Mount Royal Tunnel– Double Arch Replacement & Rehabilitation for REM Project

2024 Canadian Consulting Engineering Awards

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The Mount Royal Tunnel–Double Arch Replacement & Rehabilitation project in Montreal involved a critical 540-meter upgrade of the 5km tunnel for CDPQ Infra. Hatch's design, executed by the CIMA+ HATCH JV (CCH), featured canopy spile replacement for 92 meters and observational repairs for 240 meters. This complex and completely underground work was pivotal in eliminating the double arch concerns from the Réseau Express Métropolitain (REM) transit project's critical path.

Innovation

The REM is Quebec's largest public transit project in the last 50 years. Located in Montreal, Quebec, Canada the new automated light rail network will include 26 stations and span the greater Montreal area with 67 km of new tracks.

A section of this light rail network goes through an existing tunnel: the Mont-Royal Tunnel (MRT). Opened in 1918, the double-arched tunnel required repair and upgrade work to meet current safety standards and to adapt the tunnel to the REM's electric light metro (LRT) system. In particular, the double arch section is directly beneath McGill Avenue with relatively shallow soil cover.

The MRT project addresses the concerns of the southernmost 540 m of the tunnel. It represents an innovative tunnel demolition and replacement method that was developed and successfully implemented for the replacement and enlargement of an existing 100-year-old masonry double arch tunnel completely underground. The method involves the use of a unique sequence of successive advances consisting of canopy spile arch ground support, double arch demolition and installation of a new single arch structure on a fast-track schedule. Collectively the process has been denoted “The Sequential Demolition Method”.

The Project also included the development and the implementation of an innovative observational rehabilitation approach that was designed to be flexible and could be modified in response to observed structural conditions once exposed. The design details had to be changed several times during the project to adapt to the tunnel’s specific situations, like the risk of explosion in the tunnel that was settled using precise remote equipment. Moreover, the application of the observational design resulted in a smaller scope of work for the north section as the center wall was reevaluated as in a good condition. In the south section, an innovative drainage mesh called Dolenco was used for the first time in Canada to minimize the water ingress and grouting works before the application of the sprayed waterproofing membranes.

Challenges to the work was establishment of appropriate steel rib bedrock bearing, avoidance of unexploded “boot legs” from the original construction and installation of waterproofing layers. Utility protection and settlement prediction and monitoring were also necessary parts of the work. Designer being on site on a 24/7 basis with a permanent technical support of senior engineers provided a continuous progress. As a result, the demolition portion of the work at the south section was achieved 102 days ahead of schedule.

Complexity

The tunneling project under the city had to be reconceptualized to comply with new health and safety standards due to the COVID-19 pandemic. This adjustment was critical to ensure the safety of the workforce while adhering to government directives. Tunneling under the current City infrastructures with shallow soil cover required close coordination and tight monitoring plan to meet the fast-track schedule and minimize the soil loss and surface settlement. The replacement method involved the use of a unique sequence of successive advances consisting of canopy spile arch ground support, double arch demolition and installation of a new single arch structure on a fast-track schedule. This method required 12 sequences, each consisting of seven rib advances, to replace a section of the tunnel. The advances involved the demolition of existing double arches and the erection of a single arch structural steel rib, with shotcrete infill between the ribs. The discovery of explosive material in Mount Royal Tunnel, a remnant from its original construction, complexified the design. To minimize rock excavation, the steel rib posts were shortened to rest on competent rock benches.

The rehabilitation method employed an observational approach, adaptable to the conditions once the structure was exposed. It included initial works like inspections, grouting, and condition assessments. It was followed by escalating repair levels based on these assessments. Despite the challenges, including the pandemic and the unexpected explosive material, the project's flexibility and innovative solutions contributed to its success, showcasing the team's resilience and ability to manage complexity.

Social and/or Economic Benefits

The fast-track schedule and successful construction management help assure that the MRT was removed from the critical path of the overall project and secure the new transit opening schedule the population.

The REM project's viability relied on the successful rehabilitation and/or replacement of the MRT. The tunnel being located downtown, and the 540m being partially demolished for a new underground station, the client's had significant constraints with its alignment & station designs and surface footprint. Both repair and replace options were considered at this point to present every possible and feasible option to the client. A comparative analysis has been made including pros and cons and potential risks for each option. These options really helped the client come up with the best suited solutions for his needs and this has allowed them to plan ahead of time and have an appropriate schedule and budget in mind before starting the project.

The MRT design will assure durability for the REM project which serves the community by creating a new light rail system connected to 3 out of 4 subway lines in Montreal, all underground. REM will offer frequent reliable urban transit service 20 hours a day, 7 days a week to improve quality of life for citizens and promote economic development in Greater Montréal.

Environmental Impact

The rehabilitation method involved the implementation of an innovative observational rehabilitation approach that was designed to be flexible and could be modified in response to observed structural conditions once exposed. The rehabilitation work consisted of 3 stages: Initial Works including preliminary inspection, cementitious and chemical grouting for groundwater control; Condition Assessments and; Escalating Repair Levels selected and modified based on observed conditions and condition assessments. By taking the time to properly assess the steel and concrete existing condition, pipe arch canopy that was initially considered for the north section as well, did not need to be applied. Following the site validation, quality of arch blocks and steel thickness condition, showed that this was not mandatory. The rehabilitation option has been selected to assure that no unnecessary work was done. In the north section, replacing the entire center wall has been considered but the center wall capacity analysis and site validation showed that all the steel elements of the wall were in acceptable conditions. Therefore, an updated design was proposed using welded nelsons studs, mesh and shotcrete to avoid replacing something that did not need to be replaced. These decisions helped reduce the steps of the project by avoiding all unnecessary work and use of material.

Project's innovative approach to the Mount Royal Tunnel project demonstrates the commitment to sustainability and environmental stewardship. The REM project is expected to reduce greenhouse gas emissions by 35,000 tons per year, making it a crucial component of the city's efforts to combat climate change.

Meeting and Exceeding Owner's/Client Needs

The REM project, a significant undertaking, involves intricate design and construction. Typically, contractors collaborate with designer Engineering Joint Ventures to conceptualize and execute such projects. However, in the case of a critical segment of the Mount Royal Tunnel, the REM client opted to entrusted the design to the Joint Venture formed by CIMA+ Hatch and decided to execute the work using a traditional time-and-material method.

Working closely with the contractor, adapted the design to accommodate specific methods, including the use of remote demolition equipment. However, an unforeseen challenge arose during the COVID pandemic: procurement delays. To mitigate these impacts, strategic decisions were made. For instance, the tubes required for the canopy were selected early in the design phase and arrived prior to construction. Additionally, risk analysis and communication with adjacent stakeholders, such as the city of Montreal, facilitated changes in injection materials, avoiding lengthy procurement delays.

Given the project's tight schedule and its position on the critical path, expediting the drawing production became paramount. To minimize any adverse impact on the schedule, the design team considered worst-case scenarios resulting with drawings serving as a versatile toolbox for on-site implementation.

Ultimately, the project's success hinged on several factors, including regular communication between the designer, the client, and the contractor. The decision to internally replace a section of the tunnel with a sprayed concrete lining (SCL) was based on cost-effectiveness, adherence to the schedule, flexibility, durability, and compatibility with the contractor's preferred methods. Despite challenges, this collaborative effort exemplifies exceptional project management and problem-solving.


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