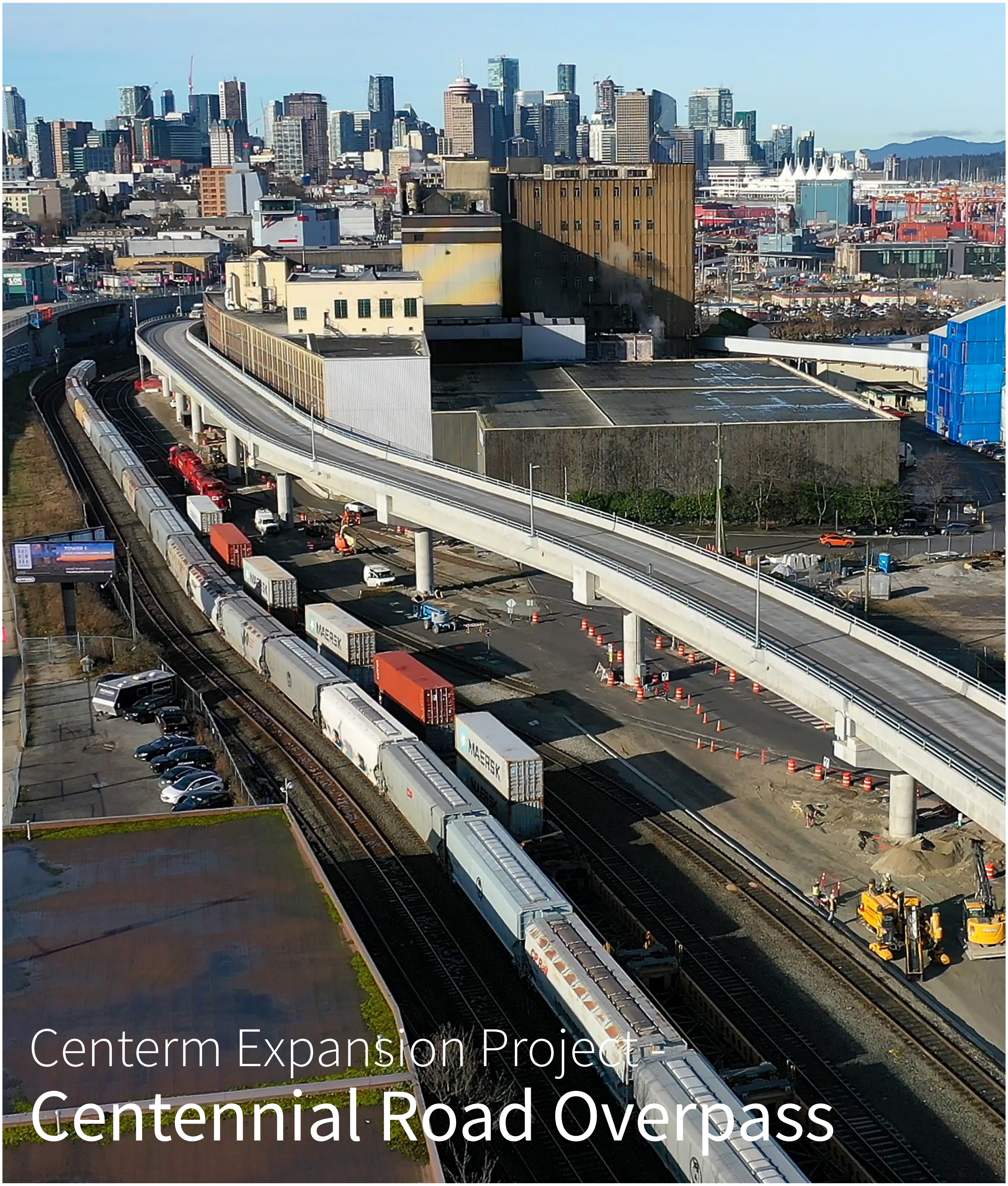


Centerm Expansion Project -
Centennial Road Overpass

2022 Canadian Consulting Engineering Awards

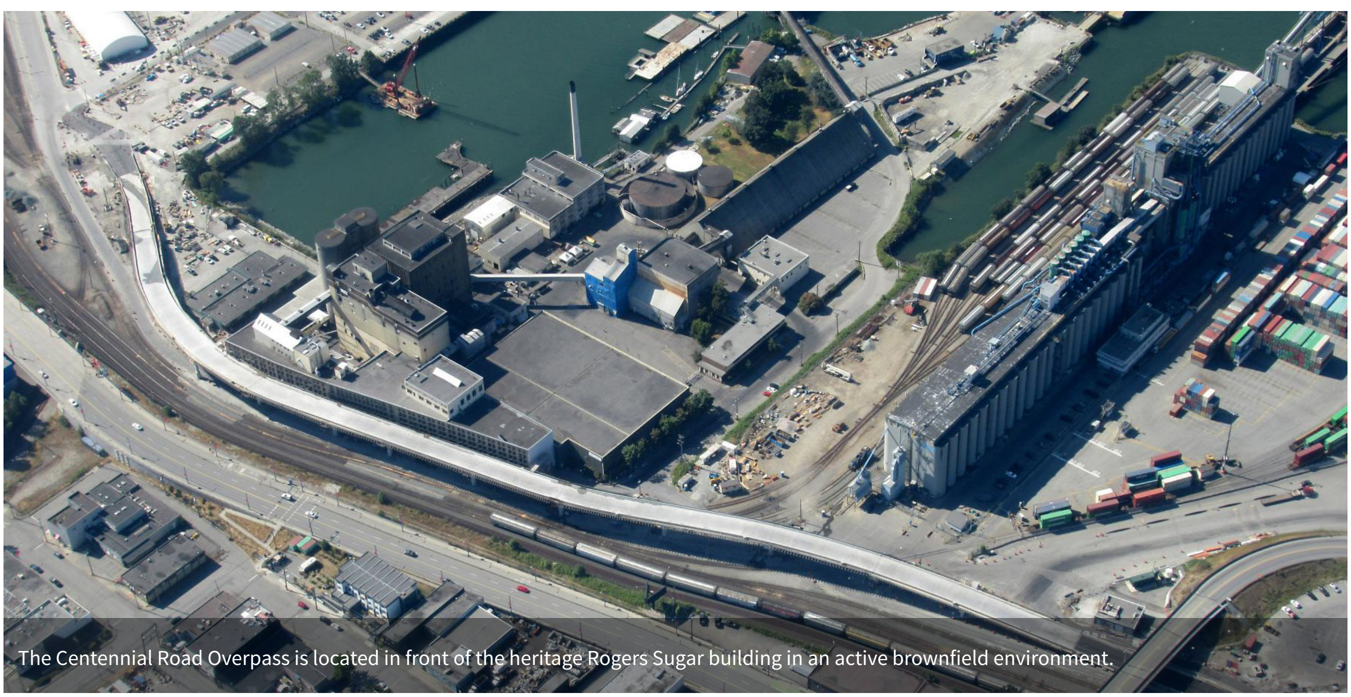
Submitted by Hatch Ltd. | 400 - 1066 West Hasting Street, Vancouver, BC V6E 3X2
T: +1 604 689 5767 | F: +1 604 689 3918 | www.hatch.com

HATCH

Executive Summary

The Vancouver Fraser Port Authority (VFPA) is building the Centerm Expansion Project and South Shore Access Project to help meet the increasing demand for containers shipped through the Port of Vancouver. A key part of this project is the construction of a new overpass on Centennial Road to bypass rail tracks thereby reducing rail and road congestion. The Centennial Road Overpass (CROP) is a 13-span, 600-m-long composite concrete girder bridge that provides a grade separation for truck traffic from three rail crossings. With construction staging considered early in design, the CROP was configured to accommodate unhindered operations of two of Canada's biggest container port facilities during the bridge's construction.

Hatch was the bridge designer and managed the design development for this challenging structure to overcome various site constraints such as the numerous busy train crossings, a large adjacent historic building, and an extensive number of underground utilities. Irregular substructure elements such as eccentric hammerhead piers, straddle bent piers, and irregularly shaped pile cap foundations were incorporated to overcome these constraints. The bridge was also designed in an active seismic zone with compressible and liquefiable soil. The designers developed the preliminary and detailed structural designs using finite-element models to capture the seismic responses of the various irregular substructures. A lightweight expanded polystyrene (EPS) fill embankment complete with a concrete rigid-frame bridge was designed for the east embankment to protect an underlying 6-m-deep underground sewer chamber. Two-stage mechanically stabilized earth (MSE) walls were also designed to limit the footprint of surcharge at the west embankment. Coupled within the proximity with many existing utilities and properties, early engagement and coordination with stakeholders were critical in arriving at a constructible structural solution. The completed structure accommodated complex interfaces and satisfied the project intent of improving the transportation network without undue disruption to ongoing container terminal operations. The overpass is essential to the goal of increasing Centerm's throughput by 60% to 1.5 million 20-foot equivalent unit containers (TEUs), while only increasing its physical footprint by 15%.

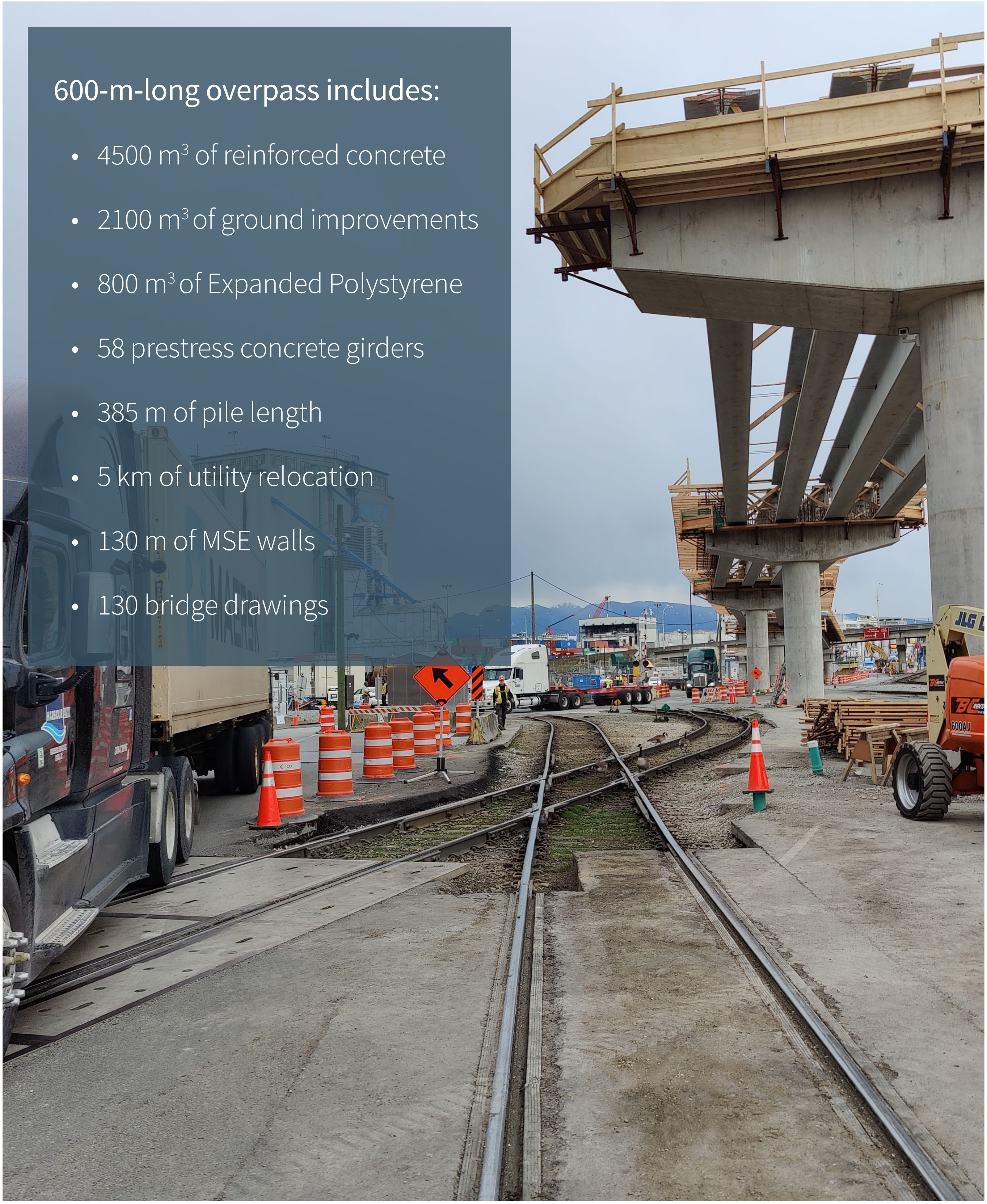


The Centennial Road Overpass is located in front of the heritage Rogers Sugar building in an active brownfield environment.

Project Highlights

600-m-long overpass includes:

- 4500 m^3 of reinforced concrete
- 2100 m^3 of ground improvements
- 800 m^3 of Expanded Polystyrene
- 58 prestress concrete girders
- 385 m of pile length
- 5 km of utility relocation
- 130 m of MSE walls
- 130 bridge drawings



Technical Innovation and Complexity

Project Objectives and Background

The Port of Vancouver is the largest port in Canada and the fourth largest in North America by tonnes of cargo, facilitating trade between Canada and more than 170 trading economies around the world. Centerm is an existing container terminal on the south shore of Vancouver's inner harbour, and handles one-fifth of goods shipped in containers through the Port of Vancouver. The Centerm Expansion Project and South Shore Access Project comprise of series of on-and off-terminal improvements to Centerm container terminal and port roads, with a capital cost exceeding $400 million. These improvements will increase both throughput and sustainability at the terminal.

The Centennial Road Overpass is a critical component of this project, and significantly improves the movement of goods to and from the Port of Vancouver by providing rail and road grade separation for through traffic, and eliminates delays caused by active rail crossings. As part of this project, an at-grade service road is maintained under the overpass, providing access to other terminal tenants, transport of oversized loads, and alternative routing for other traffic including emergency vehicles. The result of the revised configuration is dramatically increased traffic capacity and reduced delays for all traffic to and from terminals on Vancouver's south shore. The overpass is essential to the goal of increasing Centerm's throughput by 60% to 1.5 million 20-foot equivalent unit containers (TEUs), while only increasing its physical footprint by 15%.

Project Challenges

The overpass is in front of the heritage Rogers Sugar building along Centennial Road. Rail tracks run directly beside and cross the structure, confining its envelope and making train impact load a design consideration. Utilities including Metro Vancouver storm water and sanitary sewers, Vancouver Fraser Port Authority and City of Vancouver infrastructure, and BC Hydro, Telus, Fortis and third-party fibre-optic services all further constrained the location and geometry of the overpass. Geotechnical considerations included the existence of a 5m thick liquefiable soil composed of compressible soil layers such loose sand, trace silt, and wood waste, and the requirement to impose no additional load or settlement on existing underground infrastructure. Hatch's design team spent extensive collaborative effort on constructability, spatial requirements, and design interfaces to successfully achieve design consent, while developing a host of bespoke solutions to overcome these challenges.

Project challenges include a narrow workspace corridor and ongoing construction zone traffic.

Throughout its length, the overpass is heavily constrained by existing infrastructure, be it tenant or municipal facilities, rail and utilities, all in a brownfield operating environment requiring that traffic be maintained throughout the construction period. An extensive 3D model was developed from historical records, coupled with site surveys and stakeholder inputs, to identify and resolve potential conflicts. The overpass geometrical alignment involved straight tangents coupled with reverse and superelevated curves necessary to fit within its available envelope. Its profile was dictated by the at-grade road's headroom requirements determined by its turning movements. Detailed and iterative stakeholder coordination meetings and reviews were held throughout the engineering development to achieve buy-in of the final design.

The design also needed to accommodate construction within a constrained workspace. The proximity of the structure to railway infrastructure and its location in a narrow corridor with high volumes of truck traffic created significant construction challenges. Construction methodologies, equipment sizing, transportation and erection logistics, and sequencing were all considered in the design development in close collaboration with the contractor.

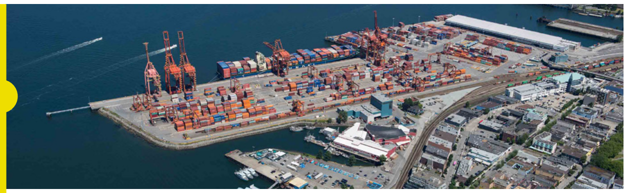
Rail and road grade separation for through traffic, and eliminates delays caused by active rail crossings.

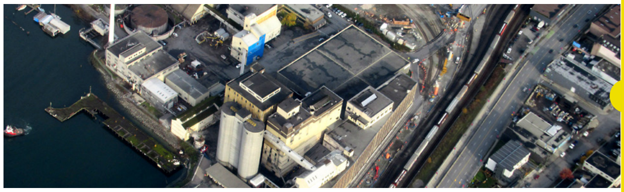
A shared use underlying road and rail crossings can be seen under the elevated structure.

Project Milestones

February 2019

Award of Project



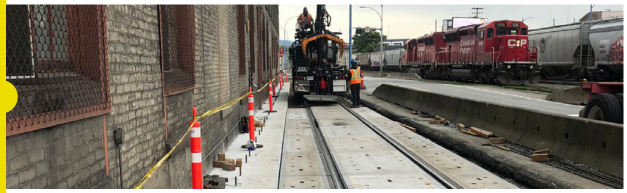


March 2019

Utility identification and stakeholder liaison started

July 2020

First IFC package submitted

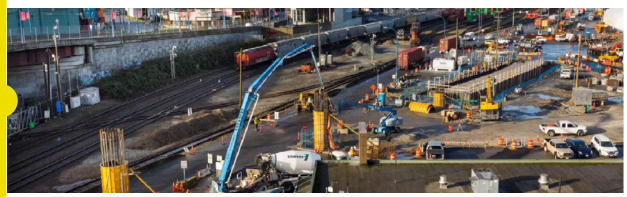


September 2020

First pile installed

January 2021

MSE west embankment started

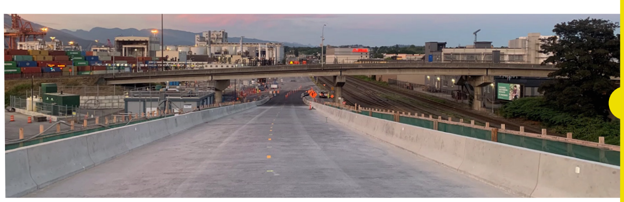


March 2021

First girder lifted

April 2021

EPS east embankment started



June 2021

Approach slabs and parapets completed

July 2021

Bridge open to traffic

Solutions, Technical Excellence and Innovation

The Centennial Road Overpass signature design features include:

- Conventional bridge structural components founded on deep foundation with minimal footprint;
- Consistent pier configurations with minor adjustments to meet specific criteria at select pier locations;
- Ground improvements targeted to minimize utility relocation and retain pre-construction soil conditions; and
- Typical bridge deck construction using standardized means and methods.

In short, complexities were overcome in the design such that the overpass could be constructed with components and methodologies widely adopted in the industry.

Road Safety and Geometry Constraints

The eastern approach was located in consideration of the headroom available under the existing Clark Drive overpass and proximity to the newly constructed roundabout at the Clark Drive entrance. Adjacent pier locations were chosen by optimizing girder span lengths and slopes to achieve headroom requirements for nearby rail crossings and a U-turn route for the at grade roadway, all while minimizing conflicts with underground utilities. The overpass complex alignment was formed by two tangents, a double curvature, and a tight radius curvature hinging around the corner of the heritage building at the west approach. The double curvature was designed to join the overpass tangent segments in front of the heritage building and the pump station where the tangent could not be continuous due to existing rail tracks constraining the geometry. At the west approach, a tight radius curvature was needed to provide a reserved area for future use and also for the underlying roads.

Improving Geotechnical Performance

Bridge spans could not be built at the east approach as the underground was fully occupied

East embankment of the Centennial Road Overpass and the existing bridge above.

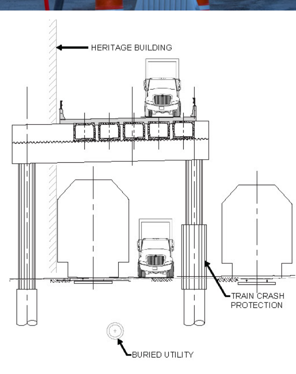
by utilities that could not feasibly be relocated. These utilities were also founded on soft, compressible, and liquefiable soil. To mitigate this poor ground condition, an embankment consisting of lightweight fill expanded polystyrene (EPS) blocks was designed. A concrete rigid frame structure was also designed to span over and protect major Metro Vancouver sewer infrastructure. The west approach was designed to meet utility proximal requirements and saw stone column ground improvements to mitigate liquifiable soil. A two-stage mechanically stabilized earth (MSE) wall was designed to pre-load the site and form the west approach, including a crash wall to protect against possible train derailment. The stone columns and approach were constructed in conjunction with a vibration and settlement monitoring program that was developed to ensure no adverse impacts to existing Metro Vancouver underground infrastructure.

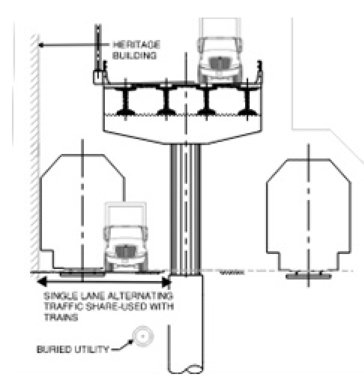
Conventional bridge structural components founded on deep foundation with minimal footprint. Consistent pier configurations with minor adjustments to meet specific criteria at select pier locations.

Mono pile with single column piers were designed to avoid conflicts with buried infrastructure. At times, these piers, while maintaining consistent detailing, were designed off-centre of the bridge deck as required by the underground model and/or geometry of the at-grade access roadway. At locations where mono piers could not be made to work, straddle bents were utilized, again using typical pile, column and pier cap techniques. In total, the structure's 14 piers included two straddle bents, seven off-centre piers, and five regular piers. In one location, additional strengthening of the pier for heavy construction was designed to protect against train impacts in the case of a potential derailment from adjacent tracks.

Single-lane bi-directional road and share used with trains.

CROP's 14 pier columns were located to allow the existing road underneath the bridge to serve as an alternate route during and after construction. During construction, the existing road was restricted to a 250-m-long narrow corridor for single direction truck / train traffic and foundation construction. After construction, the narrow corridor serves as a low volume road and alternate routes. The designer had to balance all the site geometry constraints for the bridge arrangement along this narrow corridor. The geometry constraints included the CN/CP track clearance envelopes, rail diamond which could not be impacted, Rogers Sugar Building structure a rail siding and deeply buried utilities whose relocation was not an option because of their proximity to the active tracks. Hatch's solution was to balance these constraints and utilize the remaining space by designing a single-lane, two-way signalized traffic road, with rail shared use under the bridge deck.

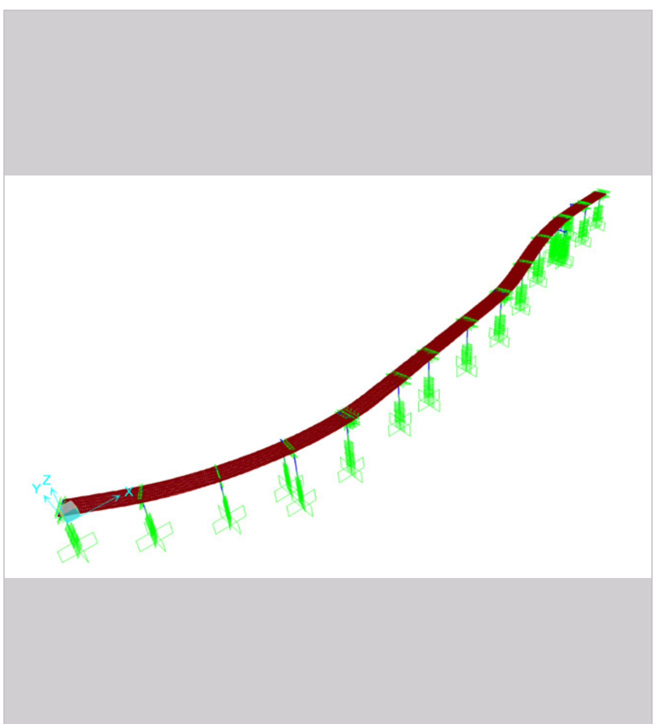




Substructure positions and single-lane alternating traffic shared used with trains.

Seismic Performance-Based Design (PBSD)

Seismic design of the Centennial Road Overpass followed the latest CAN/CSA-S6-14 Canadian Highway Bridge Design Code to explicitly demonstrate structural performance in three return periods of the seismic event, i.e. 475, 975, 2475 years, and the subduction movement. Given the bridge's irregular geometry, performance-based design was required. Analyses were performed to meet the specific strains criteria of the concrete and rebar as damage control of seismic response and structural sustainability. Concrete reinforcement was designed to confine hinge formation at strategic locations in different components of the bridge to maintain serviceability and for visual inspection after different level of earthquakes. Sophisticated three-dimensional structural modelling was required because of its irregular alignment, off-center-mono-pile-single-column piers, straddle bent piers and the compound effect of joining multiple-continuous-span structures for the viaduct. Seismic analyses including response spectrum, inelastic static pushover and non-time history were performed to demonstrate no significant strength degradation per the criteria of each seismic event.



Three-dimensional structural modelling was performed due to the overpass' irregular geometry.

> *The Hatch team's technical skills, attention to detail and creative design solutions have allowed us to work collaboratively to deliver this major Project within tight timelines and meet the port authority's mandate to enable Canada's trade while protecting the environment and considering local communities.*
>
> Gilles Assier
> Director, Container Terminal Construction
> Vancouver Fraser Port Authority

A Collaborative Approach

Hatch aimed for a collaborative approach to the design in order to achieve a cost-effective solution for all stakeholders with minimal operational impact through construction. In the pre-construction stage, value-engineering was performed for the best value between the reference design's steel girder concepts versus the conventional prestress concrete girder bridge configuration eventually adopted. Single column piers were used for the shallower concrete girders for the vertical clearance needed to avoid rail track relocation, thus avoiding complex transportation logistics and operational impacts that would result in increased costs. Other design considerations included bridge structure, road, and underground civil design, electrical, rail, geotechnical, environmental, and architectural inputs all within a context of constructability for achieving multi-party stakeholder buy-in. Weekly design review meetings with construction specialists and other subject matter experts were held throughout design development. An extensive utilities identification program was developed with the contractor and in conjunction with review of record drawings and aerial photos, a detailed 3D model was created to coordinate new foundation piling, and construction was completed with no field conflicts encountered, a significant achievement. In the construction phase, site crews worked closely with the design office for timely responses when issues needed to be resolved when unexpected field conditions were encountered.

Social, Economic, and Environmental Benefits

Stimulating the Local and International Markets

The Centennial Road Overpass was proudly designed by our locally based team. More than 30 multidisciplinary team members logging in more than 15,000 million hours of work helped guide the Project to completion. Overall, the Project encouraged growth in the local technical and trades job markets and allowed our team to receive the unparalleled experience of working in familiar neighbourhoods while supporting Canada's economic trade.

The Centennial Road Overpass Project is an important component of the Centerm Expansion Project and South Shore Access Project to improve the movement of goods in the Pacific gateway to support Canada's trade while protecting the environment and considering local communities. The region's major port is now better served for through traffic, enhancing Metro Vancouver's ability to manage the enormous increase in Asia- Pacific trade.

Sustainability

One of the Vancouver Fraser Port Authority's objectives for the overall project is to obtain an award level of Envision Gold from the Institute for Sustainable Infrastructure. The Institute for Sustainable Infrastructure is a non-profit organization created to develop and maintain a rating system that recognizes the need for sustainable, resilient, and equitable infrastructure. The Centennial Road Overpass design considerations in this regard included materials sourcing, waste generation and disposal, as well as construction duration and methodology. The successful completion of the overpass within the framework developed is a significant milestone toward achieving the Envision Gold standard.

The Centennial Road Overpass design considerations in this regard included:

- Quality of life – with the opening of the overpass, there has been a reduction in truck traffic and associated noise on city streets, enhancing public health and safety.
- Leadership – stakeholder involvement was a key component for design consent; Design-Build project delivery method fostered collaboration and teamwork between consultants, owners and contractors.
- Resource allocation – sustainable procurement practices were considered. Concrete girders were design instead of steel to minimize the transportation footprint of ordering steel from oversea. Recycle asphalt pavement and concrete were used for the construction.
- Natural World – managed storm drains of the overpass and local roads through existing outfalls; doubled the usage of the brownfield area by constructing the overpass and an underlying 5-m-wide alternating route for terminal and local traffic.
- Climate and Resilience – the completed overpass reduces rail and traffic congestion resulting in improved travel times and lessened idling vehicles. Thus, resulting in reduced greenhouse gas emission and air pollutant emissions along with improved infrastructure integration.

ENVISION™

Institute for Sustainable Infrastructure

Meeting the Client's Needs

Achieving the Vision

The Project's final design met all stakeholder, operational and safety requirements by using conventional bridge structural components in combination with intricate engineering detailing to overcome site constraints. The completed structure accommodated complex interfaces and satisfied the project intent of improving the transportation network without undue disruption to ongoing container terminal operations.

Construction of the Centennial Road Overpass was safely achieved on time and without incident, including no underground conflicts of foundation piling with complex existing infrastructure, and was opened to traffic in July 2021. The overpass has been in continuous use since this time, fulfilling its purpose in providing through traffic access to and from terminals on Vancouver's south shore. Its sustainability goals have also been achieved through efficient construction utilizing locally sourced and readily available materials. The overpass is also reducing the carbon footprint of container transport to and from the terminals through the elimination of delays resulting from rail crossings.

Project Successes

IMPROVED CONNECTIONS
within and between the Port of Vancouver and local communities

COMPLEX STAGED DESIGN & CONSTRUCTION
providing uninterrupted traffic flow

REDUCED CONGESTION & TRAVEL TIME
to and from the Port of Vancouver

SEISMIC SAFETY
improved for lifeline and vital economic corridor

IMPROVED SAFETY
for vehicle operators and passengers

Centennial Road Overpass Project Videos by the Vancouver Fraser Port Authority and links publicly available online:

Newly completed Centennial Road Overpass

Time-lapse of construction

Drone video of construction

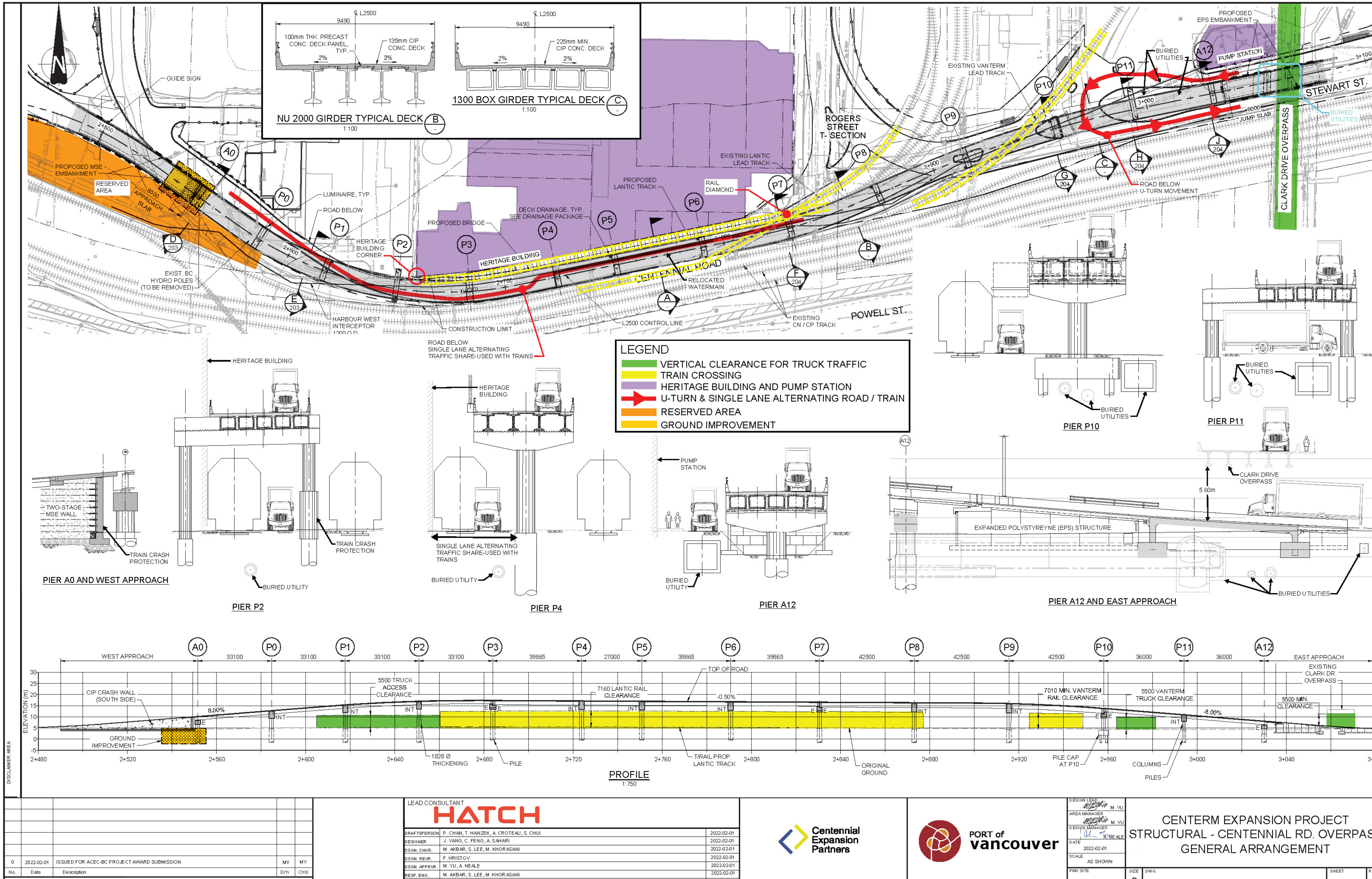
Substructure construction

Girder installation

Superstructure construction

Celebrating the completion of construction

Complex and Confined Environment



Project Photographs

+ The Centennial Road Overpass is bounded by rail siding tracks, rail crossings, and the Rogers Sugar heritage building.

+ Temporary traffic detours were staged in a constrained workspace and brownfield environment resulting in no interruption to facility operations.

+ Construction of the Centennial Road Overpass accommodated the continuity of existing active railway traffic.

+ Spatial requirements drove substructure design with superstructure optimized for girder erection and deck construction.

+ Hammer Head Pier with off-centre column to allow for traffic movement. Box girders were used to streamline deck construction.

+ Single column piers were used for the shallower concrete girders near the Rogers Sugar heritage building for the vertical clearance needed to avoid rail track relocation.