 Practical Case Study: Mortar Conservation for the Connaught Building, Ottawa, Ontario, Canada

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Abstract This paper refers to a case study, the Connaught Building, a heritage classified building constructed between 1913 and 1916 in Ottawa, Canada. The following issues will be discussed; the philosophical approach for conservation of masonry in Canada based on the Federal Heritage Buildings Review Office of Canada (FHBRO) Code of Practice by Public Works and Government Services Canada (PWGSC), the condition of the Connaught Building masonry prior to the conservation project completed between 1996 and 2000, the conservation philosophy followed during conservation, issues encountered during design and construction, the importance of the production of accurate record documents and maintenance manuals, the program of monitoring of stone parapets for thermal movement performed by Heritage Conservation Directorate (HCD) of PWGSC, current findings of masonry condition in 2008/2009, and maintenance work currently being executed on the building. The study will conclude with lessons learned and on-going work being carried out in Canada to further improve the work of heritage masonry conservation.

1 Introduction

The Connaught Building (see Fig. 1) is a “Classified” federal heritage building, constructed between 1913 and 1916 to the designs of Chief Architect David Ewart. Located in a prominent location in downtown Ottawa, and built to house the new Ottawa Customs Examining warehouse and offices for the Department of Customs and Internal Revenue, the building continues to be occupied by Revenue Canada. Under the leadership of Sir Wilfred Laurier, the government of the day began numerous projects to begin the transformation of Ottawa from a city
dominated by the lumber industry into "The Washington of the North". The heritage character of this property is defined by the exterior elevations which were designed in the modified Tudor Gothic style. The symmetry of the massing reflects an underlying Beaux Arts layout. Various elements of its architectural design contribute to define the heritage value such as; articulated stonework, buttresses, corbelling, niches, carved embellishments and elaborate window and door surrounds. The wall finish is primarily of sandstone with granite plinth detailing.

The building is a seven storey steel structure with a mechanical penthouse above. The steel is encased in concrete with concrete floor and roof slabs. The exterior walls consist of stone cladding, with multiple wythes of brick backup, and terra cotta with plaster on the interior. The stone cladding is of varying thickness keyed into brick backup in various locations. Below the third floor level, the stone exterior is Ashlar Granite, while above this level consists of Nepean and Wallace Sandstones. The scotch work is Nepean Sandstone. The quoins, window surrounds, ledge stones, buttress capstones, and all stone above the roof ledge, such as parapet and turrets, are Ashlar Wallace Sandstone.

There are no control joints on the building. Therefore, at each change of direction on the exterior masonry, there is an opportunity for movement to occur in the building without damaging the masonry. The large windows and doors in the elevation provide natural breaks for masonry walls, and these points are also a way for the building to move. The layout and the perimeter parapet walls present challenges in conserving and maintaining the historical masonry façade. These challenges, lessons learned, and on-going work will be discussed further throughout the paper.
2 The philosophy for conservation of masonry in Canada in the 1900’s

The original mortars used to construct the Connaught Building were lime based mortars, with lime as the principal binder. However, in the 1920’s the cement industry was developed. Due to this, the regular practice of repointing evolved to raking out the outer layers of the existing mortar for 12 to 25mm and replacing it with cementitious mortar. The cement base mortars were seen to be stronger and more durable, and at that time there was no experience with the consequences of that decision. Results in the short and long term were shrinkage, debonding, damage to adjacent stone, and build up of salts in stone adjacent to repointed joints. No attempt was made to fill voids deeper in walls, or remove and replace deteriorated or debonded mortar deeper within the joints, mainly because maintenance was done when a failure was evident. This practice appears to have been common around the world.

There was no site quality control on repointing work. Correctly designed details were not always implemented in the construction processes. Lack of curing was common, which lead to premature shrinkage and failure to bond. Proper maintenance was often lacking, leaving joints open, which is detrimental in the Canadian climate. Some additional poor conservation practices include: stone damage during removals, use of incompatible materials such as caulking to seal joints, application of mortar over stone face, and insufficient removal of existing mortar. In conclusion, in the early 1900’s the change of mortar formula was not assessed properly, and this issue occasioned a negative impact on historical masonry.

3 The philosophy for conservation of historical masonry by PWGSC

All classified buildings must follow the code of practice provided by FHBRO that states less intervention leads to increased value of heritage character. Therefore, the minimum intervention is the preferable option for any action on a classified building. In many cases, however, when maintenance has not been done, the degree of intervention required to improve the condition of the building may be higher.

Fig. 2 demonstrates the relationship between intervention and conservation of heritage character.
The Standards & Guidelines for the Conservation of Historic Places in Canada is published by the Government of Canada “to provide sound, practical guidance to achieve good conservation practice; to develop a pan-Canada set of Standards and Guidelines; to assist people who intend to apply for government financial incentive for conservation”[1]. This guideline also promotes minimal intervention for conservation of any heritage building.

4 Mortar research in Canada in 1990’s

During the early 1990’s a series of buildings in the National Capital region were assessed by PWGSC, especially those located in the Parliamentary Precinct. Following this review, it was felt necessary to develop a mortar research program. This was initiated in September 1994, with a primary objective was to identify durable repointing mortars which would be practical in their application and compatible with the specific traditional stone masonry. This research program was the most comprehensive on a Canadian level. Physical and mechanical properties, as well as frost resistance, were combined under the same program. [2] The main idea was to simulate the Ottawa climate by replicating the rainfall history from the particular façade of the wall, and recreating 25+ cycles of freeze thaw. This research was a collaboration among PWGSC, the Institute for Research in Construction (IRC) and Suter Consultants Inc. (SCI). The research program focused primarily on Nepean and Ohio sandstones.

In conclusion, two mortar mixes were found adequate for Canadian climate: Cement:Lime:Sand = 1:2.5:8 and Cement:Lime:Sand = 1:1.6 with air entrainment agent (AEA). AEA was a great advance in frost resistance, however it was difficult to control on site. Therefore, PWGSC, with NRC, started a group of interested professional manufacturers and practitioners to meet and discuss issues related to heritage masonry in Canada. From this exchange of ideas, the manufacturers of lime created type “SA” hydrated lime that solved the problem of adding air entrainment by drops on a construction site.
Since 1995, PWGSC and their partners have undertaken a major program to study several elements that impact historical masonry. [3] The close collaboration between conservation professionals, the Heritage Masons at PWGSC, and the NRC and their mortar researchers, was the ideal way of working. Issues which arose on-site were immediately addressed with a study in the laboratory; the results were then directly applied, and monitored over time. One of the main gains of this association was the introduction of the Vicat-cone test on construction sites as a way to test the workability of the mortar immediately after preparation. This test is related to the compressive strength test, therefore the immediate result on site can predict the compressive results of the mortar.

5 **Condition of the masonry prior to 1996 Conservation Project (The Connaught Building)**

Observed conditions included all of the poor practices noted in Part 3, as well as inadequate repairs on stones, use of non compatible materials, and cementitious patches on stone spalls. These issues all contributed to damaging the exterior masonry of the building, in addition to damage caused by the severity of the Canadian climate. There is an 80°C variation in temperature throughout the year which causes severe thermal movement of stones. When the mortar in stone joints is debonded, either due to thermal movement or lack of curing, water will permeate the joints. With just one change of season, the effects of freeze/thaw will cause the saturated joints to open wider. Additionally, heavy usage of salt during winter in Canada causes severe damage to mortar and stones. This damage not only occurs at grade level where the salt touches, but also occurs on higher levels of buildings as a result of evaporation of salt water.

The lack of control joints on the building results in excessive opening of vertical joints next to quoins and around window jambs. Infrared Thermography on the Connaught Building showed extensive air leakage around windows, carrying moisture through walls. There were also major problems with air leakage on high turrets due to stack effect. Lastly, changing mechanical conditions inside the building over 100 years has caused greater negative pressure which drew more moisture into masonry.

6 **Conservation philosophy carried out on the Connaught Building between 1996 and 2000**

Starting in 1996, a conservation program of the entire building façade was initialized by PWGSC, based on their philosophy for conservation of historical masonry by PWGSC.
Unlike previous common practices, the importance of full depth repointing was highly recognized. Full depth repointing was performed to eliminate deep voids in the mortar joints, with the goal of minimizing moisture in the wall and the resulting damage due to freeze-thaw. Solid full depth mortar joints improve both seismic and thermal performance of a masonry wall as mortar acts as liaison between masonry units. This also prevents masonry units from rotating due to uneven filling of joints.

Cement lime mortar 1:3:9 was selected based on PWGSC testing in 1990’s. It balances the need of using a weak lime mortar as in the original construction, with the greater durability provided by the cement to resist the severity of the climate. The lime provides the necessary flexibility and bond strength, while the cement provides the durability. Hydrated lime Type SA was used to provide air entrainment, an important factor for Canadian climate conditions. An angular aggregate was sourced to provide better strength and performance of mortar when using hydraulic limes. Curing of mortar was an area of contention until the NRC/PWGSC research demonstrated that the Canadian climate requires at least three (3) days of wet curing to keep moisture in the lime based mortars and allow carbonation to occur.

Proper architectural details such as flashing are necessary to protect upward facing ledge joints, which require high maintenance in our severe climate due to exposure, and to prevent the surface deterioration of sandstone in exposed locations, such as ledges and parapet capstones, due to constant wetting and drying.

One of the main factors contributing to the success of the masonry conservation was the site quality control of the work. One of the main issues was the need to carry out site review at each stage of repointing, as joints are raked out, backpointed and finishpointed, to ensure proper execution of work. Completion of mortar testing through all stages of work is also important to maintaining quality control.

7 Accurate record documents/maintenance manuals

The need to produce record documents and maintenance manuals is critical for the long term maintenance of any facility, and especially for heritage structures. These documents reflect any changes to the original design and record all interventions which have been carried out. More specifically, they provide information on the materials used in the construction/intervention. These materials can then be monitored for future performance and compatibility. This information is then available and provides clear direction for future maintenance/intervention.

The implementation of Building Information Modelling technology (BIM) will provide a facility management tool to make existing design information more
readily available, to better monitor how materials perform, and to improve management of building maintenance.

8 Subsequent monitoring

Further monitoring by John G. Cooke & Associates Ltd. in 2001-2002 and yearly from 2007 to the present, has revealed that the intervention work carried out from 1996 to 2000 is performing well, with the exception of failed mortar joints on all parapets and turrets above roof level, around large window openings, and on prominent water shed details. The reason for these failures is consistent with the research discussed below.

9 Monitoring of stone parapets for thermal movement

Research was done on the parapet to determine the amount of thermal movement experienced by the wall. Findings from the monitoring readings to date indicate that movements exhibit cyclical trends with respect to both seasonal and daily temperatures.

The following conclusions from the monitoring program were made:

- Both southwest turret and parapet movements are in direct correlation with exterior temperature variations.
- Movements between the turrets and the parapet wall occur independent of each other and at different rates, contributing to cracking and stone displacement.
- Turrets show general overall movement in the east-west direction. During the summer months the turrets move inward, while the parapet wall shows a slight increase in length. The movement of the turrets corresponds to the movement of the thickness of the turret wall between interior brick and the exterior stone. Exterior cracks between the turret and the parapet wall become narrower during the summer months while turret interior cracks become larger during the summer months.

Masonry joints which are repeatedly debonding can have a flexible joint filler introduced to allow movement. One of the areas with the most extreme thermal movement noted is on the Southwest turret. This turret is unheated, therefore heating throughout the winter is recommended.

10 Maintenance work currently being executed

Maintenance work is currently under way on the areas of joint failure noted above. Based on the observed performance of our previous interventions, we are
following the same procedures and using the same materials with our ongoing maintenance work. The record/maintenance documents are being updated to reflect these new interventions.

11 Conclusion, lessons learned

In conclusion we consider the following points to be of main importance:

• Understand the Heritage Values of a building and choose the appropriate intervention;
• Understand how the building works as a whole and in particular zones;
• Develop an approach that follows accepted conservation practices;
• Carry out strict site quality control (evaluation of the masons before starting the project, Vicat cone test, curing techniques);
• Look for more support if there are gaps of knowledge in existing research;
• Define practical and easy ways of implementing the tasks on site;
• Monitor results and revise approaches if negative results are obtained;
• Develop a maintenance manual;
• Re-visit the building at least once a year in spring to monitor conditions.

12 References

3. List of research on several elements that impact historical masonry:
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