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Case Study

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CASE STUDY ON THE DESIGN AND CONSTRUCTION OF DELTAPORT CAUSEWAY OVERPASS

Stuart Culpan, P.Eng.[1,3] and Jianping Jiang, PhD, P.Eng.[2]
[1,2] WSP/MMM Group, Canada
[3] CulpanS@mmm.ca

1 PROJECT OVERVIEW

The Deltaport Causeway Overpass in Vancouver B.C. was the centerpiece of a $45 million upgrade of the transportation infrastructure at Canada's busiest container port terminal. The project included the design and construction of a curved overpass located on a narrow causeway in an area of highly sensitive soils. It was delivered under a design-build model as part of the Port of Vancouver's Deltaport Terminal Road and Rail Improvement Project (DTRRIP). WSP/MMM Group led the design team and was prime consultant providing design management, civil and structural engineering design, and construction inspection services.

The aim of the DTRRIP project was to increase the throughput capacity of the terminal, improve the flow of trucks and trains accessing the port, reduce vehicle idle times, and improve safety. The new overpass was instrumental in separating road and railway traffic at the critical bottleneck junction, and the project was successful in contributing an additional 200,000 container units of annual capacity.

This case study will describe the technical challenges and the innovative engineering solutions used in the design and construction of the overpass. It will detail the structural solutions that were developed by the design team to accommodate the tight geometric constraints of the site that minimized construction impacts on the day-to-day operations of the terminal.

2 DESIGN INNOVATIONS AND LESSONS LEARNED

2.1 Slender Bridge Columns

Due to the close proximity of the rail tracks to the new bridge, the available space for the bridge columns was severely constrained. This required the use of very slender concrete columns. The innovative design used small-diameter reinforced concrete columns with an externally-bonded fiber-reinforced polymer (FRP) wrap. The principal tensile fibers of the FRP wrap, oriented transverse to the column's vertical axis, restrained lateral expansion of the column by providing confinement to the concrete – similar to that of spiral reinforcing bars. Under earthquake loading, the columns were designed to form plastic hinges at their top and bottom thereby dissipating energy and limiting the force transferred into the piles. The FRP wrap was designed to provide confinement for the concrete core, and ensured the columns had sufficient ductility to meet the structural design capacity. The FRP wrap was applied to the columns after they had cured, and was a simple, cost-effective solution to overcoming the geometric constraints of the site.

2.2 Franki Piles

The depth to bedrock precluded the use of deep-pile foundations, consequently shallow bridge piles were chosen to support the structure. The piles were constructed using expanded-base concrete ‘Franki’ piles that were founded within a zone of stone-column ground improvement. The piles were constructed by driving a zero-slump concrete mix out the bottom of a steel casing to form the load-bearing compression and tension bulbs. Franki piles were well suited to the Deltaport site because the subsoils were comprised primarily of sand – which allowed for easy formation of the bulbs. The stone-column ground improvement strengthened the soil surrounding the piles and provided the required vertical and lateral support under service and earthquake loads. The Franki piles, in conjunction with the ground improvement, resulted in significant project savings. If traditional bridge piles had been used, such as driven steel pipe piles or drilled shafts, they would have been installed to a much greater depth at a much higher cost.

2.3 Liquefiable Soils

The potentially liquefiable soils at the site dictated the use of a state-of-the-art lightweight-fill solution for the bridge-approach embankments. The three approaches were constructed using expanded polystyrene (EPS) blocks, aka “geofoam”. By harnessing the super lightweight properties of EPS-geofoam it allowed the embankments to be constructed at a relatively shallow depth, and limited the weight applied to the load-sensitive foundation soils. The seismic performance of the embankment was also a key design consideration; by limiting the seismic inertial force, the associated deformations were reduced and the post-earthquake performance criteria could be satisfied. The lightweight-fill approaches weighed only one-seventh of a traditional granular-fill approach, and were a more cost-effective solution than lengthening the bridge or constructing vast swathes of ground improvement.

2.4 Geometric Site Constraints

Due to the tight property constraints and the proximity of existing rail tracks and other port infrastructure, the bridge geometry was extremely complex. The overpass was located on a compound-curve with transitioning superelevation, and accommodated a bifurcating roadway alignment to facilitate the construction of an off-ramp at mid-span of the bridge. The AutoCAD software program ‘Civil 3D’ was used to define and coordinate all geometry for the overpass. The software features of Civil 3D enabled a detailed and dynamic model of the structural elements to be developed, which included piles, columns, cap beams, girders and bridge deck. The 3D model was also used to provide a comparison between the finished roadway and the existing ground surface to optimize the founding elevation of the EPS-geofoam blocks.

Figure 1: Deltaport Causeway Overpass, Vancouver, B.C.

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