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A CASE STUDY IN THE ASSESSMENT AND REPAIR OF FREEZE-THAW DAMAGE TO TTW BRICK WALLS

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ABSTRACT

This paper describes the assessment of masonry deterioration and the repair program at three essentially identical buildings with walls constructed of TTW brick. Each building has six storeys with a combination of flat and sloped roofs. Extensive brick deterioration and leakage into the buildings were the driving forces behind this work.

INTRODUCTION

Original Construction

The buildings were constructed between 1979 and 1980. The exterior TTW brick walls are load bearing (see Fig.1). There is a layer of parging on the back face of the brick. The interior of the wall comprises batt insulation, a polyethylene vapour retarder and drywall fastened to steel studs. The insulation was intended to be held away from the parging by strings strung between the studs. These were not effective, so the insulation was in contact with the parging. There are sloped roofs at the tops of some of the walls (Fig.2) and flat roofs with brick parapets elsewhere.

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The floor slabs are 64mm thick concrete slabs supported on Hambro joists. The ceiling drywall of the rooms is fastened to the bottom of the joists. The joist space is used as a return air plenum for the heating and cooling systems. The drywall at the exterior walls does not continue above the finished ceilings. Therefore the ceiling space was not physically separated from the exterior wall construction except where the polyethylene vapour barrier was in place.

The base of the walls and lintels were generally provided with through-wall polyethylene flashings, however, the flashings were not reliably secured to turn up the inside surface of the parging. Drain holes were provided through the masonry. Several of these had been sealed in the past to address insect infestation and leakage.

Damage to the Walls
Deterioration of the brick walls and leakage into the building started within a few years of construction. Visible deterioration included spalling of the brick faces at various locations on the building walls as well as on landscaping walls and parapet walls at balconies and the roof. Legal action was taken by the building owners against many of the parties involved in the construction. For years, attention was focused on the exterior brick damage. After nearly 10 years of legal proceedings and examinations by several parties, the drywall was removed from the interior face of exterior walls in 5 apartments. Spalling of the inside faces of the bricks, which dislodged the interior parging, was found to be significantly more extensive than the exterior spalling. Leakage was found to occur wherever the parging on the interior was not intact.

CAUSES OF DETERIORATION

The deterioration of the bricks was studied at length, and various reasons for the damage were put forward by experts.

Freeze-Thaw Susceptible Brick
Based upon one set of laboratory durability tests, it was claimed that the bricks were excessively freeze-thaw susceptible. Subsequently, extensive testing of the properties of the bricks was performed. While it was found that the bricks did not meet current standards, they met the standards in place at the time of construction. The original test results were not duplicated but there were some allegations about the relative durability of the brick. (The court agreed that the bricks met the standards at the time of construction and therefore were not defective.)

We reviewed several other buildings with very similar wall construction, and did not find the same deterioration even in buildings where the bricks were similarly frost-susceptible (as indicated by spalling at grade or adjacent to horizontal surfaces). This suggested that factors other than the brick properties were required to cause the extensive deterioration.

Missing Vapour Retarder in Plenum Space
The polyethylene vapour retarder did not always continue to the underside of the floor slabs above. In most locations investigated, some of the vapour retarder (and insulation) had separated from the top track of the stud assembly. This could have been caused by air pressure differences. The result was that most of the parging on the back face of the brickwork was exposed to the air in the plenum space. It was proposed that damage to the masonry could be prevented by accessing all plenum spaces to permit the vapour retarder to be made continuous. Humidity levels and parging surface temperatures were monitored for a period of time during the winter. Our analysis indicated that condensation was probably the result of air circulation within the wall. Interior air flow from the plenum, down behind the drywall and out the drain holes was likely many times more significant than condensation related to vapour diffusion. Once the parging had separated from the brickwork, more extensive air leakage, and condensation, would occur. Installation of an air barrier would be required to correct this. We did not feel that modifications to the vapour retarder would have a significant impact on the problem.

Several observations led us to believe that while condensation did occur and probably caused water damage to the interior finishes and steel studs, it was not likely the cause of the masonry deterioration.

The patterns of damage on the exterior walls generally followed vertical bands, rather than horizontal bands which would be expected if the damage were related to the horizontal plenum spaces.

Laboratory testing of the water resistance of the parging layer was performed on brick panels cut out of the walls. The sample was placed in a horizontal position with the parging up. Water was ponded on the parged face. With the parging intact, no leakage through the sample was detected after several days. As soon as a hole was made through the parging, leakage occurred. The parging layer therefore provided a high level of resistance to water flow. We hypothesized that condensation would occur on the back face of the parging, but that it would not soak through the parging in quantities sufficient to saturate the bricks and cause freeze-thaw deterioration. This indicated the source of water which was saturating the bricks was from the exterior.

We also believed that where the parging was intact, it formed a reasonable air barrier, likely preventing condensation related to air leakage.

Excessive Run-off
The vast majority of the damage occurring was related to water running off the sloped roofs onto the bricks. The sloped roofs had no eavestrough, and no overhang. Water flowing down the roofs was directed straight onto the brick. Dark staining of the brickwork related to moisture absorption could be observed below each of the sloped roofs during a rain or thaw. The exterior brick damage generally correlated with these run-off zones.

However,in the presentations made during the litigation, this correlation was contested for what appeared to be non-technical reasons. The large interior openings confirmed our hypothesis. The spalling of the interior faces of the brick and the dislodged parging matched the outline of the run-off patterns on the outside of the walls almost identically, in all locations checked. Damage and leakage were much more extensive on the upper floors than on the lower floors.

We believe that once the parging on the inside of the walls was displaced due to the brick spalling, the result was increased leakage, condensation and saturation which accelerated the deterioration.

Air leakage would increase where the parging was missing as the parging was the most air-tight element of the wall. Our calculations indicated that this air leakage would have generated significant volumes of condensation in the brick, adding an additional water load to the already spalled brick. This likely accelerated the rate of spalling occurring at the interior face of the brickwork.

Leakage into the building primarily occurred wherever the parging was not intact, which also corresponded to runoff locations. Prior to the separation of the parging layer, leakage was isolated to small cracks, joints or gaps in the parging, particularly around window and vent penetrations. Without the intact parging layer, leakage became extensive.

MECHANISMS OF BRICK DETERIORATION

The spalling on the exterior faces of the bricks had two forms: a surface spalling of thin layers of brick, and deeper cracking of the bricks at the depth of the cores (Fig.3). The surface spalling was visible from the ground, and had attracted attention to the damage, but during the repairs it became apparent that the deeper spalling through the cores was actually more extensive and structurally significant. This deeper damage to the bricks could only be detected by sounding the bricks.

The surface spalling appeared to be caused by the expansion of the water in the pores of the brick matrix during the phase change from water to ice.

The cracking of the bricks at the depth of the cores appeared to be related to freezing of bulk liquid water filling the cores. Water likely reached the cores by soaking through the brick, and also at locations where brick ties were placed close to the outside surface of the mortar joints, resulting in voids in the mortar joints through which water flowed to the cores.

BASIS OF REPAIR TO MAIN BUILDING WALLS

The basis of our repair was that these walls could be made to perform adequately providing the parging on the back face of the brick was intact and free of holes or cracks, and water was not allowed to concentrate on the brick faces.

The walls below the sloped roofs were deemed "wet walls". The damage to the bricks on these walls had progressed to the point that correcting the runoff alone would not be sufficient remedial work. Extensive repair to the bricks and parging/air barrier was also needed. Following cost comparisons of repair and cladding options, these walls were clad with an air barrier applied to the exterior of the brick, insulation and precoated steel panels.

The walls which did not have sloped roofs shedding onto them were called "dry walls". Brick damage was significantly less, except at the corners where they met the wet walls. It was decided that masonry repair was feasible, and that these walls did not need to be clad. This helped maintain the appearance of the buildings by leaving significant areas of exposed brickwork.

Wet Walls

Prior to installing the cladding, the integrity of the load bearing masonry walls was restored. Where there was extensive spalling to the depth of the brick cores, the load bearing capacity of the wall was significantly reduced. In large areas of deep spalling, vertical panels of brick were removed with the wall shored on the interior, and new "columns" of brick were installed (Fig.4). These brick columns were designed to take over the vertical load-carrying function of the adjacent sections of wall. Adjacent to the new columns, the spalled faces were removed, and the bricks patched with a polymer modified mortar.

A trowel-on, cementitious, air barrier material with a low vapour resistance was installed over the faces of the bricks on the walls to be clad (Fig.5). This replaced the air barrier function of the generally detached parging. Calculations verified that condensation from vapour diffusion would not form at the inside face of the new air barrier. Sufficient insulation was provided on the exterior side of the air barrier material to move the dew point outside the air barrier layer.

A free draining insulation was applied to the exterior face of the air barrier, and covered with a rain-screen design metal cladding.

No repairs to the interiors of the "wet walls" were performed, except at locations of water damage. While the steel studs and bottom track were badly rusted, occasionally to the point of disintegration, it was decided to leave the drywall in place. Deterioration of the walls was not expected to continue after they had dried out. Replacement of the studs and drywall will be performed when the units are redecorated.

Dry Walls

To effect air barrier repairs on the dry walls, the interior drywall was removed starting from the corner of the wet wall until the parging was found to be intact. The spalled interior faces of the bricks were repaired. Hollow sounding parging was removed and replaced. Parging was installed on the back faces of all new bricks. The parging was continued around the corner onto the wet walls for a small distance to attempt to create an overlap with the exterior air barrier on the wet walls (Fig.5). While this connection was not perfect, we felt that the mortar joints in the brick work helped to connect the two air barriers. The interior finishes were then restored. These repairs were started at the top of the building, and stopped when intact parging was found on one floor, generally the third or fourth floor. Very little repair was required inside the units on the first and second floors. Disruption to occupants was kept to a minimum.

Flashings were installed along the edges of the sloped roofs to prevent water from blowing off the sides of the sloped roofs onto the dry walls.

Some minor leaks have occurred since the repair was completed, but these amount to approximately one percent of the leaks which existed prior to the start of the repairs. Each of the leaks has been found to be related to isolated conditions resulting in concentrated run-off onto the exposed brick of unrepaired walls. These locations are being addressed by installing deflectors to redirect the water, and installing a masonry sealer on exposed brick to minimize the amount of water soaking into the brick.

OTHER REPAIRS

In addition to the damage on the main building walls, masonry damage had developed at various other locations.

The roof level parapets were constructed of one wythe of TTW brick with metal cap flashings. Neither face of the brick was protected with counterflashings or parging and the cap flashing was not provided with drip edges. The bricks were so cracked and spalled that the walls had to be completely demolished and rebuilt. The cause of the damage was run-off from the metal caps, and saturation as a result of exposure to water on both faces of the wall. During the winter, snow drifts accumulated against the back face of the parapets. The rebuilt walls were counterflashed for their full height on the roof side. New cap flashings were designed to shed water away from the brick.

The sixth floor balconies had parapet walls constructed of a single wythe of TTW brick with bare brick exposed on both the interior and the exterior. These balconies were enclosed with glass greenhouse type window systems at the time of construction because the waterproofing installed on the balconies generally leaked. However, the balconies were not heated or insulated. These spaces were used as interior spaces, with the sliding doors leading to the suites often being left open during the winter. The bricks of the balcony walls were extensively spalled on the inside surface. This was caused by leakage through the poorly installed and poorly detailed enclosures, and heavy condensation caused when moist interior air contacted the cold brick faces. Without insulation or parging, the surfaces were completely unprotected. Repair to these balconies consists of venting the balconies so they remain at the exterior temperature, and either replacing the enclosures with water tight systems, or removing the enclosure and waterproofing the balcony floor.

The landscaping walls are either TTW brick screen walls or brick clad concrete retaining walls. Deterioration was most pronounced where soil had been raised to the level of the brick caps in planters, or where runoff from patio roofs was shed onto the walls. Ice expansion in cores was the predominant failure mechanism in the caps. Surface spalling was also common on the faces where exposed to runoff or snow piling. Remedial measures included lowering the soil level, installation of counterflashing, repair of brick, and strict instructions to maintenance personnel not to allow snow or soil to accumulate to the level of the brick.

SUMMARY

The building repairs described above are currently complete with the exception of the sixth floor balconies and some landscaping walls. The occupants did not have to move out of their units during the work. They are generally pleased with the new appearance of the buildings. The majority of owners have just lived through their first fall and winter in almost fifteen years without leakage. The repair procedure was the lowest cost approach presented by any of the involved parties. This was important given that the court judgement was against a bankrupt company. The owners have received no compensation for the work.

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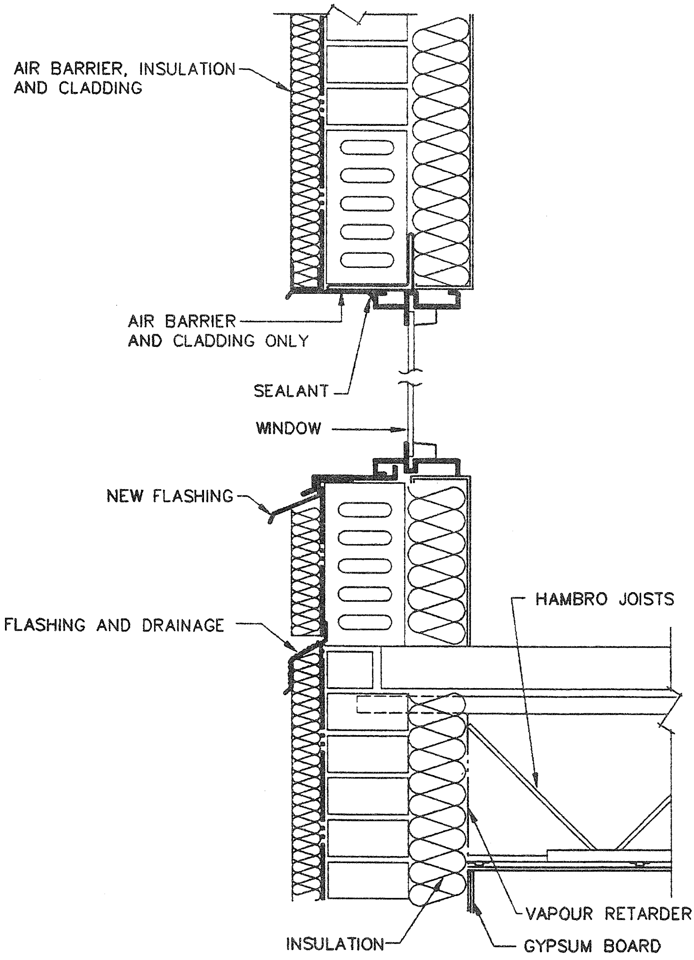

Fig. 1 Wall Section (with Retrofit Cladding)

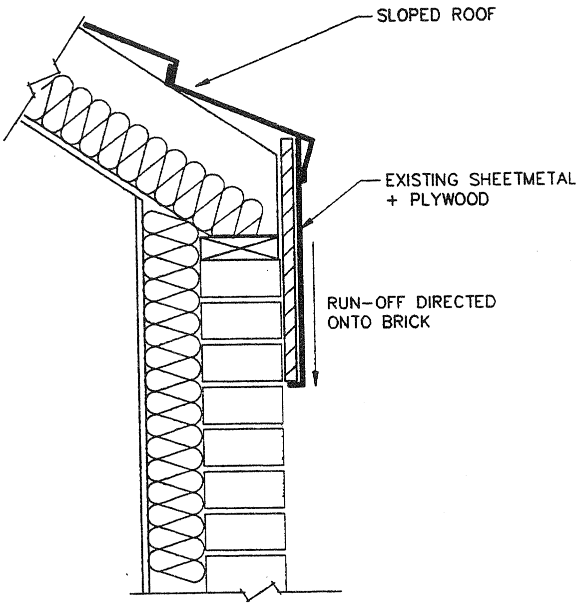

Fig.2 Sloped Roof Junction with Brick Wall

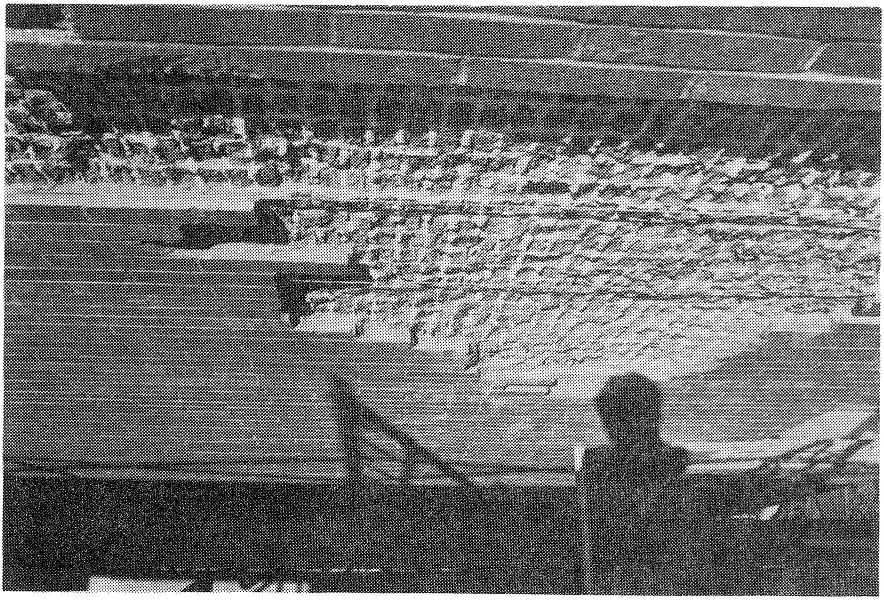

Fig.3 Bricks Removal where Fractured to Depth of Cores

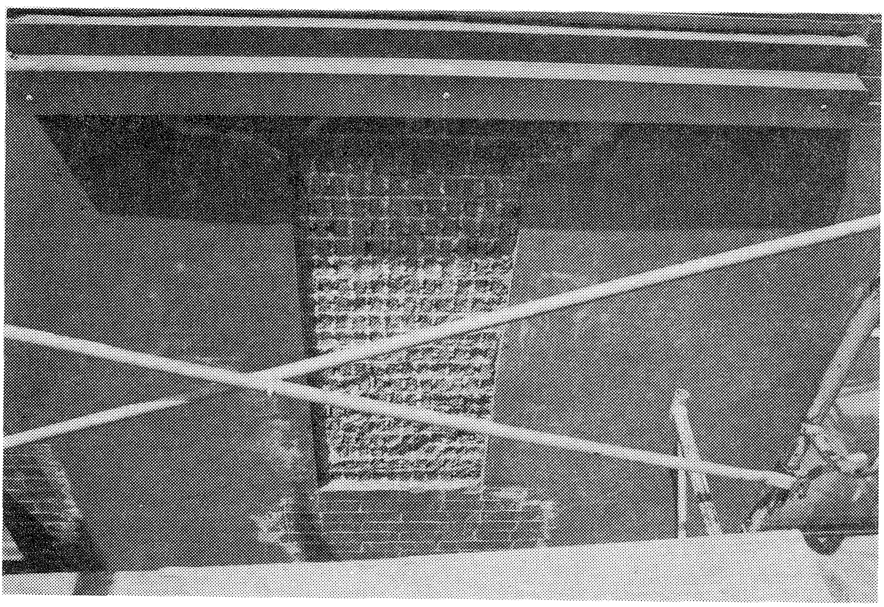

Fig.4 Brick Panel to be Replaced with New Brick "Column"

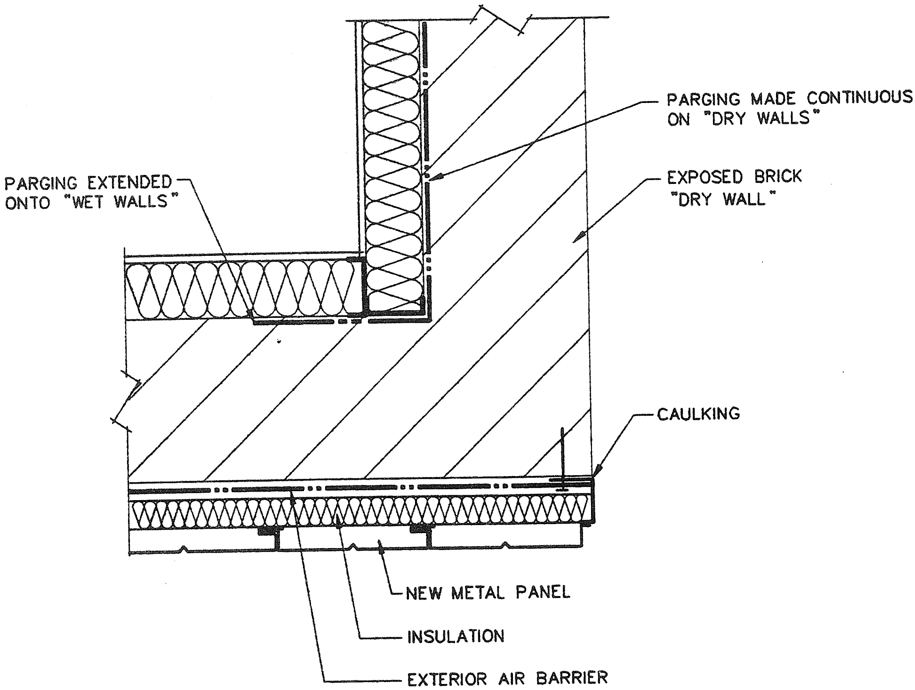

Fig.5 Plan Section of Wall (with Retrofit Cladding)