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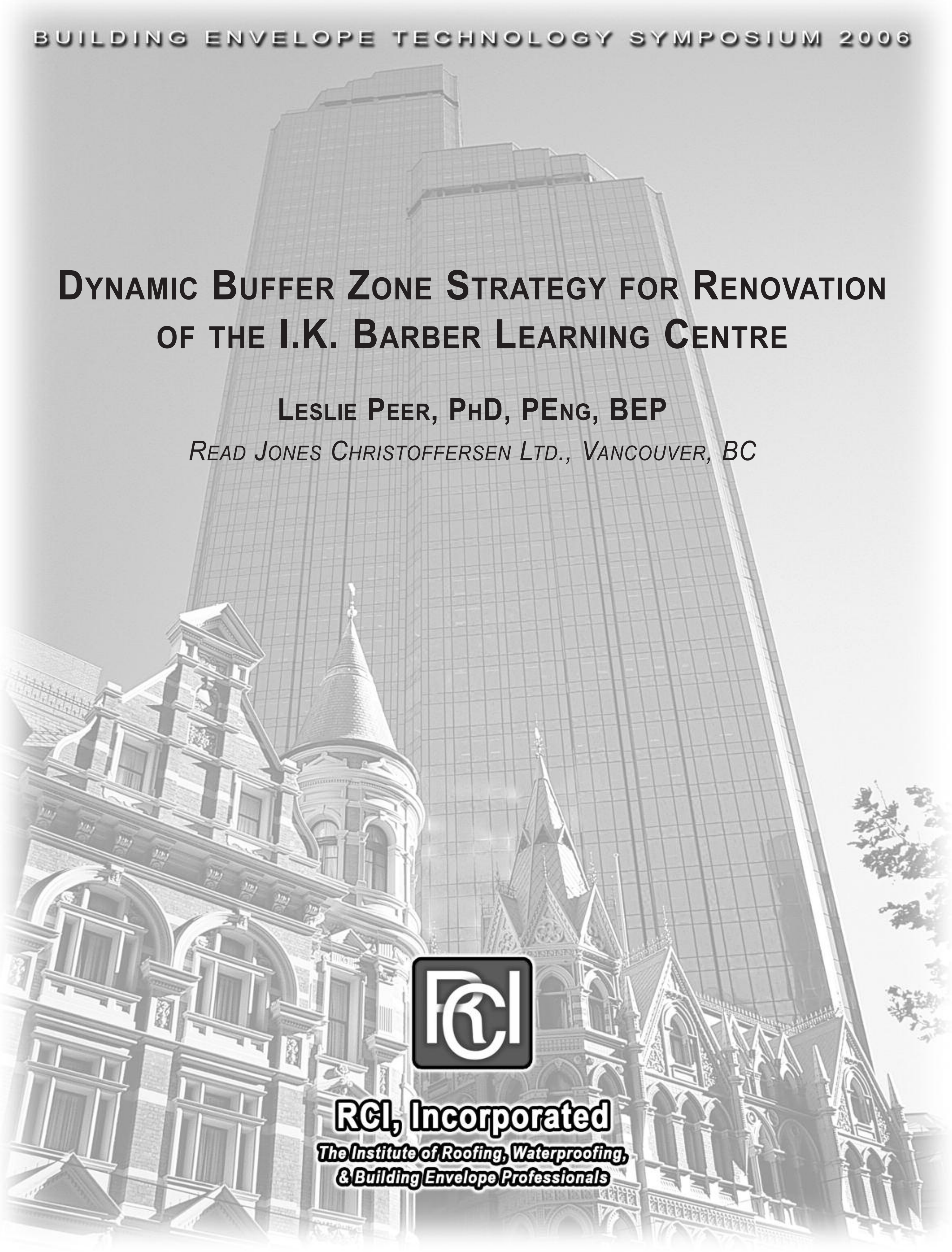

DYNAMIC BUFFER ZONE STRATEGY FOR RENOVATION OF THE I.K. BARBER LEARNING CENTRE

LESLIE PEER, PHD, PENG, BEP

READ JONES CHRISTOFFERSEN LTD., VANCOUVER, BC

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ABSTRACT

The original University of British Columbia Library is currently being renovated into the I.K. Barber Learning Centre, retaining and incorporating the oldest portions of the original building. The new building employs a high-efficiency building envelope system and is heated and cooled with in-slab circulated water systems. Insulation levels and humidity control in the new building required improved performance of the masonry portion of the building to make it functional with the new mechanical systems. This paper describes the work required to reduce water leakage through the original granite masonry construction, provide continued adequate drying of the exterior walls to the interior, and protecting the wood structure from moisture damage.

SPEAKER

LESLIE PEER, PHD, PENG, BEP – READ JONES CHRISTOFFERSEN LTD. – VANCOUVER, BC

Leslie B.B. Peer, PhD, PEng, BEP, is an associate in the Restoration Group at Read Jones Christoffersen Ltd. in Vancouver. He studied structural engineering and building science at the University of Toronto, and materials engineering at Cambridge University. He has been consulting for 15 years in the fields of materials engineering, façade engineering, building science, and instrumentation, and is a specialist in evaluating and predicting the durability of concrete, steel, and timber structures. His current practice consists of a wide variety of construction and renovation projects involving building envelope design, specifications for durability, investigation, and quantification of damage to structures, and specifications for rehabilitation of structures.

DYNAMIC BUFFER ZONE STRATEGY FOR RENOVATION OF THE I.K. BARBER LEARNING CENTRE

1.0 INTRODUCTION

The University of BC is located in Vancouver on Point Grey with a seaside view. The campus was located there in a clearing in the forest in the mid-1920s, during construction of several main campus buildings, among them the Science, Library, and Theological college buildings. These are magnificent concrete frame and granite masonry structures, which contribute to the cultural heart of the campus. The concrete structure and masonry shell of the library building were completed in about 1925. Construction extended into World War II and interior finishes were not finally completed until about 1950, due to wartime constraints.

Almost immediately thereafter, the building was extended with storage space for the rapidly growing university collection and student population. Additions in the 1950s and 1960s brought the building to its functional size limit. Several new libraries have since been added to the campus. With a donation from I.K. Barber, the original library building is now being renovated into a modern Learning Centre to find its new place at the heart of the campus.

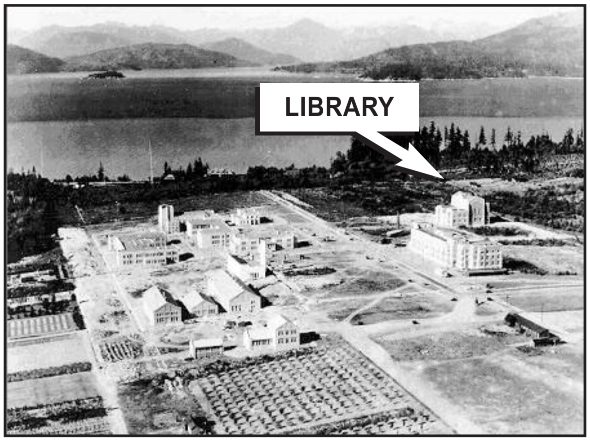


Figure 1 – Aerial view of UBC Campus looking north, circa 1930.

1.1 EXISTING BUILDING

The existing building has a reinforced concrete frame consisting of concrete basement walls, concrete floor slabs, and concrete columns. The roofs are wood, triple-framed with long span timbers on trusses. The main roof is a slate shingle roof, and the lower roofs are moderately sloped asphalt membranes. The walls are two wythes of infill brick masonry with granite facing, load-bearing on concrete slab edges and the foundations. The (lightly) reinforced concrete frame has shallow arches at locations where exterior walls span over interior spaces.

The brick and granite were laid simultaneously to form a monolithic wall. Every 3 to 4 feet, a granite stone was laid end-on to provide shear ties in the masonry wall. Damp-proof courses were installed over window heads and continuously under the parapet. Roof structure bears on the masonry and concrete frame at different locations, showing the tradition of construction, which, at that time in BC, treated concrete and masonry as integral fabric. Room interiors had classic shapes and finishes, mostly formed on interior clay tile infill walls, which hid the concrete structure and mechanical piping, and provided deep window reveals.

FORM AND FUNCTION

The library, however beautiful, probably functioned much as a stone castle in the early days, heated by brute force but still cold in parts on some days. Modernizations and interior fittings, including ornamental plaster work, central plant steam heat, and large additions brought the building function to recognizable standards for the second half of the century.

Storage space for collections did not have the tight constraints now dictated by preservation science. Collections were originally housed on shelving and later transferred to steel stacks in well-heated wings of the additions.

WALLS

The original building envelope functioned as a mass wall, able to absorb, store, and release water at rates deemed acceptable at the time. The granite employed was

Figure 2 – Interior of masonry wall showing damp-proof (1) course above window lintel (2), bond stone (3), and efflorescence on masonry (4).

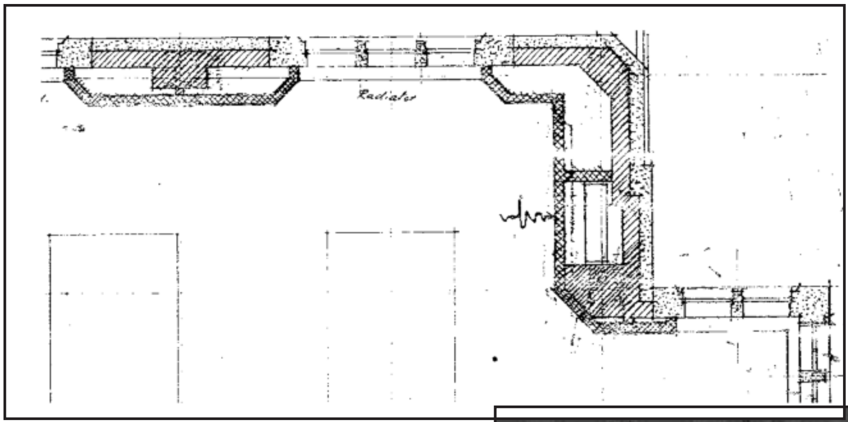


Figure 3 – Extract from original drawing showing granite (1) and brick masonry composite wall (2), wall cavity (3), interior clay tile wall (4), window (5), and brick or concrete pilasters (6).

Figure 4 – Original steel-framed windows in set-in granite mullions.

quarried on the coast of BC and is largely impermeable. The brick masonry behind is low-fired and very absorptive, on the margins of acceptability under modern ASTM C62 requirements. A thorough evaluation was undertaken after demolition of the interior finishes for the purposes of both structural and envelope design. All materials found were noted to be in good condition, except where extensive efflorescence on the interior face of the wall caused spalling and flaking of some brick surfaces.

Thermal conductivity of the original exterior walls was high, with a U value for the composite wall ranging from 7 to 17 W/m^2.K (R0.8 to R0.3 F.hr.ft^2/BTU). Composite values for the assembly vary, depending upon assumptions made for connectivity of mortar collar joints and moisture content of the masonry. Modern walls in Canada have thermal conductivities of about 0.4 W/m^2.K, about 10 to 20 times less conductive to heat flow.

Water-tightness of the original walls was somewhat less than desirable despite the high quality of the original stone and mortars. The stone, while largely impermeable, does not bond well to mortar because it is siliceous and dense. Numerous small cracks develop in granite walls, mostly at head joints, and these contribute to substantial moisture penetration into the walls. The presence of asphalt through wall courses in the project demonstrates that masons of a century ago were under no illusions about water penetration through masonry. In service, the composite walls leak through the outer course of masonry, and the water was absorbed by the inner course of masonry until it reached saturation. After saturation was reached, water leaked down the wall until it appeared on the floor or at window heads. Removal of water from the inside of the masonry walls occurred by evaporation into interior air, mostly before it became a nuisance.

WINDOWS

Windows are single-glazed, steel-framed, with operable sashes deep set into the masonry. The frames were built into the exterior masonry as it was laid. Almost all are in good condition after 80 years in service and were retained intact.

ROOFS

Lower roofs on the original building were probably tar/pitch, built-up roofs sloped at about 15%. They had been replaced with 2-ply, SBS-modified asphalt roof membranes over new plywood and some were insulated. Cast iron drains from these roofs were found to be a significant source of water leakage where they had corroded at penetrations through masonry walls on their way to exterior rainwater leaders.

Figure 5 – Slate roofing on main hall restored c. 2000.

The upper roof is shingled in local slate and was restored five years before the redevelopment was contemplated. As such, it is in good condition and is being retained unaltered. Several features of this decision provide challenges to the current project, in that it was restored without the addition of insulation, and the roofers provided a 6-inch continuous vent along the ridge.

MECHANICAL

The mechanical systems in the original building consisted of steam heating, distributed via hot water radiators and passive and mechanical extraction ventilation, which vented interior air directly to the exterior. The roof of the main room had a ridge vent 6 inches wide running the whole length of the room that vented interior air continuously. It is not known if the ridge vent was original or installed as part of the slate roof renovation. Estimates of energy usage were not made because the building ran off central steam heat, and probably because they were depressing. The combined systems provided adequate control of interior conditions in the library, which is remarkable, given the moisture load provided by the exterior walls. Another building proving that, with sufficient energy consumption, anything is possible!

1.2 NEW BUILDING

FORM AND FUNCTION

The new building retains the 1924 portion of the original structure as a main entrance and reading rooms, and provides new wings north and south for collections storage, reading space, faculty and staff offices, and teaching space. The intent of the building is to be a state-of-the-art resource center for the campus and remote sites across the province by Internet access.

An attempt was made to retain the interior finishes during the course of construction but had to be abandoned where removal of finishes was required to get access for other work. The interior character of the original building is to be rebuilt in detail on the new interior finishes.

Collections are housed in a central book vault provided with a robotic retrieval system. The vault is located in the core of the north wing and has almost no access for personnel from the rest of the library. The vault has separate environmental controls to precisely maintain the environment required for storage of archival material.

Figure 6 – View of new wing with heritage core beyond.

MECHANICAL

One of the major sustainable design features of the new portions of the building is the radiant heating and cooling system provided in the library spaces. Piping is embedded in the soffits of concrete slabs of the new building spaces and provides distributed heat and cooling. Ventilation air is provided at a rate of 0.2 air changes per hour per occupant, and is introduced through heat recovery ventilators in centralized units. The building does not have a humidity control system for occupied areas of the library, except in the book vault mechanical system and special collections areas.

Heating in the heritage portion of the building is provided by radiators connected to the new hot water distribution system. These will run at lower water temperature than originally.

ENVELOPE

The building envelope assemblies reflect the energy efficiency goals of the new building and respond to the performance constraints of the mechanical systems. The

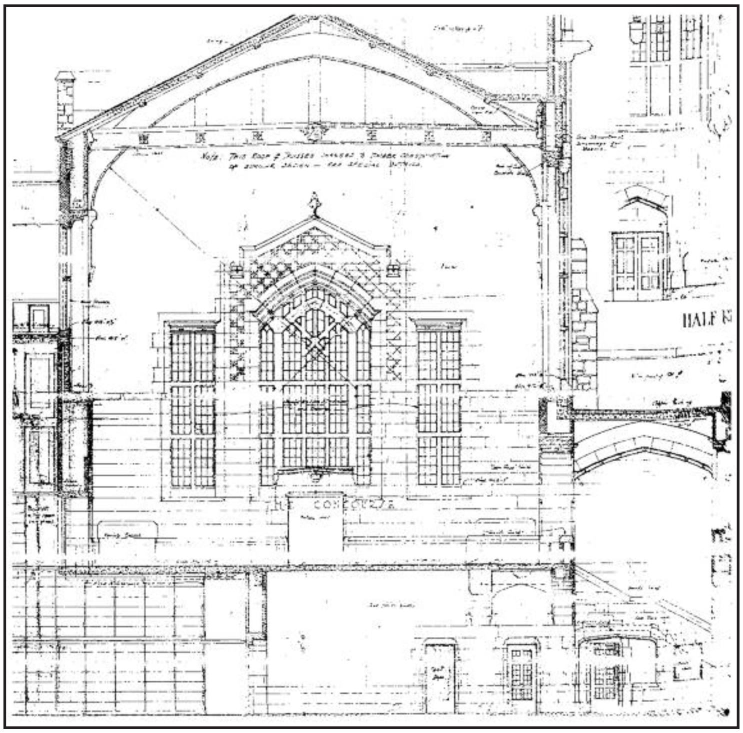


Figure 7 – Section through main hall from original drawings, showing masonry parapets and roof wood trusses that bear on concrete columns.

walls and roof have high effective insulation levels (RSI=2.1 $W/m^2.K$ or R=15 $F.hr.ft^2/BTU$ for walls and RSI=1.4 $W/m^2.K$, R=20 $F.hr.ft^2/BTU$ for roofs), and curtain walls are triple-glazed (U=0.35 $W/m^2.K$ with shading coefficient of 0.4) to reduce peak heating and cooling loads to compensate for slower response time of the new mechanical system (compared to traditional space heating systems).

Early designs for the heritage core explored adding insulation to the inside surface of brick on exterior walls. Analysis eventually indicated that this would have prevented drying of the walls and was abandoned as a concept. Without replacing the brick with concrete, it was clear that accommodation of moisture load from the walls was key to integrating the heritage fabric with the new building systems. In arriving at a solution, comfort in the heritage portion of the building had to be provided by insulating the occupants from the stone masonry in the interior partition walls. Moisture loading from evaporation of water leakage had to be accommodated elsewhere. These requirements dictated the need for a 'buffer zone' between the occupied spaces inside the library and the outside walls, where sufficient air could be circulated to accommodate the moisture load from the exterior walls without it mixing with interior air.

2.0 ASSESSMENT OF EXISTING ENVELOPE PERFORMANCE

The process of designing envelope modifications to the heritage core began by understanding the behavior of the walls in their original configuration. Windows were not to be altered, and roofs were to be insulated, so these elements were not difficult to design. The main slate roof is not insulated and was not part of the renovation since it was renovated five years previously. Various aspects of wall performance were analyzed until they were understood, and then the new design adjusted to provide for them.

2.1 INSULATION

The original walls were not insulated. Massive masonry walls tend to assume a mean temperature between the interior and exterior air temperatures, and varying slightly about the daily average temperature. The temperature studies for the wall assembly on this project indicated that masonry temperatures ranged between 7 and 16˚C in the wall cavity (interior side), while the exterior portion of the main wall mass ranged from 4.5 to 18˚C most of the time. Temperatures outside this range occurred during occasional extended hot and cold spells, which can occur in Vancouver. Temperatures in the wall cavity air ranged from 8 to 24˚C over the course of the year.

Freeze/thaw deterioration of the granite is not a problem; however, the low-fired clay brick masonry is not frost resistant. Adding insulation to the inside of the brick walls would reduce the masonry temperature, probably leading to frost damage of the masonry, and therefore was not pursued.

Figure 8 – Typical crack in granite masonry head joint. Presence of moss in the joint indicates persistent water presence in otherwise tight mortar joints.

2.2 MOISTURE CONTROL

Sources of Moisture

Investigation of moisture sources after all interior finishes were removed revealed quite distinct patterns of wetting of the masonry. Water infiltration originated at parapets, ornamental stone features, rainwater pipe penetrations, and cracked head joints throughout the masonry.

University staff reported that the building had been repointed periodically, but that it had little effect on reducing leakage. This is borne out in most granite facades where head joints re-open immediately after repointing due to temperature cycling in the façade and poor mortar-to-stone bond. Head joint cracks in this building were less than 0.5 mm wide. Eliminating moisture infiltration through granite was not considered a viable repair strategy. Eliminating moisture leakage from rainwater leaders was pursued by installing new stormwater handling systems inside the building.

Moisture Travel Paths

Moisture was observed to travel down through the masonry, in some cases only a few feet until reaching a damp-proof course, but in some cases the full three-story height of brick wall. Observations of moisture patterns indicated that about 25% of all masonry was saturated sufficiently to have heavy efflorescence salt accumulations, indicative of long-term drying from the interior surface. At most locations moisture content in the brick approached absorptive saturation, with the brick damp to the touch, discolored, and in many places, drip-

Figure 9 – Efflorescence on interior face of wall showing location of long-term evaporation of water from the brick.

ping from damp-proof courses.

When this behavior in the masonry was confirmed, two options were explored for controlling moisture in the wall assemblies. The first involved limiting moisture travel in the masonry by removing the porous brick masonry and applying cast or sprayed concrete directly to the inside face of the granite masonry. The second option involved re-creating conditions inside the masonry wall so that it could continue to wet and dry along the existing pattern. The first program was not adopted because of the relatively less intrusive and cheaper second solution. However, if concrete reinforcement had been required for improving seismic protection, it would likely have been selected as the preferred method.

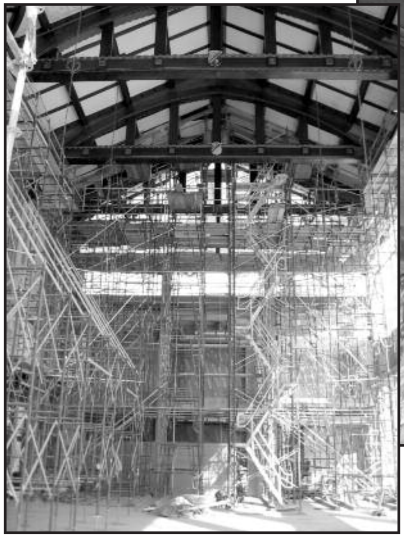


Figure 10 – Main hall with scaffolding to support trusses while end-bearing timber is replaced where rotted from contact with masonry.

Figure 11 – Removal of masonry from truss ends to isolate wood from masonry.

Structural and Masonry Damage

Damage to the masonry consisted of frost deterioration of isolated bricks and some flaking damage to bricks in areas of persistent wetting, caused by lime accumulation (crypto-florescence). Neither form of damage was severe, and was predicted not to jeopardize building performance in the long term.

Some fairly severe structural deterioration was discovered where timber roof framing bears on wet masonry. A program to repair four main truss ends, and many minor beam ends contributed to project delays of about four months. Main roof truss ends were rebuilt in laminated steel and wood, and all wood was shortened or masonry around the beam ends excavated to create 2-inch pockets to isolate the wood from damp masonry. The pockets were lined with 1-inch extruded polystyrene insulation to keep wood fiber in interior air conditions.

3.0 DESIGN OF NEW ENVELOPE

Both building envelope options were designed before eventual selection of the dynamic buffer zone system was made. This section describes design of the buffer zone system. The design premises allow the original masonry fabric to function virtually as if no changes had been made to the building, while maintaining conditions for occupants to modern standards. An interior wall maintains conditions in the occupant zone, and a connected wall cavity between the interior and exterior walls allows circulation of air to dry the masonry. Air in the "buffer" zone is expected to be much more humid for parts of the year and is expelled directly from the building without mixing with occupant air.

Separation of interior and exterior environments in the new wall system takes place at the interior wall assemblies to maintain the occupant comfort zone. The interior walls are the primary air barrier, and are insulated to protect interior air against cold masonry, reducing heat loss and maintaining surface temperatures at levels sufficient to prevent condensation. Exterior air is circulated between interior and exterior walls by means of convection over the height of the building.

New interconnections of the wall cavity space were cored along slab edges between new structural supports. Air in the buffer zone circulates at a sufficient rate to remove infiltrating moisture through a combination of air temperature and stack height, which generate buoyancy and vent area to permit sufficient flow. Air is taken in at ground level and exhausted at roof level without mechanical assistance.

3.1 FUNCTIONAL PARAMETERS

The university mandates a design service life of 100 years on all projects delivered under its design guidelines. Deterioration of building fabric due to long-term moisture problems is obviously undesirable on a landmark project. Discussions of cost, long-term risk, and conservation of heritage fabric influenced the ultimate choice of a design solution. Initial cost, project schedule, good occupant comfort, and low long-term maintenance effort proved to be primary decision factors.

Heritage Features

The heritage value of the building lies in its façade with its exterior appearance, and in the room interiors with their form and decoration. The façade could not be significantly altered or over-clad, and similarly, parapet head joints could not be covered with flashing. The exterior appearance is maintained completely by the design, and little stone work is required on the project, with the exception of adding the low-level vents.

Mechanical Constraints

The new mechanical system was modified to provide extra heat to the main reading room, which does not have roof insulation under the slate (as anticipated by the design). Heating provision in the smaller reading rooms was augmented to compensate for reduced insulation levels. An effective R-6 insulation is provided in the new interior walls, which allows sufficient heat flow into the cavity space to evaporate water

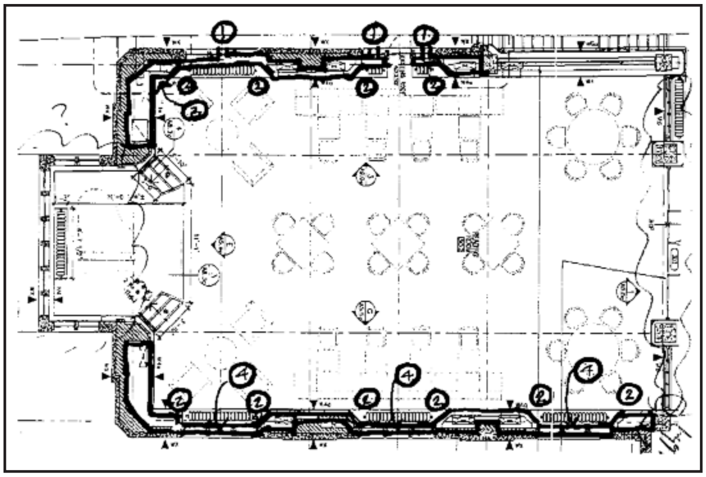


Figure 12 –Plan view of new dynamic buffer zone showing wall cavity (2), and holes in floor (4).

from the masonry.

The mechanical system has limited potential to absorb moisture load from the masonry, a function the previous system provided with apparent ease for several generations by expelling copious amounts of heated air. An alternate route for transport of moisture out of the walls was therefore required and provided in the wall cavities.

3.2 DESIGN SOLUTION

CALCULATIONS OF PERFORMANCE

Simulations of wall performance confirmed that moisture, once absorbed through exterior masonry, cannot re-evaporate back out through the same stone. Infiltrating water is instead stored in the very sorptive brick immediately behind the stone, and was then released via gradual drying to interior air in the building. This is anomalous performance, since most buildings dry primarily in the direction of heat flow. In this case moisture travels against the direction of heat flow because the saturation coefficients in the brick masonry are high enough to overcome the vapor pressure gradient established by the heat flux.

Evaporation rates from brick on this project ranged from 6 to 12 g/hr.m^2, depending on brick density. At this rate, saturated brick in the building required service temperatures on the inside masonry surface to be an average of 8˚C to evaporate moisture from the brick seasonally. Exterior air entering the wall cavity requires heating to this temperature from exterior ambient conditions, which average about 5˚C over winter months in Vancouver. The evaporation capacity of exterior air heated by that margin is about 4.2 g/m^3. Air-flow rates required to remove moisture were calculated as less than 1 l/s.m^2 of wall area in the worst temperature conditions (January and February).

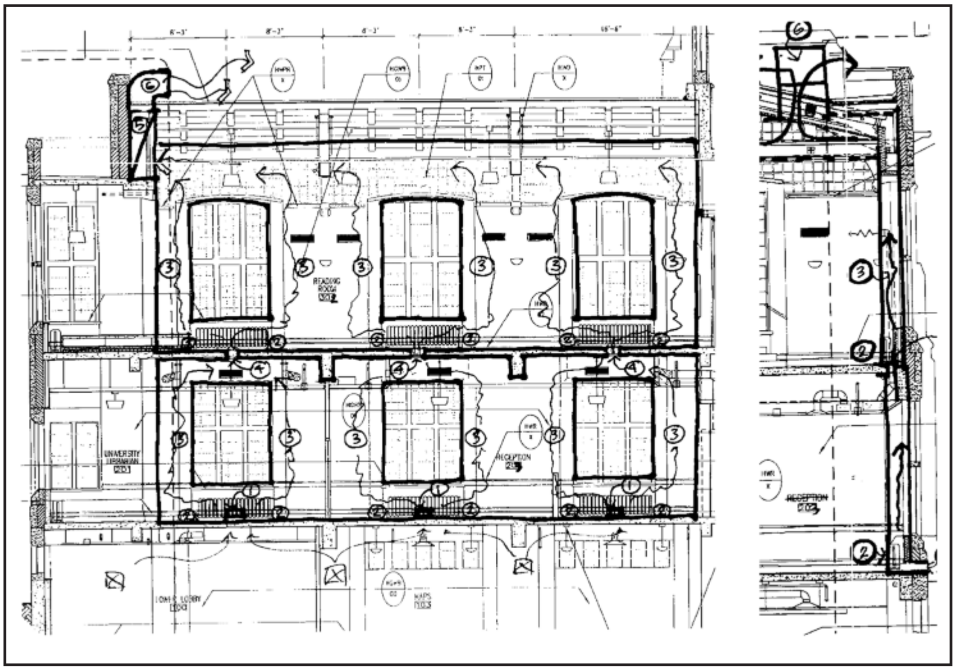


Figure 13 –Elevation of DBZ showing air intakes (1), convection paths (3), reused ventilation shaft (5), and sheet metal hood (6).

It is fortunate that in Vancouver, colder winter conditions are anomalous and mostly associated with artic highs bringing sunshine or Alaskan gulf lows that bring snow. Such conditions persist for several weeks and do not seriously disrupt the annual wetting/drying cycle of the masonry. Thermal gradients in the wall maintain cavity temperatures at about 8˚C during most of the winter, and reduced insulation behind radiator panels will add extra heat to assist heating air beyond that required by the design.

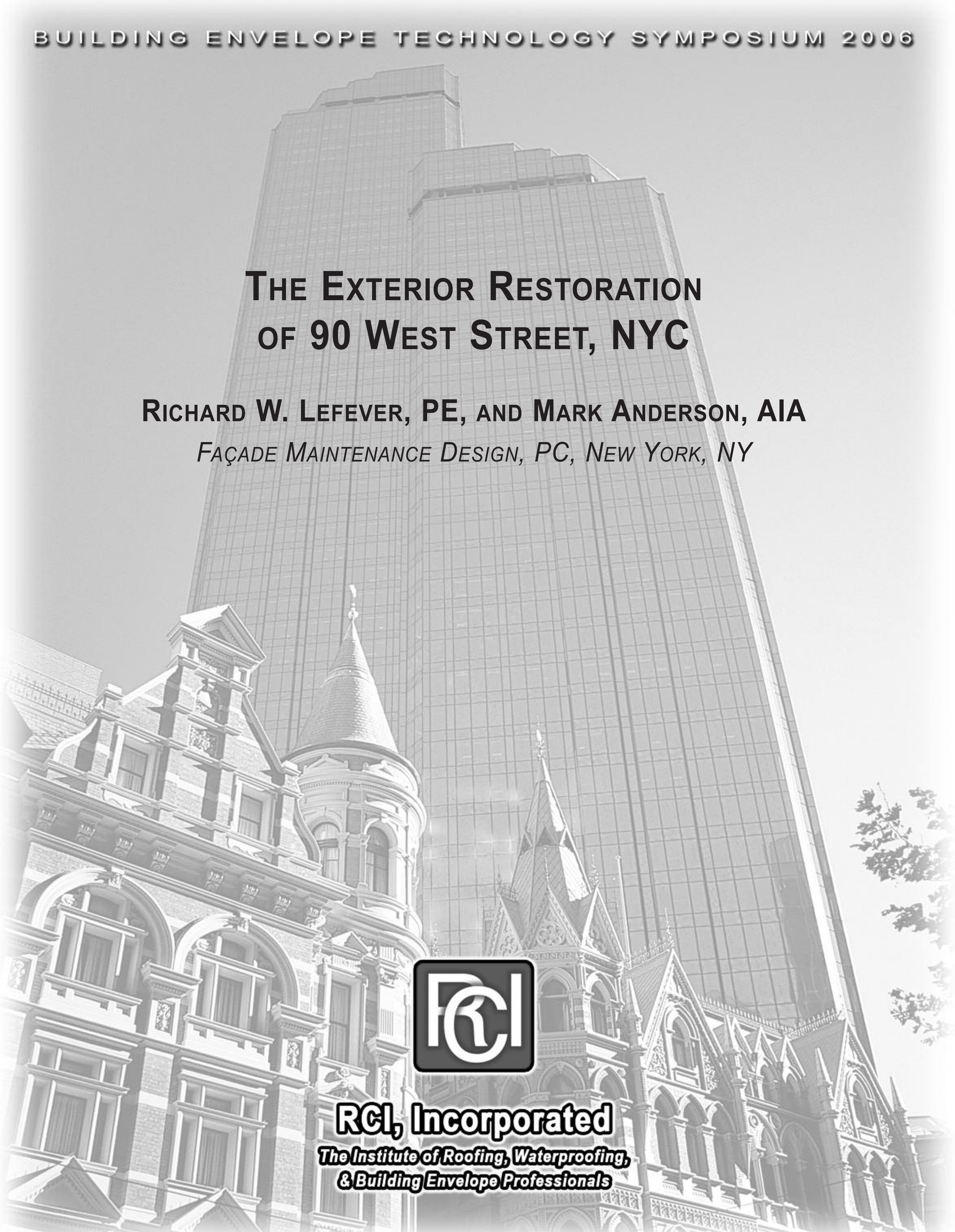
CONTINGENCY FEATURES

The design does not rely on mechanical ventilation or secondary heating sources to maintain building function. The design calculations result in a system that is sufficiently similar to wall ventilation strategies on successful older buildings of the last century to be believable. However, since the system is unproven, there are contingency plans to monitor performance and augment moisture removal rates, should that be required.

Conditions in the wall cavity will be monitored with moisture sensors connected to the building's DDC system for the first few years after occupancy to check that evaporation rates are controlling moisture accumulation, and that air-flow rates are sufficient to remove moisture. Electrical drops have been roughed in to provide heat sources linked to humidistats, and for roof top ventilation to accelerate air flow, should they be required to increase moisture removal rates. As a final contingency, the university can opt to overclad or alter parapets and other features on the façade to reduce infiltration loads, if required.

4.0 ACKNOWLEDGEMENTS

The design team members who were instrumental in producing the design are: Helmut Kassautsky, MAIBC, of Downs Archambault Ltd. Architects for architectural designs; Milenko Vujivic, PEng, of Earthtech for calculating of air flow rates in wall cavities to match ventilation requirements. We thank the UBC Properties Trust and UBC Plant Operations for their attitude towards innovation in design.



THE EXTERIOR RESTORATION OF 90 WEST STREET, NYC

RICHARD W. LEFEVER, PE, AND MARK ANDERSON, AIA

FAÇADE MAINTENANCE DESIGN, PC, NEW YORK, NY

RCI, Incorporated

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