Rehabilitation of Three East Pine Street Bridges

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ABSTRACT: The existing three span bridges over the canals on East Pine Street in the City of Long Beach, New York, have been rehabilitated to single-span bridges. To achieve this, a number of obstacles have been overcome. These include procuring funding, meeting headroom restrictions for marine traffic, allowing for grade change limits for road users, abandoning of the initial precast concrete segmental design at 95% completion, fast tracking design on a new alternative to meet fiscal deadlines and developing a three-dimensional model to ensure that the load transfer between members satisfied deflection limits. On site, the Contractor has had to contend with limited space being very close to residential properties, unexpected asbestos on the existing piles, difficult bolting configurations on moment resisting connections and creating innovative methods to erect the steelwork. The site team had to address problems that arose due to limited sight distances for vehicles turning onto the side streets.

1 INTRODUCTION

1.1 Location and background

The City of Long Beach is located on an island off the south shore of Long Island in Nassau County, New York (Figure 1). The island is separated from Long Island by Reynolds Channel. On the east side of Long Beach, there are four canals, orientated north-south, bounded on the southern end by East Chester Street and connected to Reynolds Channel at the north end. These four canals are Bob Jones, Hagen, Ouimet and Sarazen, all named after professional golfers from the mid 1900’s (Figure 2).

![Figure 1. Location of Long Beach](image)
East Pine Street is orientated in an east-west direction and crosses Hagen, Ouimet and Sarazen Canals at about their mid-length. East Pine Street is a local street with a speed limit of 15 mph. It has one vehicle lane in each direction, one parking lane in each direction and two sidewalks separated from the roadway by a utility strip. The curb-to-curb distance is 10.98m (36 feet).

The area around the canals is residential; the boundary area for the residences includes direct access to the canals. In addition to carrying traffic and pedestrians over the canals, East Pine Street carries a 250mm (10 inch) diameter watermain, which is part of a water supply loop for the residences. Overhead primary and secondary electricity, telephone and cable communication cables span the canals along the south side of the bridges. East Pine Street provides access for local residents to the area and is an important route for emergency services and school buses.

1.2 History

It is not clear when the canals were first built or whether the canals or East Pine Street came first or together. Prior to 1968, East Pine Street crossed the canals on fill, with a corrugated steel culvert allowing the canal to pass through the fill (Figure 3). The culvert size permitted very small boats to pass through within a limited tidal range. Drawings dated 1966 for a dredging contract indicate that East Pine Street consisted of one sidewalk and one lane in each direction for road traffic for a total width of approximately 7.62m (25 feet) over the canals.
In 1968 the culverts were replaced by three span bridges. These bridges maintained the full width of the East Pine Street approaches. The bridges consisted of precast concrete planks supported by reinforced concrete abutments and pier caps on steel pipe piles filled with concrete. Access to the south side of the bridge for marine traffic was improved. However, the size of the boats was still limited by headroom and tide level (Figure 4).

Over time, the pier pile caps and the protection to the piles (asbestos jacket) was being damaged by boats colliding with them, and, more significantly, the underside of the precast planks started to spall; which exposed the steel tendons and caused corrosion due to the aggressive marine environment. In 1989, the asbestos jackets on the piles were replaced by fiberglass and grout jackets. Netting was installed after the concrete started spalling and falling on boaters below. However, the netting eventually became a health risk, due to birds nesting in it. The fiberglass protection to the pier piles was damaged by further boat collisions. When the load rating for the bridge was reduced to an unacceptable level, it was determined that rehabilitation was required.

1.3  Moving forward

In 1997, the Federal Government set up funding for local projects that was to be administered through the states. This funding, known as “Pass Through Funding,” was administered in the
State of New York under the “Procedures for Locally Administered Federal Aid Projects.” The bridges are owned and are maintained by the City of Long Beach. The condition inspections of the bridges are carried out by the New York State Department of Transportation. The poor condition of the bridges made them a suitable candidate for the Pass Through Funding with the Federal Government providing 80% and the City of Long Beach 20% of the funds.

With a source of funding in place, the City of Long Beach procured the services of Dewberry-Goodkind, Inc. (formerly Goodkind & O’Dea, Inc.) to commence the rehabilitation design Phases I to VI in accordance with the New York State Department of Transportation (NYSDOT) Design Procedure Manual. Phase IV was completed in June 1999 and a single-span structure was selected for the rehabilitation design.

The single span option eliminated the maintenance problems caused by boat collisions with the pier piles and pile caps. To achieve the single span of up to 28.390m (93.14 feet), permission was given by NYSDOT to use a proprietary concrete precast segmental superstructure called Channel Bridge.

2 DESIGN

2.1 Design issues and solutions

East Pine Street is practically level over its length. This changes dramatically at each bridge with approach grades of up to 6.88% (Ouimet) to effectively provide a “hump” over the canals. This hump varies from a 360mm (≈1.2 feet) (Sarazen) to 478mm (≈1.6 feet) (Ouimet) rise. Within limited tidal ranges, some boats can pass under the bridges (Figure 5). As well as providing a single span superstructure, it was necessary to maintain or improve the clearance under the bridges for marine traffic. The ability to increase the grade on the approaches, however, was restricted by a number of factors. The first was that the bridge approaches were not American Disabilities Act (ADA) compliant. The second was that the change in grade on the approaches could only begin within 5m (≈16.4 feet) of the bridges because of adjacent crossing streets and existing driveways. The third was passenger comfort traveling over the sudden change in grade. Because the bridges had been constructed using precast concrete planks, grade breaks occurred at each abutment and pier. By providing a vertical curve for the new superstructures, the headroom was improved for marine traffic and the passenger ride comfort was improved, both without increasing the approach grades. The ADA requirements could not be met without lowering the clearance to the canal, which would not have been acceptable to the US Coast Guard or residents on the canals south of the bridges.

Figure 5. Typical approach view of the post-1968 bridge.
NYSDOT requires that the existing approach curb lines be maintained across the bridge. However, the selected single span option of the Channel Bridge cannot provide this as there is only one size set of forms available in this region. Increasing the width of the bridge to comply with the requirements would require a new set of forms, precluding this option on the basis of cost. A waiver to this requirement was obtained from NYSDOT.

Due to US Army Corps of Engineers requirements, a permit to place sheet piling or other types of piles in the canals would be difficult to obtain in a timely manner, if at all. The Channel Bridge requires substantial temporary support works during erection. The temporary works would utilize the existing piers in the canals, the demolition of which would be carried out after the superstructure was completed.

As-built drawings were not available for the existing bridges; hence, the piles supporting the abutments had to be assumed and confirmed during construction. While the existing abutments were designed to support the relatively uniform load from the precast concrete planks, the new superstructure would require support primarily at the four corners. The initial approach was to consider drilled shafts, one in each corner. However, the presence of existing obstructions (including bulkhead tie-downs, surface water drainage outfalls and the unknown locations of the abutment piles) led instead to the use of 325mm (12.8 inch) diameter pipe piles. While eight piles would be needed to support each corner of the bridge, the pilecaps and the piles were designed to allow flexibility in locating them. The contract documents were written so that the contractor was aware that the existing piles had to be exposed before the final positions of the new piles could be determined. A provision was also made for the possible incorporation of the existing piles into the new pilecaps and the consequent reduction in the number of new piles needed. During construction, at each pilecap, seven new piles were to be installed while two existing piles, found acceptable following dynamic load testing, were to be incorporated into the new pilecaps.

To address horizontal loading from seismic, wind and braking forces, it was desirable to batter the piles. However, due to the close proximity of the steel sheet pile bulkhead on the canal face and obstructions on the approach face to the proposed abutments, the piles were designed to be driven vertically and to take the lateral forces in bending. Consequently, the pile wall thickness was specified to be 13mm (≈ \( \frac{1}{2} \)”). This was not a readily available size, and a contractor would have to place orders for this material, well in advance, to meet the steel mill rolling schedule.

2.2 The Channel Bridge

The Channel Bridge was developed by J Muller International and this type of design has been used on many bridges in Europe, particularly in France. A number of the bridges have been built in the United States, some of which are in the State of New York. The superstructure consists of precast concrete segments and uses post-tensioned strands both longitudinally and transversely to resist the bending forces. Deep beam sections protrude above the deck, and these transfer the deck loads to the abutments and/or piers. Erection is relatively quick making it attractive for use over highways where prolonged closures for erection need to be avoided. The Channel Bridge design also has a significant advantage in providing a shallow deck profile which increases the under-clearance, an attractive feature over the canals for providing clearance for marine traffic.

For the bridges over the canals, one sidewalk was to be carried on the deck of the bridge. The other was designed to cantilever from the outside edge beam and would also carry a water distribution main.

With the design approximately 95% complete, an issue arose over the cost and availability of the Channel Bridge. Late in the design, the ownership of the forms changed hands. This change, combined with licensing issues with the patent holder and the increased cost of supplying the completed segments by the new form owner, resulted in an increase in the project cost estimate by more than 60%. Meetings were held with the City of Long Beach and with NYSDOT Region 10. It was clear that the funding available for this project could not accommodate this increase in the construction cost. For the rehabilitation to proceed, an alternative had to be determined quickly. It was now early July 2000, and the Federal funding had to be committed to the project by September of that year. To ensure this commitment, the Plans, Specifications & Estimates (PS&E) submission had to be completed by early September.
2.3 A fast-track alternative selection and design

When the Design Report was completed in June 1999, it had one single span alternative, the Channel Bridge and six other alternatives, which included three span options, a “carry out repairs” option and a “do nothing” option. Based on the response from the boating public, the City of Long Beach made a commitment to have a single span. A single span also had reduced future maintenance advantages over a three span bridge. Hence, the other June 1999 Design Report alternatives were not suitable.

Using the determination that the superstructure road depth would have to be limited to 540mm (≈ 21 inches) to maintain or improve the existing headroom for marine traffic and the approach grades, a number of structural systems were investigated. Material options considered included steel, cast-in-place concrete, precast concrete and timber gluelam beams. While a redundant superstructure of 540mm maximum depth could be developed to span the 28.39m, without becoming overstressed, none were found that could do so within acceptable deflection limits. The use of through girders and floorbeams was found to provide a solution. For this system, steel plate girders and steel box girders were investigated. Maintenance problems due to difficult access ruled out the box girders. A system of two through girders and floorbeams has an inherent lack of redundancy, which is not desirable. To mitigate the redundancy issue, the floorbeams rest on top of the girder bottom flanges, and the through girders have redundant capacity in bending and shear.

The girders would have to be located behind the back of the curb-lines because the floorbeams would not meet deflection criteria when the girders were set to the back of the sidewalks. Also with the girders at the back of the sidewalks, part of the abutment pilecaps would be on private property, which could raise new issues and delays. Therefore, both sidewalks are cantilevered from the through girders.

A new Design Report was prepared and issued on July 26, 2000, and design of the new superstructure commenced in detail while review and acceptance of the proposed superstructure alternative by NYSDOT proceeded.

2.4 Deflection and stress governs

To keep design, fabrication and erection costs down, it was decided early in the design to use one bolt size for all connections; set a consistent floorbeam and stringer spacing; set a consistent floorbeam and stringer size; and use rolled steel sections as much as possible. This consistency was applied to all three bridges. Since the span of each bridge was not the same (Sarazen 27.940m [91.67 feet], Ouimet 27.135m [89.03 feet] and Hagen 28.390m [93.14 feet]), the differences for the floorbeam spacing were taken up in the distance from the last floorbeam to the beginning and end of the bridge.

For the design of the structural steelwork, Allowable Stress Design was used. For the design of concrete elements, Load Factor Design was used. The design was carried out to AASHTO Standard Specifications for Highway Bridges as amended by NYSDOT. The superstructure was designed for two lanes of HS20 loading. This loading was permitted instead of the current requirement of HS25 because it was rehabilitation and not a new or reconstructed bridge.

The final design resulted in two through girders with fifteen 15 floorbeams spanning across the roadway, spaced at 1.8m (5.9 feet) centers. Between each pair of floorbeams are 6 stringers, spaced at 1.94m (6.365 feet) centers. To carry the sidewalks, 17 steel beams cantilever from each of the through girders, each one lining up with a floorbeam except at the ends of the bridge. A structural cast-in-place monolithic concrete slab was used for the road and sidewalk decks.

To help meet stress and live load deflection criteria, moment connections were required throughout. A moment resisting connection was designed and used between the stringers and floorbeams (Figure 6). This ensured that the live load on the bridge was distributed over a sufficient number of floorbeams, the design of which is controlled primarily by bending stress limits. The beams were also close to the allowable deflection limits. The moment resisting connections were achieved within the depth limitations using a bolted angle for positive moments and the deck slab for negative moments, both of which occur depending on the location of the live load.

Composite action between the deck slab and the floorbeams was also necessary to help meet the stress limit criteria. As per AASHTO, the floorbeams were designed with a combination of
three applied stress demands. First, the beam self-weight plus the wet concrete and formwork were taken by the beam alone. Second, the superimposed dead load from a future wearing course was taken by the beam/concrete composite section with $n = 27$ (where $n$ is the ratio of the modulus of elasticity of the steel to that of the concrete): $n = 27$ allows for the effect of creep from long-term loading. Finally the HS20 live loading was taken by the beam/concrete composite section with $n = 9$. To achieve the composite section, shear studs were required between the floorbeams and the concrete (Figure 6). The minimum stud spacing was 125mm (5 inches).

Figure 6. Detail of the moment connection – stringer to floorbeam.

A knee brace connection was used between the floorbeams and the through girders. This provided lateral bracing to the through girders and brought the floorbeam within acceptable stress and deflection limits (Figure 7). The design of the through girders is controlled by deflection criteria. To “hide” the girder steelwork from view and to protect it in the event of a collision, the portion above the deck was encased in concrete. The added stiffness of the concrete allows the girder deflection due to live loading to come within acceptable limits as required by AASHTO (L/1000) for pedestrians on the bridge.

The sidewalk beams were fabricated decorative steel beams and designed to vary in depth with the bottom flange in the shape of an “S” curve. The beam depth was increased to develop a full moment connection at the through girder (Figure 7).

With the limited depth available for the superstructure, the floorbeam bottom flanges were notched at the through girders, thus the undersides of both the floorbeam and through girder flanges were at the same elevation (Figure 7). The floorbeams were W360 x 237, leaving 180mm (7 inches) for the deck slab. The deck slab thickness increased to 300mm (12 inches) spanning from the end floorbeam to the abutment backwall (Figure 8).

To carry out the design of the superstructure, it was modeled as a 3-D grillage and analyzed using STADD analysis software.
2.5 Other design and specification details

Grade 345W structural steel was used throughout. The steel had to be painted because it was too close to the water level and the corrosive marine environment. Painted weathering steel was considered and used because if maintenance was not performed on the paintwork, the life of the bridge would be prolonged by the weathering steel, despite the environment.

To ensure that the client would not have to deal with metal stay in place forms corroding and becoming a hazard for marine traffic, the use of removable forms was specified. Since the forms were interchangeable, it also resulted in their reuse on all of the bridges with only minor touchup each time.

The use of the through girders allowed the adaptation of the abutment pilecaps from the abandoned Channel Bridge design with minor modifications for the final design of the bridges.

The structural concrete was specified at 21 MPa (3,000 psi) with 420 MPa (60 ksi) steel reinforcing. Both the top and bottom layers of reinforcing were epoxy coated due to corrosive salts from both the road deck with deicing and from the canals below. All of the structural concrete was Class HP and a DCIS corrosion inhibitor was added to the mix for both the sidewalk and road decks.

A jointless deck was used at each abutment with structural approach slabs tied to the deck in both the road and sidewalks. Portions of the old abutments were retained and connected to the new pilecaps and a new continuous backwall used to support the structural road, sidewalk and approach slabs (Figure 8).

Multi-rotational bearings were used, the SW bearing being fully fixed, the NW bearing allowed to slide N-S, the SE bearing allowed to slide E-W and the NE bearing being able to slide in all directions.
2.6 Aesthetics

In elevation the bridge was designed to appear slimmer than it is. The color “Hamilton Blue” (Benjamin Moore) was used on the exposed steelwork, along with the set back of the through girders from the edge of the 125mm (5 inches) thick sidewalk slab and the shallow sidewalk beams. This allowed the exposed portions of the girders and sidewalk beams to blend in with the water below.

On the sidewalks, a bicycle height railing was used because it was considered likely that bicyclists would ride on the sidewalks. The selected railing was a decorative picket fence with the railing and posts designed for the AASHTO loading. The picket fence was also painted with a Hamilton Blue matching color (Figure 9).

The portion of the through girders above the road level was encased in lightweight aggregate concrete (Figure 9). A form liner for an Ashlar Stone Pattern was specified along with a color pigment and finish stain (Benjamin Moore HC 105) to give a grey stone appearance.
3 CONSTRUCTION

3.1 How the construction was expected to proceed

The contract was let to Bi County Construction Corporation of Medford, New York, in March 2001, being the qualified low bidder. The bid price was $4,456,456.00. Each bridge was to be rehabilitated in sequence, with full closure of the bridge allowed, the next bridge could only be closed after the previous bridge was reopened to traffic. This restriction was in place to maintain access for the local residents with minimized diversions and to ensure that only one section of the watermain was out of service at any given time. Water service was maintained via the remainder of the service loop. The overhead utilities were being temporarily diverted to cross the canals a little south of the bridges. Access to the canals by marine traffic was maintained throughout the contract.

The basic construction sequence included: demolition of the bridge deck, piers and portions of the abutments; the installation of piles; construction of the modified abutments and backwalls; and installation of the bearings. This was followed by the structural steelwork erection and painting of connections: forming and pouring the road and sidewalk deck slabs, approach slabs and concrete barrier encasements for the through girders: watermain installation: sidewalk picket fences installation and restoration work.

3.2 Some details and problems

Early into the contract, it was discovered that not all of the asbestos had been removed in 1989. Asbestos was found where the existing pier piles entered the pilecaps and also below the mud line. This resulted in some delay to the work at each bridge while the asbestos was abated. It also forced the contractor to change the intended method of demolition (Figure 10).

The resulting delay due to the asbestos abatement resulted in the pouring of two of the bridge decks in the winter instead of just one. The winter of 2001/2002 was relatively mild, but this past winter proved to be very problematic. Daily observance of the unreliable 10-day weather forecast to predict a suitable window to risk booking labor and equipment for the road and sidewalk deck pours was necessary. To protect the concrete from freezing and to achieve curing in the minimum time period allowed, deck heating (Figure 11) was used along with double layers of thermal blankets.
With the first bridge complete, an extensive home for pigeons had been created. These birds seemed to migrate to the bridge in high numbers in rapid fashion. To counter this, a prevention system called “Bird Coil” was installed (Figure 12). The coils were installed on the top face of the bottom flanges of the through girders and floorbeams. The stringer flanges were not wide enough for the birds to nest on. The coils were selected over needle type systems to prevent boaters from being inadvertently “injured” by them. The coils have been very effective.

3.3 Floating the bridge

High Steel Structures based in Lancaster, Pennsylvania, were subcontracted to fabricate the structural steelwork. Once all the members for each bridge had been fabricated, the bridges were “assembled” at the yard and each connection was aligned, reamed and temporarily bolted. Each element of the steelwork, including the connection angles was given a distinctive identification
mark to help ensure that assembly on site would proceed smoothly. This was critical with so many connections to be made and the need for each hole to line up as drilled in the yard. Prior to shipping the beams and girders to the site, they were painted to the finished color, except for connection areas and surfaces in contact with the concrete.

The erection sub-contractor was Village Dock, based on Long Island. While a field-welded splice option was allowed under the contract for the through girders, the contractor elected to ship and erect them fully fabricated. Since it was not practical to use a crane capable of picking and setting the girders due to the very limited space at each bridge, the sub-contractor developed a scheme which used two cranes and pontoons. The crane on the arrival side of the bridge lifted the girders off the trucks and placed them with one end on the pontoon and the other end on the ground. Once secured to the pontoon, the girders were floated across the canals (Figure 13). Once across, the cranes, one on each side of the canal, set them over their bearings. To ensure stability until the floorbeams were installed and to avoid damage to the bearings caused by excessive lateral rotation of the girders, the girders were shimmed clear of the bearings.

Figure 13. Through girder end supported on the pontoon while being floated across the canal.

The most difficult connection to assemble and torque up was the stringer to floorbeam (Figure 12 on the previous page). High Steel Structures shipped the members with some of the connection angles bolted in place. After learning lessons on the first bridge, Village Dock specified which connection angles to ship fully assembled to the beams and girders on delivery for the next two bridges making the assembly and torque work more efficient. Each bridge had 3,230 twenty-two millimeter diameter (7/8 inch) bolts (Figure 14).
CONCLUSIONS

4.1 The end product

The final contract amount is $5,223,788.74. The most significant causes of this increase over the bid is a result of the asbestos abatement on the pier piles and changes in the way the local electric power authority, LIPA, is reimbursed for cable diversion work. The rehabilitation of the bridges has been completed, and they have been opened to traffic. These bridges provide a much smoother ride for vehicle passengers than the previous bridges. The defects that were affecting the capacity of the previous bridges have been eliminated, and the hazard caused by the piers to marine traffic has been removed.

For those who approach and view the bridges from the north or south, they present a more elegant profile (Figure 15).
The design presented a number of challenges: limited time, which is becoming a “normal” challenge; and an analysis, which was complicated by the constraints of the single span, the wide deck and maintaining or improving the clearance over the canals while not increasing the approach grades (Figure 16). The design of the floorbeams was controlled by bending stresses. For the floorbeams, deflection limits were close to controlling the design. For the through girders, deflection limits controlled the design.

![Figure 16. Typical view along the approaches to the bridges.](image)

The contract progressed well with the Client, Contractor and Engineer working as a team to resolve issues as they arose on site. The Contractor and Sub-Contractors were creative in their approaches to dealing with the challenges that the construction of these bridges presented.

### 4.2 What could have been done differently

One of the most difficult operations was painting of the connections. They were difficult to access for blast cleaning and painting (brush applied) without the deck formwork or concrete in place. On the last bridge, because of the cold weather, the blast cleaning and painting was carried out after the deck was completed and the bridge opened to traffic.

Simplification of the connections would be preferred for both erection and painting. However, given the physical restrictions imposed on the design, it is not likely that further simplifications would have been possible. The option of painting all of the connection areas and connection angles in the fabrication yard and designing the connections for that condition should be considered on future similar projects. The option of galvanizing, which may resist handling damage better than the paint, should be considered for future designs. Galvanizing the through girders would present a challenge.
4.3 Allowable stress verses load factor for the steelwork

The floorbeam design could have been carried out using Load Factor Design, but it would not have resulted in a smaller section. The deflection would then have controlled the design and that would still have resulted in the section used.

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Bird Coil – Is a registered product of Bird Barrier America, Inc.

Figure 3 – Long Beach East End Civic Association/City of Long Beach, Dept of Public Works