MASONRY RESTORATION OF THE OLD CIVIL ENGINEERING BUILDING, FREDERICTON CAMPUS, UNIVERSITY OF NEW BRUNSWICK

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ABSTRACT

This paper discusses the scheduled activities, methods and materials used for the masonry restoration of the Old Civil Engineering Building at the University of New Brunswick Fredericton Campus, which was designed and built in 1900. This building is characterized by a fieldstone below grade and red sandstone above grade foundation which supports the above load bearing unreinforced brick cavity walls with sandstone arches, sills, lintels and band courses. Wood floor joists and roof trusses bear on the two inner wythes of the four wythe cavity wall. Remedial work was performed on the two exposed elevations, while the other two elevations are concealed with building additions. Extensive deterioration of the soft lime rich mortar from weathering, dislodged mortar from the settlement of stones, and outward deformation of the frail dry pressed brick walls supporting the roof joists were attributed to the initiation of this restoration project.

The masonry restoration activities began with drainage tile and membrane fabric installation to prevent water entry, severe efflorescence and spalling of the interior foundation brick. Reconstruction of the deformed upper brick double wythe wall supporting the roof joists was performed by using new and existing brick, tied with horizontal bed reinforcement, while matching the original frieze panels, dentil and corbelled ledger courses. Attic floor joist ties were installed to provide lateral support for the walls. Partial and complete repointing of the two elevations was performed while matching strength and colour of the original mortars used. Repair of loose and broken facebrick was required at several locations using salvaged brick while displaced sandstone arch keystones and coping above the main entrance arch were reset. Cleaning of the delicate masonry was accomplished using physical and chemical methods to remove soot, paint splatters, organic growth, and lime stains on brick below sandstone components. Helical cavity wall ties were installed with rotary percussive drills in conjunction with the existing random flat metal and brick ties. Under all aspects of this project, emphasis was placed on maintaining the detail and appearance of the building prior to the restoration activities.

Keywords: masonry restoration, repointing, cleaning, cavity wall ties, foundation waterproofing.

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INTRODUCTION

The Old Civil Engineering Building was designed by F. G. Ernest Fairweather, Architect, from Saint John, New Brunswick in 1900. This building has provided offices and lecture rooms for engineering faculty and students for over a century. Previous modifications to this structure involved removing coal fired boilers in the basement, demolition of masonry chimneys above the roofline, partitioning of office space, replacement of asphalt shingles, and mechanical equipment installation in the attic level. Building additions to the original structure were constructed to the north and west elevations. More recently, an estimate to replace the original windows was initiated in 1998 by UNB Physical Plant and the deteriorated condition of exterior masonry components was discovered at this time. An investigation was conducted by a local architect for remedial action.

In 1999, a tender document was prepared by UNB Physical Plant to address the critical issues which resulted from the investigation, and was awarded to a local contractor. The scope of work included foundation repairs and drainage provision, reconstruction of the brick wall above the east elevation arched windows, partial roof replacement, repointing and cleaning of the masonry, resetting or replacing loose, broken or displaced masonry units, cavity wall tie installation, lateral support provision at the attic level, and complete window replacement in the original building and 1947 building addition. The focus of this paper will address the masonry restoration activities to the exposed elevations of the original building.

BUILDING DESCRIPTION

The Old Civil Engineering Building was constructed as a three storey building with elevations that will be identified as the north, south, east and west elevations. Only the south, east and 915 mm (3') of the north elevation in the northeast corner remain intact and exposed to the environment. The remaining portion of the north elevation underwent a building addition in 1947, and the west elevation was entirely concealed by a building addition in 1957. The main entrance of the building is located on the east elevation which consists of two 8.8 m (29') long left and right walls separated by a 7.9 m (26') center wall projecting 915 mm (3') outwards, as illustrated in Figure 1(a). The south elevation is approximately 16 m (53') long and illustrated in Figure 1(b).

Foundation Wall

The 762 mm (30") thick foundation wall has an approximate 76 mm (3") cavity that separates the exterior fieldstone and red sandstone wythe from the interior clay brick wythe. The total depth of the foundation wall in between the footings and the top of the finished first floor is approximately 3.4 m (11'). The fieldstone wall extends approximately 1.1 m (3.5') below the window sills to the footings and was coursed in a random rubble pattern with mortar joints struck flush. The red sandstone is rustic surfaced with sawn abutting faces and the units were placed in a random ashlar bond pattern with red pigmented beaded mortar joints. The top of the foundation wall is capped with a 250 mm (10") thick brown sandstone band course which is tapered 102 mm (4") inwards to the above supported brick cavity wall. Window openings in the foundation wall have red sandstone lintels and sills, with typical openings of approximately 1220 mm (48") wide by 1170 mm (46") high.

(a)

(b)

Figure 1. (a) East elevation and (b) South elevation prior to masonry restoration.

Multi-Wythe Cavity Wall

The exterior walls in between the foundation wall and the attic floor joists were designed as unreinforced load bearing brick cavity walls. Four wythes of clay brick are separated by a 76 mm (3") uninsulated cavity with an approximate wall thickness of 500 mm (20"). The cavity wall is approximately 7.9 m (26') high and was tied together with randomly placed header bricks and sheet metal ties. Bearing on the interior wythes of the cavity wall are wood floor joists at the first and second storeys spaced at 1.6 m (7'-2") with dimensions of 150 mm x 330 mm (6" x 13"), and at the attic level, 150 mm x 230 mm (3" x 9") attic floor joists spaced approximately 18" apart bear in the east-west direction and three roof trusses spaced 13' apart fabricated with 8" x 8" compression members and 200 mm x 250 mm (8" x 10") tension chords with 31.75 mm (1-1/4") steel tension ties bear in the north-south direction. Bricks were placed in a running bond pattern with sixth course Flemish headers with no provisions for expansion joints. Red-pigmented mortar joints were struck flush with bed joints having an average thickness of 11.1 mm (7/16"), and head joints having a thickness in between 1.6 mm to 25.4 mm (1/16" to 1"). The non-glazed smooth textured bricks were salmon coloured and were manufactured in a dry pressed process. These bricks were distinguished with “M. RYAN” inscribed in a diamond shaped indentation on the top surface. Average dimensions for the bricks are 216 mm x 102 mm x 60 mm (8-1/2" x 4" x 2-3/8").

Fine grained brown sandstone units with sawn bearing and abutting faces were used for lintels, sills, arches, band courses, entrance steps and entrance arch facade. The sandstone components are rustic surfaced except for the sill stones, entrance steps and beaded entrance coping stones, which are smooth surfaced. Window openings at the second floor left and right walls have sandstone Roman arches and all other windows have solid sandstone lintel blocks bearing on the exterior double brick wythes. The two interior brick wythes of all window openings have segmental Rowlock brick arches. The sloped sandstone sills extend to the interior face of the interior wythes, and bricks were placed across the jamb openings over the 76 mm (3") cavity without flashings. Window openings have an approximate maximum width of 1.2 m (4') and a height in between 2.3 m to 2.7 m (92" to 106"). On the east elevation, a continuous 318 mm (12-½") sandstone band course abuts the sill stones of the first floor level windows, and a 200 mm (8") sandstone band course forms the springing line of the second floor level window arches. A 200 mm (8") sandstone band with the same length as the lintel blocks is located at a third of the window height below lintel blocks.

Double Wythe Wall

A 25 course double wythe brick wall was constructed above the exterior wythes of the cavity wall to support 76 mm x 178 mm (3" x 7") roof joists spaced at 560 mm (22"), that were nailed to a continuous 76 mm x 230 mm (3" x 9") wood bearing block without anchorage to the brick wall. Ten brick courses were exposed to the environment in which eight courses formed an indented frieze panel that was surmounted by dentil and corbelled ledger courses. The ledger course supported a continuous wood nailer block partially embedded in the above brick course to anchor painted galvanized sheet metal fascia and soffit, stiffened with modillions spaced at 813 mm (32"), concealing the overlying fifteen brick courses. The drip edge was integrated into the sheet metal cornice with a roof projection of three feet from the double wythe wall. Wood soffit framing spaced at 1.1 m (44") passed through the double wythe wall and was nailed to wood hangers suspended from the roof joists and to an insulated stud wall for office partitioning. The soffit framing was discontinuous upon passing through the wall at the exterior location in which the framing was spliced with a lap joint. The brick in the concealed portion of the wall was placed in a running bond pattern with a header course at approximately mid-height that tied the two wythes together. The top of the wall beneath the bearing block is capped with a soldier course. Brick pilasters projecting 250 mm (10") from the centers of the end walls were 430 mm (17") wide and were not drawn on the original blueprints. Lateral support for each end wall was provided by three steel strap anchors spaced 2.7 m (9') apart. The attic level of the center wall was finished with a gable roof with a triple wythe brick pediment wall. A circular window is located on the pediment with surrounding triple Rowlock brick and sandstone voussoirs in each of the four quadrants. The perimeter of the pediment wall is finished with corbelled and dentil courses adjacent to the sheet metal cornice.

EXISTING CONDITIONS

Foundation Wall

A lack of proper water drainage adjacent to the foundation wall, eroded mortar joints, and a finished grade above the sill stones on the left wall has resulted in moisture migration into the wall. Severe efflorescence had resulted in spalling of the interior wall brick surfaces over the years. The beaded mortar joints in the red sandstone were previously repointed with a red-pigmented Portland cement mortar, which had mostly been dislodged due to stress concentrations from thermal movements, and an inadequate depth of raking was employed. Water entry was permitted into the wall through cracked mortar joints, which resulted in moisture retention beneath the non-porous hydraulic cement repointing mortar. The condition of the red sandstone was sound with the exception of surface soiling from accumulated dirt. Upon excavation, it was observed that the mortar binding the fieldstone units was mostly deteriorated with large tree roots embedded in the joints below the left wall window sills.

Surface Condition of Masonry Walls

All exposed surfaces were weathered with extensive soiling. Organic growth from vines was present along the entire southeast corner to the centers of the south and east elevations. Paint spatters were present near the upper portion of the wall from previous painting of the sheet metal cornice and window frames. Heavy soot accumulation was present along the frieze panel, possibly as a result of the by-products released from the previously removed coal fired boilers. Lime staining or efflorescence was present on brick surfaces below all sandstone components.

Mortar

A soft lime mortar was used in the original construction, which offered little resistance to removal with hand tools. The red-pigmented mortar was weathered with the ungraded aggregate being washed to the surface, but remained intact in several locations on the brick walls. Eroded mortar joints, primarily the head joints, were present in all sandstone components permitting water migration into the wall. Mortar joints in the brickwork below the sandstone lintels, sills and band courses, and mortar joints in the frieze panel below the cornice and roof valleys were eroded as a result of water runoff. Evidence of longstanding structural movement was observed in the brickwork with diagonal cracks formed in mortar joints on the east elevation above the entrance arch coping stones and lintel beams.

Brick

Weathering of the brick surfaces had converted the original hard fired surface to a soft, friable condition. Most bricks were sound, and the longstanding life of the bricks can be attributed to the soft lime mortar absorbing stresses from the brickwork. Few loose, spalled and cracked bricks were observed throughout the building.

An investigation was performed by a local engineering consultant to determine the material properties of bricks sampled from inconspicuous locations of the building. Compressive strength tests were performed on five brick specimens in accordance with CAN3-A82.2-78 (CSA 1978). The average compressive strength of the brick was 36 MPa and exceeds the minimum value of 20.68 MPa. Absorption tests of eight brick samples in accordance with CAN/CSA-A82.1-M87 (CSA 1987) resulted in an average absorption from a 5 hour boiling test of 18.1% that satisfies the requirements under moderate weathering conditions, but the saturation coefficient of 0.94 exceeds the maximum allowable value of 0.88. Recommendations from the report were to prevent direct roof runoff on the brickwork and to prevent saturation of bricks under repeated cycles of freezing and thawing. Initial rate of absorption test (IRA) of three brick specimens in accordance with CAN/CSA-A82.1-M87 resulted in average IRA of 37 g/30 in2/min that exceeds the maximum value of 30 g/ 30 in2/min. It was recommended that the bricks be pre-wetted to reduce suction prior to reusing the original bricks.

Sandstone

Blistering and light spalling of sandstone surfaces had resulted from environmental weathering. The brown sandstone surfaces were darkened considerably in areas of water accumulation on lintels, sills, band courses and entrance coping stones. Cracked or fractured sandstone components could not be located.

Masonry Deformations

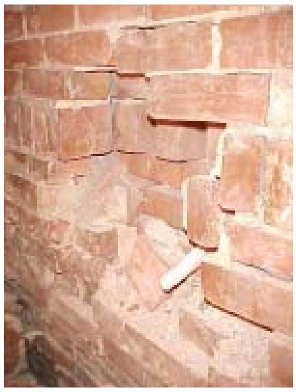
The keystone on the second floor right window arch had settled approximately 50 mm (2"), displacing the window frame below. One of the five 1.4 m (4-1/2') foot long beaded coping stones had differentially settled approximately 40 mm (1-1/2") towards the entrance arch keystone and resulted in a diagonal crack forming in the above brickwork. The eight brick courses in between the continuous second floor window sill stones and coping stones were bulged outwards by approximately 25 mm (1") in between the diagonal cracks that had formed at the two ends as illustrated in Figure 2.

Figure 2. Settled coping stone and deformed brickwork.

An outward deformation of approximately 50 mm (2") was observed in the double wythe brick wall above the attic floor level on the left and right walls - see Figure 3(a). The primary contributing factor associated with the wall deformations was a lack of attic ventilation, where brick closure was installed in between the wood bearing block to the underside of the roof sheathing between the roof joists, and the soffit was not vented. A history of extensive ice accumulation was observed along the roof edge, and had accumulated below the cornice and roof valleys along the frieze panel. The mortar joints along the corbelled ledger and dentil courses were extensively deteriorated with loose bricks, and the surmounted wood nailer block was also deteriorated. This is believed to be the location of prolonged water entry into the masonry that caused the progressive outward deformations to occur. Water stains were observed on roof joists and sheathing in between the brick wall and the roof edge from water backup underneath the asphalt shingles during ice formation.

At the interior location, the mortar had a powdery texture and would crumble into individual grains when removed with hand tools. Bricks were easily removed by hand in the courses adjacent to the frieze panel indicating the interior wythe was under very little compressive load, as illustrated in Figure 3(b). An inward bulging of the lower interior wythe was observed at several locations, indicating a separation of the two wythes. The mortar joints above the frieze panel were in general sound with no cracking.

(a)



(b)

Figure 3. Typical deformations and deterioration of the double wythe walls at (a) exterior location and (b) interior location.

MASONRY RESTORATION ACTIVITIES

The contract agreement for the *Masonry Restoration and Window Installation* of the *Old Civil Engineering Building* project was a lump sum price with cash allowance. The lump sum price included the following masonry restoration activities to the east elevation and 915 mm (3') returns to the north and south elevations: repointing of all masonry, cavity wall tie installation, lateral support provision at the top of the cavity wall, reconstruction of the left and right walls above the arched windows, resetting displaced window keystone and entrance coping stone, reconstruction of brickwork overlying entrance arch, and partial asphalt shingle replacement and roof bituminous membrane underlayment installation of the lower 3.7 m (12') of the roof. Lump sum activities for both the original building and 1947 addition included complete masonry cleaning, foundation drainage and waterproofing membrane installation, and complete window replacement. A cash allowance provision was included in the contract document to cover certain areas of uncertainty or for further improvements. Cash allowance activities included repointing the south elevation and 1947 addition as required, repairs to deteriorated portions of cornice sheet metal, soffit framing and partial roof sheathing replacement and attic ventilation provision. The masonry restoration activities of the original building are outlined in the following sub-sections.

Repair, Waterproofing and Drainage of Foundation Walls

It was necessary to protect the stonework and wall core against persistent dampness and the disruptive effects of roots. A four foot wide trench was excavated to the footings along the east elevation foundation walls and the soil was removed from the site. Masonry cleaning was performed by using a medium pressure spray, in the vicinity of 0.6 MPa (100 psi) parallel to the surfaces, and permitted to dry for 48 hours prior to repointing. Loose debris was removed with hand tools and loose fieldstone units were reset. Type N mortar standard mix proportions specified by CSA A179-94 (CSA 1994) was used for repointing the fieldstone below grade. A cement mortar was chosen to provide some alkali resistance to the soil and groundwater with a compressive strength not exceeding the fieldstone. Foundation waterproofing was accomplished using Volclay Voltex Bentonite Geotextile waterproofing membrane below the finished grade over the fieldstone. This product was originally designed for concrete foundations, and a variation to the manufacturer's written instructions was employed by overlapping the seams by approximately 610 mm (2') instead of nailing the fabric flush to the surface. This variation was required because the membrane had to contour around the irregularities in the stone wall. A 102 mm (4") perforated PVC pipe was placed downgrade to the nearest catch basin to the north of the 1947 building addition with a surrounding 150 mm (6") envelope of 19mm (3/4") crushed rock and an overlying filter fabric. The trench was backfilled with 50 mm (2") maximum aggregate sized free draining pit run gravel compacted to 90% M.P. Following the remaining restoration activities, a 150 mm (6") splash belt with 19 mm (3/4") no fines crushed rock was placed on filter fabric, and corrugated galvanized steel window wells were placed below two windows on the left wall were the finished grade was previously above the sill stones.

Cleaning Exposed Masonry

Cleaning older masonry buildings is not always recommended, and could lead to adverse effects if special precautions to the specific structure are not taken. Physical and chemical treatments must be selected and used properly to avoid further deterioration to delicate materials. This building was cleaned primarily for aesthetic purposes in order for the brick surfaces to be uniform in colour because the repointing process would clean brick areas adjacent to the mortar joints from tooling and cleaning excess mortar. A uniform colour in reconstruction areas would also be difficult to blend soiled brick with adjacent areas if not cleaned.

A medium pressure spray of 0.6 MPa (100 psi) was used to clean all of the exposed masonry. The direction of spray was applied near parallel to the surfaces to prevent further deterioration and erosion of the masonry surfaces and mortar. Excessive soaking of the masonry was avoided to prevent ingress of water into the walls that could lead to further deterioration of masonry components, and to minimize the risk of efflorescent salts leaching to the surfaces from within the lime mortar and clay bricks. Areas of excessive soiling, paint spatters and organic growth were cleaned with nylon bristled brushes and wood/plastic scrapers. Tri-sodium phosphate (TSP) was permitted to be used to remove stubborn stains, but was only tested on two small areas. Following approximately 72 hours of drying, soluble salts had leached to the surfaces causing efflorescence in these areas, and the TSP was not further used.

Repair and Repointing of Cavity Wall

Mortar joints were raked to a depth of 2 ½ times the joint thickness, but not less than a depth of 25 mm (1"). Mini grinders with 127 mm (5") cutting discs were permitted for raking bed joints of brickwork after demonstrated skill was established of preventing damage to adjacent bricks. Hand tools were used for raking all sandstone joints and head joints of brickwork which pose a high risk of the bricks in the adjacent courses being cut.

Following joint raking, 8 mm diameter HELIFIX DryFix stainless steel helical remedial ties were placed 610 mm (24") horizontally, and 400 mm (16") inches vertically on the east elevation cavity wall. Ties were placed along corners and surrounding all openings. Pilot holes were drilled to the full 400 mm (16") length of the ties with a rotary percussive drill along bed joints and the ties were installed with a hammer drill using the DryFix power driver attachment until the ties were recessed below the face of the masonry. Ties were installed at an upward angle of in between 10 to 15 degrees.

The lime mortar selected for use with all of the original sandstone and brick had proportions by volume of 1 part lime to 2 parts sand with sufficient water to provide a workable mix, and a maximum 28 day compressive strength of 0.5 MPa. A red dry powdered inorganic pigment was proportioned to 10% by volume to closely match the original mortar colour, and was selected from a small test panel with two other pigment proportions. The sand for the lime mortar was sieved in accordance with CSA A179-94 (CSA 1994) to conform with the gradation limits. Loose brick were reset and spalled and fractured brick were replaced with sound reconstruction brick during the repointing process. Concave tooling was used for all brickwork and brown sandstone to provide a greater water tightness of the joints from the previous struck flush tooling, while all red sandstone foundation wall mortar joints were beaded to match the previous appearance. Excess repointing mortar was cleaned from the brick surfaces using Sure Klean 600 with nylon bristled brushes and plastic scrapers. The primary chemical in this product is hydrochloric acid, which is acceptable for use on clay bricks, but has adverse effects on sandstone where hygroscopic iron chlorides form and irreversibly stain the surfaces black with crystallization within the sandstone forming that exerts destructive pressures within. Underlying sandstone was covered with plastic sheets when this cleaner was used. Sure Klean light duty concrete cleaner with primary chemicals of phosphoric and gluconic acid was used for cleaning the sandstone and within areas of close vicinity.

Repairs to the settled entrance coping stone was performed in conjunction with the sequential brick construction in the overlying 8 brick courses to the second floor window sills. The outward deformed exterior wythe bricks were removed to the center of the two end diagonal cracks with wood shoring placed 1.2 m (4') apart, and was reconstructed prior to further brick removal. While the bricks were removed, repairs to the adjacent wythe were performed in conjunction with resetting the settled coping stone with stainless steel anchors and slate shims. Resetting the keystone in the right wall arched window was accomplished once the above double wythe wall was removed. The mortar between flanking voussoirs was raked out to loosen the keystone. The keystone was carefully lifted with a hydraulic jack and slate shims were installed to secure the stone in place.

Reconstruction of Double Wythe Brick Masonry Walls

It was determined that full reconstruction of the double wythe walls bearing on the east elevation cavity walls above the arched windows was required. In order to provide sound salvage brick for replacement of damaged brick throughout the building, reconstruction plans included rebuilding the interior and exterior concealed wythes with new 55 MPa Lantz Tapestry Red bricks manufactured by Shaw Brick Ltd.

Prior to brick removal, a temporary wood stud wall was constructed bearing underneath the roof joists to the attic floor joists at the interior location. It was necessary to remove the sheet metal cornice to access the exterior wythe, and to remove all of the wood soffit framing which had been mostly deteriorated. Accurate records of the wall details, especially at the frieze, were documented and photographed prior to brick removal. Bricks at the underside of the roof joist bearing block in the first few courses were removed with hand tools, but bricks in the subsequent courses could be removed by hand. The header course tying the two wythes together was observed to contain mostly cracked brick, as the wythes had diverged from each other. Pilasters were removed, and observed not to be integrated into the wall, indicating they were later constructed to help support the outward deforming walls. Once brick removal was complete, loose brick at the top of the exterior wythe of the cavity wall were reset to form a solid substrate for the reconstructed walls.

The existing lateral support spacing for the attic floor of 2740 mm (9') exceeded the required maximum spacing of 2400 mm (7'-10") as prescribed in Clause 16.4 of CSA S304.1-94 (CSA 1994). To exceed this requirement, 400 mm (16") long double L127x127x8 angles were designed and connected to each floor joist. Anchorage was provided by connecting the angles to the floor joists by staggering four 9.5 mm (3/8") lag screws on each side, the angles were tied to the inner wythe adjacent to the cavity by drilling 19 mm (3/4") holes to place 190 mm (7-½") long 16 mm (5/8") threaded rod with Ramset Ceramic 6 epoxy, and slotted grooves were placed on the double angles to be connected to the double wythe wall with conventional rectangular masonry ties. Brick closure over the cavity was removed for the placement of these angles, and the previous flat bar lateral supports were removed.

Prior to the wall reconstruction, steel studs were installed between every other roof and floor joist at the interior location to provide support for the new soffit framing lumber. Rectangular masonry ties were placed at the mid-height of the studs to connect to the newly reconstructed wall. Steel channel shaped lateral supports for the top of the reconstructed walls were fastened to the underside of the wood bearing block with lag screws at a spacing interval of 1.2 m (4'). At this time, attic ventilation improvements were performed by removing the brick closure above the bearing block to the underside of the roof sheathing was removed, and ventilation ducts were installed in between roof joists to the above enclosed attic level.

The indented frieze panel, dentil and corbelled ledger courses were reconstructed with the original bricks using the prescribed lime mortar as illustrated in Figure 4(a). Bricks were pre-soaked prior to reuse. The interior wythe and concealed exterior wythe (Figure 4(b)) were constructed with new brick using Type N mortar with mix proportions as specified by CSA A179-94 (CSA 1994). To be conservative, the lime mortar was used in between courses of original and new brick. The wood nailer block for the sheet metal soffit that was previously embedded into the course above the corbelled ledger course was replaced with continuous 2x6 lumber anchored with threaded rods embedded into the masonry with toe nailed perpendicular 2x4 lumber surmounting the ledger course. The wythes were tied together using 9 gauge continuous truss type galvanized steel bed joint reinforcement, spaced vertically every 3 courses. Passages were left open in the walls for the soffit framing during reconstruction while the masonry ties from the studs were anchored to the wall. Soffit vents were installed into the sheet metal to provide functional attic ventilation to assist in preventing further extensive ice accumulations.

(a) (b)

Figure 4. Reconstructed exterior wythe at (a) exposed frieze and (b) concealed area behind cornice.

CONCLUSIONS

The restored east and south elevations are illustrated in Figure 5. Recommendations for improvements or changes to materials used would be as follows: 1) The lime mortar should be changed to a Type K as specified by CSA A179-94 (CSA 1994) with proportions by volume of 1 Portland cement : 3 lime : 12 sand with the same 28 compressive strength of 0.5 MPa. The lime mortar takes approximately 3 days to initially set and gains compressive strength over several months, which is not practical for use under rushed contractual obligations. Several mortar joints were accidentally washed out during cleaning. The Type K mortar has the advantage of a quicker initial set with moist curing that would be less susceptible to damage. However, the mortar should be tried on a test panel to ensure the cement does not cause efflorescence to occur in the masonry. 2) Repointing the south wall by cash allowance has caused the wall to appear aesthetically unpleasing. There were three distinct bands of eroded mortar that required repointing, possibly caused from weak mortar batches during original construction, and few other locations of spot repointing. Also, a 915 mm (3’) return in the southeast corner was also repointed. In any circumstance, the mortar does not blend with the original mortar perfectly, and where 50% of the wall was repointed in total, the remaining portion should have received the same. In comparison, the east elevation that was completely repointed appears undisturbed and perhaps what the masonry may have resembled a century ago. 3) Although there are no visual deformations to the south elevation, remedial cavity wall ties should have been installed to preserve the integrity of the wall.

(a) (b)

Figure 5. (a) East elevation and (b) South elevation, following restoration.

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