THE PITT RIVER BRIDGE

Vancouver B.C.

Category C

INTERNATIONAL BRIDGE TECHNOLOGIES, INC.

THE PITT RIVER BRIDGE

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PROJECT DESCRIPTION

OVERVIEW & BACKGROUND

Where the Lougheed Highway crosses the Pitt River just outside Port Coquitlam, British Columbia, Canada, the need for a new bridge was becoming urgent. Twin 2-lane swing bridges had shouldered the burden until now, but were feeling the strain of increasing traffic from residents traveling to and from the greater Vancouver area. Creative efforts including counter-flow traffic control had maximized all of the capacity that these old bridges could offer for this major thoroughfare.

As part of the British Columbia Ministry of Transportation's (BCMoT) regional plan to upgrade the transportation flow in the Lower Mainland, known as the Gateway Project, the bottleneck at Pitt River became one of the first priorities to fix. The solution was a new 8-lane bridge, with seven lanes dedicated to traffic and one as a combined pedestrian and bicycle throughway. The project also included significant improvements to the connecting interchanges and general traffic movements.

FIRM'S ROLE IN THE PROJECT

International Bridge Technologies, Inc. (IBT) developed a unique conceptual design: a skewed cable-stayed bridge supported by three planes of cables with a main span of 190m (625ft). IBT also performed the final design of the deck, towers and stays, and was responsible for construction engineering.

ROLE OF OTHER CONSULTANTS AND CONTRACTORS

In mid-2006, a design-build contract generated interest from many proposers, from which three teams were short listed. In November 2006, the team of contractor Peter Kiewit Sons and engineering consultant MMM Group Limited, including a partnership of Associated Engineering (AE) and IBT, provided the latest in engineering innovation.

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ORIGINAL APPLICATION

INNOVATIVE SOLUTION

Preliminary studies for the site explored many options, including launched girders and arch bridges. Initially, cable stayed bridges were ruled out due to roadway and alignment challenges. The required roadway was both wide and variable, ranging from 40m to 45m. Generally, cable stayed bridges are not economical in this configuration. However, the challenges of the poor soils, high steel costs and the complication of working above an operational swing bridge eventually drove the design team to explore an unconventional solution.

The end result was a truly unique development in cable supported bridges. To address the deck width, three planes of stays were used. This had the effect of reducing the transverse flexural demand by a factor of four, creating a significant savings. In addition, the cable planes were angled slightly relative to one another, accommodating the varying geometry while maintaining simple, repetitive details.

Grade 350MPa weathering steel was used for both the 1.5m-deep main girders and the 1.0m-deep floor beams. A future lane will be added by shifting the pedestrian and bike path outboard of the stay cable plane on the north side of the bridge with a light weight cantilevered deck. The capacity for the future element was built into the permanent structure.

The innovative detailing did not end with the three stay cable planes alone. Since the spans were relatively short for a cable-stayed structure, it was possible to frame the main longitudinal girders directly into the pylon legs. This resulted in several benefits for construction and design with greatly improved seismic performance. The deck acted as a stiff diaphragm in plane and helped distribute forces between the flexible perched foundation in the river and the more rigid pylon foundation on shore. This behavior was also enhanced by the planar stay arrangement that gave the bridge deck stiffness in the longitudinal direction.

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Technical Value to the Engineering Profession

BRIDGE ANALYSIS

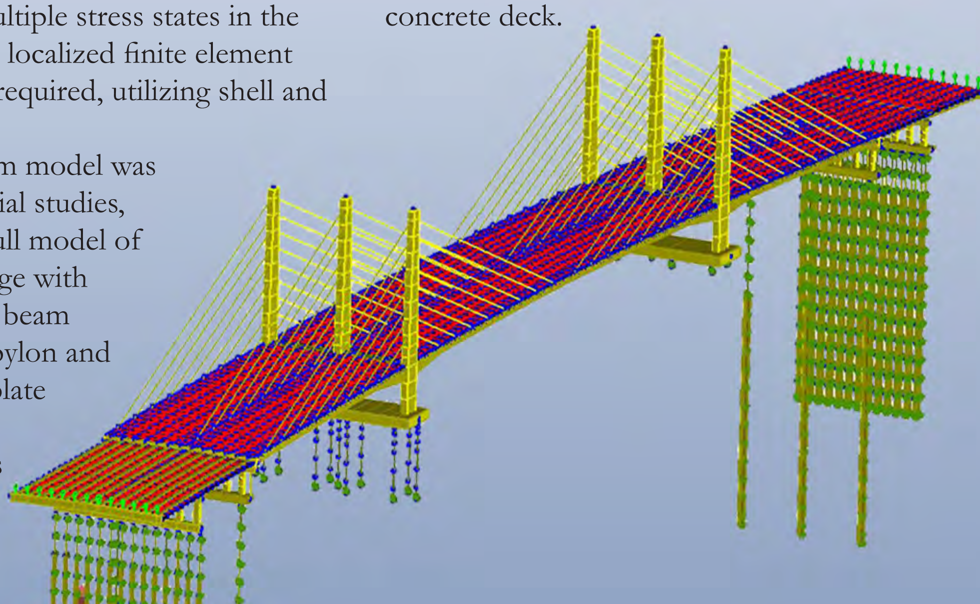
Due to the unconventional design features, it was understood that rigorous analysis would be required. Conventional cable-stayed bridges are typically symmetric along two axes, but the Pitt River Bridge would have neither. In addition, the 3-planes of cables required proper balancing transversely such that the girders would not be unequally loaded.

The bridge designers used a 3D structural analysis program, with the ability to accomplish the multiple analytical tasks that would be needed for design. This included live load influence line generation with multiple lane combinations for optimal load cases, seismic analyses using both response spectra analysis and non-linear time-history, loss-of-stay cable condition with accumulation of different static states, and staged construction of the bridge deck in balanced cantilever with multiple stress states in the stay cables. Some localized finite element studies were also required, utilizing shell and brick elements.

A general beam model was developed for initial studies, but eventually a full model of the complete bridge with a combination of beam elements for the pylon and steel girders and plate elements for the concrete deck was implemented.

The response spectra and time history seismic analyses indicated peak design forces in the pylon within the bottom frame (three legs plus cross-beam) as expected, but also indicated large forces extending above the cross-beam as the individual pylon legs exhibited some independent mode shapes. The upper legs were not designed to hinge under the maximum seismic loads, but confinement detailing was extended to this zone in order to ensure stable behavior if seismic loads were to exceed predicted loads.

The analysis model for the construction stages was also quite detailed. The contractor chose to lift the steel frames in separate halves, which required that the sequence be modeled explicitly. In addition, the stay cable staging, determined by the designers, required first a stressing phase with the steel girders alone and a second stressing stage with the composite concrete deck.



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COMPLEXITY

EXTREME LOADING

Due to the conditions at the site, extreme loads had to be considered for the design of the bridge. The evaluation of multiple levels of earthquake forces on bridges that are deemed important to regional transportation is common in a seismically active area. In the United States, this usually takes the form of a service level earthquake where the bridge must resist the forces largely intact for immediate use after the event, and a life-safety earthquake where the bridge may sustain significant damage, but no collapse.

For the Pitt River Bridge, four levels of earthquake motions were specified. Using probabilistic considerations, the service earthquake was set at a 10% exceedance within 50 years (or 1 in 475 year return period), a limited damage earthquake was set at 5% exceedance (1 in 975 years), and a life safety earthquake was set at 2% exceedance (1 in 2475 years). Finally a subduction earthquake was included for evaluation, primarily to consider movements that might amplify liquefaction effects.

SITE CONDITION

The Pitt River is fed from Pitt Lake and flows into the Fraser River, which ultimately leads to the Pacific Ocean. Because of its proximity to the coast, it is subject to tidal flows. At the bridge site, the river is 300m-wide and a maximum 20m-deep. The tides result in an interesting interaction with the existing bridges, where the flow of water creates scour, but a reversal in direction causes a restoring effect. This was validated by soundings performed in advance of the bridge design. Even with this behavior, approximately 8m of maximum scour was considered as a design condition.

The geotechnical conditions at the site were not favorable. As expected in and around the river, deep layers of soft soil were present. The firm till layer existed some 30m below the mudline. While it could be shown that skin friction had the ability to carry the vertical loads of the bridge, the Owner stipulated that the piles be embedded into the till.

As is the case in Vancouver, and generally true along the length of the North American Pacific coast, the site is located in a seismically active area. This resulted in significant depths of soil subject to liquefaction and lateral spread of the river bank.

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Economic Considerations

Design Solution

Many of the benefits noted in the design of the bridge also resulted in benefits to construction in both cost and schedule savings. In addition to the limited marine construction for the foundations and the open access of the stay cables in the pylon, the design of the bridge deck itself helped the construction process.

With the bridge design innovations implemented, a rigorous comparison between a traditional steel girder option and the cable-stayed option was prepared by the contractor at the tender phase. The comparison indicated that the cost of the cable supported bridge was approximately 10% to 20% lower than the conventional option. The Kiewit team was ultimately the low bidder for the project, and notice to proceed was given in January 2007. Project costs were CAD $198,000,000, with the main bridge accounting for approximately half of the total.

A final noteworthy aspect of the construction was the performance of a load test of the 1.83m piles. The cost-effectiveness was justified by the allowance to use a higher pile load capacity, thereby reducing the number of overall piles, but the effort to perform the test was significant. A configuration of five production piles at the eastern pylon foundation, with the test frame loading the middle pile and using other four as reaction piles, was successfully tested to a capacity of 43MN. This was one of the largest, pile load tests ever performed.

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Community Benefits

IMPROVED PUBLIC TRANSPORTATION

The Pitt River Bridge and interchange will improve the capacity and performance of transportation facilities in the central vicinity of the Pitt River Bridge. More specifically, the Mary Hill Interchange will increase access from the provincial highway to the community, therefore encouraging development opportunities in the community through improved transportation facilities and access. There is up to 16m of vertical marine clearance, as well as facilities for cyclists and pedestrians.

The Pitt River Bridge will carry 4 east-bound lanes and 3 west-bound lanes of traffic across the river, and the substructure is designed to accommodate a future 8-lane cross section. This will provide the flexibility to accommodate future public transit or special purpose traffic lanes, should they be considered.

Exceeding Client/Owner Needs

IMPROVED RELIABILITY & SAFETY

Bridge construction began with pile driving in August 2007, only six month after notice to proceed. The closure of the main span occurred in June of 2009 and the bridge was open to traffic in October 2009. Objectives were successfully met:

- Design elegance
- Parallel cables in a harp arrangement
- Slender, sizable deck
- Improve traffic flow
- Improve safety for cyclists and pedestrians
- Provide the needs of growing industry

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