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PERFORMANCE OF MASONRY IN HIGH HUMIDITY ENVIRONMENTS

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ABSTRACT

Case studies are presented to establish why some conventional masonry wall systems fail when exposed to high humidity environments in cold climates. The condition of masonry, air/vapour barriers and thermal insulation after extended exposure is discussed followed by a brief analysis of the failures. Changes to design, construction and operation are offered.

INTRODUCTION

Canadian designers have significant experience producing durable masonry buildings in moderate service environments. We are learning however, that masonry wall systems can easily be overstressed by exposure to high humidity interior environments and low external temperatures. The durability of masonry systems in these environments depends on material selection and detailed system design that reflects an understanding of the interaction of the structure, mechanical system and building envelope.

The following case studies are drawn from a series of swimming pools constructed in a Northern Canadian climate. The example structures were designed and constructed in the 1970's.

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FIRST CASE STUDY

Exterior Wall Construction

Constructed in 1974, the first swimming pool had exterior walls composed of concrete face brick, an air space, 50mm (2 inch) semi-rigid glass fibre insulation, trowel applied vapour barrier and 200mm (8 inch) concrete block back up. The concrete block is glazed for the lower portion of the pool wall with acoustic block above.

Operating Conditions

The pool and associated whirlpool space operate between 27 and 29°C (80-84°F) and between 60 and 65 percent relative humidity. The building generally operates under a positive pressure of 5 Pa with respect to outdoors.

Performance Problems

Masonry damage is evident around the perimeter of the pool and administration building. Both brick and mortar systems are extremely wet over large areas during periods of cold weather. Photo's 1 and 2 show typical patterns of deterioration including loss of mortar brick spalling and brick displacement.

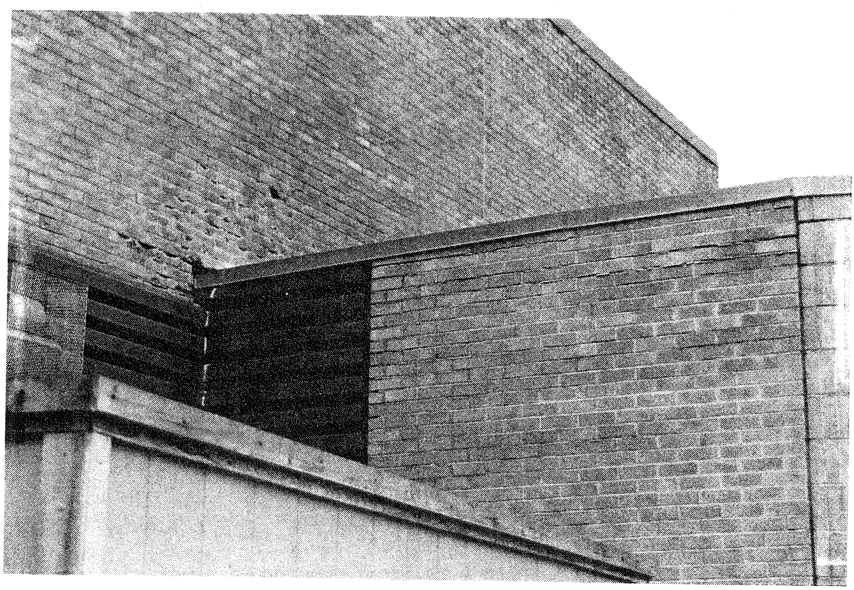

Photo 1 - Brick Spalling Junction of Whirlpool with Main Roof

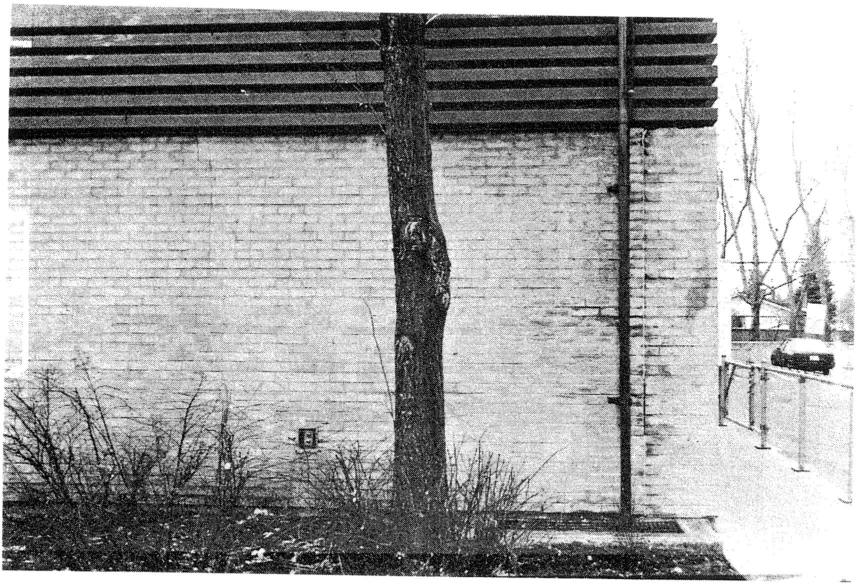

Photo 2 - Saturated Brick on Administration Wing

Site Observations

Our site investigation included a thermographic scan and test openings to establish the condition of the masonry. The thermographic scan showed patterns indicative of air leakage and warm air entrapment at junctions. These patterns, most intense on the south elevation, corresponded with locations on the exterior where brick spalling and moisture staining was most evident. Photo 3 shows the air leakage at the roof/wall junction and Photo 4 shows air leakage at the junction of the whirlpool and main pool. This location corresponds with the damage shown in Photo 1.

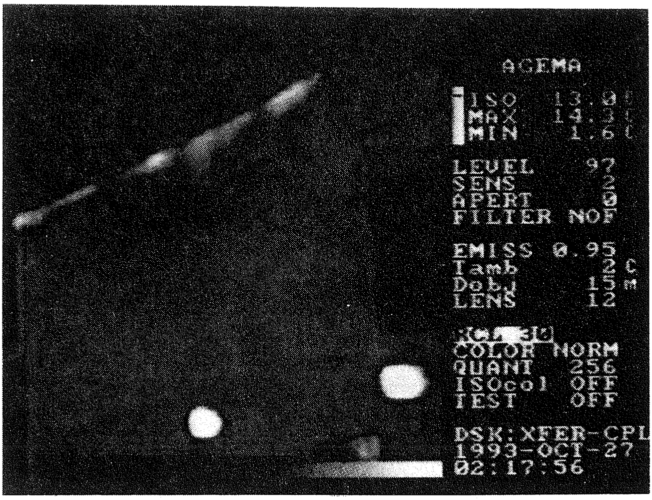

Photo 3 - Air Leakage at Roof/Wall Junction

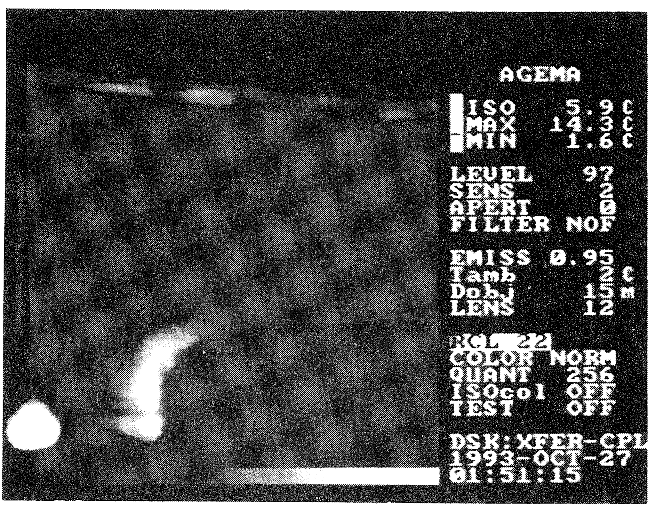

Photo 4 - Air Leakage at Junction of Whirlpool and Main Pool

A test opening was conducted from the exterior at the roof/wall junction to establish the current condition of wall components. The concrete face brick at this location was displaced near the parapet with little bond left at mortar joints.

The wood blocking at the parapet was saturated and masonry anchors for the blocking were showing significant corrosion. The glass fibre insulation was streaked with dust indicating substantial air movement. (Photo 5)

Photo 5 - Saturated Materials, Corroded Anchorage and Dust Streaked Insulation at Parapet.

Brick removal revealed the trowel on asphalt mastic vapour barrier on the exterior of the block infill. At steel structural columns, spandrel beams and open web steel joist bearing points polyethylene had been used to bridge across from block infill to adjacent block. (Photo 6)

Photo 6 - Polyethylene Boots over Structural Steel/Block Interfaces

Analysis of Observations

The brick wetness and deterioration on this building are consistent with continuous air leakage over a long period of time. The air leakage has resulted from a positive pressure difference across the building envelope generated by wind, mechanical systems and stack effect combined with building envelope design details that are prone to air leakage. Air leakage paths from interior to exterior include:

- The junction of blockwork and steel spandrel beams at the perimeter of the pool building. (Figure 1)
- The connection of the whirlpool and main pool building.
- The porous acoustic block on the upper portion of the main pool wall.

The amount of water entering the exterior wall cavities via air leakage is much greater than can dissipate to the exterior before material damage occurs.

The architectural details and site investigations reveal an asphaltic vapour barrier has been applied to the exterior of the block walls. At penetrations for structure and services the continuity of this vapour barrier is maintained with polyethylene sheets. These two materials in combination are not however capable of withstanding the pressure difference necessary to act as an air barrier. Re-detailing is necessary to reinstate the air barrier within the wall assembly.

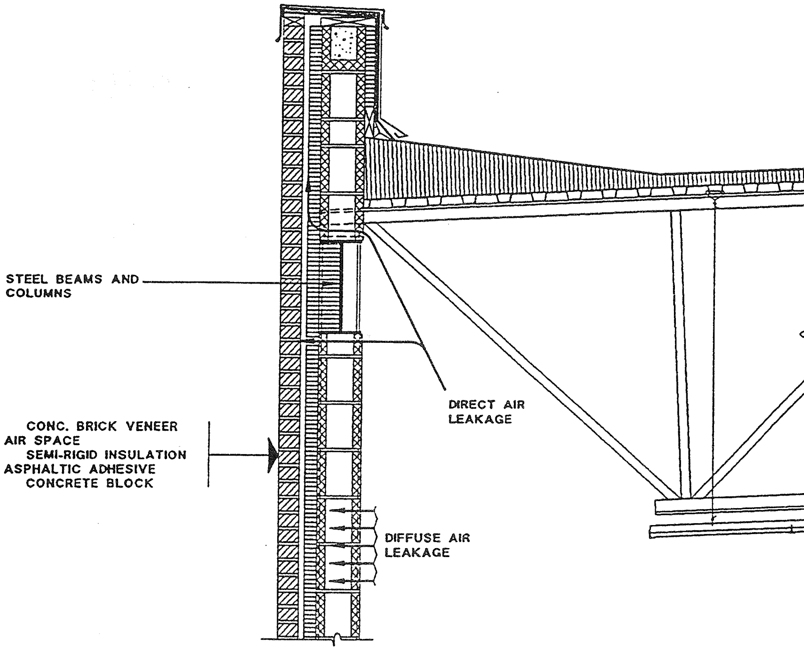

Figure 1 - Locations of Air Leakage

SECOND CASE STUDY

Exterior Wall Construction

Our second building was constructed in 1972 with an addition in 1978. The exterior walls are 200-250 mm (8-10 inch) concrete block, a 90mm (3.5 inch) cavity with semi-rigid glass fibre adhered to the exterior of the structural block with an asphalt vapour barrier/adhesive. The exterior is 100 mm (4 inch) fluted concrete block. Material in the later addition varied slightly, but the design concept was carried through.

Operating Conditions

The pool is operated at 24°C (75°F) and 67 percent relative humidity. At the time of our review, the indoor pressure was measured at 4 Pascals below exterior.

Performance Problems

The exterior concrete block cladding on this structure is experiencing significant displacement near corners and parapets where mortar is in very poor condition. (Photo 7)

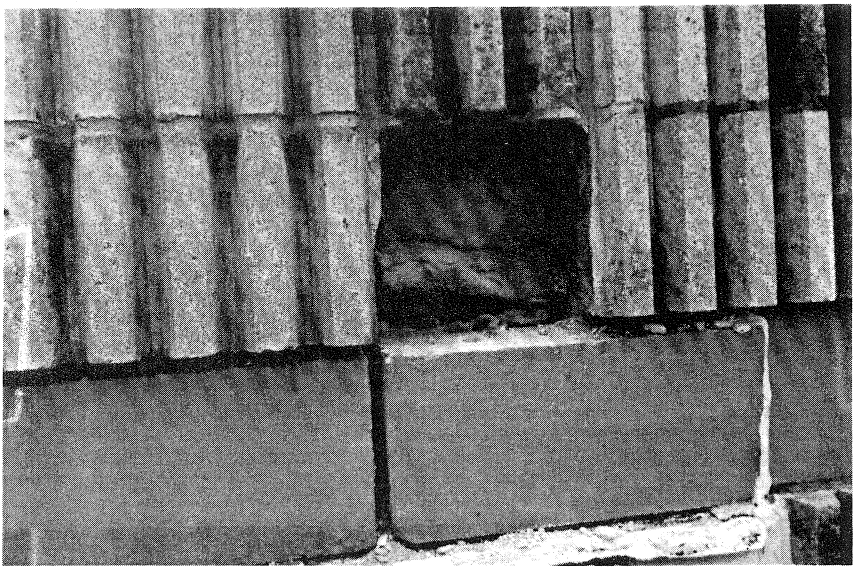

Photo 7 - Mortar Missing, Concrete Block Displaced near Parapet

The block is visibly wet, fractured and approaching an unstable condition in some areas. (Photo 8)

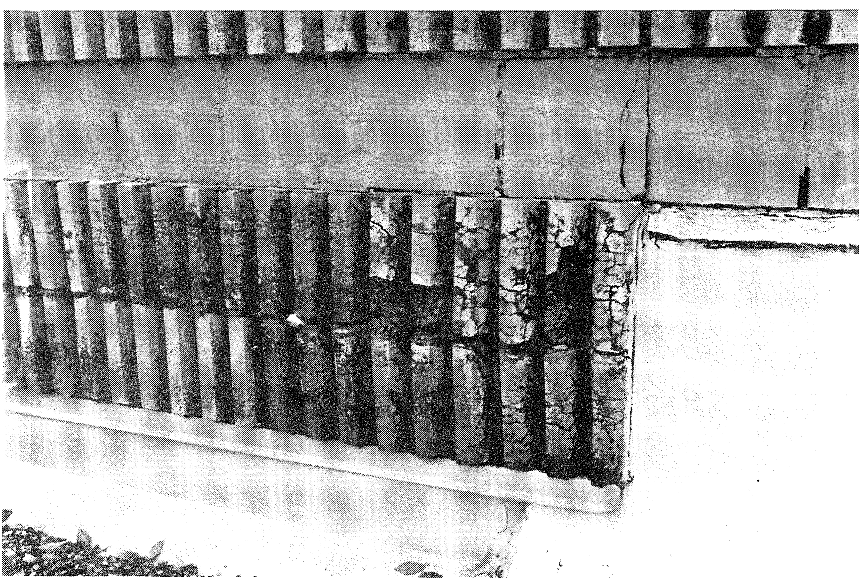

Photo 8 - Badly Fractured Concrete Block Cladding

Site Observations
Once again we conducted both a thermographic scan and test openings to establish the existing conditions.

Our thermographic survey provided characteristic signatures of air leakage at the roof to wall junction of the main pool building and at connections between the pool and administration area below. Smoke pencil testing confirmed these leakage sites. Observations from within the swimming pool included dust patterns on the interior acoustic insulation indicative of diffuse leakage through the interior wythe of concrete block.

Several test openings revealed serious masonry damage associated with air leakage paths. At the upper pool roof/wall junction mortar was found to be wet and friable. In some locations upper courses had settled to contact the course below. (Photo 9)

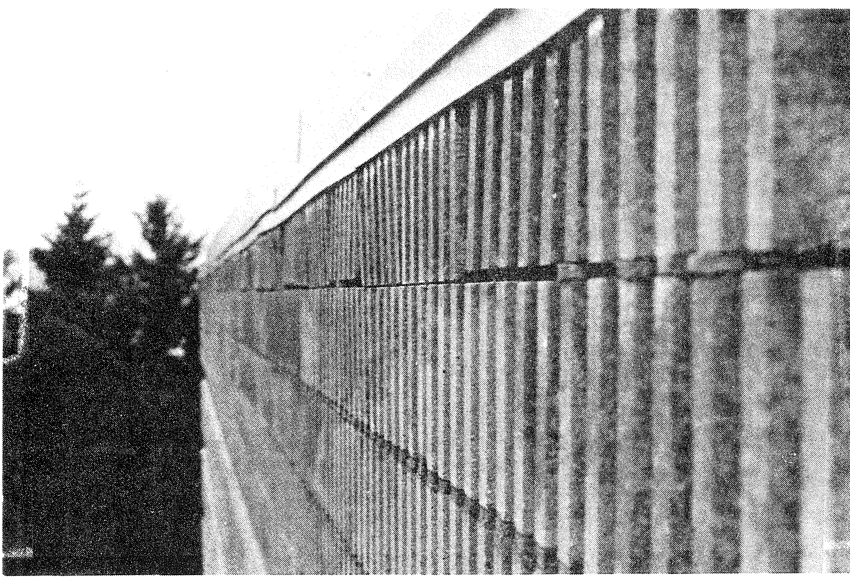

Photo 9 - Deteriorated Mortar Leaves Blockwork Unstable

Neoprene flute closures were observed in the lower flutes of the metal roof deck but in line with the inner face of the 250 mm (10 inch) block. A mastic type sealing strip was placed along the flute above the inner surface of the north wall. Despite these, warm air could be felt leaking from the wall to deck interface. (Photo 10) Glass fibre insulation was wet.

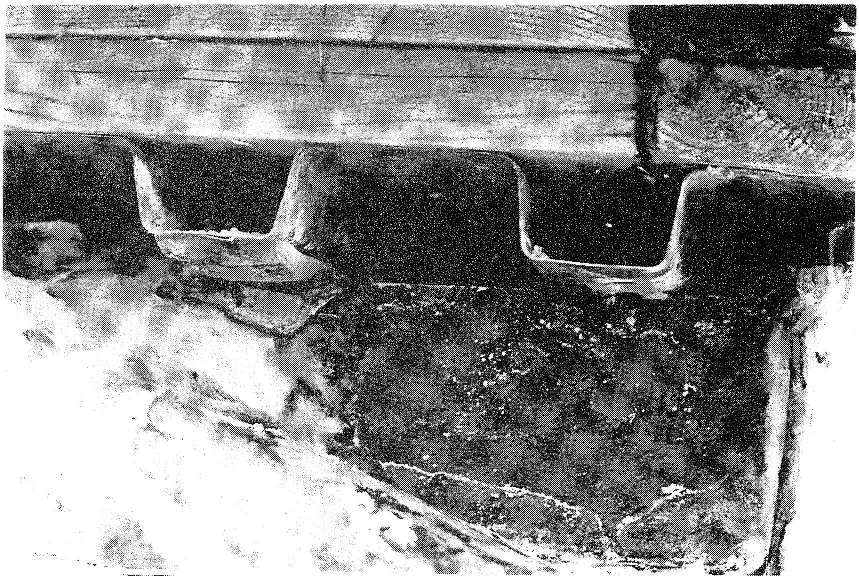

Photo 10 - No Closures were Provided in Troughs or Fluted Deck

A second test opening was conducted at the intersection of the upper roof wall with the lower administration area roof. At this location, mortar had no consolidation, and concrete block was fragmented. (Photo 11)

Photo 11 - Serious Concrete Block Deterioration

Photo 12 - Air Leakage from Top of Flashing

When the construction was reviewed from within the ceiling space of the administration area below, insulation was found to connect the ceiling space within the wall cavity above. (Photo 13)

Photo 13 - Wall/Lower Roof Intersection Showing Lack of Air Seal at Junction

Analysis of Observations

Block and mortar damage observed in this building can be attributed to air leakage, condensation collection and subsequent freeze/thaw damage. The deterioration is so great that structural failure of the facade is very likely. Certain design features intended to protect the envelope from high humidities were actually included in the original design (such as mastic type vapour barriers, and metal deck closures) but they have proven ineffective. The degree of air leakage at the roof/wall interfaces was significant at all test opening locations and appears to be the primary source of moist air in the cavity. Diffuse air leakage and vapour transmission through the block interior walls and an incomplete mastic type air/vapour barrier is a secondary but possibly significant source of moisture. (Figure 2)

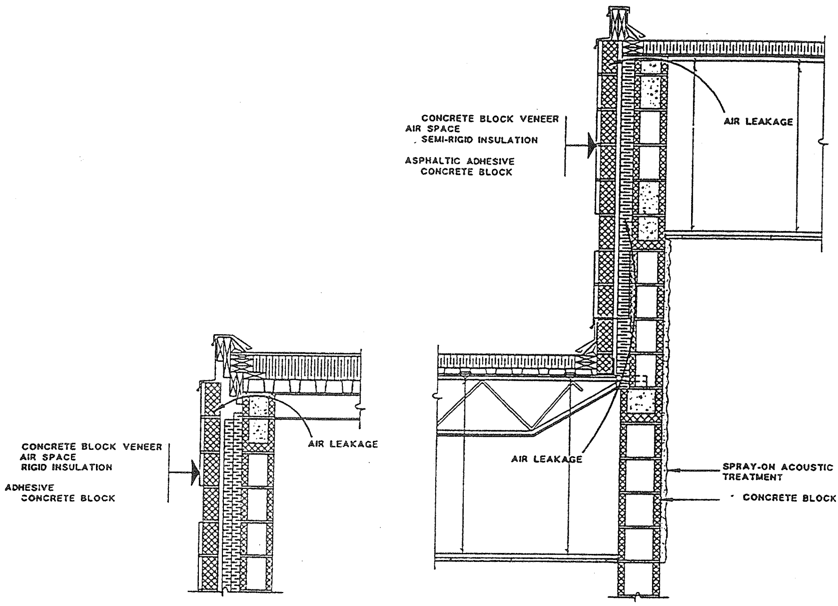

Figure 2

CONCLUSION

The interior and exterior wythes of masonry employed in both case studies cited are likely to meet current standards for material durability. They failed in service because the envelope system that they formed part of did not adequately control the leakage of moist air from the interior of the building to the cold exterior wall cavities. Design and operations lessons include the following:

- Mastic type air and vapour barriers over concrete block require membrane type connections to and across adjacent structural materials, at intersections between walls and roofs and at all penetrations. These membrane connections require structural support and complete continuity to maintain air tightness under air pressure gradients. The thickness of trowel or spray applied mastics over concrete block must be carefully monitored during construction to ensure the resulting membrane has both the required permeability and resistance to air leakage.
- Mechanical pressurization of building envelopes that are required to maintain high relative humidities must be kept at an absolute minimum.
- Early signs of damage including mortar loss, wetting patterns or efflorescence should be investigated and remedial action taken before serious masonry problems develop.