

4D Journal

A LARSA Publication

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Bridging the Pitt

By Daniel Tassin, P.E., P. Eng. and Christopher Hall, P.E., International Bridge Technologies, Inc.

Where the Louheed Highway crosses the Pitt River just outside Port Coquitlam, British Columbia, Canada, the need for a new bridge was becoming urgent. Twin, two-lane swing bridges had shouldered the burden until now, but they 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 squeezed out all possible capacity the old bridges could offer for this major thoroughfare. A permanent solution was clearly needed. But rather than following a conventional design, the design team found that a three-plane cable-stayed bridge was the least expensive option against the extreme seismic, tidal, and geotechnical conditions the designed bridge would face.

As part of the British Columbia Ministry of Transportation's (BC MoT) 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 eight-lane bridge, with seven lanes dedicated to traffic and one as a combined pedestrian and bicycle through-way. The project also included significant improvements to the connecting interchanges and general traffic movements.

In November 2006, the team of contractor Kiewit Construction and engineering consultant Marshall Macklin and Monaghan (MMM, formerly ND Lea), including a partnership of Associated Engineering (AE) and International Bridge Technologies, Inc. (IBT) performing the main bridge design, submitted a unique solution: a twin tower cable-stayed bridge supported with three planes of cables and a main span of 190m.

A cable-stayed bridge was not the obvious choice. The main span of 190m was relatively short and a cable stayed structure was not explicitly required.

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WELCOME to the 4th Dimension



This year, LARSA is proud to note an expanding market for infrastructure and development in the United States, but we are also pleased to see a large growth in the use of our software on projects around the world. In this issue of the 4D Journal you will find detailed descriptions of some of the features of our program as well as some interesting examples of the real life applications of LARSA 4D in the design and analysis of major bridges and structures.

It is our continual goal to improve the LARSA 4D program to better suit the evolving needs of our clients and in 2009 we hope to create a variety of new ways to provide support and training to better help you reaching your goals.

Best of Luck,

Ali D. Karakaplan, Eng. Sc.D
President, LARSA, Inc.

Upcoming Conferences

26th International Bridge Conference

June 14-17, 2009
David L. Lawrence Convention Center
Pittsburgh, PA

5th NYC Bridge Conference

August 17-18, 2009
Ritz-Carlton Hotel, Battery Park
New York, NY

PCI's Annual Convention/Exhibition & Bridge Conference

September 12-15, 2009
Marriot River Center Hotel & Convention Center
San Antonio, TX

Western Bridge Engineers' 2009 Seminar

September 21-23, 2009
Sacramento Convention Center & Sheraton Grand Hotel
Sacramento, CA

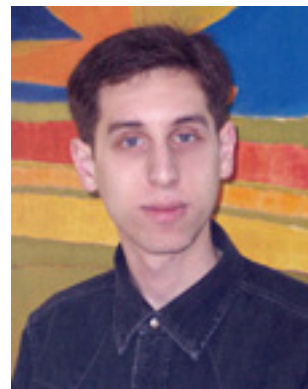
21st Annual ASBI Symposium

October 25-27, 2009
Hilton Hotel
Minneapolis, MN

World Steel Bridge Symposium

November 17-20, 2009
Henry B. Gonzalez Convention Center
San Antonio, TX

Meet the 4D Team



Joshua Tauberer is LARSA, Inc.'s Chief Software Architect. Working with LARSA, Inc. for the past eight years, Joshua has been responsible for the development of many aspects of the software including the user interface, influence line and surface analysis, the upcoming composite section construction, and program documentation. Joshua is currently attending the University of Pennsylvania where he is earning a Ph.D. in Linguistics. His joint passion for technology and politics has resulted in Joshua's creation of an open-source website known as GovTrack.us that tracks the activity of the U.S. Congress, just one of the many software projects Joshua juggles.

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Front Cover: Artist rendering of Pitt River Bridge provided by International Bridge Technologies

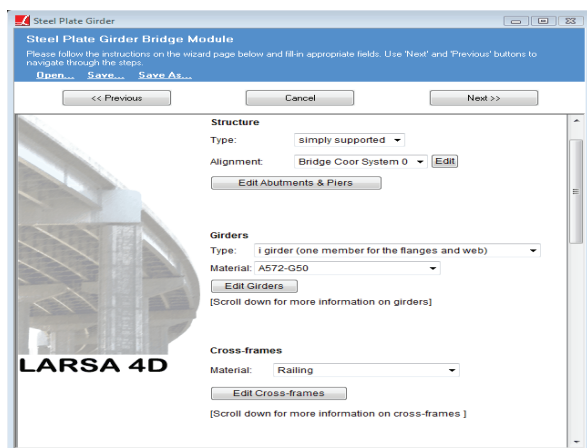


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LARSA 4D is analysis and design software for bridges, buildings, and other structures, developed by LARSA, Inc. in New York, USA. This journal is sent as a courtesy to our clients and corporate friends. We welcome feedback and suggestions for future stories to info@larsa4d.com.

I-Girder Bridge Design for AASHTO LRFD

Part of the ever expanding software systems from LARSA, Inc., the Steel Plate Girder Bridge Module is an AASHTO LRFD code check tool intended for bridges with curve or skew, large displacements, nonlinear behavior, haunches, or unusual modeling requirements. The module combines the 3D modeling and analysis strengths of LARSA 4D and its Time-Dependent Staged Construction Analysis with a rigorous implementation of design code requirements. Its wizard-like interface guides the user through the process of model generation, analysis, and ultimately code check.



The Steel Plate Girder Bridge Design Module

Model Generation

In the first component of the module, model generation is available, providing a parametric approach to creating bridge models. The user enters the horizontal and vertical curve of the bridge centerline at control points, deck, girder, pier and abutment geometry, special loading, etc., and the module will generate a complete bridge model based on the specification ready to be analyzed. The model includes geometry and loading, but also structure groups and construction stages. If the structure calls for unusual geometry, loading conditions, or construction order, the generated model can be revised in LARSA 4D before moving on to the code check step. The model can also be easily regenerated with new parameters during the project's design phase. Some model generation options are also customizable, such as cross-frame type where the user can define new cross-frame geometry.

Bridge alignment is configured using LARSA 4D's Bridge Path Coordinate Systems, a unique tool that simplifies the process of entering the 3D geometry of the bridge centerline. Bridge Paths can include multiple curved segments, elevation with parabolic curve fitting, and superelevation. Using a Bridge

Path also simplifies the analysis results by providing a coordinate system perpendicular to the bridge at every location.

The module also supports different modeling techniques for the girder. For example the I girders can be modeled as beam elements representing the whole girder or as a combination of beam and plate elements where plates represent the web and the flanges are represented with beam elements. Support for box and tub girders is currently in the process of development as well. Cross-framing can be created as diaphragms, X frames, or K frames.

Code Check on Existing Models

Fully integrated into LARSA 4D, the module not only creates 3D finite element models but also has the capability of recognizing bridge components (spans, girders, cross frames, etc.) from existing models created without the help of the module. This expands the loading and code checking capabilities to not only module-generated models but also to most any user-generated model.

Analysis

Staged Construction Analysis, a key feature of LARSA 4D, provides a complete step by step construction simulation including live loads, detailed deck pouring simulation and traveler loads and provides a comprehensive summary of girder construction. Time-dependent material effects including creep, shrinkage, and steel relaxation can also be included, along with advanced construction activities such as support changes, tendon stressing, and temporary loading.

Code Check

The second component of the module, code check according to AASHTO LRFD 2006 with 2007 additions, uses the forces and stresses computed on the full 3D model generated by the module with LARSA 4D's nonlinear analysis. This provides greater flexibility than a 2D grillage analysis. Model curvature, soil-structure interaction and bearings, post-tensioning, long-term material time effects, and any other advanced modeling technique which can be entered into LARSA 4D will have an effect on the results of the code check. Live load results are based on LARSA 4D's influence surface analysis.

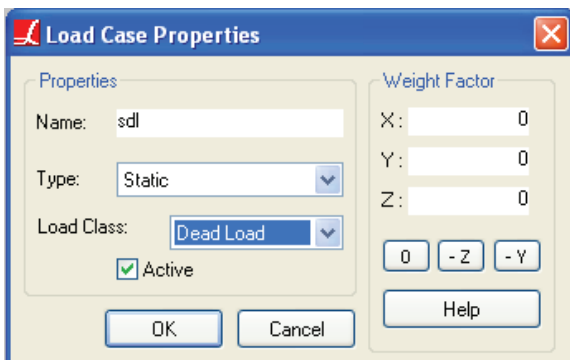
Checks are also made concerning section proportioning, strength, constructability and serviceability. With "quick code check" cross-section code checks can be performed without

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Load Class Tracking

in Staged Construction Analysis

Code compliance requires creating factored load combinations, with different factors applied to different classes of loading, such as dead load, live load, creep, and shrinkage. The Staged Construction Analysis of LARSA 4D reports cumulative effects after each construction step, but it is also possible to extract the partial effects of each load class. Starting with 7.01.60, the partial class-based effects of support, slave/master, and element deconstruction activities are now available, and these are crucial for creating code-based load combinations in a Staged Construction Analysis. We discuss below setting up a model for tracking class-based loading in Staged Construction Analysis and how this method applies to support changes and element deconstruction.



To use load class tracking, choose a load class for each load case.

Setting up the Model

In a Staged Construction Analysis model that will use class-based load tracking, it is necessary to ensure that each load case is assigned a load class. Load classes can be chosen from a pre-set list of 45 classes including “Dead Load”, “Live Load”, “Creep”, “Snow Load”, and “Prestress”. The choice of class does not impact the analysis and is used only for reporting partial effects during post-processing. To choose a load class for a load case, use the Load Cases & Combinations Spreadsheet or the Load Cases Explorer. In the Load Cases Explorer, right-click on a load case, choose Properties, and select a load class. Don’t forget to set the “Dead Load” load class to load cases for self-weight.

When setting up construction stages and steps, do not group activities together into a single step if they are assigned different load classes. For example, dead load and live load cases should be placed into separate construction steps. Element

construction and support addition activities do not add forces to the model and can be grouped with any other activity. Tendon stressing activities are analyzed separately from other activities and are automatically assigned the Prestress Load class in results.

Three other types of activities redistribute forces in the structure: support removal, slave/master removal, and element deconstruction. In each of these activities, forces internal to an element are applied back onto the structure in opposite direction. When a support is removed, the reaction is applied back into the elements connected to the support according to their reported end forces. Similarly for slave/master removals and element deconstruction. No load class is chosen explicitly for these activities because these forces are due to earlier loading. For example, if Dead Load is responsible for a reaction at a support, then when the support is removed and the reaction is applied as loads back onto the elements, the reaction added back is known to be due to Dead Load. If loading from several load classes has contributed to a reaction, the reaction caused by each load class is separately redistributed in the model. LARSA 4D tracks the separate reactions caused by each class of loading so that it can generate a separate result case during the analysis for each load class’s redistribution of force, allowing the user later on to factor each class’s effect according to a code. Again, this occurs similarly for slave/master and element removal.

Before running a Staged Construction Analysis, activate load class tracking in the analysis window by changing to the Staged Construction Options tab and selecting “Enable Class-Based Load Tracking.”

The Load Classes of Result Cases

In analysis results, each result case is assigned a single load class. You can check which class a result case is marked as by clicking the case in the Analysis Results Explorer and then looking at the information box below the explorer.

For result cases that correspond directly to a construction step in the input data, the load class will be the same as the load class of any load cases applied in the construction step. If a self-weight load case marked as the “Dead Load” class is applied in a construction step, the results for that step will be marked as “Dead Load” as well. If the construction step contained only element construction and support additions but

no load cases, the results will have the “none” load class for that step.

LARSA 4D will also generate special result cases. “PT Activity” result cases are generated for construction steps in which tendons are stressed: these load cases are marked as “Prestress Load” automatically. In the Time-Dependent Staged Construction Analysis, special Creep, Shrinkage, PT Relaxation, and Other PT Losses cases are created. These cases are assigned to separate load classes for these effects.

When a construction step contains a support or slave/master removal or element deconstruction, LARSA 4D automatically redistributes forces separately by load class, as described above. When this occurs, separate result cases will be generated for each load class that contributed to the element internal

forces. By creating separate result cases, the partial effects of each load class in the support, slave/master or element removal can be inspected.

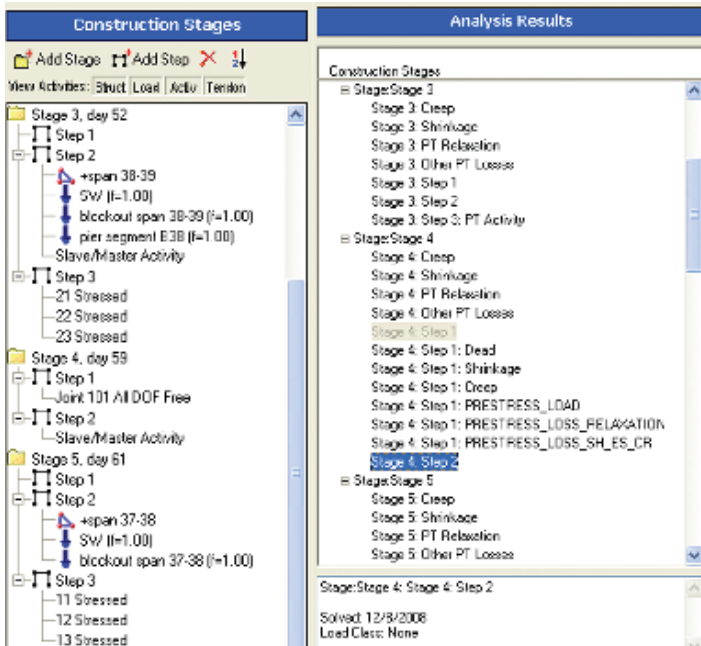
Accessing Class-Based Results

LARSA 4D has several results tools which make use of load classes.

In spreadsheets and graphical results, the user has the option to view: full cumulative results, meaning the total effect on the structure of all loading and activities up to the construction step selected; incremental results, meaning the changes since the immediately preceding result case; and load-class extracted results, which reports the partial effect due to a single load class up to the construction step selected, by adding together the incremental effects of all construction steps for that load class up to and including the selected construction step.

Factored combinations of class-based results can be created with Linear Result Combinations, found in the Results menu. Using Linear Result Combinations, one can combine both the full cumulative results reported by a result case or the load-class extracted results. Full cumulative results are normally used to combine separate result cases of a basic static analysis. In Staged Construction Analysis, one can use load-class extracted results to make a factored combination of the partial effects at the last construction step. Here, one factors the extracted effects of different load classes but for the same result case. For instance, one can combine the dead load at the last step of construction with the prestress losses at the last step of construction, or at any other step of construction.

The Auto Load Combinations tool in the results menu can be used to create linear result combinations automatically for code-specified combinations by selecting from the available results cases for each of the load classes referred to by the code. •



When load class tracking is used, separate result cases may be generated automatically when force redistributions need to be divided by load class.

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the need of an actual model or analysis results. Users can produce a detailed code check report by simply entering the girder and deck materials, dimensions and forces.

Verification

LARSA software has always been designed to earn the trust of its users. For this reason, code check results can be verified with the detailed output reports that the module provides. Reports show the line-by-line computations that follow the design code, with equation number references to the code, as well as of course the bottom line: whether the structure passes or fails. LARSA also collaborated with its client HDR on the verification of the code check module to ensure that no real or hypothetical scenarios were overlooked.

Using the Module

limiting unbraced length to achieve the nominal flexural resistance of $R_b R_h F_{yc}$ under uniform bending. 6.10.8.2.3-4	$L_p = r_t \cdot \left(\frac{e}{F_{yc}} \right)^{0.5} = 115.2936 \text{ in}; \text{ where } r_t = 4.787 \text{ in}, e = 2.90e7 \text{ lb/in}^2, F_{yc} = 5.00e4 \text{ lb/in}^2$
Elastic lateral torsional buckling stress 6.10.8.2.3-8	$F_{cr} = \frac{cb \cdot R_b \cdot \pi^2 \cdot e}{\left(\frac{L_b}{r_t} \right)^2} = 118.4575 \text{ kips/in}^2; \text{ where } cb = 1.000, R_b = 1.000, \pi = 3.142, e = 2.90e7 \text{ lb/in}^2, L_b = 19.61 \text{ ft}, r_t = 4.787 \text{ in}$

Detailed code check reports include equations and numbering from the AASHTO LRFD code to help the user verify the results.

The module is available in LARSA 4D version 7.01.60 and later and can be found in the Tools menu. •

PITT RIVER BRIDGE

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Traditional steel girder or concrete box-girder would appear to be a plausible solution where a shipping channel necessitated a span of approximately 125m. This was certainly the anticipated solution from the BC MoT.

SITE CONDITIONS

The Pitt River is fed from Pitt Lake and flows into the Fraser River, which ultimately leads to the Pacific Ocean. Due to 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 in the contractual requirements that the piles be embedded into the till.

Marine vessels navigate the Pitt River, and an obvious goal was to eliminate the need for swing bridges. The new bridge would require 16m of clearance above the high water elevation.

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.

All of these factors would contribute to the selection of the

cable stayed alternate.

One aspect of the site conditions was favorable. The first two-lane bridge was built in the 1950's and the companion bridge in the 1970's. Instead of being side by side, they are separated by a gap of approximately 50m. This allowed for construction of the main bridge to occur without shutting down the existing bridges and minimizing disruption to the approaching traffic, a rare luxury for construction of a replacement bridge.

EXTREME LOADING

Due to the conditions at the site, extreme loads had to be considered for the design of the bridge. It is becoming common in seismically active areas for the evaluation of multiple levels of earthquake forces on bridges that are deemed important to regional transportation. 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 not collapse.

For the future Pitt River Bridge, four levels of earthquake motions were specified. Using probabilistic considerations, the service earthquake was set at 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.

With each of these earthquakes, the owner provided a set of performance criteria that the bridge must satisfy. The service earthquake requires the bridge to be opened to traffic immediately after the event and show minimal damage such as limited cracking to concrete elements and no permanent offset. The mid-level earthquake allows more damage than the service, but the bridge must be operational for emergency vehicles. Finally, for the highest earthquake, significant damage is expected where spalling of concrete and steel yielding can occur, but the bridge must be able to remain standing under its own gravitational loads.

Geological studies determined peak amplified ground accelerations at the site could reach values on the order of 0.65g (at T=0.4 sec) for the service earthquake and 0.90g (at T=0.6 sec) for the maximum earthquake.

In addition to large earthquake forces, large vessels were identified with the potential to strike the bridge piers. A detailed



study, using probabilistic methodologies established a maximum impact load of 37MN.

DESIGN SOLUTION

As noted earlier, a conventional girder bridge was a plausible solution for the site conditions described. However, as part of the type study during the tender phase of design, it became apparent that a cable stayed span had numerous advantages.

For the river crossing, foundation work in the water carried some level of risk. It was found that a longer span cable-stayed bridge would require only one pier in the water and at a distance well away from the existing swing span. This limited the contractor's risk and reduced the amount of costly marine construction.

The characteristics of the single pier in the water led to additional benefits, such as less exposure to ship impact forces. Ultimately the water foundation supporting the west pylon would require 11-1.83m diameter steel piles with 25mm walls and partially filled with structural concrete. The foundation pilecap was perched at water level avoiding the need for a cofferdam. The other main pylon was located on the eastern bank of the Pitt River with the same type of piles, but with nine total. Each of the remaining supports for the back span used 3-1.83m diameter steel piles.

While the advantages of the substructure for the cable-stayed span were clear, the design of the superstructure would face challenges. Based on the foundation layout and other initial studies, a span arrangement of 95m-195m-95m was determined as optimal. The eight-lane bridge, which was required to have the ability to expand to nine lanes in the future, would nominally be 40m wide and include a 5m widening at the west end to accommodate an interchange. In addition, the project requirements included a provision for the loss of two adjacent stay cables simultaneously.

Considering the sizeable deck area, a conventional twin plane stay arrangement would require stay cables with a large quantity of strands and a tall tower to reduce the inclination angle from the bridge deck. Also the wide deck would require heavy floor beams to carry the load to the edge girders. The cable-stay bridge option did not seem feasible until an unconventional and innovative solution was considered. Instead of two planes of cables, a concept with three planes was developed.

The three-plane cable stayed bridge, with a corresponding line of main steel girders, proved to be an extremely efficient solution. The extra line of support cut the span length of the

steel floor beams in half, reducing the flexural demands by a factor of four, and the extra framing members gave increased redundancy for the loss of 2-stay design condition. The final quantity of structural steel for the bridge per deck area was 135kg/m². The corresponding reduction in steel weight led to cables with fewer strands. Each outer plane of cables required approximately 30 cables of 15.7mm diameter, 7-wire strand. The central plane cables used approximately 60 strands each. The stays were aligned in a parallel harped arrangement, giving redundancy to the anchorage connections.

The innovative detailing did not end with the three stay planes alone. Because 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 to construction, which will be discussed later, but for design it greatly improved the seismic performance. The deck acted as a stiff diaphragm in plane and helped distribute forces between the flexible perched foundation in the river to 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.

As noted earlier, the deck required widening by 5m within the western side of the bridge. The girders splaying outward would have generated out-of-plane bending by the deviating cable forces on the pylon legs. This would have been problematic for the pylon design, but a slight adjustment allowed planar loading to be maintained. A straight chord for each of the girder lines was taken from mid-span of the bridge to the end of the widened back-span, with the pylon placed in-line with the chord. The result was a slight change to the pylon leg offsets and a rotation angle of about 1-degree, with the benefit of greatly reducing out-of-plane forces.

With the bridge design innovations implemented, a 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 attributed to the cable supported bridge was approximately 10% to 20% lower than the conventional option. The Kiewit team was ultimately the lowest bidder for the project, and notice to proceed was given in February 2007. Project costs were CAD\$ 198,000,000, with the main bridge accounting for approximately half of the total.

BRIDGE ANALYSIS

The unconventional design features noted above clarified 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 three

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planes of cables required proper balancing transversely such that the girders would not be unequally loaded.

The bridge designers chose to use LARSA 4D largely due to its ability to accomplish the multiple analytical tasks that would be needed for design. This would include 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 condition with accumulation of different static states, and staged construction of the bridge deck in balanced cantilever with multiple stress states in the cables. Some localized finite element studies were also required, utilizing the program's shell elements.

Due to geometric complexities, the bridge model was developed in great detail. 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. A software function that allowed multiple members to be defined by offset from the same node helped reduce the size of the models and limit analytical runtimes.

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 the loads were higher than predicted.

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 cable staging determined by the designers required a first phase on the steel girders alone and a second stage on the composite concrete deck. Utilizing the analysis software's internal functions for staged construction, the management of the multiple stages was done in the same model file.

The result of the staged analysis was to determine a sequence of construction as the bridge is built out, but also a staggering of the transverse cable stressing as such to avoid excessive lateral tipping of the bridge deck.

BRIDGE CONSTRUCTION

Many of the benefits noted in the design of the bridge also resulted in benefits to construction in both cost and schedule savings. Already highlighted were the limited marine construction for the foundations, and the open access of the stay cables in the pylon, but the bridge deck itself also took advantage of details in the design to help in construction.

The spacing of floor beams was chosen to be 3.333m, with the stay spacing at 10.0m. Therefore each bridge deck erection

step required the lifting of a 10.0m segment with three floor beams. As discussed earlier, the multiple planes of stays reduced the demands on the steel girders thereby reducing their weight. The contractor's decision to lift each segment in two halves reduced the weight of each pick to a maximum of 25 metric tonnes (mT). Kiewit designed a beam and winch lift set with the capability to adjust the slope of the segment frame for fine tuning. The precast concrete panels were divided into 6 segments across, and were each less than 10mT. The panels could then be placed with a conventional RT crane placed on the deck, which also has the capability to relocate the beam and winch frames. The frames were brought to the bridge by either barge or a land based crane. Overall, the construction of the bridge was accomplished by the assembly of relatively small pieces, not commonly associated with cable stayed bridges.

The frame erection process will be used for construction of most of the bridge except for the initial pieces at the pylon and then near the end of completion where pieces will be stick-built. The operation to set the first steel girder pieces was a relatively simple process, with the girders anchored to the face of the pylon by PT bars connecting each side through a base plate. The base plate includes vertical shear keys with matching female keys on the pylon side with a grout layer sealing the connection. The rigid framing eliminates the need to stage and balance the initial girder frames as with a conventional floating deck.

The stay cables, supplied by Dywidag Systems International, are stressed at the pylon entirely with monostrand jacks (stand-by-strand). A ring nut is supplied for future adjustments if necessary. The seven-wire strands are galvanized and wax filled, with an outer polyethylene coating. Each cable is protected by a high density polyethylene (HDPE) pipe, with helical spirals on the exterior. External dampers were determined to be necessary only at the two longest stays.

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 is believed to be one of the largest pile load tests ever performed.

STATUS

Bridge construction began with pile driving in August 2008, only six months after notice to proceed. As of January 2009, the eastern side is half complete (four cables sets) and the western side is one quarter complete (two cable sets) with final delivery scheduled for the end of the year. •

Follow the project in real time with the construction camera at www.ibtengineers.com.