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Glazing in Fire-Resistant Wall Assemblies

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Abstract

Increase in the use of glazing in buildings combined with building code requirements for fire-resistant wall assemblies has led to the development and full-scale testing of a system of fire-resistant glazing protected by automatic sprinklers. The test results and the system requirements, benefits and limitations are described.

Introduction

A new approach to the design and construction of fire-resistant glazed wall assemblies incorporates an active fire protection measure. Although still at the development stage, it promises to provide designers with greater flexibility in meeting the intent of code requirements.

Fire Protection Principles

Strategies for fire protection are generally based on the application of a single principle or a combination of two: passive techniques such as compartmentation and active techniques such as use of sprinklers. Compartmentation, a long-established passive fire protection principle recognized in building codes, is intended to limit fire spread by means of physical barriers. To be effective the barriers must be complete and substantial. For this reason assemblies incorporating glazing, other than minor quantities of wired glass, are seldom used in the walls of fire compartments.

The other well-established principle of controlling fire spread uses active fire protection systems, typically automatic sprinkler systems. To be effective they must be engineered to meet the hazard and have an adequate and reliable water supply.

Code Requirements

Fire protection engineers recognize the need for regulations to limit fire spread within structures and from one structure to another. Building codes often specify fire compartmentation by means of fire-rated walls and floors. Compliance with these requirements is, however, sometimes achieved at the expense of the functional or environmental qualities of a building. For example, the area of glazing permitted in an exterior wall may be severely restricted if that wall is located close to another building or a property line. Yet if the wall were to be constructed without glazing it would limit the potential use of the floor space located along that side of the structure.

Similarly, a building design may specify, for security, aesthetic or functional reasons, visual openness between compartments, which are required by the applicable code to be separated by fire-rated construction. Such conditions often occur in a building containing an atrium. The problem is how to provide as much glazing as possible in these walls without reducing the level of fire protection.

Exterior Glazing

The quest for fire-rated construction incorporating glazed areas greater than those permitted in building codes for wired glass was a major consideration in 1969 at the proposed First National Bank building in Chicago, Illinois.[1, 2] The applicable building code required that the outside of the building be protected against fire in an adjacent building, but the architect preferred not to use wired glass in this wall.

Proposal

It was suggested that tempered glass protected by a water spray would provide resistance to thermal shock and prevent the passage of radiant and convective heat from a fire in the adjacent building.

Tests

A deluge type system (i.e., all sprinklers operating at the same time), was tested at Underwriters' Laboratories Inc.[3] The sprinklers were installed on the outside face of the building, as were the heat detectors that activated them. A wetting agent was added to the water supply.

Results

It was demonstrated that the glazing could withstand a 45-min fire exposure if protected by a specially designed window sprinkler system.

Interior Glazing

In 1984 a major addition was planned for the Hospital for Sick Children in Toronto, Ontario. It was intended that the existing structure would be connected to the addition by means of an atrium, with patients' rooms overlooking the landscaped interior space. As the National Building Code of Canada[4] prohibits the use of atriums in health care occupancies, the patients' rooms were required to be separated from the atrium by 2-h fire-rated walls.

Proposal

Drawing on the Code equivalency provisions, it was proposed that the patients' rooms be separated from the atrium by a tempered glass assembly protected by a window sprinkler system. Full-scale fire tests were undertaken to demonstrate the equivalence.

As the proposed system did not utilize the deluge technique, the information developed for the First National Bank tests was not entirely applicable. Instead, a special closed-head sprinkler was developed to provide an effective water spray pattern to cover the glazing. The fire exposure was to be on the same side of the glazing as the sprinkler. The assembly was therefore exposed to a fire on the room side, represented by the standard time-temperature curve.[5]

Tests

Window assemblies. Three types of window assembly were tested at the National Research Council of Canada's National Fire Laboratory:[6]

Series 1 - wired and tempered single glazing installed in hollow steel frames;

Series 2 - double-glazed assemblies (tempered and ordinary glass) installed in hollow aluminum frames;

Series 3 - tempered single glazing installed in a hollow aluminum frame.

Sprinkler installation. Sprinklers were located on the vertical centreline at the top of the glass and the deflector was positioned to ensure uniform water coverage (Figure 1). Water flows to the sprinkler are noted in Table 1.

Procedure. The test procedure essentially followed the specifications in CAN4-S10l-M82, "Standard methods of fire endurance tests of building construction and materials."[5] The air pressure inside the burn room was positive for all tests. The sprinkler was permitted to fuse normally and the water flow rate was adjusted if dry spots formed on the fire-exposed face of the glass.

Following fire exposure and water shutdown in one test (test 3.1), the unexposed face of the assembly was subjected to a non-standard hose-stream test to determine whether the glazing could withstand the impact of a hose stream even after 2-h of fire exposure.

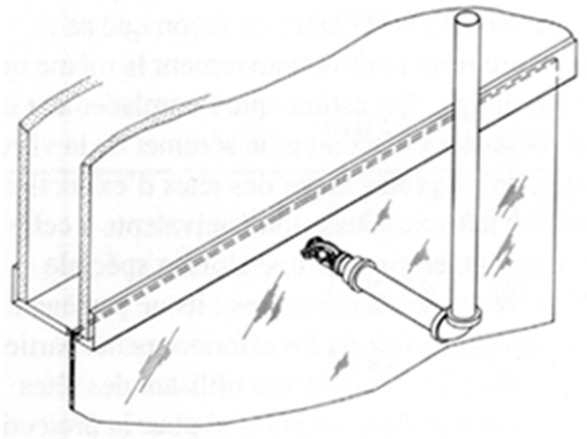

Figure 1 Sprinkler located at top of glazing

Results

Damage to assembly. The tempered glass remained intact for the duration of all tests in which sprinklers were located inside the burn room. The Series 2 tests of double glazing were terminated, as shown in Table 1, to reduce fire damage to the roof assembly; the tempered glass on the fire-exposed side did not break. The outer pane (plain glass) cracked early (after 10- 15 min), but remained in place for the duration of the tests. The assembly subjected to the hose stream test successfully withstood that additional test criterion. Where wired glass was used (Series 1), the glazing cracked prior to sprinkler activation and there was extensive cracking during the tests, although no noticeable openings appeared in the glass.

Sprinkler performance. Sprinkler activation times are shown in Table 1. In general, the quick-response sprinklers reacted two to three times faster than standard sprinklers. water flow data are also shown in Table 1. In general, varying the water flow rates tended to affect the centre of the glazing more than the edges and frames. water flow rates of 100 to 115 L/min prevented dry spots from forming. As the glass widths varied, the per metre flow rates also varied from 70 to 90 L/min/m.

Table I. Summary of Test Data

Test No.	Glass type[1]	Dimensions (mm)	Sprinkler activation time (s)	Water flow (L/min)	Water flow per m width (L/min/m)	Duration (min)
1-1	W	1105x1516	11[2]	60-100	54-90	100

1-2	W	1105x1516	34[2]	80-120	72-109	120
1-3	T	1105x1516	16[2]	80-110	72-100	140
1-4	T	1105x1516	63	100	90	120
1-5	T	1105x1516	59	100	90	120
1-6	T	1105x1516	-	-	-	6.5[3]
1-7	T	1105x1516	-	-	-	5.0[3]
1-8[4]	W	1105x1516	315	50-90	45-80	120
2-1	T/P	1492x2073	18	100-110	67-74	93
2-2	T/P	1492x2073	21	110	74	45
3-1	T	1680x2590	34	100-115	60-68	120

Notes:

1 W - wired, T - tempered, P - plain

2 Early sprinkler response due to excessively high initial temperatures

3 Glass breakage time in tests without sprinklers

4 Sprinkler on side not exposed to fire

Summary

1. Glazed assemblies protected by sprinklers, as described in this Digest, will withstand a fire exposure equivalent to that provided by the standard exposure; at least 2 h for single-glazed assemblies and at least 90 min for double-glazed assemblies.
2. When sprinklers are installed on the fire-exposed side, both quick-response and standard sprinklers respond in sufficient time to prevent tempered glass from breaking. An exploratory test of sprinklers installed on the unexposed face (Test 1-8) did not show whether even quick-response sprinklers can react quickly enough to prevent tempered glass from breaking.
3. Minimum sprinkler waterflow rates to prevent dry spots on the glass appear to be 70 to 90 L/min/m width, but lower flow rates may provide sufficient protection. window height may play a role in minimum flow rates.
4. Tempered-glass assemblies with areas greater than five times and dimensions greater than 1.8 times those specified for wired glass in the National Building Code of Canada are able to withstand the standard fire exposure for at least 2 h if sprinklers are located on the fire-exposed side.
5. Radiated heat flux levels on the unexposed side are reduced by more than 90% by the window sprinkler systems used in these tests.

Limitations of the Technique

Designers and fire protection engineers using the active fire protection system described should exercise caution. Each detail is important.

Sprinkler Design and Location

Many water spray tests were conducted in an effort to determine the best sprinkler to use, its location, and the orientation with respect to the glass. It is clear that the spray pattern must cover the upper corners and centre of the glass and frame. Any slight deviation from the orientation or location of the sprinkler as tested could result in dry spots on the glass. For this reason ceiling-mounted sprinklers may not give the required uniform coverage and could lead to premature failure.

As uniform distribution of water is essential, pane sizes larger than those tested or of different geometry may present a problem. Long vertical glazing may also be difficult to protect since the water evaporates as it runs down the glass and glass temperatures in the lower portion may become excessive.

Frame and Glass Sizes

In determining glass pane and frame sizes, allowance must be made for expansion of the glass on heating.

Water Supply

The water supply is critical. As the assembly may be a substitute for passive fire separation, the design should be of the same reliability as that expected from a rated fire separation. To achieve this, window sprinklers may need to be fed from a separate riser or through a separately valved connection from a sprinkler system in an adjacent area. Electrical supervision of valves would definitely improve the reliability of the technique.

Response Time

Quick application of water to the glass is essential. The location and response time of the sprinkler must be such that activation occurs before the glazing reaches a critical temperature level. Should sprinkler activation be delayed long enough to allow the temperature of tempered glass to rise to approximately 250°C, glass failure could occur. For this reason the sprinkler must be located so that its temperature will always be approximately the same as that of the glazing. A sprinkler located adjacent to and at the top of the glazing is considered to provide optimum protection.

Other Limitations

Glazed assemblies protected by sprinklers do not provide protection equivalent to that of a firewall or a special wall separating hazardous areas: they do not provide protection against explosion or partial collapse. Systems using ceiling sprinklers to protect glazing have demonstrated[7] weaknesses in response to rapid temperature rise; but one with the sprinkler located near the glass should lessen that problem.

Conclusion

Combined passive and active fire protection can increase the functional and aesthetic qualities of enclosed spaces. As with all fire protection measures, care must be exercised in the design, installation, and maintenance of the active fire protection system described in this paper to ensure its reliability during the life of the building.

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