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Seismic Upgrade of the Canadian Parliament Building: Part 5–Superstructure Strengthening

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ABSTRACT

A seismic upgrade of Centre Block, Canada's Parliament building is currently underway. A seismic isolation system will be used to significantly reduce the lateral force its superstructure will experience in an earthquake relative to its current fixed based condition. However, despite this reduction, some strengthening is still required. This includes strengthening of its hollow terracotta tile floors, water and ventilation towers, select load bearing walls and heavy decorative ceilings. This presentation focuses on the unique seismic upgrading strategies chosen for these specific elements. A description of the vulnerability of each element is summarized, and details of the upgrade strategy for each is presented.

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

INTRODUCTION

Centre Block, Canada's iconic and historic Parliament building, is currently undergoing a seismic upgrade to protect it from potential earthquake damage. The upgrade will significantly reduce the lateral force experienced by the building's superstructure during seismic activity, thanks to the use of a new seismic isolation system. However, despite this improvement, some superstructure strengthening is still required to ensure the building can withstand a 1-in-2475-year event earthquake. These upgrades are being implemented in accordance with the 2020 National Building Code of Canada (NBCC) to ensure that the building meets current seismic safety standards.

A holistic upgrade strategy is being implemented, which includes improving the performance of the building's hollow terracotta tile floor diaphragms, strengthening of its water and ventilation towers, strengthening of select load-bearing walls and seismic restraint of its heavy decorative ceilings.

SEISMIC UPGRADES TO SUPERSTRUCTURE

Hollow terracotta tile floor diaphragms

Centre Block's hollow terracotta tile floor diaphragms are one of its key structural elements that require seismic upgrade. The vulnerabilities of these floors include their brittleness, lack of connection to load-bearing walls and discontinuity of the diaphragm at each wall. Furthermore, the floor diaphragms rely on historic steel-to-steel connections that have inadequate capacity to resist seismic axial forces in addition to vertical gravity shear forces. Consequently, an earthquake could compromise their gravity-carrying capacity.

To address these vulnerabilities, two upgrade strategies were experimentally tested: 1) strengthening with a thin ultra-high performance concrete (UHPC) topping and 2) strengthening with in-plane steel bracing. Both strategies were found to be viable, with each improving in-plane shear capacity and reducing damage to the terracotta. However, the UHPC topping outperformed the in-plane steel bracing in the testing and requires less physical space to implement. As a result, it was selected as the preferred floor diaphragm upgrade strategy wherever possible throughout Centre Block.

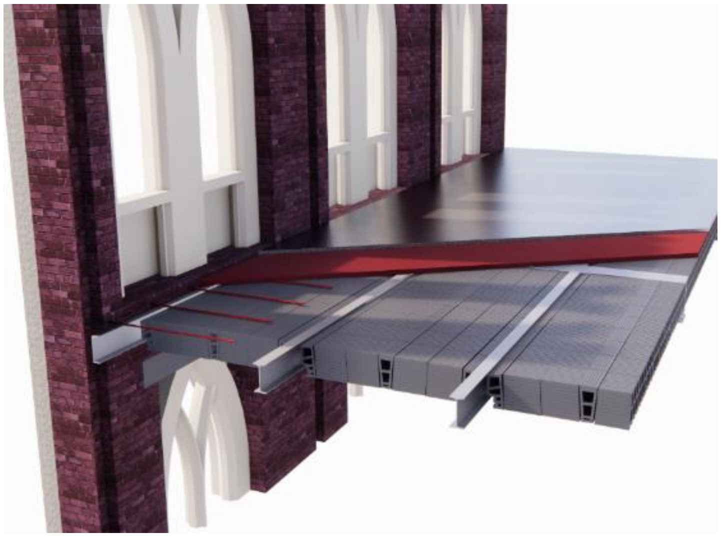

Figure 1: UHPC topping diaphragm upgrade

Figure 1 illustrates the upgrade concept. The UHPC topping, applied directly to the topside of the existing hollow terracotta floor tiles will be 60 mm thick, improving both its in-plane shear capacity and in-plane stiffness. Reinforcing steel bars, drilled and epoxied into the adjacent masonry walls will provide a diaphragm shear connection as well as out-of-plane wall restraint. Banded reinforcing steel within the UHPC topping will address diaphragm chord and collector forces.

Water and Ventilation Towers

Centre Block's four water and ventilation towers (see Figure 2 for example), located along its north facade, were identified as seismically vulnerable. These towers had previously required emergency repairs due to deep cracks forming at their corners. Analysis indicated that these cracks are likely due to thermal incompatibilities between the brick and sandstone materials used to construct their walls, in addition to moisture ingress and freeze-thaw cycling. Furthermore, the towers have inadequate connections to the main building's floor diaphragms and insufficient seismic overturning resistance.

Figure 2: East ventilation tower

To address these vulnerabilities, a 350 mm thick interior reinforced concrete lamination was chosen as the preferred upgrade option for the towers. This was deemed to be the optimal choice due to its stiffness compatibility and better thermal compatibility with the existing masonry than a steel bracing alternative. This upgrade option also permits a relatively simple solution to the deficient diaphragm connections to Centre Block's floors.

Load-bearing masonry walls

With implementation of a seismic isolation system, most of Centre Block's unreinforced masonry walls have adequate lateral capacity. However, at a few select locations, some walls require strengthening due to their low axial load and high geometric aspect ratio. This deficiency will be addressed by installing vertically drilled anchors from the tops of the walls into the level 1 beams above the isolation plane. The anchors will then be post-tensioned, increasing the walls overturning and shear resistances. In addition, improved wall-to-floor diaphragm connections will allow force redistribution as necessary, providing additional protection to the most vulnerable walls.

Heavy heritage ceilings

Centre Block's seismic retrofit requires special consideration of its heavy heritage ceilings, which will be preserved in-place during the renovation (see Figure 3 for example). These ceilings include thick suspended plaster, suspended concrete, and vaulted stone. While the expected in-plane seismic deformation demand for these ceilings are small, vertical accelerations during a seismic event are a significant concern. Additionally, these ceilings often have poor connections to the primary structure.

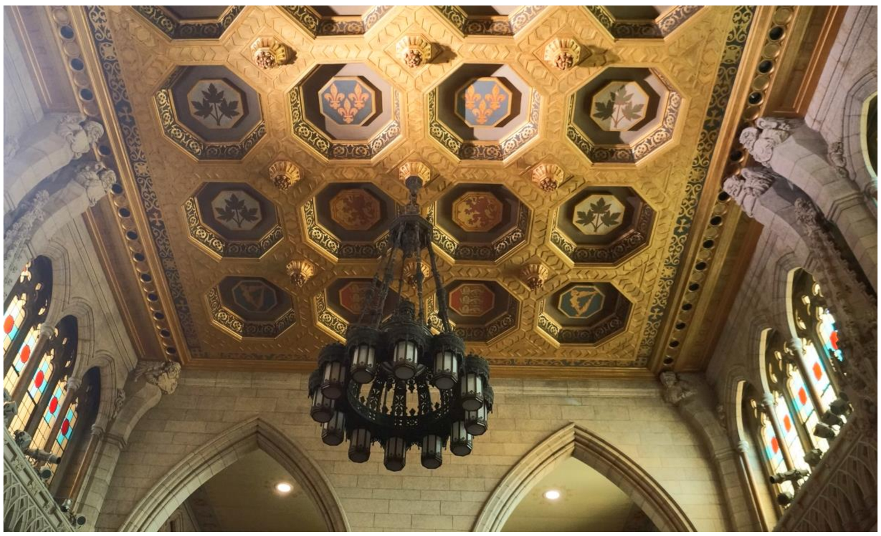

Figure 3: Suspended ceiling above the Senate Chamber

To address these vulnerabilities, new bracing and upgraded hangers will be installed as well as additional tensile reinforcement using a fibre-reinforced cementitious matrix (FRCM) are to be added at support points on the topside of suspended ceilings. The self-supported vaulted stone ceilings rely solely on an arching mechanism for their stability but are not structural members and therefore only support their self-weight, making them particularly vulnerable to seismic shaking. Additional ballast will be introduced over the spring points of the arch, increasing the total compression load in the arches cross section, increasing its resistance to the horizontal and vertical seismic forces. These upgrades will help to ensure that the heavy heritage ceilings in Centre Block are protected during a seismic event and will continue to be a cherished part of Canada's heritage.

SUMMARY

Centre Block is undergoing a major seismic upgrade consisting primarily of the introduction of a seismic isolation system. However, additional strengthening is also required within the superstructure to ensure the building can withstand a 1-in-2475-year event earthquake. Upgrades include strengthening the hollow terracotta floor diaphragms, water and ventilation towers, load-bearing masonry walls, and heavy heritage ceilings. The upgrade strategies aim to improve the performance of the building during seismic events by adding strength and stiffness to the floor system, providing greater structural continuity, and increasing the capacity to resist seismic forces. These upgrades will help ensure that the building's structural integrity and heritage fabric are preserved and protected for future generations.

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