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Seismic Upgrade of the Canadian Parliament Building: Part 2 – Conceptual approach

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ABSTRACT

Centre Block's seismic upgrade is particularly complex due to the historic materials used in its construction and the heritage finishes that adorn its walls, floors, and ceilings. At the schematic design level, two general upgrade approaches were explored: a conventional seismic upgrade and an upgrade incorporating seismic isolation. Although not commonly used in moderate seismic zones, the upgrade incorporating seismic isolation was found to be highly effective, less intrusive and providing a greater level of protection to the building and its finishes.

This paper provides an overview of the seismic isolation system design. Key decisions relating to the location of the isolation plane and provision of movement gaps to adjoining structures and grade are explained. Finally, a summary of the basement strengthening work and Peace Tower foundation work required to implement the system is discussed.

Keywords: seismic upgrade, unreinforced masonry, heritage, seismic isolation

INTRODUCTION

Centre Block, Canada's heritage designated Parliament building was constructed in 1916 in a period predating modern seismic design (see Figure 1). Its structure comprises unreinforced load-bearing masonry walls above grade in combination with some embedded structural steel frames, unreinforced concrete walls below grade and hollow terracotta tile floors. The 92 m tall tower on the south façade, known as the Peace Tower, was constructed with unreinforced concrete with an exterior wythe of sandstone.

Figure 1: Centre Block, Parliament Hill, Ottawa

The building is located on Parliament Hill, Ottawa, a region of moderate seismicity. A seismic assessment of Centre Block found that its unreinforced masonry walls have less than 30% of the capacity required to resist National Building Code of Canada 2015 (NBC 2015) seismic loads, and that its hollow terracotta tile floors have limited capacity to act as structural diaphragms. The building is currently undergoing a major rehabilitation, including a seismic upgrade for the NBC 2020 seismic hazard data.

In the rehabilitation schematic design phase, two different seismic upgrade schemes were considered. The first scheme proposed strengthening Centre Block's unreinforced masonry walls with the strategic application of reinforced concrete laminations and the complete replacement of its hollow terracotta tile floor slabs. Whilst feasible, the quantity of strengthening required to effectively protect the stiff unreinforced masonry walls constituted a large intervention and significant disruption to the building's heritage finishes. The second scheme explored using a basement level seismic isolation scheme to reduce superstructure seismic demands. Although many buildings in high seismic zones have used this approach, it is uncommon to consider such an approach in a moderate seismic zone like Ottawa. It is typically assumed that the cost of retrofitting a building with a seismic isolation system is cost prohibitive.

This was not found to be the case for Centre Block. The reduction in superstructure demand afforded by the seismic isolation system resulted in the elimination of much of the strengthening work that would otherwise have been required in the fixed based condition. Most of Centre Block's unreinforced masonry walls were found to have adequate capacity to resist the reduced seismic loads, and it became feasible to strengthen its hollow terracotta tile floor diaphragms with a thin topping only.

The large reduction in superstructure seismic force is partly due to the shape of Ottawa's seismic hazard acceleration response spectrum. At increasing periods of vibration, Ottawa's spectrum exhibits a rapid decrease in spectral acceleration demand. The relative decrease is greater than what is commonly observed in a high seismic zone spectrum (such as in Western Canada). This means that a very significant force reduction can be achieved by seismically isolating a stiff, short-period structure like Centre Block, since seismic isolation minimizes the seismic energy that can be transferred from the ground to a building's superstructure by lengthening its natural period of vibration.

Each of the seismic upgrade approaches were developed to a 90% schematic design level to allow each option to be costed by the project's construction manager. It was concluded that the upgrade approach incorporating seismic isolation would be lower in cost and require less time to complete. Consequently, the seismic upgrade approach incorporating seismic isolation was selected by the client as the approach that best balances the structural requirements of the project against the functional program and heritage conservation objectives, as well as providing an improved post-earthquake performance and lower implementation cost.

The project is currently in design development, with advance structural design packages for the isolation system ready to be released. The following sections provide an overview of the seismic isolation system design and commentary regarding key design decisions.

OVERALL ISOLATON SYSTEM CHARACTERISTICS

- Centre Block's seismic isolation system will require approximately 580 bearings.
- The bearings will be a combination of natural rubber, lead-rubber and flat sliding.
- The maximum horizontal shear at the isolation plane has been assessed through non-linear time history analysis to be approximately 3.5 % of the building's superstructure weight.
- The maximum expected horizontal displacement of the isolation system has also been assessed through non-linear time history analysis to be approximately 150 mm.

MAIN BUILDING ISOLATION SYSTEM DETAILS

- The isolation plane for the main building will be located near to the underside of Centre Block's level 1 slab. This elevation was chosen since insufficient basement clear height exists to create a foundation level isolation crawl space, and the basement space is required to accommodate mechanical and electrical systems. The implication of this choice is that all services passing vertically through the isolation plane to the superstructure above need to accommodate the movement of the isolation system.
- The seismic isolation bearing layout was selected to accommodate Centre Block's existing load bearing structure of walls and columns above Level 1. The resulting bearing spacing is approximately 4 m.
- A gravity load transfer structure is required above the seismic isolation bearings to transfer building weight that is currently supported between bearing locations. Transversely post-tensioned concrete 'sandwich' beams,

approximately 1200 mm deep will be used to strengthen the existing unreinforced concrete basement structure. The typical basement strengthening work is illustrated in Figure 2.

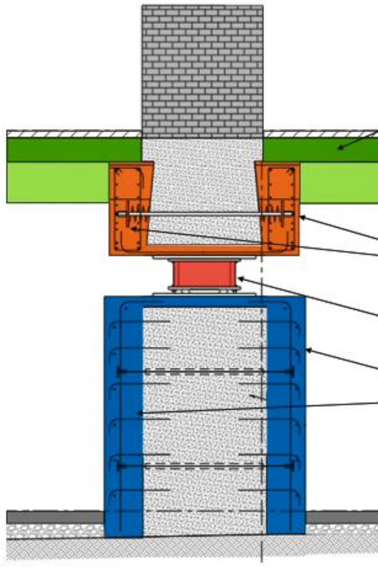

Figure 2: Centre Block basement strengthening

- The existing unreinforced concrete basement structure below the seismic isolation bearings will be strengthened with reinforced concrete laminations to provide sufficient lateral stiffness and overturning resistance.
- A hidden below grade perimeter seismic 'moat' is required to permit unrestrained movement of the isolation system. A detail of the typical perimeter condition is shown in Figure 3. A seismic movement joint between Centre Block's superstructure and Library of Parliament that adjoins the building to the north will also be introduced.

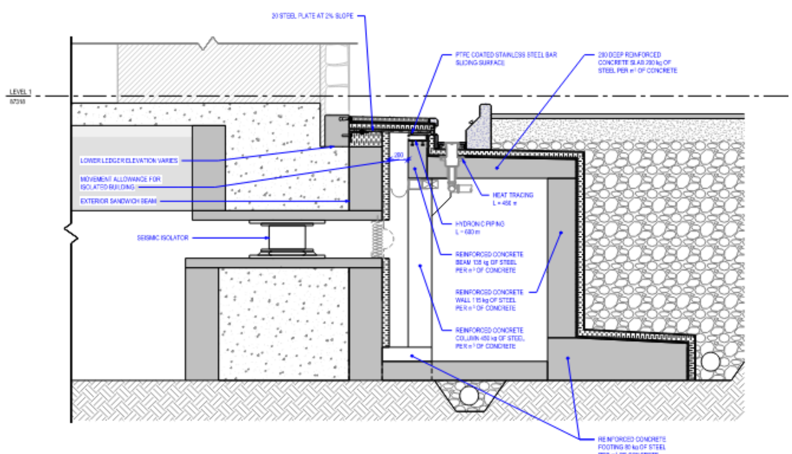

Figure 3: Perimeter seismic moat

- Most elevators crossing the isolation plane will be hung from the superstructure in suspended steel frames. A seismic movement gap between the suspended frames and the below grade structure will be provided. Two elevators that provide below grade access to the building's interior light courts will cantilever up through the isolation plane with a seismic movement gap provided between them and the above grade structure.

PEACE TOWER ISOLATION SYSTEM DETAILS

- The Peace Tower will be supported on 30 seismic isolation bearings and connected to the main building's seismic isolation system. This choice was made to avoid the need for a large seismic movement joint between the Peace Tower and Centre Block. A small 'stress-relief' joint at floors above Level 1 will be introduced between the Peace Tower and Centre Block to accommodate their differing dynamic response.
- A 2 m thick suspended transfer slab will be used to transfer the weight of the Peace Tower on to its seismic isolation bearings (see Figure 4). This slab will be fully connected to the Level 1 slab of Centre Block.

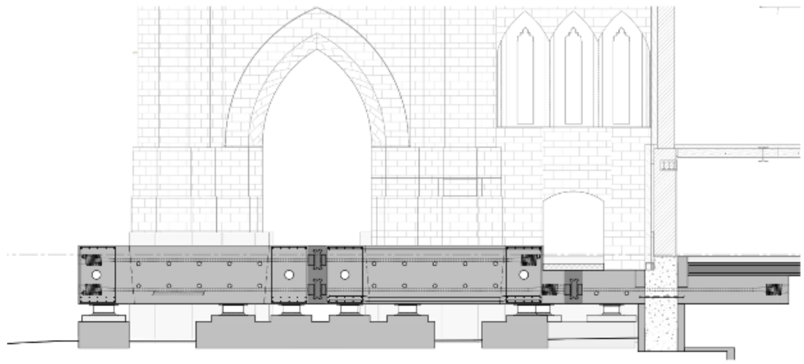

Figure 4: Peace Tower transfer slab

SUMMARY

Centre Block's seismic upgrade will incorporate an isolation system to reduce seismic demands on its superstructure. This will be a unique application of seismic isolation in a moderate seismic zone requiring a unique isolation system design. Both the maximum isolation system base shear and lateral displacement will be considerably smaller than what is typically seen in high seismic zone applications.

ACKNOWLEDGMENTS

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