Performance of Curtain Wall with Sheet Metal Backpans

ABSTRACT

The control of fire spread in a high rise building depends on a number of active and passive measures. Fire spread control at the perimeter slab edge involves an interaction of wall, floor and connecting fire stop materials. Glass and metal curtain walls, the most common cladding for high rise buildings, have evolved differently in different countries and present varying conditions at the slab edge. Canadian designed curtain walls, due to their incorporation of pressure moderating technology to address water penetration, typically are constructed with a sheet metal backpan at the slab edge. The backpan forms the air barrier and vapour barrier of the system. By its position it also forms an integral part of the slab edge firestopping system. In this paper an experimental test programme exploring the behaviour of curtain walls incorporating sheet metal backpans under fire test is described. Critical performance parameters related to the integrity of the slab edge fire control are identified and general design guidelines are provided.

INTRODUCTION

Glass and metal curtain wall systems used on high rise buildings are typically suspended from the slab edge resulting in a perimeter void between the back of the wall and the slab edge. The National Building Code of Canada (NBCC), along with the model U. S. building codes, requires the perimeter void to be sealed to prevent the passage of flames, smoke and toxic gases in the event of a fire. This seal is to be accomplished with materials that provide the same fire rating as the floor assembly without regard to the rating of the exterior wall. Curtain walls are typically not fire rated assemblies. It is difficult to imagine a non-rated wall assembly holding traditional mineral wool fire stop in place for the 1 or 2 hours required by the floor rating. This however is precisely the expectation inherent in most current wall construction.

In addition to potential perimeter firestop integrity issues, it has long been known that fire/smoke can spread from floor to floor within the wall itself or by reaching through broken glass and travelling up the exterior of the building. Basic fire tests in accordance with ASTM E119 assume that fire only exposes the underside of the slab, the perimeter joint and the upper interior portion of the curtain wall below the slab to fire. As illustrated in Figure 1, flames passing through broken windows will impact the exterior face of the curtain wall. Recognizing this

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behaviour ASTM is developing a draft Standard Test Method for Determining the Fire Endurance of Perimeter Fire Barrier Systems Using the Intermediate Scale, Multi-Storey Test Apparatus was developed. This test assists in clarifying the performance of perimeter fire protection system in multi-storey curtain wall installations.

Figure 1 – Paths for fire passage floor to floor

Partly to respond to competing claims that Canadian designed curtain wall with sheet metal backpans would not meet mandated firestop provisions and partly in the interest of product development, a specific curtain wall was tested in accordance with ASTM draft standard. In this paper the test procedures and testing of the fire endurance of slab edge firestopping are described for a curtain wall incorporating a sheet metal backpan. Conclusions drawn from the testing are presented.
TESTING PROGRAMME

Test Setup

The test assembly mandated by ASTM draft standard consists of a two storey curtain wall mock-up cladding two concrete test rooms as illustrated in Figure 2. Propane burners mounted in two locations create fire conditions in the lower room. The burners operate to standard ASTM E119 time-temperature test conditions. Surface temperatures are measured on the unexposed surfaces of the assembly and limits on temperature rise are incorporated in the test criteria. The measurement of temperatures addresses the issue of combustible material adjacent the wall being ignited by heat transmission. The passage of heat, flame or hot gas must not be sufficient to ignite cotton waste on the unexposed side. The integrity of the firestop material itself is also tested by cycling the material from its maximum to minimum width to simulate building movements over time.

The curtain wall assembly used in the test programme consisted of an aluminum framed panelized system incorporating double glazed insulating glass units in the vision area and single glazed spandrel glass backed by insulation and a metal backpan in the spandrel area. Each curtain wall frame measured approximately 1500mm wide by one storey in height. The frames were attached to the slab.
edges with 14.5mm thick aluminum anchor angles fixed to the slab via a steel embed and to the frame via a 12.5mm diameter steel bolt.

Each curtain wall frame interlocked at the vertical edges via split mullions and at the horizontal edges via nested rail halves forming a stack or expansion joint. The lower edge of the nested rails that formed the sill was positioned approximately 510mm above the floor surface. The spandrel area was approximately 1232mm high. The interlock of the split mullion halves was designed to provide a snap together positive engagement. The nesting halve of the stack joint rail included interior and exterior gaskets to effectively seal the interior space. The assembly details at the intersection of mullions and stack joint rail provided a nominal sealed closure to the ends of the mullion tubes at each floor level. The tubular intermediate rail at the head of the vision lite was composed of two mechanically interlocked halves. Minimum frame wall thickness was 2.5mm; minimum frame width was 65mm and minimum frame depth was 100mm.

The insulating glass units consisted of two 6mm thick heat strengthened lites sandwiching a standard aluminum tube spacer. The unit measured approximately 2200 high by 1500mm wide. The unit was retained by a standard pressure plate complete with 6mm diameter steel pressure plate screws on the horizontals and structural silicone glazing on the verticals. No glass is installed in the first floor as dictated by the draft standard.

The spandrel lite consisted of a 6mm thick clear heat strengthened lite. The spandrel unit was approximately 1232mm high by 1500mm wide. The lite was backed by an externally vented air space and then the spandrel backpan assembly.

Figure 3 shows the arrangement of the spandrel backpan assembly in the initial test programme. The backpan itself consisted of a 22gauge galvanized steel sheet installed in line with the interior surface of the curtain wall framing and fixed to the frame sidewalls with steel screws. The perimeter was sealed with silicone sealant. A 75mm thickness of semi-rigid mineral fibre insulation was adhered to the backpan with latex adhesive and held with steel insulation retainer straps.
The opening between the backpan and the slab edge was packed with 100mm thick mineral wool firestopping material achieving a minimum compression of 33%. The insulation was topped with a 3mm thickness of spray applied smoke seal.

Test Results

Testing of the above described mock-up was conducted in accordance with the protocol outlined in ASTM draft standard. The initial testing indicated that the spandrel backpan stayed intact and in position at the level of the slab edge. However once the aluminum framing in the vision area was consumed the stiffness of the backpan/insulation alone at the lower edge of the backpan was not sufficient to prevent buckling of the pan and breach of the floor slab seal. Flame passed between the backpan and the firestop. The insulation in the backpan at the level of the slab edge also slumped away from the backpan.

Recognizing the need for increased stiffness at the slab edge an 18 Ga. formed galvanized steel stiffener was installed. The hat shaped stiffener was 100mm wide and 75mm deep with 25mm flanges. The stiffener was attached to the backpan at the flanges by #10 steel sheet metal screws. The stiffener was positioned at the level of the slab such that the screws holding the upper flange to the backpan were 56mm above the slab. Three channel shaped patch fittings were attached to the stiffener to act as further retention of the insulation. The stiffener arrangement is illustrated in Figure 4.
A repeat of the fire test resulted in no breach of the firestop. Based on the test programme the wall/joint assembly was designated an F rating (time assembly resists penetration of fire) of 2 hours and a T rating (time that maximum temperature on non-exposed side of assembly remains below 181 deg. C) of 45 minutes.

DISCUSSION

The testing programme demonstrated that for a particular design and configuration of curtain wall with specific modifications to the spandrel backpan assembly, adequate firestopping performance at the slab edge could be achieved. The testing served to identify a number of parameters that impact the fire performance at the slab edge. The primary parameters appear to be the overall wall configuration, the spandrel assembly and the glass type. The secondary parameters include the details of the wall system design. The actual perimeter firestopping materials are common to current construction and are therefore not a unique parameter.

Overall Wall Configuration

The most significant aspect of the overall wall configuration is the extension of the spandrel assembly above and below the floor slab. The extension of the spandrel below the slab edge forces any flames at the wall plane to project outward at a lower level providing some protection to the glass above. The extension of the spandrel above the slab edge further protects the more vulnerable glass from flame impingement. Only one spandrel configuration was tested however based on the observations made during the testing it is likely that any
significant variation in overall spandrel height or configuration would markedly alter the fire endurance of the assembly.

Spandrel Assembly

The need to add additional stiffening at the slab edge to reduce overall buckling of the pan was not originally envisioned but relatively easily addressed. The stiffening requirements are significant in that most current architectural specifications include little or no mention of spandrel stiffness requirements. Prior to the testing programme the author routinely enforced a maximum deflection requirement of 6mm at the slab edge under the design wind load. This requirement was in part to ensure adequate stiffness to retain firestop insulation, to provide a relatively stiff surface to adhere smoke sealants and to provide a relatively stiff chamber to assist in pressure moderation within the spandrel outer cavity for rain penetration control. The testing suggests a more defined stiffness of additional members for retaining firestop materials.

In addition to the slab edge stiffener, the insulation retention straps and the channel insulation retainers added to the stiffener, play a role in preventing slumping or dislodging of the spandrel insulation in the fire event.

Glass Type

During the test flames projected out of the opening and at times contacted the vision glass of the upper floor. Heat treated glass has considerably greater resistance to thermal shock than annealed glass. While heat strengthened glass is not sufficient to prevent breakage at the site of the fire event, it provides increased resistance to flame or smoke transfer to the floor above.

Wall System Design

The impact of the wall design details was not explicitly tested in the experimental programme however certain aspects of the design would appear to have a secondary influence on fire performance. Panelized curtain wall systems commonly utilize split Mullions and the degree of interlock varies with different suppliers. The system tested utilizes a positive mechanical interlock which would enhance the integrity of the frame to frame connection.

At the sill level expansion joint many contemporary curtain wall systems are assembled resulting in a continuous Mullion with no closure or break to the Mullion cavity floor to floor. This presents an ideal open channel for the passage of flame and more importantly smoke from floor to floor. The system tested incorporated a metal barrier at each floor level and nominal sealing of part of the Mullion junction.
CONCLUSIONS

The most obvious conclusion that can be drawn is that the integrity of slab edge firestopping and smoke sealing is dependant on the integrity of the curtain wall and that most contemporary Canadian (backpan) curtain walls do not provide adequate integrity. However, with a few specific design changes, adequate integrity can be provided. These changes do not provide a fire rating to the wall as conventionally defined, but retard the spread of fire and smoke vertically consistent with the intent of the firestop design. Like many aspects of fire protection testing, design changes are specific to particular walls, however general design guidelines include:

The overall configuration of the wall is critical. Testing has demonstrated adequate performance can be achieved when a minimum spandrel height of 1232mm with a minimum of 510mm of the spandrel extending above the floor slab is provided.

Spandrels incorporating sheet metal backpans require the backpans be specifically stiffened at the level of the slab edge, insulation retention clips and the use of insulation retention straps to maintain the integrity of the backpan.

Heat strengthened glass is required to increase resistance to thermal shock in the vision area.

The results of the testing also indicate that a positive mullion interlock and closures to the mullion tube sections assist in maintaining the wall integrity and blocking smoke passage.

In order to obtain the quoted performance of firestopping, the curtain wall must contain the specific elements outlined above. These elements impose architectural design constraints particularly with respect to the height of the spandrel area. They also raise issues with other wall types such as floor to ceiling window wall in non-sprinklered high-rise residential buildings. In these assemblies the slab edge forms the firestop but the minimum spandrel heights provide no sheltering projection to the wall above.

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