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Case Study

How A Vibration Monitoring System Protected Commercial and Residential Buildings During The Excavation Of A New Combined Sewage Storage Tunnel (CSST)

A view of the Ottawa River as it passes next to Parliament Hill in Ottawa, Ontario - Canada's capital city.

BACKGROUND

As the City of Ottawa's population exceeds the one million-mark, local infrastructure required a considerable upgrade to accommodate the city's growth. Ottawa's downtown has a historical combined sewer system using the same pipes to transport both sanitary and surface water to treatment facilities. During heavy rains or snowmelts, this system can become overwhelmed, resulting in raw sewage bypassing water treatment facilities and flowing straight into the Ottawa River.

CHALLENGE

An environmentally friendly solution was needed that would protect the Ottawa river from future contaminated overflows.

The Combined Sewage Storage Tunnel design called for excavating two tunnels through the rock using a Tunnel Boring Machine (TBM) that would provide an equivalent storage capacity of 18 Olympic sized pools (43,000 m^3 or 56,000 yd^3) as an overflow buffer. Such a design would require varying tunnel depths anywhere from 10 m (33 ft) to 21 m (69 ft) beneath the surface. Nine large shafts would serve as access points. The project needed to ensure that the excavation work advancing through the dense downtown core would not generate vibrations potentially damaging to the thousands of adjacent commercial and residential properties.

CASE STUDY OVERVIEW

Applications:

- Tunnels/Subways
- Construction
- Civil Projects
- Blasting
- Remote Access

Location:

Ottawa, Ontario, Canada

The Challenge:

Excavate 6 km (3.7 miles) of tunnels through the city's downtown core while ensuring all buildings are protected from vibrations caused by the Tunnel Boring Machine and other machinery.

The Solution:

A fleet of 90 Instantel vibration monitoring units, placed throughout the city in and around nearby buildings in a remote monitoring configuration.

- Micromate
- Minimate Pro
- Series III

Monitoring Timeline:

- 2016 - 2020
- Continuous monitoring
- Histogram-Combo

Key Benefits:

Provide near real-time vibration data to ensure compliance with regulatory requirements and the City of Ottawa contract specifications.

3.7 m (12 ft) Diameter Tunnel Boring Machine

APPROACH

The tunnel was excavated by Dragados-Tomlinson Joint Venture (DTJV) using a 3.7 m (12 ft) diameter Tunnel Boring Machine (TBM) along with surface sites requiring urban drilling and blasting, mechanical excavation and shoring techniques. Such machinery produces an array of complex vibrations that propagate through the different layers of ground composition.

A comprehensive vibration and noise monitoring program was created to monitor all work for contractual compliance. A network of monitoring equipment advancing in tandem with the TBM required ongoing installation and maintenance. More than 60 Instantel monitoring units reported vibration data during peak construction periods with a subset reporting for the entire duration of the operations that lasted from the summer of 2016 until early 2020.

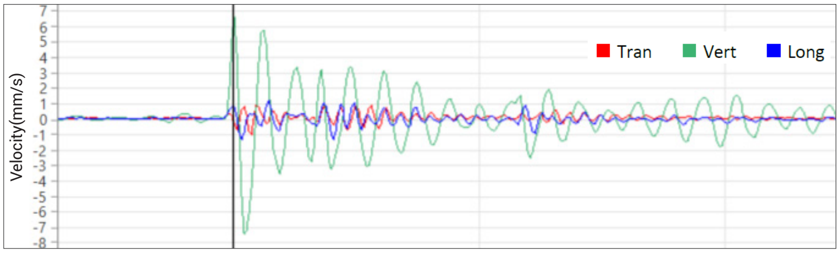
Pre-construction inspections were offered to all affected buildings, utilities, structures and facilities within 75 m (246 ft) of the tunnel alignment and surface sites on the CSST project. The inspections were intended to document the pre-existing state of each structure to provide a baseline for assessing and evaluating any future concerns. As such, vibration monitoring was performed on a vast variety of structures: buried utilities, residential structures, commercial structures, historical structures, high-security government facilities, concrete caisson walls, bridge abutments, and fresh concrete.

RESULTS

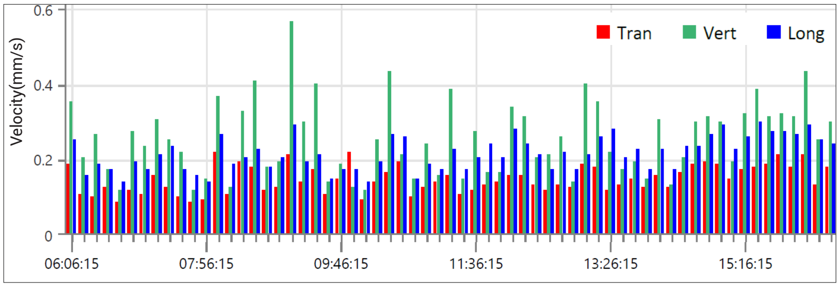
Measurements were compared to the ISEE standard for sound/noise and vibration and according to project-specific limits dependant on Transient, Continuous and Blasting generated vibrations.

The following graphs are recordings of registered vibrations during excavation operations. As the tunnel boring was ongoing 24 hours per day, a continuous Histogram bar graph registered all peak velocities for specific intervals, while individual waveforms were recorded for instances where the peak velocities exceded a reference threshold.

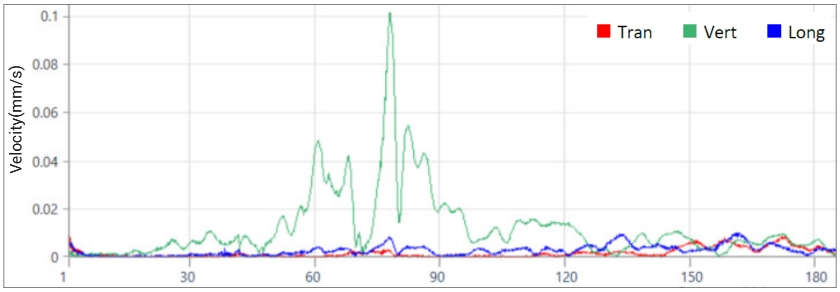
A spectral analysis chart (Fast Fourier Transform FFT) separates the complex waveform into its actual frequency components. This important data is often used to assess the damage, as lower frequencies can cause the risk of damage to structures.



A vibration waveform recorded during excavation activities in three dimensions.



A "Histogram" bargraph with peak velocities recorded on a continuous cycle throughout the day.



A spectral distribution graph revealing the frequencies with the greatest velocities in three dimensions.

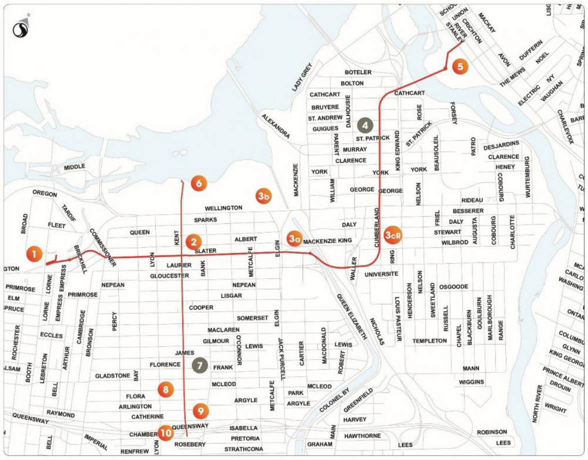
... RESULTS CONTINUED

A total of over 35,000 monitoring events were recorded throughout the various construction operations. Many factors contributed to whether an event was triggered, some of the more significant factors but by no means an exhaustive list were:

- Building types (Historical buildings, government buildings, medical buildings)
- Building foundations (Rubble, concrete, reinforced concrete)
- Excavation techniques (TBM, blasting, drilling, mechanical excavation, shoring)
- Ground composition (Solid bedrock, cracked bedrock, soil)
- Distance from operations (Ex. 15 m (49 ft) from a blast vs 75 m (246 ft) from TBM)

These factors contributed to the complexity of the project vibration characteristics. Definitions were created for three vibration trigger levels: **Threshold**, **Response,** and **Shutdown.** Each of these levels varied depending on the section of the tunnel and operation. A notifications platform was set up that initiated automatic notifications by SMS or email to inform on three levels **1. Triggered Waveform**, **2. Warning** and **3. Exceedance.** This helped to organize and prioritize the three vibration levels.

Further to that, monitoring units at different sites were uniquely programmed and combined with the notification platform such that their **Trigger**, **Warning** and **Exceedance** levels could be managed separately to ensure the stakeholders received properly categorized readings in each instance.



Map of the two inter-connected tunnels.

Complaints by property owners regarding potential damage to their structures were filed with the City of Ottawa. In every case, the vibration monitoring contractor (Explotech) was able to analyze each of these concerns with the use of Instantel's vibration monitoring report data to determine whether or not construction could have caused the noted issue(s).

> "The monitoring data proved to be incredibly helpful and was referenced in the responses to the effected stakeholders in every instance."
>
> Mitch Malcomson P. Eng. with Explotech Engineering

CONCLUSION

This large scale urban project has spanned four years, with the North-South portion of tunneling completed in August 2018, the East-West portion of tunneling completed in October 2019 and the remainder of operations in 2020. It has generated over 900 interim summary reports and over 35,000 events that were instrumental in advancing the project while protecting the city infrastructure and private properties. The structural integrity of the commercial and residential properties was maintained through carefully monitoring and ensuring all vibrations stayed within the specified limits.

Case Study Partner