FACTSHEET

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Ministry of Transportation and Infrastructure

Can a bridge be built on a river delta?

Bridging major rivers through soft deltaic soils is a challenge that bridge engineers have developed and honed over centuries of bridge foundation design.

A recent bridge engineering feat of note, the Sutong Bridge – the world's second longest cable stayed bridge – crosses China's Yangtze River delta over soft soils to depths of 240 meters, with piles installed to depths of about 100 meters.

Like the Sutong Bridge, the George Massey Tunnel replacement bridge will span a river delta with deep, soft soils. While the George Massey Tunnel replacement bridge will be considerably smaller than Sutong, the geotechnical similarities of the Yangtze River delta to the Fraser River delta offers assurance of the feasibility and effectiveness of the deep pile foundations planned for use here.

Carrying that weight with deep foundation piles:

Deep foundation piles are steel pipes or concrete cylinders that are either driven or bored into the soil to support the weight of the bridge and keep it in place during regular operating conditions as well as in the event of earthquakes and high winds (this is known as bridge stability and integrity).

The pile material, diameter and length are designed to support all loads transferred from a bridge deck and bridge piers into the ground, in consideration of soil properties at the site and current bridge design codes.

Soil properties are established from a variety of test methods including laboratory testing of soil samples taken from bore holes. For large projects like the George Massey replacement bridge, full scale test piles are also often installed and loaded to compare calculated pile strength and behaviour with site-specific data.

For the George Massey Tunnel replacement bridge, five very large steel test piles were driven to depths of almost 70 meters and loaded to confirm that each pile can support loads of as much as 2,000 tonnes – a weight of about 153 fully loaded transit buses.

Foundation design for the new bridge will be based on the extensive geotechnical subsurface investigations and studies undertaken since 2014. This work includes:

- Results of the 108 bore holes.
- Extensive testing of soil samples taken at the site at different depths.
- Comprehensive historic geotechnical information, including during tunnel construction in the 1950s and during the tunnel seismic retrofit program in 2006.

- Two very deep drill holes completed to establish the depth to firm ground.

What's under the surface at the George Massey replacement bridge site?

Drill holes confirmed that soft soils extend to a depth of 314 meters in Richmond and 317 meters in Delta. Below the soft soils is a very dense, strong layer that is several hundred meters thick. This dense material, known as "till," consists of very dense gravelly clay or sandy clay that was deposited by glaciers and compacted over centuries between the geologic periods known as the Pleistocene and the Holocene periods. Solid rock is estimated to be at depths of between 600 to 700 meters.

Sands near the surface are potentially liquefiable in the event of an earthquake, which can considerably reduce the frictional strength of the sands. The new bridge foundation design calls for ground improvements to prevent these sands from liquefying. Typically, this is done by constructing stone columns in the sand to a sufficient depth. The piles are then installed in the improved ground.

The tunnel was constructed on and within the near surface sand layer, and independent reports have suggested that the tunnel would suffer extensive irreparable damage in the event of even a moderate earthquake. Previous engineering analysis has also confirmed that it would be challenging, financially impractical and very risky to improve the ground under the tunnel, including risk of irreparable damage to the tunnel.

This is why the Phase 2 of the seismic retrofit program did not proceed in 2007 as originally planned. The Phase 1 seismic retrofit was completed to improve safety by structurally reinforcing the individual tunnel segments and installing an early warning system. Tunnel maintenance challenges associated with soil conditions and aging equipment continues and the tunnel is approaching the end of its service life.

For every challenge, there's an engineering solution:

Thousands of hours of professional geotechnical and bridge structural engineering have been dedicated to ensuring that the new George Massey replacement bridge and its supports are appropriately designed for the conditions at the crossing site and for a major seismic event.

The engineers on the project have decades of professional experience on projects in B.C. and throughout the world, and B.C. has a strong record of building safe and robust bridges.

Deep foundation pile bridges around the world:

In British Columbia, the following bridges have been constructed with deep foundation piles:

- Alex Fraser Bridge, friction piles on the north side with end bearing on the south side.
- Port Mann Bridge, end bearing piles along bridge length into till.
- Pitt River, end bearing piles into till along length.
- Golden Ears, friction piles into underlying silts sands and clays.

In addition to our experience in British Columbia, deep foundations in soft soils have been widely used around the world:

- The Sutong Bridge in China – the second largest cable stayed bridge in the world, which crosses the lower Yangtze River in water that is more than 30 meters deep and where soft, compressible soils reach depths of 240 meters. The bridge is founded on 114-meter long piles designed to withstand very significant loads including typhoons, earthquakes and impact from major ships.

- The Rion Antirion Bridge in Greece – a multiple span cable stayed bridge that crosses over an active fault line and is founded in soft soils where rock is believed at depths of 1,000 meters.
- Numerous major bridges over the Mississippi River in the United States.
- The Jamuna River Bridge in Bangladesh, where bedrock is at a depth of 6,000 meters and the bridge is designed to withstand significant seismic activity, ship collision loads, and riverbed scour to depths of 45 meters.

Benefits of a new bridge to replace the George Massey Tunnel:

The new bridge will be built to modern seismic standards, designed to withstand a 1-in-2475-year seismic event. Building a tunnel to the same required standards is a much more costly, complex and environmentally invasive process, involving river-bottom dredging and bringing in layers of sand, gravel and loose stone to reinforce the earth onshore and in the Fraser River below the water

A new bridge can be constructed with minimal disturbance in the Fraser River, as the main piers will be on land, at the edge of the river, and then used as a base for construction, rather than in the river

A new bridge can be built within the existing right-of-way so will require less private property and have less impact on agriculture, parks, recreation and the environment. Emergency response is much easier and safer on a bridge compared to a more confined space like a tunnel.

The new bridge to replace the George Massey Tunnel will be built to accommodate future rapid transit. The new bridge will also offer a better and safer travel experience for users, but particularly for cyclists and pedestrians who will be able to freely cross the Fraser River at this location for the first time ever in an open air environment.

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