John Stewart - Charles Costain - Keith Blades

EXAMINATION AND TREATMENT OF SALT RELATED SPALLING, PARLIAMENT BUILDING, OTTAWA

Introduction

In 1858 Queen Victoria selected Ottawa as the permanent capital of Canada, ending the system whereby the capital alternated between Quebec City and Toronto. Accordingly, a competition was set for the design of three Parliamentary Buildings to be constructed in Ottawa. The Centre Block where Parliament sits, is the principal of these buildings and is flanked on either side by two Deparmental buildings, the East and West Blocks, which were designed to house the Privy Council, the Office of the Governor General and all of the various Government departments of the time. The buildings were constructed between 1859 and 1867, " in a plain, substantial style of architecture, the masonry to be coursed hammer dressed, with neatly pointed joints, cut stone quoins, window dressings, cornices and entablatures " (1). Thiy style was referred to as " Civil Gothic " by the architects of the time [1], and later as " Picturesque Eclecticism " (2).

The East Block occupies a unique position in Canada's architectural history. Of the three Parliamentary buildings, only the East Block remains today in a similar form to that at the time of its completion in 1867. The Centre Block was destroyed by fire and subsequently rebuilt and the West Block has been substantially altered by major interior renovations. A recent restoration program (1974-1980) has restored the interior of the East Block to that of the 1880's and the building once again serves as offices for Parliamentarians from the House of Commons and Senate.

At an early stage of the restoration work it was realised that major

[1] Thomas Stent and Augustus Laver, 1859.

problems existed to the interior masonry of the main entrance and architectural feature of the building, the south west tower (Fig. 1).

Construction of the South West Tower

The tower construction is comprised of massive loadbearing masonry walls that support a first floor entrance vestibule, a balcony at the second floor level, a masonry vaulted ceiling, three intermediate floors, a copper-clad timber roof and decorative wrought-iron cresting (Fig. 2, 3 and 4). The masonry rises some 50 metres above ground, and it is a further 20 metres to the top of the decorative cresting. The foundation walls are 2.4 metres thick and bear directly on bedrock. The total weight of the tower is estimated to exceed 5,500 tonnes.

Externally on the west and south faces, between the first and third floor level, arches spring from buttresses, tapering from 2.4 to 1.5 metres thick, to enclose infill panels 75 centimetres thick. Window and door openings, framed with secondary arches, penetrate these panels. Apart from these infill panels, all walls are constructed of inner and outer coursed masonry skins with a rubble filled core bedded in a weak sand: lime grout.

The exterior stonework is a combination if rock-faced, squared rubble walling and dressed ashlar. The latter is used for the quoins, surrounds to openings, and decorative features. Internally, dressed ashlar, which varies from 15 centimetres to 30 centimetres in thickness, forms the finish to the tower walls. Sandstone was selected for all of the visible stonework. The rubble work is in a local quartzitic sandstone and the ashlar is a siliceous sandstone from the Amherst beds in Ohio, U.S.A. The core material is principally waste limestone, (used elsewhere as an inner skin to masonry walls) and is local to Ottawa.

Identification of the Problem

As restoration neared completion and studies on the condition of the mansonry were completed, it became apparent that additional investigation and analysis work was required in the tower vestibule, where the ashlar was visibly deteriorating (Plate 1).

Externally, cracked and open joints in the stonework, particularly evident in the sloping surfaces of the buttresses, were repointed to prevent further ingress of moisture to the tower walls.

Internally, deterioration was widespread, the loss of surface exceeded

2.5 centimetres in a number of locations and spalling of the ashlar occurred at regular intervals.

Analytical Investigation

The flakes of spalling stone covering the walls had a layer of white crystalline powder on their underside. Samples of the subflorescence were removed and studied using the microprobe of a scanning electron microscope, which showed the presence of only silicon, sodium, and sulfur (only elements with atomic number greater than ten are detected by the instrument used). The silicon is due to the presence of small particles of sandstone, and the sodium and sulfur are present in the subflorescence. X-ray powder diffraction analysis of the subflorescence identified it as anhydrous sodium sulfate (Na_2SO_4).

In order to assess the size and scope of the problem it was necessary to determine the extent to which the walls were contaminated with soluble sulfate. To do this, sampling points were selected having an arrangement that would give the maximum coverage: twelve in damaged areas and nine in undamaged areas (Figs. 3 and 4). Dry cores were taken from each of the selected locations. Water lubrication was not used as this might have leached soluble sulfate from the cores.

These cores were split into ten centimetre subsamples, dried and crushed to pass a sieve with 150 μm openings. Further subsamples of these were leached with distilled water to remove soluble sulfate, filtered, and analyzed by the nephelometric technique of A.I. Vogel (3).

These values of sulfate concentration were plotted for each cores as a function of depth; four examples are shown in Fig. 5. Calculating the mean value for the sulfate concentrations of the cores from damaged and undamaged areas showed that the damaged areas had a higher average sulfate concentration than the undamaged areas. A plot of the mean levels of soluble sulfate for these two groups is shown in Fig. 6. The mean soluble sulfate content of all cores is 0.074%.

To find out how sensitive the ashlar is to attack by sodium sulfate, three cubes were cut from the sample cores and subjected to salt destruction tests[2]. Figure 7 shows the results of the test, in which the three cubes lost

[2] Specification C88 of the American Society for Testing and Materials, with the following modifications: 5 cm cubes of ashlar were immersed for 24 hours in the sodium sulfate solution, removed, dried at 110 °C for 24 hours weighed, and reimmersed. The end of the second heating was taken as the end of the first cycle.

between 28 and 47 percent of their weight by the fourth cycle. In addition, two of the blocks were structurally destroyed and all three had lost their original surfaces by the fourth cycle. This indicates the ashlar is sensitive to attack by sodium sulfate.

Discussion of the Analytical Results

The damage to the ashlar is due to the presence of sodium sulfate in the walls. The conclusion is based on the following facts: only sodium sulfate subflorescence was found in the walls, the damaged areas have a higher concentration of soluble sulfate than the undamaged areas, and the ashlar is sensitive to sodium sulfate attack. The problem is made more serious as the salt contamination is not localized on the surface; rather, it is distributed throughout the wall with a large reservoir of soluble sulfate at a depth of 20 to 75 centimetres in both the damaged and undamaged areas (Fig. 6). This means that while the spalling is a surface phenomenon, the salt causing it is located deep within the walls.

The most likely source of the sulfate is contaminated rainwater. The exterior sandstone of the East Block has layers of gypsum adhering to it resulting from the action of sulfuric acid contaminated rainwater[3] on the calcareous mortar of the pointing. This rainwater has penetrated the walls through the damaged pointing on exterior surfaces and over the years has built up the reservoir of soluble sulfate within the walls.

Proposed Treatment

To prevent further damage it is necessary to stop the strain on the surface of the walls resulting from the crystallization and hydration of sodium sulfate. This could be accomplished by removing the salt from the walls. This does not seem a practical solution, however, because the thickness of the walls would make leaching by poultice very slow and expensive, and the cost of dismantling and rebuilding to any depth is prohibitive.

The approach to stabilization that is being taken involves the removal of the other agent necessary for the transportation, crystallization and hydration of the sodium sulfate — namely water. Crystallization and subflorescence are caused by liquid water in the interior of the walls dissolving,

[3] Much of the sulfuric acid contamination of the local rain probably resulted from a sulfite pulp mill located one kilometre from the Parliamentary Complex. This mill was demolished in 1973.

transporting, and depositing the salt behind the surface. This water is allowed into the walls from damaged pointing. To stop this, the damaged pointing has been replaced, which should eliminate any further entry of water and allow the walls to dry. In time, a lowering of the water content should halt the capillary travel of liquid water and stop further subflorescence and spalling due to crystallization on the interior surfaces.

Damage due to the hydration of the sodium sulfate could still occur after the walls are dry due to a high relatively humidity in the sub-surface pores. This would be caused by the temperature of the walls being lower than that of the air in the interior of the building, thus decreasing the capacity of the air in the pores to hold water.

Sodium sulfate hydrates to the decahydrate ($Na_2SO_4 \cdot 10H_2O$) with an increase in volume of at least 200% (4) at a relative humidity of 73% (calculated from equilibrium vapour pressure at 13°C [5]). If after the walls are dry, the relative humidity in the first 30 centimetres of stone can be kept below 73% then no further hydration and spalling should occur. This can be accomplished by controlling the partial pressure of water vapour in the interior air by the use of dehumidification units.

At present the walls have six relative humidity/temperature probes inserted in sampling holes. These will be monitored twice daily for at least a year. It is expected that the walls will slowly dry out and the interior relative humidities decrease. Once this has occurred the sub-surface relative humidity will be constantly monitored and kept below 73% by dehumidification units.

It is hoped that the combination of good maintenance of the exterior walls and environmental control of the interior of the tower will halt any future spalling. If this technique is successful, then it will be applied in other areas of the Parliamentary Complex suffering from sodium sulfate attack.

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5. Hamad S. E. D., « A Study of the Reaction $Na_2SO_4 \cdot 10H_2O \rightarrow Na_2SO_4 + 10H_2O$ in the Temperature Range 0 to 25° C » *Thermochimica Acta*, 17 (1976), pp. 85-96.

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THEME: MATERIAUX

TITRE: EXAMEN ET TRAITEMENT D'EPAUFRURES DUES A LA PRESENCE DE SELS, EDIFICES DU PARLEMENT, OTTAWA.

RESUME:

L'Aile Est du Parlement d'Ottawa est l'un des édifices les plus marquants du patrimoine architectural canadien. Au cours de récents travaux de remise en état on a découvert de graves épaufrures sur les murs intérieurs de l'entrée principale, dans la tour du sud-ouest. Les auteurs traitent du programme de recherches qui a permis de diagnostiquer la cause de ce phénomène et présentent des recommandations en vue de la stabilisation des murs et l'arrêt des dégradations.

L'analyse chimique d'efflorescences prélevées sur les murs et de carottes prélevées en profondeur, pratiquée en liaison avec des relevés architecturaux de la tour, a permis d'attribuer ces épaufrures à la présence de dépôts de sulfates solubles amenés par la pénétration d'eaux de pluie contaminées. La méthode de stabilisation préconisée suppose un entretien régulier des surfaces extérieures des maçonneries et une surveillance des conditions atmosphériques à l'intérieur de la tour pour prévenir une répétition du phénomène.

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SUBJECT: MATERIALS

TITLE: EXAMINATION AND TREATMENT OF SALT RELATED SPALLING, PARLIAMENT BUILDINGS, OTTAWA.

SUMMARY:

The East Block of the Parliamentary Complex in Ottawa, is one of the most significant heritage buildings in Canada. Recent renovations revealed that two of the inner walls of the main entrance, the south west tower, are suffering from severe spalling. This paper discusses the investigative programme which identified the source of the problem and recommends ways to stabilize the walls and prevent further damage.

Chemical analysis of subflorescence and cores from the walls, combined with an architectural examination of the tower, identified the source of the problem as deposits of soluble sulfate introduced by the penetration of contaminated rainwater. The approach to stabilization which is being taken relies on regular maintenance of the exterior stone work and the control of the environment inside the tower to eliminate future damage.

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TEMA: MATERIALES

TITULO: EXAMEN Y TRATAMIENTO DEL DESCASCARAMIENTO RELACIONADO CON SALES EN LOS EDIFICIOS DEL PARLAMENTO DE OTTAWA.

SUMARIO:

El bloque oriente del Conjunto del Parlamento en Ottawa, es uno de los más importantes edificios patrimoniales de Canadá. Trabajos recientes revelaron que dos de los muros interiores de la entrada principal, en la torre sudeste, estan sufriendo un severo deterioro por descascaramiento. Esta ponencia trata del programa de investigación que identificó el origen del problema y hace recomendaciones sobre los métodos para estabilizar los muros y prevenir deterioros futuros.

El análisis químico de eflorescencias y núcleos procedentes de los muros, combinado con la inspección de los elementos arquitectónicos de la torre, permitieron identificar la fuente del problema, que era en el depósito de sulfatos solubles arrastrados por agua pluvial contaminada. La proposición que se adopta para estabilizar los muros se basa en el mantenimiento de la cantería exterior, y el control del medio ambiente en el interior de la torre, para eliminar los daños en el futuro.

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Предмет : МАТЕРИАЛЫ

Название : ИССЛЕДОВАНИЕ И ОБРАБОТКА НАБУХАНИЙ, ВЫЗЫВАЕМЫХ СОЛЯМИ, - ЗДАНИЕ ПАРЛАМЕНТА, Город ОТТАВА

Краткое Изложение :

Восточный блок Парламентарного Комплекса города Оттавы является одним из наиболее значительных наследственных зданий Канады. Недавно произведенные обновления показали, что в двух средних стенах главного входа и в южно-восточной башне появились крупные набухания. Авторы описывают программу изучений позволившую установить причину этого феномена и рекомендуют способы для стабилизации стен для предотвращения дальнейшего ущерба.

Химический анализ флюоресценции поверхности стен и образчики взятые из внутренности этих стен, вместе с их архитектурным исследовании признали, что причина всей этой проблемы это отложении растворенного сюльфата, вносимого загрязненной дождевой водой. Способ применяемый для стабилизации рассчитывает на регулярную поддержку внешней каменной обшивки и на улучшение условий внутренности башни в виду предотвращения феномена такого рода.

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TEMA: MATERIALI

TITOLO: ESAME E TRATTAMENTO DI SFALDAMENTI MURALI CAUSATI DA SALI. COMPLESSO DEL PARLAMENTO DI OTTAWA.

SOMMARIO:

L'ala Est del Complesso del Parlamento di Ottawa è uno dei più significativi elementi del patrimonio architettonico canadese. Nel corso di recenti lavori di restauro furono rilevati gravi sfaldamenti nei muri interni dell'entrata principale, nella torre di Sud-Ovest.

Il presente saggio tratta del programma di ricerca che ha permesso d'identificare la causa del fenomeno e dei vari metodi di consolidamento e di prevenzione consigliati per evitare ulteriori danni.

Le analisi chimiche delle efflorescenze e di alcuni campioni prelevati dai muri, insieme ad un esame architettonico della torre, hanno permesso di attribuire tali sfaldamenti alla penetrazione di acqua piovana contaminata.

Il metodo di consolidamento intrapreso fa affidamento sul regolare mantenimento delle superfici esterne delle costruzioni e sulla sorveglianza delle condizioni atmosferiche all'interno della torre per eliminare ogni possibile danno futuro.

Nobuo Ito

WOOD AS A MATERIAL FOR JAPANESE BUILDINGS

1. *The Kinds of Timbers*

Japan is situated in the temperate zone and has a mild, humid climate which has favoured the growth of abundant forests throughout the country, therefore wood has been the most important material for Japanese buildings throughout the ages.

The trees growing in Japan could be grouped into the broad-leaved and the coniferous trees. Of the two groups, the conifers have been used for the material for buildings, and among them, notably the Japanese cypress (Chamaecyparis obtusa Endl.). The timber of this tree has been treasured as material for buildings, since the olden days, because of its fine grain, beautiful texture, high durability and pleasant aroma. However, as it has become more and more difficult to be obtained, due to the uncontrolled felling throughout the ages, it has been replaced by the Japanese pine tree (Pinus densiflora Sieb. et Zucc. and P. thunbergli Parl.) since about the 14th C. A.D. Though the pine tree is a very good material as far as its durability is concerned, it easily exudes resin and suffers from attack by insect pests. Further, a straight timber could not be obtained easily by our ancestors with their still undeveloped technique, because this tree tends to form a sinuous stem unless in a favourable environmental condition.

Among the conifers, there is also the Japanese cryptomeria (Cryptomeria Japonica D. Don) which grows abundantly in Japan. Though this tree has been used since the olden days as a useful material for smaller objects because of its fine texture and softness which facilitates the workmanship, it has been considered unsuitable for buildings because of the doubt over its durability and its susceptibility to weathering. However, it can be found in some of the lighter buildings such as the tea houses of the *sukiyazukuri*