10th Canadian Masonry Symposium, Banff, Alberta, June 8 – 12, 2005

RESTORATION & STABILIZATION OF A DAMAGED & DETERIORATED CHURCH TOWER

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ABSTRACT

A case study is presented which focuses on the development and implementation of a restoration strategy that attempted to stabilize and restore durability to a severely deteriorated and damaged church bell tower. Investigations had confirmed that extensive lateral movement of buttress stone masonry units had occurred and a restoration strategy was therefore required which could restore durability to the structure while permitting ongoing movement to be better accommodated. The various stages of the restoration strategy are presented, including stabilization, strengthening and repointing of the masonry. Details of some of the limited rebuilding work are also presented, together with waterproofing, flashing procedures and other ancillary work.

KEYWORDS: church tower; helical ties; repointing; restoration; stabilization;

INTRODUCTION

The severe blizzard that hit the Canadian Atlantic Provinces during February 2004 was strong enough to dislodge the 90-year old First Moncton United Baptist Church's bell tower copper roof. For a short while it hung precariously over one side of the tower, buffeting against the stone masonry. During the temporary re-roofing project that followed, extensive damage was noticed for the first time - not only within the obvious areas of impact, but widespread throughout the upper levels of masonry and particularly within the four corner buttresses. A preliminary visual investigation using a 24.m (80 ft) boom truck confirmed that extensive movement of dimension stone masonry units had occurred - obviously over many years. Immediate concerns regarding stability and structural integrity led to the installation of temporary strapping at several levels around the exterior perimeter of the tower. Subsequent investigations included detailed visual examinations, the use of ground penetrating radar (GPR) from the interior to determine the extent and nature of any hidden damage, and tensile strength testing of both the exterior sandstone masonry units and the double-wythe back-up clay brick. Further information on GPR can be found in literature [1 – 6]. A limited number of openings were also made from the interior to confirm the nature of the masonry assembly construction. (For a view of the tower, please see Figure 26, after Conclusions.)

It was considered likely that the excessive lateral movement was caused by the infiltration of rain-water into cracks - the cracks having first been caused by shrinkage, differential settlement and/or movement from temperature change, wind-loading, etc. Formation of ice and the subsequent development of stresses during expansion may have then contributed to the excessive movement that had taken place – up to almost 25-mm (1.0 in) at the upper-most levels within the corner buttresses (Figure 1). A major concern was the evidence that two of the four keystone units within the upper louvered window lintels had become dislodged (Figure 2). Although it was impossible to determine whether this was the cause or the result of the movement process, it was considered likely that lateral movement of masonry units would have been increased as a result of any lateral thrust imposed on the buttresses by the dislodgement of the keystones.

Figure 1 - Evidence of considerable lateral movement within buttresses.

Figure 2 - One of the dislodged keystones.

An inspection of the interior revealed a vertically oriented step-crack (Figure 3). The crack aligned with the exterior northeast buttress at the church roof eave level and it was believed that its occurrence was due to reactions to the exterior movement described above. An inspection of the round windows on each elevation, as well as the surrounding masonry, revealed that moisture was penetrating open masonry joints, often bypassing poorly installed flashing details. It was also evident that water was entering through gaps around the window frames (Figures 3 and 4).

Figure 3 - A step crack within the interior aligned with the exterior buttress joint.

Figure 4 - Evidence of water penetration at several locations.

Rainwater had obviously been gravitating between the outer and exterior wythes, thoroughly saturating the upper levels of the tower masonry assembly and ultimately freezing during the winter months. This resulted in deterioration of the interior brick and, in particular, contour scaling of the exterior rock-faced finished window surround (voussoir) sandstone units - many of which had been improperly fabricated for their bedding plane (Figure 5 and 6).

Figure 5 - Evidence of moisture saturation on the interior.

Figure 6 - Evidence of contour scaling and damage to voussoir stones.

An unusual form of damage to the masonry above the louvered windows was also evident within the interior, the nature of which indicated that a lateral inward thrust had occurred at some time (Figure 7). This event could have occurred as a result of lateral movement of the buttresses, the dislodgment of the keystones, or the impact of the copper roof as it pounded against the exterior masonry. In addition, the wooden joists that supported the middle level floor were badly deteriorated due to repeated wetting/drying actions, with at least one of the joists having become detached. The suspended floor deck was also in a poor and potentially dangerous condition (Figure 8).

Figure 7 - Evidence of an inward lateral thrust of the masonry.

Figure 8 - Evidence of deterioration to one of the wooden floor assemblies.

INVESTIGATION

The results of the GPR evaluations indicated that there were very few concerns regarding the current stability of the masonry assembly (Figure 9). However, the tests did indicate the presence of moisture within the masonry assembly - particularly below window units - and the location of cracks could also be determined. The only hidden damage that could be detected was within the area where impact from the copper roof could have been expected to cause damage.

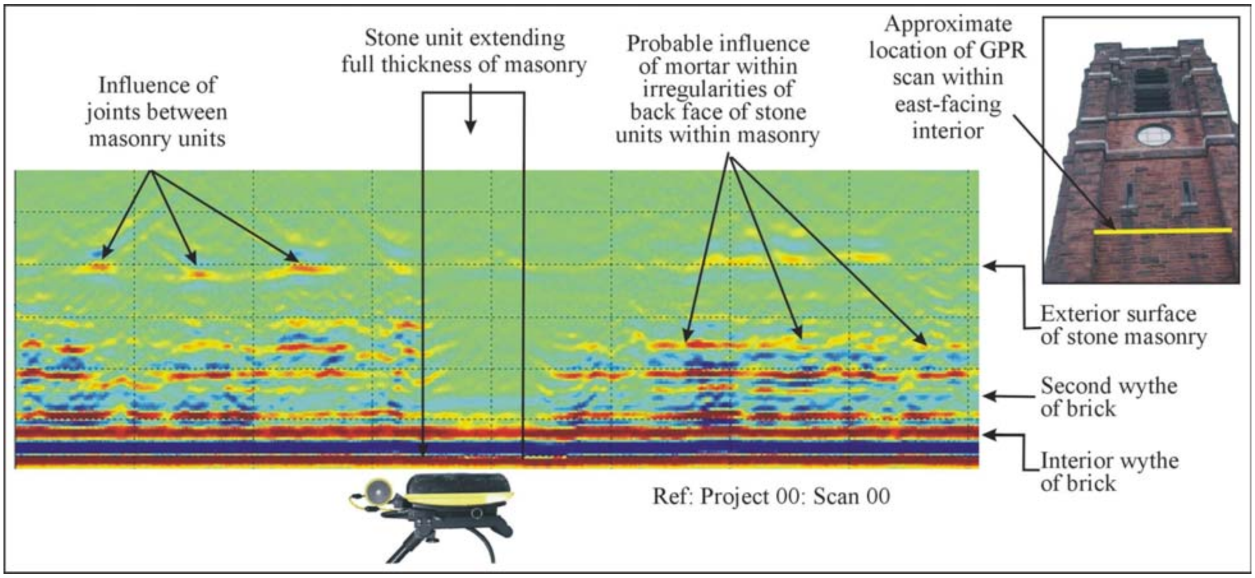

Figure 9 - Example of information provided by the GPR investigation.

The tensile strength testing indicated that satisfactory pullout strengths could be developed (Figures 10 and 11). However, it was determined that lower results could be avoided by installing the ties at 45-degree angles to prevent terminating the ties within the critical embedment length in the mortar joints. Typical results were in the order 4.0 to 6.0 MPa (600 to 1000 psi) when installed through brick and 7.0 to 10.0 MPa (1000 to 1500 psi) when installed through stone.

Figure 10 - Tensile strength testing of the masonry ties

Figure 11 - determining pull-out strength of masonry ties.

RESTORATION PHILOSOPHY

To provide an understanding of the reasoning behind the restoration strategy that formed the Scope of the Work, the following restoration philosophy was established and included within the contract documents.

"Although primarily a place of worship and community for its congregation, the First Moncton United Church building is an architecturally significant structure which is classified as an historic property. In addition, for the general population of Moncton, the church bell tower is and has been a familiar and instantly recognizable landmark. It is the intent of the restoration strategy that the work to stabilize, restore and preserve the damaged and deteriorated bell tower structure conforms to the requirements of the City of Moncton Heritage By-Law - the major objective of the latter being to preserve to the extent possible the original character of a building. However, the challenge to the design of the restoration strategy - and the basis of this philosophy - is to achieve the stated objective while returning the tower to a condition that can adequately resist weathering actions and permit the building to accommodate stresses that would otherwise develop during natural movement caused by extreme changes in temperature, excessive wind-loading, etc. It is obvious that the tower is currently not in a durable condition - nor is it able to adequately accommodate natural movement stresses."

RESTORATION STRATEGY

It had been previously recommended by others that at least partial masonry removal and reconstruction of the tower was necessary and that this would have cost at least C$0.75 million. However, the results of the investigation and visual assessments indicated that stabilization and restoration of the masonry was possible. The final cost for stabilization and restoration work amounted to under C$0.40 million, including professional fees and the cost of the investigation. However, it was also considered essential that the restoration strategy should not only address the result of the damage and deterioration but also deal with the major cause of the distress - the inability of the tower to adequately accommodate movement.

The first stage of the restoration strategy addressed the problem of how to permit a limited amount of movement to continue to take place – while preventing further damage being caused to the masonry. The devised strategy included the design and fabrication of an arrangement of steel ring beams attached to each wall section at four locations within the tower. The beams were secured to the interior masonry assembly using masonry bolts with their anchorages embedded within the exterior stone wythe. The bolts were sleeved at their centre portions to facilitate the development of the desired tension upon tightening. Fabricated steel brackets were then attached to the corners of the interior walls to align with the interface between the buttresses and the walls on the exterior and the beams were secured to the corner brackets. The beams and brackets were designed and fabricated with a "sliding bolt" arrangement that permits some controlled lateral movement of the buttresses to take place (Figure 12). A cement-based mortar had originally been used within the full-height of vertical joints at the interface between the buttresses and the tower masonry walls. To better accommodate movement, the mortar was removed and the joints subsequently sealed with a mortar-colour matching elastomeric joint sealant (Figure 13).

Figure 12 - Sliding beam and anchorage arrangement.

Figure.13 - Vertical joint sealed with an elastomeric joint sealant.

Helical stainless steel masonry ties were then installed at 600 mm x 400 mm (24 in x 16 in) spacings within the interior of the three levels to embed within the exterior wythe of sandstone masonry units (Figure 14). The profile and limited flexibility of the ties permits a more composite action to take place across the multi-wythe masonry assembly without excessively increasing rigidity (Figure 15). The ties were also installed within buttress stones to stabilize them against further excessive movement, again without excessively increasing rigidity Figure 16). The ties were installed at 45-degree angles within each buttress stone above the church main roof level and thus, each unit was "stitched" to the adjacent or underlying masonry unit.

Figure 14 - Installing ties from interior.

Figure15 - Helical tie.

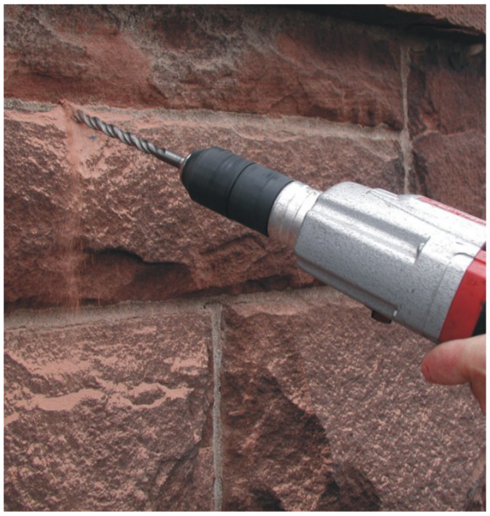

Figure 16 - Installing ties from exterior through buttress stones.

The deteriorated mortar joints were then cut-out and repointed with a prepackaged Type N mortar containing “moderately hydraulic” lime. In recognition of traditional heritage structure restoration philosophies, the repointing mortar did not contain a pigment, although the tooling and jointing styles were designed to match the original. It is anticipated that the repointing mortar will eventually weather to more closely blend with the original colour.

The sandstone voussoir units around the round windows and the masonry units within the sections of wall between the buttresses were removed and rebuilt (Figures 17 and 18).

Figure 17 - Removing a voussoir stone.

Figure 18 - Lowering one of the voussoir stones to ground level.

Rebuilding the sandstone units from around the windows presented challenges in providing support to the remaining overhead masonry and a combination of temporary and permanent shoring and bracing techniques were used for this purpose. (Figure 19).

Figure 19 - Examples of temporary and permanent shoring used to support the overhead masonry during masonry rebuilding work.

The replacement stone was sourced from a recently opened quarry near Sackville, NB and fabricated a few miles from Moncton (Figures 20 and 21). Laboratory testing proved the suitability and quality of the replacement stone which blended well with the original masonry – the latter having been classified as consisting of a "Sackville Red Sandstone".

Figure 20 - Cutting quarried stone into slabs prior to shaping and rock face dressing.

Figure 21 - Fabricated voussoir stone units ready for shipment to the church.

After the masonry rebuilding work was completed, new custom-fabricated round windows were installed (Figure 22). In view of the likelihood that future timely re-painting and maintenance would be difficult to assure, it was decided that the windows should be constructed from anodized aluminium. To eliminate previous problems with snow build-up and moisture penetration through window frames, the window units were positioned almost flush with the exterior masonry. The remains of the old roof and its temporary replacement were removed and a new deck constructed, waterproofed and flashed (Figure 23). A watertight hatch was installed and a new improved drainage system installed.

Figure 22 - New round windows installed within the reconstructed masonry.

Figure 23 - Waterproofed new deck with watertight hatch.

To relieve the lateral thrust loads on the buttresses, the dislodged keystones were jacked back into their original position and the joints repointed (Figure 24) The jacking operation avoided considerable masonry re-building work that would otherwise have been required to re-position the keystones. The deteriorated floor was removed and a new floor constructed with steel angle beams that were bolted to the interior masonry to provide more durable support and better load distribution (Figure 25).

Figure 24 - The dislodged keystones were repositioned.

Figure 25 - The newly installed floor with its steel angle beam support.

The new floor surface was waterproofed by the application of a thin-set pedestrian traffic urethane-based membrane system. The louvered window sill units were completely flashed with lead-coated copper to correct original moisture infiltration problems through horizontal masonry joints. Finally, new steel ladders and sealed hatches were installed to provide easier access to each level and the roof.

CONCLUSIONS

Prior to the detailed stabilization and restoration project, the First Moncton Baptist Church bell tower was in an advanced stage of deterioration. Lateral movement of buttress stone masonry units and serious cracking had seriously compromised the tower's structural stability. However, due to the dedication and commitment of the church's congregation and their Board of Trustees, the masonry structure has been restored and stabilized to a durable condition. Moreover, it is now better equipped to withstand the extremes of Canada's climate and accommodate the movement that previously had caused considerable damage to its components.

ACKNOWLEDGEMENTS

The author would like to thank the Board of Trustees for the First Moncton United Baptist Church for providing permission to use the stabilization and restoration of their beautiful church as a case study (Figure 26).

RESTORATION TEAM

The project was carried out by the following restoration team:-

Owner: First Moncton United Baptist Church, Moncton, NB
Prime Consultant: PJ Materials Consultants Ltd., Guelph, ON
Structural Engineer: Valron Engineers Inc., Moncton, NB
Architect: Andrew McGillivary Architect Ltd., Moncton, NB
General Contractor: Penniac Construction Ltd., Ammon, NB
Masonry Contractor: Jones Masonry Ltd., Harvey, NB
Stone Fabricator: Smith Cut Stone & Quarries Ltd., Shediac, NB
NDT Testing: Tekron Services Inc., Mississauga, Ontario

Figure 26 - The restored and stabilized bell tower

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