

CANADIAN NATIONAL WAR MEMORIAL RESTORATION

SPECIAL PROJECTS



PROJECT OUTLINE

The War Memorial is the second most important ceremonial site in Ottawa after Parliament Hill. Public Works required that the Cenotaph and plaza be restored, rehabilitated, and upgraded. Designated a “National Historic Site”, the stone arch cenotaph stands over 20m high. Through innovative engineering analysis, WSP verified the seismic performance of the monument allowing for restoration without compromising the heritage fabric. The site was restored and re-opened on time for Remembrance Day November 11th, 2016.

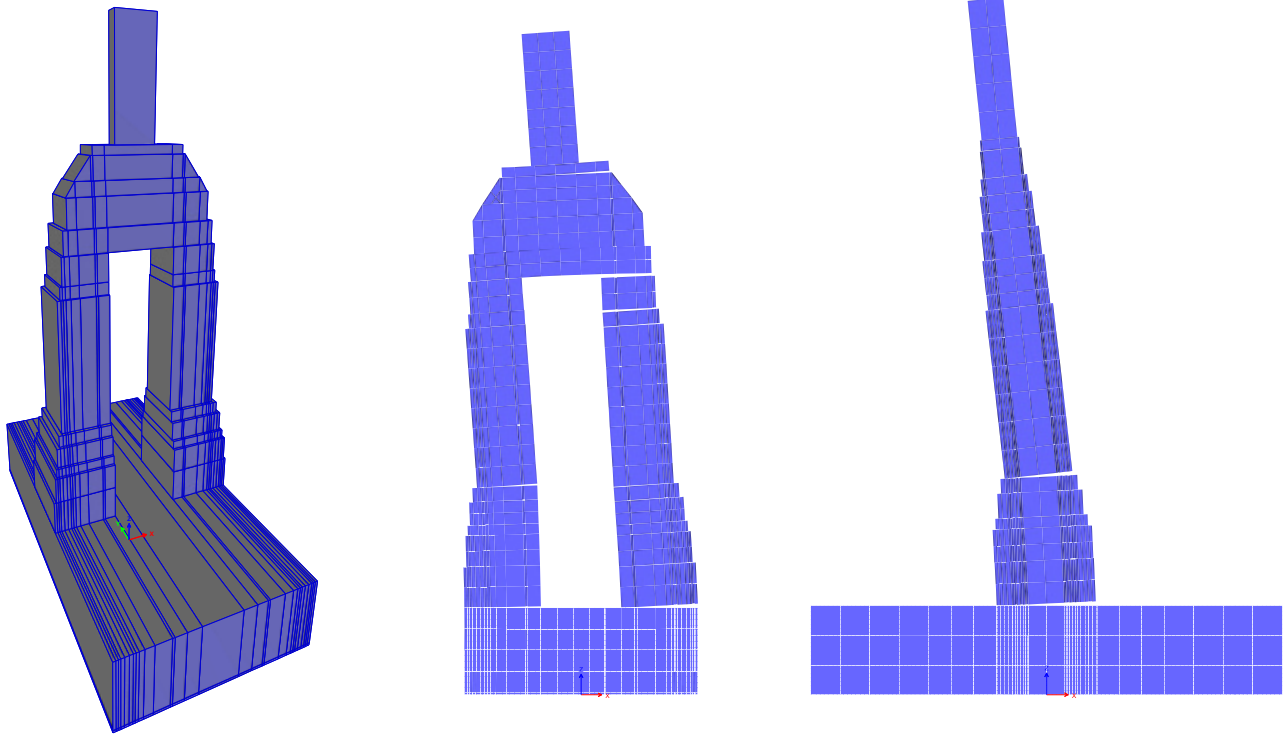
INNOVATION

Considered the second most important ceremonial site of the national capital, after Parliament Hill, the National War Memorial (NWM) stands at the center of Confederation Square in Ottawa. Built in 1937-1939 to commemorate the loss of Canadian lives in the First World War, the NWM consists of a central monument (designed by Vernon March) surrounded by a large paved plaza, and is the site of numerous ceremonial functions including the Remembrance Day ceremonies each year. In 1980, the Tomb of the Unknown Soldier was added to the site, making it not only a ceremonial site but a burial site. Confederation Square, as a whole, was designated a National Historic Site in 1984.

Ottawa is subject to moderate seismic hazard with a maximum credible earthquake of magnitude 7. The mandate from Public Works included a seismic evaluation of the Monument, proposing upgrade options to meet requirements of the National Building Code of Canada (NBCC), and developing structural rehabilitation details for the deteriorated landscaped podium slab.

The cenotaph structure consists of large individual granite blocks which are interconnected with vertical bronze pins. WSP employed innovative seismic modeling techniques to conduct multiple nonlinear time history analyses. Nonlinear gap elements were used to simulate the bronze pins at interface between the granite blocks. The gaps resisted shear, but not tension, thus allowing the stones to rock without sliding. The analysis demonstrated that the seismic performance requirements could be satisfied, without significant interventions into the heritage structure.

The structural engineering solution developed in response to the deteriorated slab supporting the plaza was divided into two phases. The first phase was to infill the existing void beneath the slab with low strength self-consolidating and shrinkage controlled concrete fill. The second phase was to construct a new durable slab to support the reconstructed stone pavers. The plaza rehabilitation was carried out with high performance structural materials particularly selected for durability and longevity, reducing the lifecycle cost of the restoration. Due to the WSP design, the project was completed in time for the November 11th Remembrance Day ceremonies.

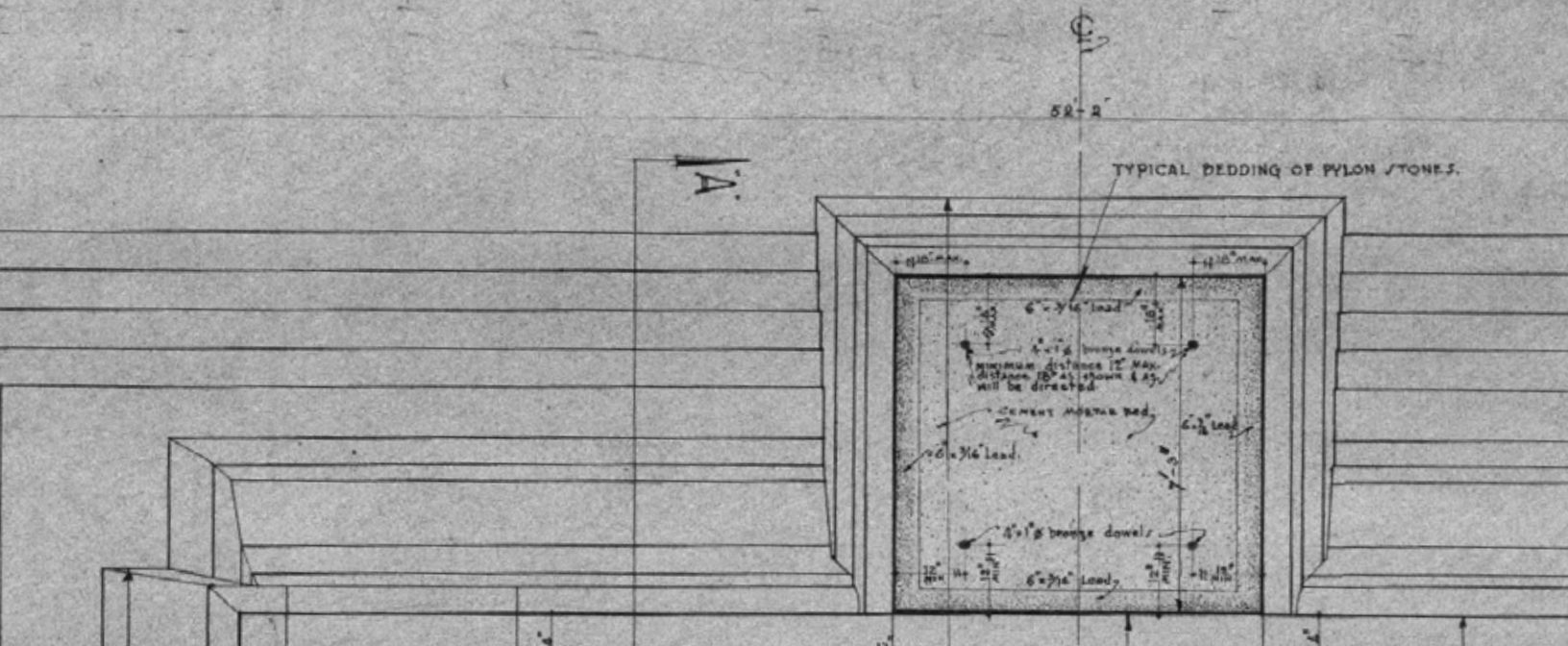
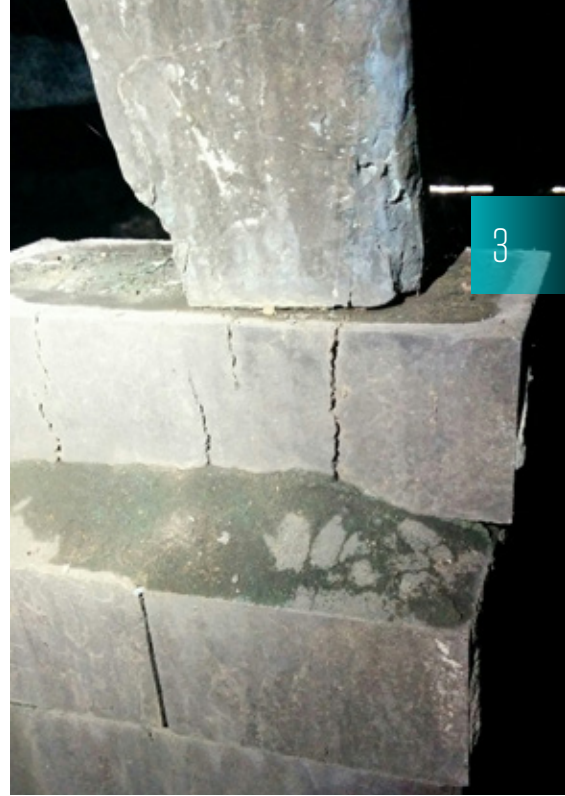


COMPLEXITY

Innovative modeling techniques were employed on the seismic evaluation of the historic and iconic Canadian NWM Monument.

Under seismic loading, it is expected that the individual stone blocks will exhibit a rocking behaviour. To capture the rocking behaviour of the granite blocks, the mortar joints were modeled as nonlinear gap elements interconnecting the finite element shell objects that represent the granite blocks. Gap elements typically transfer compression forces only, but in this analysis they were configured to transfer horizontal shear resistance only when subjected to axial compression forces. The bronze pins were allowed to resist shear when the joints opened up. Due to the nonlinear response created by the rocking behaviour of the individual granite blocks, a nonlinear time-history analysis was adopted. Analytical models of the

cenotaph were created using ETABS Nonlinear. The NWM was evaluated for seismic resistance based on the provisions of the National Building Code of Canada. The time histories run in this analysis (scaled to the seismic hazard in Ottawa) indicate that there was satisfactory performance of the heritage stone monument without needing significant or intrusive interventions. WSP was able to demonstrate that the monument is a stiff cantilever with a fundamental period of less than 0.2 sec. Allowing the analysis to include the nonlinear behaviour of the stone joints opening up, permitted the structure to absorb the seismic ground motion without experiencing structural instability. The opening of the stone joints was found to be less than 16mm, so the bronze pins could not become dislodged.



SOCIAL AND/OR ECONOMIC BENEFITS

WSP was able to bring significant value to this project on several fronts. The plaza rehabilitation was carried out with high performance structural materials, particularly selected for durability. WSP carried out a life cycle cost study for the plaza based on a 100 year life and determined that, despite the initial premium cost of the materials, the long term life cycle cost was less than 50% of more conventional structural solutions. With the restoration of the monument, the detailed and innovative analysis of the performance of the monument enabled the monument to be conserved without a major structural intervention to upgrade the seismic performance. This resulted in significant cost savings as well as preserving the original heritage fabric.

This was the site of the tragic assassination of Ceremonial Guard Cpl Nathan Cirillo by terrorist Michael Zehaf-Bibeau on Oct 22, 2014. The restoration of the Cenotaph and plaza is a sign of respect to all Canadians and particularly Canadian Veterans. The Allegorical Angel statues at the top of the Cenotaph named "Peace" and "Freedom" remind all Canadians of the importance of veterans to a free and open Society. Thousands of people are drawn to the National War Memorial every year to attend the ceremonies and pay their respects.

Days after the site was reopened to the public, the November 11th Remembrance Day ceremony was attended by Governor General David Johnston and thousands of veterans.



ENVIRONMENTAL BENEFITS

The existing plaza structure was at the end of its useful life and the restoration of the plaza required reinstating the structural system beneath the landscaping. The existing void underneath the plaza was consolidated and a new substructure for the landscaping was created using high performance concrete and stainless steel reinforcing. This created a maintenance-free structural solution for the long term life of the landscaped plaza. In Canada, the deterioration of our infrastructure due to freeze-thaw and de-icing salts causes frequent structural repairs. The materials used for the plaza structure reconstruction will help mitigate this type of deterioration of the structure.

Additional sustainability initiative included recycling and reuse. All the demolished concrete was crushed and used for granular fill and the actual stone pavers were all carefully removed and reused to reconstruct the hard landscaping.

Conducting the advanced structural analysis of the cenotaph allowed for the monument to be conserved with minimal structural intervention, and as a result, fewer materials were consumed with no additional waste produced.



MEETING CLIENT'S NEEDS

The prime expectations of Public Works was to conserve and rehabilitate the memorial and to reinstate a structurally sound plaza with the project completed before the Remembrance Day ceremony. All of these expectations were met. The structural solution to the plaza slab rehabilitation includes state of the art materials including high performance concrete and stainless steel rebar to ensure the plaza will not experience future deterioration.

Through the use of detailed innovative nonlinear time history engineering analysis, WSP validated the satisfactory seismic performance of the stone monument without needing to add interventions to the existing stone cenotaph. The heritage masonry could be conserved and restored without adding intrusive and irreversible reinforcement to the original structure. Within the bronze sculptures, WSP were able to replace hidden crumbling brick supports with new stainless steel posts.

