Extra for shipping

Bridge redirected to handle larger cargo vessels

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The Bayonne Bridge opened on Nov. 15, 1931, as the longest steel-arch bridge of its day and retained that title for more than 45 years. The single-span through-arch truss stretches 1,652 ft across the Kill van Kull. The approaches, consisting of a twin steel-plate girder system with floorbeams and slab, take the overall length of the structure to 6,974 ft.

Bigger and bigger

The Bayonne Bridge retains its stately presence to this day, but the ships passing beneath it to reach Port Newark and Port Elizabeth are becoming more massive than anyone could have imagined when Othmar Ammann designed it to accommodate the U.S. Navy's tallest vessels. The navigational clearance of 151 ft represents a potential growth constraint for the two ports as current Panamax (maximum dimensions that will fit through the lock of the Panama Canal) ships feature a height from the waterline of 190 ft. With the widening of the Panama Canal under way, the next generation of cargo ships will be even taller.

The U.S. Army Corps of Engineers (USACE) conducted a study of the existing port facilities and the impact of shipping-clearance constraints on their future economic viability. In support of the USACE study, the Port Authority of New York & New Jersey (PANYNJ) commissioned an alternatives evaluation to determine the feasibility and cost of increasing navigational clearances under Bayonne Bridge. More than 40 options were evaluated, focusing on four main themes: (1) raise the arch roadway within the confines of the existing arch; (2) raise the entire existing arch by jacking; (3) provide a lift bridge; or (4) construct a new bridge or tunnel. In addition to increasing clearance, all of the options included provisions to expand the roadway geometry to conform to AASHTO's Policy on Geometric Design of Highways and Streets for a design speed of 55 mph.

In December 2010, the PANYNJ selected the raise-the-roadway option as the preferred alternative to address the Bayonne navigational-clearance limitation. The project will increase the clearance from 151 ft to 215 ft, providing clearance for the next generation of container vessels.

Additional improvements to the facility include a new approach structure; wider travel lanes; shoulders; a median barrier; new

electrical and mechanical buildings in both states; upgrades to the existing administration building; a new 12,000-sq-ft storage building in Staten Island; a closed drainage system; the addition of fire standpipes; all new communications and telemetry systems; variable message signs; and roadway sensors.

Testing one's strength

Bayonne Bridge's arch is a riveted, steel box truss with a 151-ft navigational clearance, an elevation at the crown of 323 ft and an arch span of 1,652 ft. The arch has a center to center of arch planes of 74 ft, and the existing roadway is 40 ft wide. Each chord comprises plates and connection angles riveted together to form a box section. The upper chord is a single-cell box, while the lower chord is a dual-cell box. The arch truss is composed of three types of steel: silicon steel, carbon steel and manganese steel. As part of the design documentation process, steel samples were taken at more than 75 locations and included samples of chords, diagonals, verticals, gussets, bracing members and rivets.

Samples were tested for chemical composition, tensile yield and ultimate strengths in addition to metallurgical examinations. To date, the chemical analyses have confirmed the component steel for the various member types. The ultimate tensile strengths also have been confirmed, while yield strengths have been identified as being lower than expected. The difference is attributed to acceptance methodologies between 1930 and current practice. The design is progressing with yield strengths based on modern classification methods. This resulted in an approximate reduction of 8% from the original design values.

The basic statical scheme will be maintained, with joints at the intersection of the floor system with the lower chord. One major change will be the extension of the arch floor over the flanking tower structures. This will eliminate two expansion joints on each side of the arch, thereby eliminating a maintenance and corrosion concern.

The existing floor is a floorbeam-and-stringer framing scheme with a reinforced concrete deck. An existing sidewalk on the west side will be eliminated and replaced with a 12-ft-wide shared-use path on the east side.

The original structure was designed for a transit system. While it was never implemented, the addition of transit loading to the design provided a significant reserve for the current loadings, resulting in less demand on the arch. The excellent condition of the arch is attributed to this reduced demand.

The new roadway will make use of the space originally designed for transit by widening the vehicular lanes from 10 ft to 12 ft and adding a median barrier and shoulders.

Response needed

The main-span arch structure was modeled for both static and dynamic analyses. The concrete decks were modeled with plate elements. The 3-D bridge model was built in sufficient detail so as to analytically capture the response of the bridge to the different loading demands.

The model of the final configuration of the existing bridge was determined using stage-construction features and following the general steps of the original construction. The span was erected as a three-hinged arch with a hinge at the middle lower chord originally planned at joint L20, and with no load on the span except the weight of the arch trusses and their bracing. Then, the upper chord members in the two middle panels were riveted in place and the hinge "locked" at the lower chord. Additional loads were then placed on the span as a two-hinged arch. In the actual construction, the channel requirements made it necessary to place the temporary hinge at L14 South instead of L20, and special adjustments were necessary to restore the stresses to the values assumed in the design.

Live-load analyses were carried out using influence lines to determine maximum effects on all key components of the structure. Modal analyses were performed as the initial step for the multimode seismic spectrum analyses.

Modal analysis also was used to determine the wind loads on the structure. The total wind loads for the structural design should be the peak loads, which include the mean wind loads, the background fluctuating wind loads and the inertial loads due to the structural motions. These loads were determined through analytical and experimental methods performed by wind-engineering consultants.

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procedure focused on the identification of aerodynamic instabilities of the deck involving vertical and rotational motions. To be representative of the full-scale structure, two different modes of vibration with dominant vertical and rotational motions were selected and modeled. This test also determined wind coefficients of the deck system; while a complete model of the arch with and without the deck was tested to determine the wind coefficients on the arch itself.

A theoretical buffeting analysis was performed to estimate the bridge's responses in each of its modes of vibration to the random excitation of wind turbulence. Input parameters included static aerodynamic force coefficients, mass and polar moments of inertia, bridge dimensions, modal frequencies and shapes, structural damping and wind-turbulence properties. The loads obtained are based on the dynamic properties of the bridge provided by the design team. The lab provided 52 sets of approximate simplified wind-load cases based on linear combinations of the dynamic loads in the various modes of vibration to be applied on the 3-D model of the bridge.

Detailed analysis

The arch structure was analyzed from the initial construction stage through the reconstruction phases and eventually to the various final in-service scenarios. These detailed, step-by-step analyses enabled a realistic capture of the statical schemes and dead-load states. Step-by-step analyses considered member removal, member addition (new portals) and member strengthening.

The dominant load combination was Strength III based on the increased wind resulting from raising the roadway 65 ft. The design wind speed for a 100-year return period was derived from the analysis of data from nearby Newark Liberty Airport and verified from wind data obtained for neighboring LaGuardia and JFK airports. **R&B**

Project construction stages

The project's construction is broken down into five major stages.

Stage 1: Widen structure to the west (approaches only);

Stage 2: Relocate two lanes of traffic to the west side;

Stage 3: Construct floor system at the upper level (east half);

Stage 4: Shift traffic to the upper level; demolish existing arch floor; and

Stage 5: Complete upper-level roadway; shift traffic to final configuration.

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