Merit Award: Reconstructed

Franklin Square Bridge

Brooklyn, New York

The 200' Franklin Square Bridge is part of the Manhattan approach to the Brooklyn Bridge. Due to its trapezoidal span, each of the six pin-connected eyebar trusses that support the bridge have a different span. Since 1883, various alterations have increased dead load significantly. Preliminary analysis suggested, and subsequent sophisticated analysis proved that, the bridge wasn't safe. The New York City Department of Transportation (NYSDOT) issued an emergency contract for retrofit to the consulting engineer who performed the analysis. The final design employed six steel arches founded into the original masonry abutments to support the six wrought iron trusses.

Replacing the trusses was ruled out by the client because of the bridge's historic importance; in addition, the bridge had to remain open. The restoration of an historic structure was accomplished in an emergency situation and under stringent traffic restrictions. The client's request that the consulting engineer use arches to support existing trusses was unusual, as well as adding additional complexity. The engineer's design neither altered nor compromised the elegant appearance of Roebling's original structure, despite its complex geometry and outdated materials.

The Manhattan approach to historic Brooklyn Bridge incorporates a 200' bridge over Franklin Square in Manhattan at the junction of Pearl and Cherry Streets. The bridge's supporting structure consists of six pin-connected eyebar trusses. Each truss has a different span, because the bridge is trapezoidal in plan. Transit tracks, supported on an open steel structure, were removed and replaced with a reinforced concrete deck. The original Belgian block roadways and wooden pedestrian promenade in the center were both replaced with thicker concrete decks.

In preparing a design for the re-decking of the Brooklyn Bridge approaches, the engineering consultant performed an analysis of the Franklin Square Bridge using the current dead load. Appearances to the contrary, it revealed that the bridge trusses were overloaded. Alterations made to the bridge over its lifetime, to accommodate an increase in the volume of vehicular traffic, had increased dead load significantly.

John Roebling designed the truss members of the Franklin Square Bridge as part of his original Brooklyn Bridge scheme using materials that date to that era. The trusses were made of wrought iron common for the 1880s, but not today. Since wrought iron offers excellent ductility and consistent strength, and has superior resistance to corrosion, the bridge was able to sustain the increase of applied loads without incident since 1883, its trusses showing no visible signs of distress.

The pins connecting the truss members were made of carbon steel, a forerunner of today's A36 steel. In the simple elastic analysis requested by the client, some of the pins were found to be stressed beyond the yield threshold and, in some cases, beyond the full plastic moment capacity. The lack of visible distortion in the pins suggested that a redistribution of the forces in the eyebars was taking place. The engineering consultant deduced that there was reserve strength not indicated by the preliminary analysis, which was insufficient to determine the actual safety of the bridge.

The engineering consultant chose to perform a more sophisticated sequential failure analysis, because of the uncertainties involved. The loading was increased in steps until overall yield of the bottom chord was reached. The results of this analysis showed that the reserve against full yield was inadequate. NYSDOT issued an emergency contract to the engineering consultant for design and construction of a retrofit to provide adequate support for the increased loads.

Aesthetic and Technical Complexity

In addition to meeting safety requirements the retrofit structure would have to be attractive, in keeping with the elegance of the original bridge. It was given that the original historic trusses should not be altered in appearance. Replacing the trusses was ruled out for another reason: the bridge had to remain open to traffic.

The final design employed six steel arches spanning the full length of the bridge to support the original six wrought iron trusses; the arches were founded into the original masonry abutments. While steel arched bridges are not uncommon, the client's request that the engineering consultant use arches to support the existing trusses, in order to minimize traffic interference and for aesthetic reasons, was unusual and contributed significantly to the complexity of the project. The results more than made up for the challenge of the arch solution: the appearance of the bridge was improved by adopting this scheme over the original girder scheme.

Innovation

The arches, in which no members were perpendicular to any other members, were an extension of Roebling's complex geometry.

One way to conceptualize the design approach is to visualize that the original steel trusses of the Franklin Square Bridge were supported on falsework from underneath during construction. In the 1999 retrofit design, the engineering consultant used steel arches as permanent falsework to support the historic structure above. The trapezoidal plan of The bridge required arches with six different spans, reflecting the six different trusses above, ranging from 147 to 190'. Furthermore, the panel points on the trusses above were arranged in a pattern that was skewed to the axis of the bridge. The truss verticals, which were strong compression members directly supporting the floor beams, were used as the element into which a vertical force was introduced to relieve the trusses. Because the pattern of these vertical members was skewed to the bridge the posts set on top of the arch had to conform to this pattern.

The singular arch geometry, with virtually no members perpendicular to any other members, was a detailer's nightmare. Usually, the floor beams on a skewed bridge are made perpendicular to the main carrying members to simplify the geometry. Roebling was not so kind as to retrofit engineers, who had to extend the geometry of his original design into the much more complex geometry of an arch structure.

Respect for Original Design

The advantages of working within the limits of Roebling's geometry were that it maintained the appearance of the bridge and visually enhanced the unequal curvature of the arches. The arches added a curvilinear element to the structure that contrasted with the lattice of the wrought iron trusses and are reflective of the masonry arches crossing other streets. Working with the client, a color scheme was selected to delineate new structure from old, so that the historic and retrofitted portions were easily identifiable.

Arches were composed of three elements to facilitate erection and designed to stand alone.

It was desirable that all the arches be sprung at the same elevation and that the crowns be as close as possible to the existing structure above. As a result, the arches all had different radii. Each arch was composed of three elements, which were spliced together in the field to facilitate erection. The arches were designed as three centered arches with the radii changing at the splice points and selected to approximate a parabolic shape. In order to reflect the solid plate top chord, the arch ribs were I-sections fabricated from steel plate; bracing and columns were rolled sections with webs pierced to reflect the lattices of the existing bridge.

Pre-calculated loads were jacked into the arches at the interface between the columns and the truss panel points. Because the arches and trusses behave differently under temperature changes, these forces were calculated to relieve the bridge without lifting the truss off its bearings on hot days, while providing adequate support on cold days. The arches were further designed to stand alone without the stiffening effect of the trusses.

Social and Economic Considerations

Design and construction decisions favored traffic safety and convenience.

The arches were erected with limited lane closures. The six arch ribs were erected in six nights, with the street below the bridge closed from 9:00 p.m. to 6:00 a.m. Only one lane above the bridge was closed, so that the truss above the arch being erected could be used to lift the rib into its final position. Other work was performed with only partial closure of the street below, minimizing the effect of the construction on automobile traffic. Traffic safety and convenience was also enhanced by the design itself. The use of arches left the entire width of the street open without columns or piers, which a traditional temporary shoring scheme would have required.

Project Team

Owner
New York City DOT

Designer
Weidlinger Associates, Inc.

Steel Fabricator
Harris Structural Steel Co.

Steel Detailer
Graphics for Steel Structures

Steel Erector
Koch Skanska, Inc.

General Contractors:
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