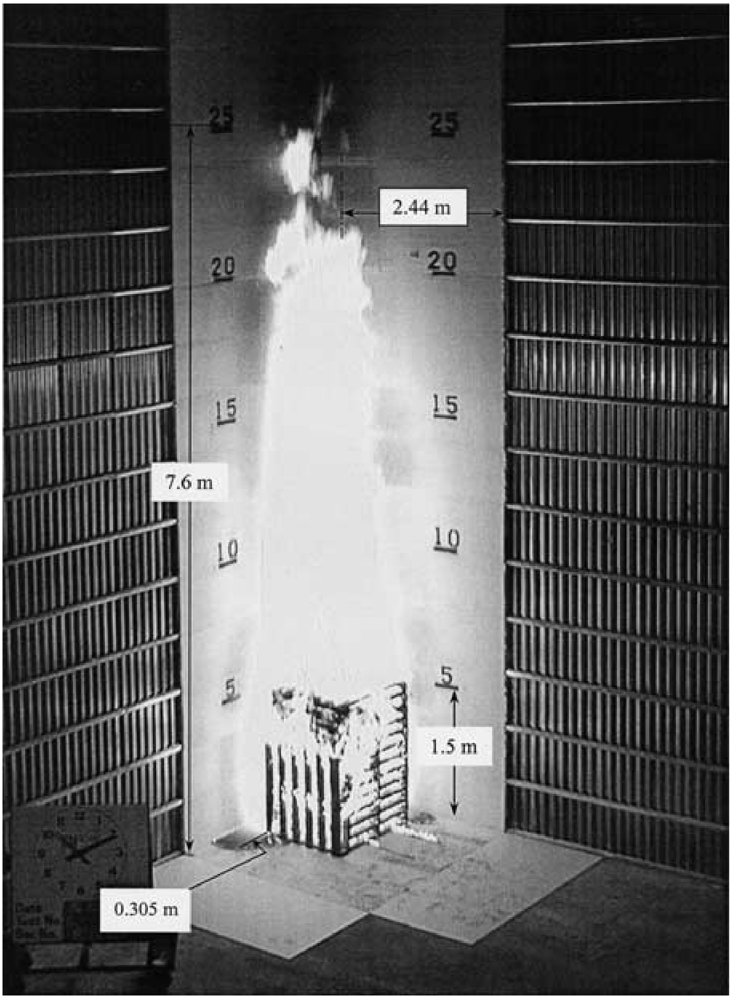

Figure 2. *Photograph of Inert-Wall Test about 650 s after ignition.*

visual flame height peaks at 9 m and the mean flame height (estimated 50% intermittency) reaches the 7.6-m (25-ft) height shown in Figure 2. Behind or near the top of the pallet stack, temperatures and heat fluxes peak much later (775–825 s) because the stack contains an ever-increasing amount of glowing char. Sudden spikes in temperature and heat flux as the pallet stack falls over onto one wall of the corner test facility at about 950 s are not included in the plotted data for the sake of clarity.

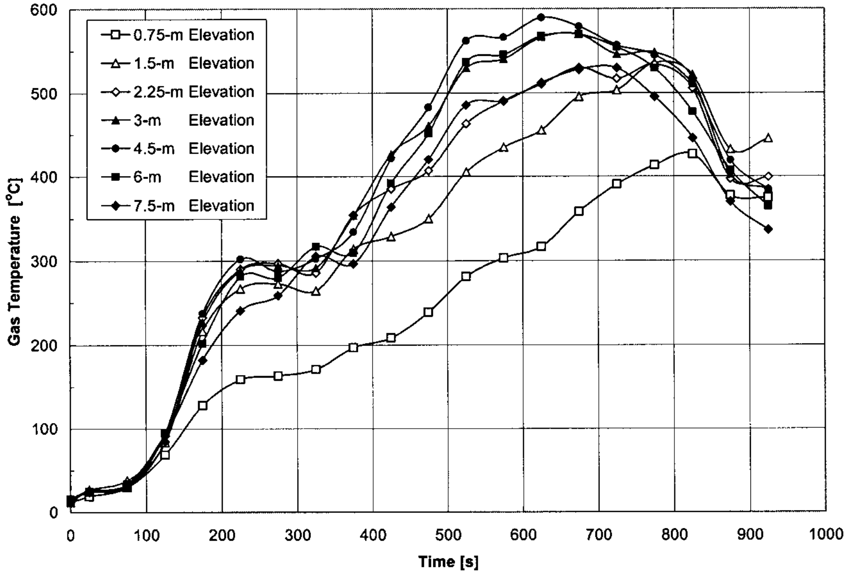

Figure 3. *Gas temperature profiles from thermocouples during 50-ft Corner Test.*

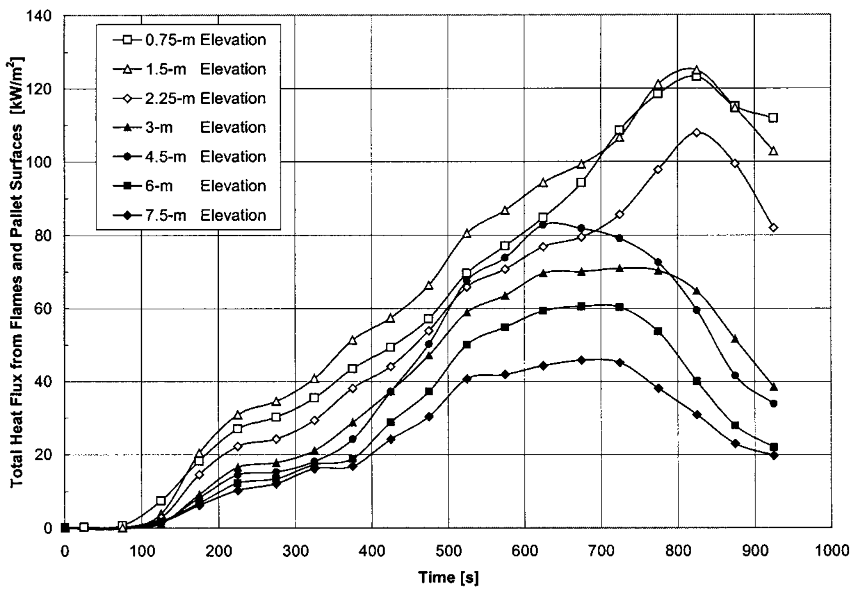

Figure 4. *Profiles of total heat flux to wall surfaces during 50-ft Corner Test.*

A key feature of the heat flux profiles shown in Figure 4 is the 7.5-m height of the wall surface that is exposed to fluxes greater than 40 kW/m^2 for about 4 min. Furthermore, a 4.5-m wall-corner height is exposed to fluxes greater than 70 kW/m^2 for over 3 min. This characteristic of the heat flux profiles, which represents the prototype exposure conditions for the postulated EIFS accident scenario, will be shown to be far more severe than that for test methods utilizing flames ejected from a compartment. The severity of the exposure shown in Figure 4 is produced not just by the 40–70 kW/m^2 heat flux range (similar to the externally applied fluxes in laboratory calorimeters [5]) but by the 4.5–7.5-m length scales associated with these heat fluxes. Such exposure conditions are expected to challenge the thin EIFS covering that protects the potentially hazardous expanded polystyrene insulation.

EVALUATION OF EXISTING TEST METHODS

Since the objective of the current study is to recommend a suitable test method for EIFS products, this section reviews existing standards to determine compatibility with the EIFS accident scenario that now includes the heat flux environment measured during the inert-surfaced corner test.

NRC-Canada Facade Test

The test method developed at the National Research Council of Canada [6], and later standardized as CAN/ULC-S134 [7], is run with a 6.3 m wide × 10.3 m high specimen having a window opening near the base 2.6 m wide and 1.37 m high. Propane fueled burners within the room containing the window can be run [8] at heat release rates from 5.5 up to 10.3 MW, although a 6.5 MW setting is taken to be the standard, since it reproduces results from earlier wood crib fires. Acceptance of a specimen is based on a maximum flame height of 5 m above the window and a maximum heat flux of 35 kW/m^2 at 3.5 m above the window.

Modified ASTM E 108 Test Method

In response to a need expressed by manufacturers and code officials for a large-scale test to evaluate the fire performance of exterior wall systems, a study was conducted in the 1970s at the University of California [9]. This study led to the development of a modified version of the standard ASTM E 108 [10] spread of flame test for roof coverings. The modified E 108 test exposes vertical exterior wall specimens, instead of a sloping roof specimen, to a 1.7-m high flame-sheet from the E 108 line-burner. In addition, the forced air flow from the blower that deflects the flame toward the sloping roof specimen is deleted in the modified test method, leaving just the air flow induced by an exhaust fan above the top of the specimen. The burner heat output in this test is about 380 kW, as in the standard E 108 test, and the specimen dimensions are 1.83 m wide by 3.05 m high, versus standard E 108 specimen dimensions of 1 m by 2.44 m high to 3.97 m high.

UBC 26-9 ISMA (NFPA 285)

The Intermediate-Scale Multi-story Apparatus [11,12] (ISMA) is the most frequently used test method for evaluating EIFS products and is widely referenced for this purpose by building code officials. The ISMA is a two-story, 4.6-m high structure that uses a 4.3-m × 5.5-m high specimen having a window near the base that is 2 m wide × 0.76 m high. There is a total of 4 m of specimen above the window, with a maximum 3.05-m distance above the window allowed for fire propagation. In addition to a maximum allowed fire propagation distance determined visually, there are a number of requirements on maximum temperature measured by embedded thermocouples at various locations to estimate the presence of flames in cavities or in the core material.

The ISMA apparatus contains two burners, one producing a maximum of 900 kW in the room behind the window opening and the second producing a maximum of 400 kW in the window opening itself (cf., the 6.5 MW heat output for CAN/ULC-S134).

ISO/DIS 13785-2 Facade Test

The ISO/DIS 13785-2 large-scale test method for facades is a "draft international standard" that explicitly includes a 1.2-m wide wing wall attached to the 3 m wide × 5.7 m high specimen to form an asymmetrical 90° corner configuration. There is a 4-m specimen height above a window opening that is 2 m wide × 1.2 m high. One edge of the window opening is 50 mm from the wing-wall corner. Heat fluxes due to flames issuing from the burn room behind the window opening are calibrated by gages in a noncombustible surface above the window opening at its center.

BS External Cladding System Test

The British Standard draft test method [13] describes an apparatus that consists of a main wall for specimen mounting that has a 2-m × 2-m opening at it base. In the combustion chamber behind this opening, a wood crib having a peak heat release rate of about 3 MW will produce a required heat flux due to flames from the opening impinging on the test specimen. The dimensions of the main test specimen are a minimum height of 6 m above the opening and a width of 2.6 m. Perpendicular to this main specimen is a wing-wall 250 mm from the side of the opening, having a specimen height equal to that of the main specimen and a width of at least 1.5 m. Thus, material is tested in a corner configuration. Note that flames issuing from the combustion chamber opening may not impinge directly on the corner formed by the nearby wing wall.

Heat Flux Exposure of Test Methods

Profiles of maximum prescribed heat flux in the full-scale test methods discussed in the preceding sections are shown in Figure 5 for all cases where values are available from reports or test specifications [3,9,11,12]. For the modified 50-ft Corner Test, an average heat flux during the 5-min interval from 500 to 800 s is selected, coincident with the nearly steady flux magnitude at elevations above the pallet fire source. The different test methods are compared in Figure 5 by plotting heat flux versus elevation above the top of the fire source, which is the area where performance of the

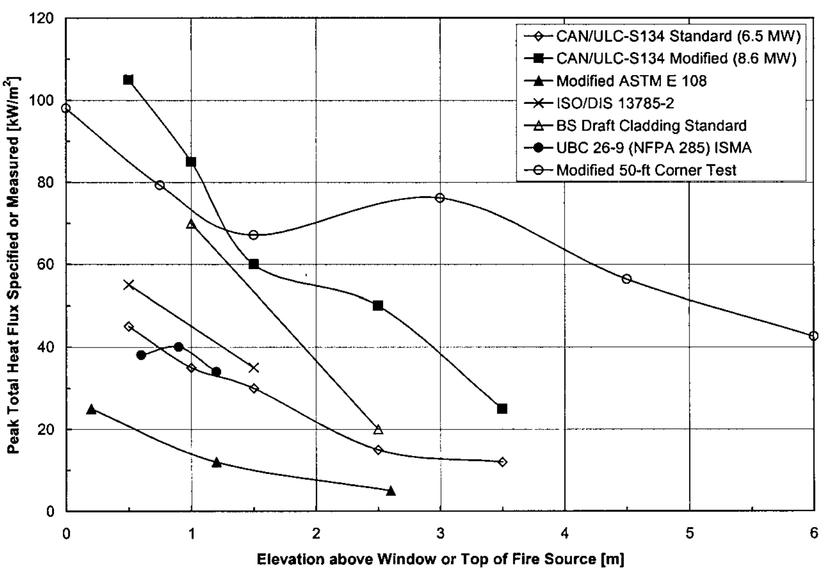

Figure 5. *Comparison of total heat flux profiles for existing facade test methods.*

specimen is judged. The top of the fire source is the top of a window opening or top of the pallet stack (the latter for the modified 50-ft Corner Test, not the base of the pallets as in Figure 4). Figure 5 shows that a heat flux above 40 kW/m^2 at an elevation above the fuel source of 6 m in the 50-ft Corner Test, defining the EIFS accident scenario, is not well-reproduced by any other facade test method. The draft BS test and a modified CAN/ULC-S134 test come closest, while the most widely used test for evaluating EIFS products, the UBC 26-9 ISMA, is a poor match to the EIFS accident scenario flux profile. Note that the peak heat fluxes shown for ISMA are attained only after 25 min of a 30-min test duration. Such a result is not unexpected since most of the test methods use a window fire exposure in which mixing of ambient air tends to cool the flames rapidly with height. On the other hand, the EIFS accident scenario involves flames that can be driven into a corner by the entrained airflow, resulting in reduced mixing and increased radiant heat fluxes.

RECOMMENDED TEST METHOD

As a result of the preceding test method comparison, it is clear that burning storage adjacent to a building could subject a 6-m height of the facade above the storage to hazardous heat flux levels. Hence, it is recommended that the 50-ft Corner Test be used to evaluate and categorize EIFS facades in commercial/industrial applications, where storage adjacent to buildings and facade heights greater than 6 m are common. This test provides the necessary height of specimen material within the exposure fire (7.6 m from floor to mean flame tip) and a sufficient specimen height (about 7.6 m) above the exposure flame to evaluate whether fire propagation has occurred. The large height of material exposed to sufficient heat flux for melting and vaporizing polystyrene is needed to simulate the accident scenario and to ensure that there is sufficient residence time in the gas motion to allow for ignition of these fuel vapors. Ample material height above the exposure fire is also needed to evaluate the upward fire propagation tendency on EIFS materials.

Experience with Recommended Test Method

Exterior Insulation and Finish System products from two separate vendors have been tested in the 50-ft Corner facility. Both of these products are judged to be acceptable according to the requirements of UBC 26-4 (the full-scale prototype [14] for ISMA) and the Modified ASTM E 108 test [9] methods. Note that a thirty-day curing period is provided after installation of the EIFS products on the facility walls before a test is performed, due to the presence of cement in the coating.

In the first test, EIFS Product A is used to cover the entire wall surface of the facility, but not the ceiling, which is unprotected steel decking. Over the top 0.3 m of the wall, a common architectural detail is reproduced, consisting of a step formed from EPS protruding out from the main wall surface by about 75 mm. It is standard practice for the fiberglass mesh/coating on the product to be installed over the upper edge of the EPS at the top of the wall and then down the back of the EPS for a minimum of 50 mm to fully protect the top wall surface. Unfortunately, this "backwrap" process is inadvertently omitted for Product A, with the mesh/coating only covering the front of the EPS up to the ceiling.

There is no upward fire propagation on or within Product A during the main part of the pallet fire exposure, but as the pallet fire decays, about 900 s (15 min) after the start of the test, flames begin to extend above the 9 m elevation in the corner. This apparent flame propagation is likely due to the observed separation of the outer fiberglass mesh covering from the underlying EPS in the corner for a significant fraction of the total wall height. Whether the mesh separation and subsequent flame spread is accelerated by the lack of secure attachment of the mesh covering at the top of the wall is unknown at this time. In any case, flames propagate a few minutes later to the ceiling and the resultant flaming ceiling jet flow (observed visually to extend 1.5 m below the ceiling) rapidly expands laterally, approaching the outer limits of the test structure.

In the second test, EIFS Product B is used to cover the entire wall surface in a manner similar to the first test, except only up to a height of 13.7 m, about 1.5 m from the ceiling. As with the first test, the ceiling is unprotected steel decking. The reason for the limited application height of the product is to avoid the ceiling-jet influence in causing lateral fire-spread, a phenomenon that is not part of the EIFS accident scenario but is observed late in the first test. The architectural detail at the top of the wall is reproduced for the test of Product B and this detail is fully protected by the "backwrap" process of extending the fiberglass mesh over the top and behind the EPS.

During the second test, upward fire propagation is observed between 420 and 480 s (7 and 8 min) after test initiation, even before the peak burning period (see temperature profiles in Figure 3) of the pallet exposure fire. This propagation leads to a rapid increase in involvement of Product B, with flames approaching the limits of the test structure.

It is clear from the visual records that Products A and B perform differently in the test method, with Product B exhibiting a much greater fire propagation hazard. If Product A had been applied to the walls in the same manner as Product B, it is possible that there would have been an even greater difference in performance. In any case, both products are "determined not to propagate flaming on the exterior surface" according to the full-scale UBC 26-4 and Modified ASTM E 108 test methods, but in spite of this, both support flame propagation in the 50-ft Corner Test.

Proposed Protocol for Recommended Test Method

It is proposed that a modified, 50-ft Corner Test would be most suitable to evaluate the performance of EIFS facades in the EIFS accident scenario. The major modification to the existing procedure [3] is the elimination of EIFS product from the ceiling of the facility, since there is no ceiling (roof overhang) effect to be simulated in the EIFS accident scenario. Because of the significant height of the facility required for this test protocol, it is also proposed that the total ceiling height be allowed to vary between a minimum of 13.7 m (45 ft) and a maximum of 15.25 m (50 ft). This will provide some flexibility in siting the test method within a facility.

It is proposed that the fire performance of EIFS products should be categorized based on whether or not there is upward fire propagation in this modified 50-ft Corner Test. A product would be acceptable, for instance, if there were no observable time-average flaming (as measured from video records) above a specified elevation (e.g., 10 m) during the test duration. The latter is governed by the burning time of the pallet fire exposure, which is a maximum of 20 min. Without self-sustained upward propagation, lateral propagation driven by thermal radiation from the large corner fire in the EIFS accident scenario (or by the ceiling-jet flow in the 50-ft Corner Test simulation) would be highly unlikely. Note that installation of extensive temperature and heat flux instrumentation to evaluate EIFS products is not recommended because it is important that the EIFS outer covering not be disturbed or punctured by transducers.

SUMMARY

An EIFS accident scenario has been defined as a prototype for judging existing fire test methods in use or those planned/proposed for use with EIFS products. The evaluation of these existing test methods shows that heat flux profiles characterizing the EIFS accident scenario are not well reproduced by most existing methods. A modified version of CAN/ULC-S134 and a draft BS standard for testing cladding systems are much closer to meeting EIFS accident scenario requirements than the most widely used North American EIFS test method, UBC 26-9 ISMA [11]. Nevertheless, neither the modified CAN/ULC-S134 nor the draft BS standard is acceptable without significant modifications or recalibration to the EIFS scenario. Because of this lack of conformity with the EIFS accident scenario from currently used/proposed test methods, a modified version of the FM Approvals 50-ft Corner Test is recommended. This test method has been used in trial testing of two EIFS products, which shows that the following procedures should be effective for EIFS evaluation:

1. Apply EIFS product only to each wall over a floor to ceiling height of 13.7–15.25 m and a width of 6.1 m in a facility similar to that used in the 50-ft Corner Test.
2. Ensure that EIFS assembly is installed so as to depict actual end-use conditions (e.g., ‘‘backwrap’’ of fiberglass mesh and protective coating, per the manufacturer’s requirements).
3. Initiate the fire exposure for a specified test duration not exceeding 20 min, allowing observation of upward flame propagation on the EIFS product.
4. Accept the fire performance of the EIFS product based on the observation of time-average flaming above a specified elevation.

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