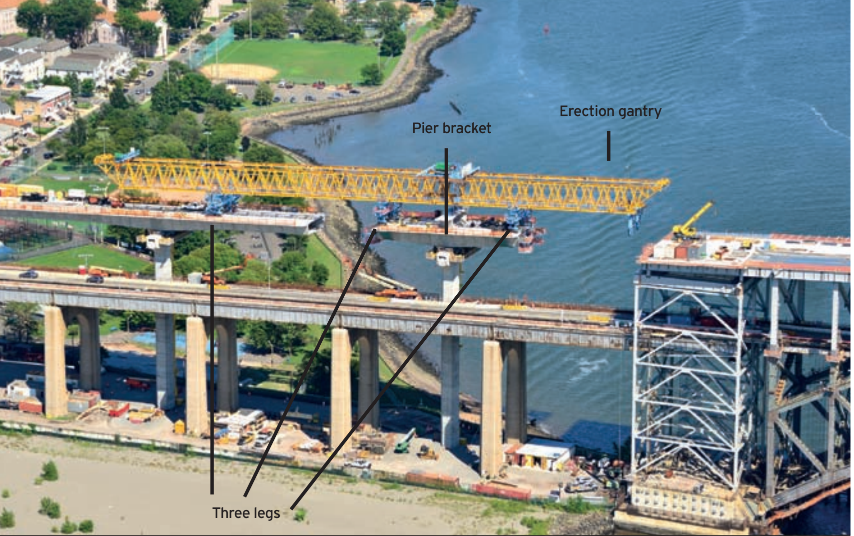


Erection gantry on the approach bridge *(Vincent Vuoto/Best Aerial Photos)*


View of the Bayonne bridge during construction *(Vincent Vuoto/Best Aerial Photos)*

SEGMENTAL SCRUTINY

Specialist bridge design software is playing a part in analysis of the construction procedure for the segmental approach structures on the new Bayonne Bridge. **Mike Kiggins**, **Richard Tremblay**, **Walter Eggers**, **Xiao Fu** and **Shukre Despradel** explain how

Traffic using the Bayonne Bridge in the USA will be shifted onto new approach viaducts later this year as work on raising the bridge deck to increase navigation clearance continues apace. The bridge, which spans the Kill Van Kull channel connecting Staten Island, New York and the city of Bayonne in New Jersey was designed by engineer Othmar Ammann and architect Cass Gilbert. When it opened to traffic in 1931, it was the longest arch span in the world with its tied-arch main span of 511m, total length of 1,762m and mid-span vertical clearance of 46m. The bridge was designated a US National Landmark in 1985.

In 2010 the owner of the bridge, the Port Authority of NY & NJ, launched a multi-year project to raise the bridge deck and existing arch to a minimum clearance of 65.5m to allow larger vessels going through the widened Panama Canal to access the port of Newark.

The construction project started in May 2013 and is expected to be completed by 2019. In August last year, the northbound approaches were completed, and the increased navigation clearance will be achieved by the end of this year. The general contractor responsible for the construction works of raising the bridge profile is joint venture Skanska Koch Kiewit.

The precast-segmental concrete approaches have spans of approximately 90m and are being built using the balanced-cantilever construction method. Precast segmental piers up to 60m tall are being built using ground-based cranes and construction of the balanced-cantilever segmental superstructure is carried out using an overhead erection gantry next to live traffic. Due to the height and slenderness of the piers, bearings are required between the superstructure and the piers.

Finley Engineering Group is responsible for the engineering of the segmental erection, while McElhanney Consulting Services is the engineer for the erection gantry along with production of gantry work plans. Given the high risk and technical complexity of the erection works, Kiewit Engineering Group, the engineering division of contractor Kiewit, is carrying out an independent design review of some of the high-risk components of the approaches: the erection gantry, pier brackets, gantry kinematics and work plans, and the longitudinal and transverse construction analysis of the erection of the northbound bridge. Due to the high-risk, fast pace and changing conditions of this job during erection, it is important that all aspects of the construction are modelled and analysed to comfortably provide quick responses to the erection team.

Kiewit Engineering Group is using Sofistik design software for the detailed stage-by-stage analysis of the bridge during construction, considering the interaction of the temporary and permanent structures.

The superstructures for the approach bridges are being built using two three-leg overhead erection gantries, one for each approach. Because of the deck-to-column bearing connection, a temporary pier bracket connecting the deck to the pier cap is required at each pier to provide stability to the pier table. Due to the slenderness of the piers, once the gantry is in place the stability of the deck is transferred to the gantry and the pier bracket is removed. Since the gantry is required to provide stability to the balanced-cantilever, it has to be designed to take unbalanced deck loads during erection, in particular the demands of a sudden, accidental release of a precast segment – known as a 'segment-drop event'.

In general, erection gantries have only one main support, which is locked longitudinally in order to avoid introducing longitudinal forces into the permanent structure. In this project, the locked main support is always located on the finished bridge and prevents the truss from rolling downhill. A minimum compression reaction on the locked main support must be maintained at all times in order to ensure stability of the system. Other main supports also have limited tensile capacity in the hold-downs which connect the truss to the support. The tension capacity in the unlocked main supports is only allowed to be exceeded during a segment-drop event.

Given the complexity of the gantry-bridge structural system, a high-level analysis was carried out in Sofistik in order to calculate the gantry demands and reactions during a segment-drop event. An initial analysis was performed using the construction stage manager module to determine the initial stress distribution under gravity load. A subsequent non-linear time history analysis was carried out with the software's ASE module where the segment drop load was modelled using a ramp-up, followed by a plateau and then a sudden drop time-force function. The ASE module is the main solver in Sofistik for both linear and non-linear analysis of beams and finite element structures. The initial ramp-up and plateau were used to gradually introduce the segment mass and avoid inducing unrealistic inertial forces. In order to capture different possible scenarios, the segment was modelled as dropping from the gantry and from the balanced cantilever.

The main focus of the analysis was to determine whether the locked main support would have the required residual axial compression for stability and the demands in the gantry-bridge structure. Compression-only elements were used to allow uplift at the unlocked main supports.

In this particular project, using a gantry designed to be launched from pier to pier would have proved heavy and uneconomical. To address this, gantry supports were placed in between piers during gantry launching and for balanced-cantilever erection. In order to check that the gantry-induced demands on the bridge would be acceptable, a detailed stage-by-stage longitudinal analysis was carried out.

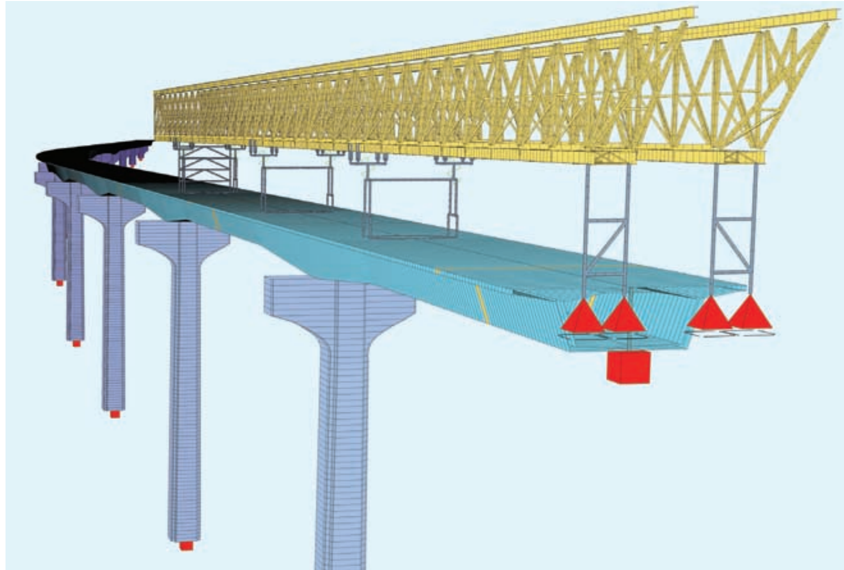
Using parametric tools in the bridge design software, the geometry of the bridge can be defined by using geometry axes following the horizontal alignment and vertical profile of the bridge. Deck variations such as top slab width, bottom slab thickness and deck height can be introduced by defining a single section and using parametric tables and/or functions based on the bridge stationing. In this project, the 3D model of the gantry was first created in CADD and then it was imported, meshed and combined with the structural model of the bridge.

In addition to the gantry loads, all other construction loads such as segment staging, counterweights and construction live load were included in the analysis. Temporary works components like pier brackets, pipe struts and closure beams were also considered in the analysis.

The pipe strut is a temporary steel shoring column located under some of the transversely eccentric piers. The outside longitudinal plate girder must remain in place in order to keep the existing bridge open during construction. As a consequence, the engineer of record introduced in the design an eccentricity between the northbound deck and the pipe strut. The structural interaction between the gantry, the balanced-cantilever structure, the pier brackets, the pipe strut, and the closure beams can only be analysed in a global model using a specialised bridge analysis software such as Sofistik.

Now that the northbound bridge is built, traffic will be switched to the new bridge to allow the existing steel approaches to be demolished.

Once the southbound bridge is completed, the pier caps on the two bridges will be connected, the pipe strut will be removed and the northbound deck transverse eccentricity will be transferred through a frame action between the two columns



Southbound New Jersey approach global model in Sofistik

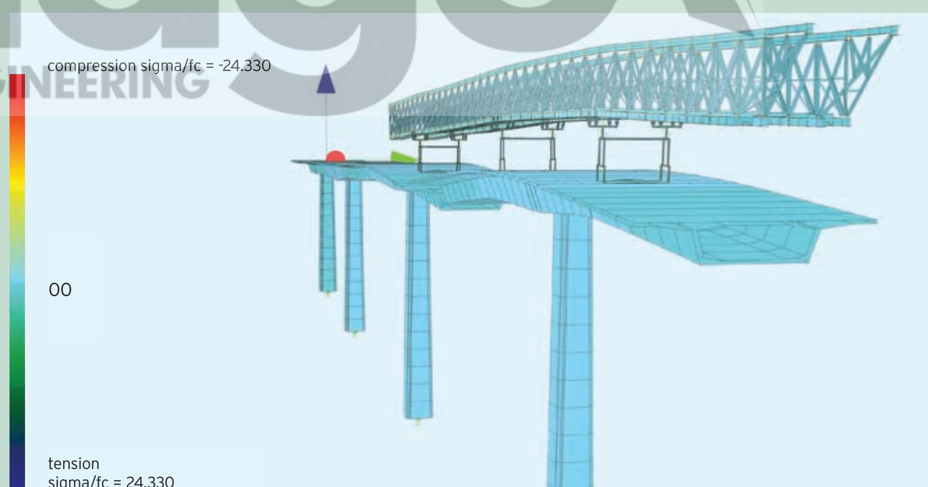
Mike Kiggins is project manager and Richard Tremblay is design manager for Skanska Koch Kiewit; Walter Eggers is technical director, Xiao Fu is structural engineer and Shukre Despradel is senior structural engineer for Kiewit Engineering Group

TOOL TALK

Sofistik international sales manager **Georg Pircher** sets out some of the relevant features that can assist with complex and typical construction analysis

Sofistik combines CADD-based parametric geometry definition with a powerful programming tool; the parametric geometry definition (computer-aided bridge design or CABD) allows the user to define the geometry in CADD by combining the roadway axis with the varying dimensions of the section geometry. Specific points of interest along the roadway axis, such as construction joints and supports, are needed to divide the deck into logical units, per precast segment, for subsequent stage activations.

As an add-on or an alternative to the graphic user interface, the programming tool's built-in text editor allows the engineer to quickly generate all aspects of the geometry, prestressing tendons, loads, analysis and results.



Deflected shape for a specific construction stage and interaction between superstructure and gantry

Once the model is set up, the activation along the time axis is carried out. Where precast segments are used, different concrete ages are combined during the analysis. As the designer needs to achieve the best possible precamber, the time settings can become complex; the concrete ages; the time steps between activations and load changes; the tendon jacking and grouting and, consequently, the cross-section changes along the time. All require good data management because, at the final stage, different result envelopes are required. The specific construction stage manager separates and combines the different stage effects into action envelopes, providing maximum and minimum forces, displacements and stresses for quick result access for both the bridge structure and the gantry. All the special tasks such as the support uplift are, naturally, taken into account as part of the staged analysis. Sofistik has been used here for a couple of individual scenarios such as a non-linear time history calculation for the complex segment placement procedure.

In addition to the very detailed global analysis using beam elements, a couple of local checks are performed. Parts of the deck are modelled with shell elements to better understand and check the force flow in the section as well as to do local checks against punching of the bottom slab, and so on. The relevant features are available as part of the Sofistik flagship package 3D FEM Ultimate.