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WILLIS AVENUE SWING BRIDGE, CARRYING A $612M PROJECT FROM DESIGN INTO CONSTRUCTION

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Abstract

The Willis Avenue Swing Bridge over the Harlem River is being replaced under a $612 million project which is the largest ever undertaken by the Movable Bridge Group of the New York City Department of Transportation. The project is massive in scope as it extends over a mile in length between two boroughs of the City, passes over the Harlem River and an adjoining railyard and provides connections between two major highways as well as three major arterial streets. The new alignment not only dramatically improves the alignment from that of the 100 year old existing bridge but also facilitates maintaining both 70,000 vehicles per day of roadway traffic as well as maintaining navigation on the river. The project centerpiece is a new four lane, 106 meter long swing span. The paper starts by describing the overall project development as well as providing specific details on the new swing span. The contractor has aggressively commenced work on the project and is progressing work on complex foundations including the river work and preparation for installing raised footing boxes in the river. The paper gives a look-ahead at upcoming construction activities and the plans to make this project a reality.

FIGURE 1: **New Willis Avenue Bridge**

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Introduction

The Willis Avenue Bridge is a principal northbound route between the Boroughs of Manhattan and The Bronx, in New York City. In addition to carrying four lanes of traffic across the Harlem River, the bridge also provides a pedestrian and bicycle route, and is on the route of the NYC Marathon. Like the six other swing spans and four lift spans over the Harlem River, the Willis Avenue Bridge Swing Span allows most vessels to pass without opening but opens periodically to permit the passage of tall vessels.

The bridge connects from the local Manhattan street network, via First Avenue and East 125th Street, as well as from the FDR Drive, a limited access highway. Bridge traffic from these two approaches is given the choice of one of three destination routes in The Bronx. Vehicles can exit to Bruckner Boulevard, or head north toward Willis Avenue or to the Northbound Major Deegan Expressway. The overall length of the bridge is over three quarters of a mile, with 3185 feet of structure and 1170 feet of approach roadways. The most distinct part of the existing Willis Avenue Bridge are the swing span and adjoining through truss spans over the Harlem River.

Hardesty & Hanover Consulting Engineers (H&H) was retained by the New York City Department of Transportation (NYCDOT) to assess the condition of the existing bridge , prepare alternate reconstruction schemes, make recommendations and ultimately prepare plans for complete replacement of the bridge including design of both a new 346 foot long swing span and the substantial approach viaducts.

The hundred year old Willis Avenue Bridge has numerous non-standard geometric features which are associated with a high accident rate on the bridge and has one of the worst condition ratings in the City. The non-standard features could not be corrected on the existing roadway alignment. Further, due to the 70,000 vehicles per day crossing, all lanes of traffic needed to maintained on the Willis Avenue bridge throughout construction.An off-line replacement to the south of the existing bridge was recommended as it allows correction of the non-standard geometry, thereby mitigating the high accident rate and allows construction to proceed on a parallel alignment with minimal impact on traffic. A new swing span was found to be the most suitable movable bridge type for this site.

The State Historic Preservation Officer (SHPO) found the Willis Avenue Bridge and the adjacent Willis Avenue Station eligible for listing on the National Register of Historic Places. The needs of SHPO in combination with the needs of vehicular and rail traffic and navigation all influenced the design parameters for this project.

At the time of the Eleventh Heavy Movable Structures Symposium in 2006, the bridge replacement construction contract was in its bidding period. Since then, notice to proceed for this five year, $612m, project was given to Kiewit Constructors / Weeks Marine, JV in late August 2007. Hardesty & Hanover is now providing Construction Support Services for the project. This paper discusses design as well as construction progress to date and plans for future work on this major project.

Existing Bridge and Approaches

The existing Willis Avenue Bridge is composed of three structures, as follows:

- The mainline structure, including the First Avenue Approach Spans, the Swing Span, the Through Truss Span, and the Willis Avenue Approach Spans.
- The FDR Drive Ramp connecting the northbound FDR Drive to the bridge. This is known as the 'A Ramp'.
- The Bruckner Boulevard Ramp connecting the bridge to Bruckner Boulevard in The Bronx. This is known as the 'B Ramp'.

In addition, a New York State DOT project is incorporated into this project which includes a new connection to the Northbound Major Deegan Expressway known as the 'C Ramp'.

The existing Swing Span is a rim bearing type which is 310 feet in length, center-to-center of the rest piers. When open to marine traffic, the Swing Span provides two channels each with a clear width of 112 feet, and unlimited vertical clearance. In the closed position, the swing span allows 24 feet of vertical clearance above Mean High Water.

Just east of the Swing Span, there is a single Through Truss Span. The mainline structure carries four lanes of traffic over the Harlem River Railroad Yard (HRY) and serves as an approach to Willis Avenue in The Bronx. The Harlem River Yard is under development as an inter-modal transfer facility and industrial/commercial park. There are currently six railroad tracks under the bridge in this area. Four the tracks serve a Waste Management municipal waste transfer facility, one is the CSXT Railroad Oak Point Link and one is intended to serve an intermodal facility. One additional track is planned at the intermodal facility. The bridge also passes over access roads within the railyard, several city streets and a bus turnaround loop connected to the 126th Street bus Depot in Manhattan.

History of the Willis Avenue Bridge

Authorized in 1894 and opened to traffic on August 22, 1901, the original Willis Avenue Bridge carried two-way traffic from First Avenue and E. 125th Street in Manhattan to Willis Avenue and E. 134th Street in The Bronx. The Willis Avenue bridge was constructed shortly after the adjacent Third Avenue Bridge. Both of these bridges were designed by Thomas C. Clarke.

The original structure included four Manhattan Approach spans, the Swing and Through Truss spans, and 15 Bronx Approach spans. The original operating machinery was steam driven, with the steam plant located in the operator's house above center span on the swing span. The end lifts were driven from the central control house by shafts running down from the house and then out to each end of the swing span below the roadway. The original deck on the river spans was timber block pavement over concrete, supported on steel buckle plates. The connection to Bruckner Boulevard was added in 1905.

FIGURE 2: Existing Willis Avenue Bridge

The bridge was converted to one-way Bronx bound traffic at the time of a major reconstruction in the 1950's which added the FDR Drive northbound connection and totally replaced the Manhattan Approach spans.

For many years, swing spans were the preferred method for accommodating marine traffic on heavily used waterways connecting low lying urban areas. This type of movable span became the predominant type on the industrial Harlem River. There are six city owned swing bridges currently crossing the Harlem River: the University Heights, Macombs Dam, East 145th Street, Madison Avenue, Third Avenue and Willis Avenue bridges. Over the past two hundred years, over twenty swing bridges have been built over the Harlem River including the seven current swing spans as well as twelve predecessor swing spans.

The Third Avenue Swing Bridge was recently replaced on its existing alignment and the 145th Street Swing Bridge recently had its movable span replaced. Earlier swing span reconstruction projects on the Harlem River involved rehabilitation rather than replacement. None of these earlier projects involved nearly as large of a scope as the Willis Avenue Bridge project.

The existing Willis Avenue Swing Span is not centered on the River, like the other Harlem River bridges. Its Manhattan Rest Pier is located at the edge of the relieving platform which defines the Manhattan shoreline. The Swing Span is flanked on The Bronx side by the Through Truss Span which provides an additional navigation channel for vessels of low height. This arrangement of river spans was justified since it minimized impacts on carfloat operations and other activities associated with the Harlem River Yard. The existing Willis Avenue Bridge, with its unsymmetrical span arrangement has been regarded by many as one of the least attractive bridges on the Harlem River. As the river uses associated with the Harlem River Yard declined, so did the need for this span arrangement. Navigation was further complicated at Willis Avenue bridge when the Triborugh Lift Span was built in the 1930's just downriver in a position favoring navigation on the opposite side of the river.

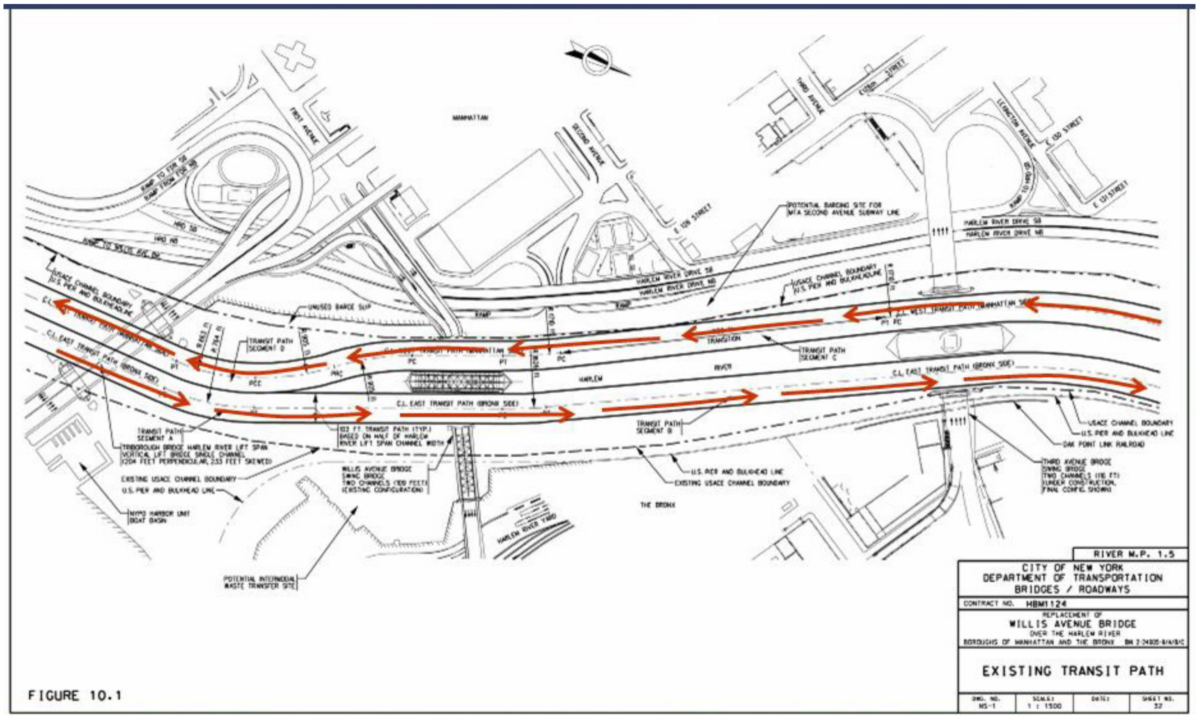

FIGURE 3: Existing Navigation Path

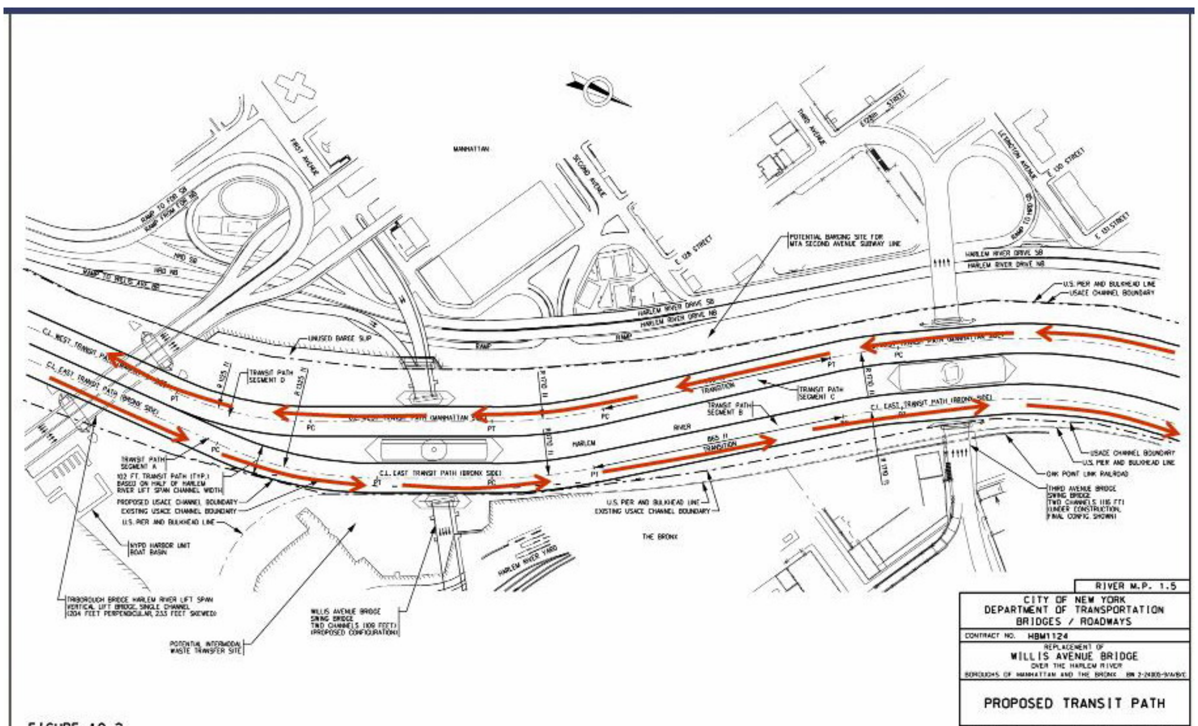

FIGURE 4: New Navigation Path

The historical high in the number of recorded bridge openings is 5,132 in 1917, and has declined steadily since then. More recently there are approximately 30 openings per year. An average of 20 of these openings per year are for maintenance purposes, and the remaining openings were to allow passage of vessels. The decline in openings of the bridge reflects the historical decline of marine traffic on the Harlem River.

Eccentric rotation and transverse movement of the Swing Span, the lack of active bridge power from the Bronx and the poor condition of the submarine cables make the continued reliable operation of the existing span uncertain. In addition, the last major mechanical and electrical rehabilitation occurred fifty years ago. Maintenance crews have kept the span working but upgrades are necessary.

Reconstruction Alternative Evaluation

The Bridge Reconstruction Project Report included development of viable reconstruction schemes for the Willis Avenue Bridge. Factors in addition to the structure condition played a key roles in selection of an appropriate reconstruction scheme.

Based on the evaluation of the bridge, the reconstruction of the bridge should meet the following objectives:

1) Ensure a minimum 30 year service life (100 years desirable).
2) Minimize future maintenance needs.
3) Eliminate the non standard geometric features.
4) Provide adequate structural capacity (MS18 minimum; MS23 desirable) and adequate fatigue life.
5) Meet applicable seismic criteria.
6) Minimize and manage potential conflicts with adjacent projects.
7) Minimize traffic impacts during reconstruction.
8) Address environmental issues, including hazardous materials, historical significance and potential impacts on parkland.

The Bridge Reconstruction Project Report provided the rationale for replacement type selection. Further assessment in the Design Report/Environmental Impact Statement (DR/EIS) prepared for FHWA eliminated all but the one preferred alternative, off line replacement with a new swing span.

Due to Coast Guard requirements, any new river span would need to be movable. A fixed bridge alternative has been eliminated from consideration, since it is not possible to provide the minimum 135 foot vertical clearance over the navigable channel and return to grade within the project limits. Various movable bridge types were considered including bascules and vertical lifts. In the end, a new swing span similar to to others in the area was preferred. This alternative was endorsed by the State Historic Preservation Office.

The swing span offers the advantage of similarity to other NYCDOT owned bridges on the Harlem River. This is a significant advantage from a maintenance standpoint. Further, swing spans provide a low and visually unobtrusive profile, continuation of historic use of swing bridges in the area and cost savings over a vertical lift span. Therefore, a swing span was recommended for the Willis Avenue Bridge and this scheme was advanced into final design.

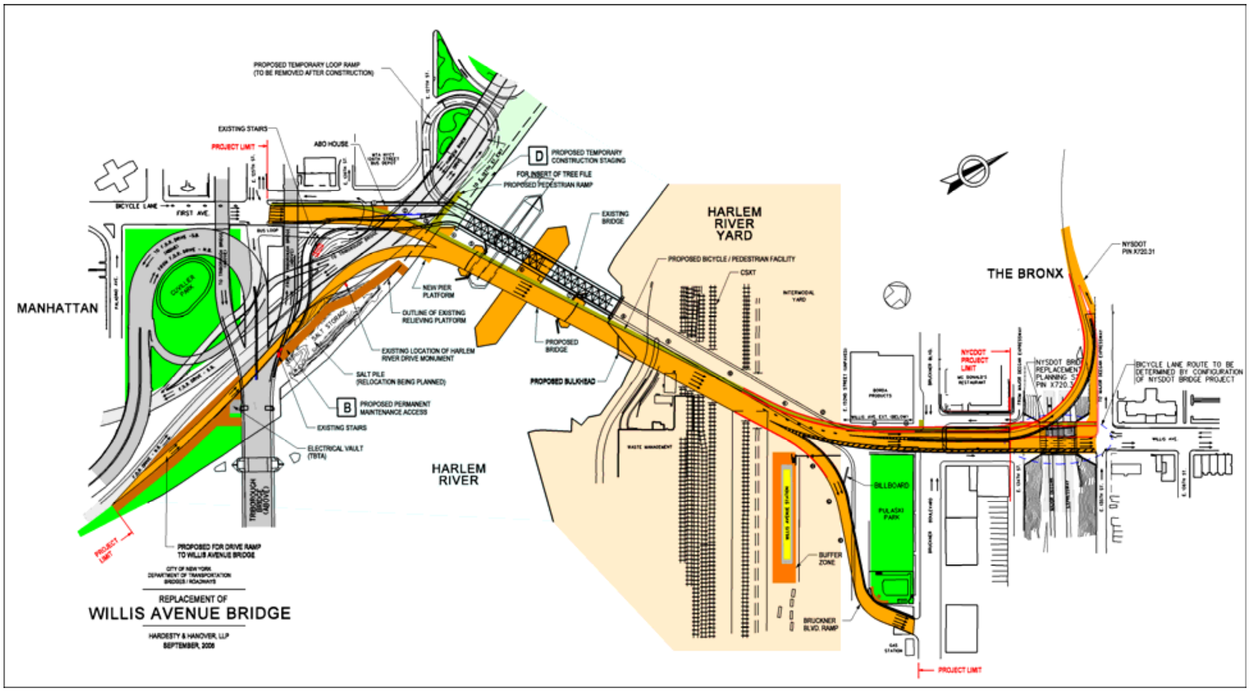

FIGURE 5: Off-line Replacement Bridge

Swing Span Design

Once the decision was made to replace the existing bridge, the alignment drove many of the design decisions. There was ample room to the south of the existing bridge for a new bridge provided that its alignment could tie in at each of the four existing ramp termini. At the Manhattan end of the bridge, the tight s-curve on the FDR Drive ramp connection was particularly problematic as was the sharp curve to the right at the shoreline marking the beginning of the swing span. The optimum alignment addressing both of these geometric deficiencies placed the bridge close to the existing bridge on an alignment that was slightly skewed to the existing one. The convergence of the two curved ramps pushed the movable span away from the shoreline to a point further out into the river. The close proximity of the existing movable span to the new one complicated the staging. Initially it was thought to construct a new vertical lift in the open position or floated in adjacent to the existing bridge while allowing the existing swing span to open below it. There were several factors that drove the choice of movable span to a swing span. Firstly, NYCDOT viewed the Harlem River Bridges as a family of similar bridges which were all operated and maintained as a group. A lift span, while not unique on the river, would be one of only a few. Secondly there were aesthetic concerns with respect to building a lift bridge at this site. The tall towers of a lift bridge were not favored by NYCDOT or the City Art Commission. Lastly, the State Historic Preservation Office conditioned their project approval on the use of a new truss type swing span.

With two swing spans built on close parallel alignments, simultaneous opening of the swing spans for passage of tall vessels would not be possible. The location of the new pivot pier was set staggered with the existing one so that foundation construction would not interfere with operation of the existing swing span. The plan is to shift navigation to one or more of the available channels with at least one channel passing beneath the existing swing span. This arrangement is used up until the new swing span is floated into position. Once the new swing span is in position, the concrete deck is placed and machinery is aligned to make the swing span operational under backup operating systems. Until the new swing span is ready for traffic, the existing swing span remains in open for traffic but can not open for navigation. Immediately after shifting traffic to the new swing span, the old swing span and flanking span are to be removed to clear space for opening the new swing span. The period between floating in the swing span and being able to open it under backup systems is limited by the Coast Guard. Once traffic has been shifted to the new swing span, the contractor has 120 days to clear the existing pier, fender system and other obstructions in the channel. Initial swing span operation is expected to be under backup systems while the final primary operation system is hooked up and tested. Test operations would occur during overnight periods to minimize traffic disruptions. The float in operation is one of the project milestones and is scheduled to occur in the Summer of 2010.

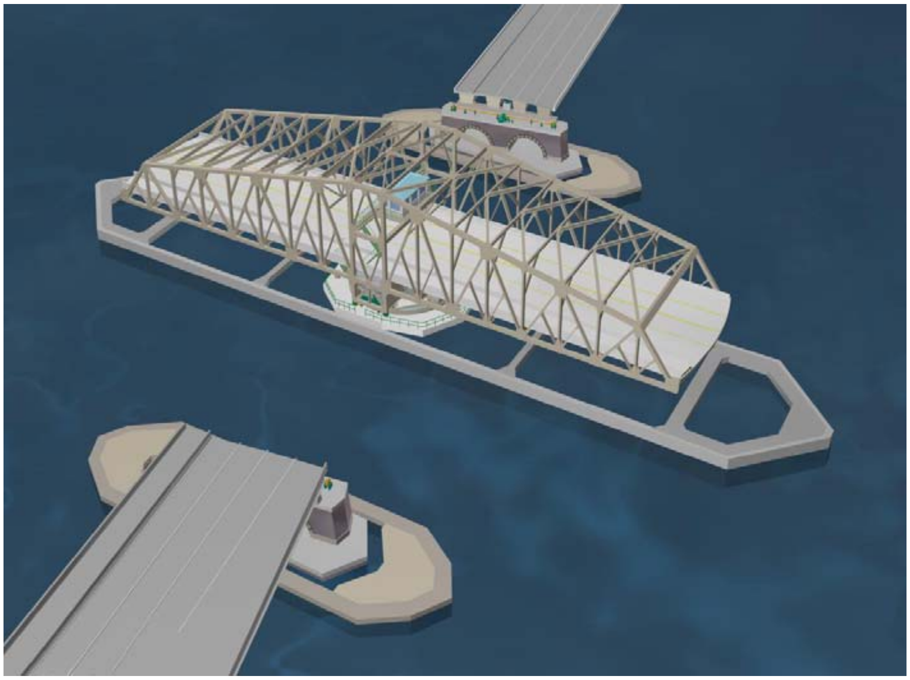

FIGURE 6: New Willis Avenue Bridge Swing Span

The new swing span is a through truss type with four lanes and a twelve foot wide bikeway /walkway. The span is slightly skewed to the channel and provides two 109 foot wide navigation channels. The overall swing span is 75 foot wide and 348.5 foot long. The floorsystem consists of floorbeams and stringers with a half depth filled steel grid deck. The truss is supported by two central floorbeams which transfer load to a longitudinal pivot girder and the center pivot bearing. These two floor-beams form the walls of a machinery room located below deck level.

Mechanical Systems

The new swing span is a center pivot bearing type with a spherical roller thrust bearing. There are eight balance wheels arranged on a 62.84 foot diameter track. Operating machinery includes a 58.75 foot diameter pier mounted rack, a pair of pinions and right angle reducers driven form a central differential reducer. The machinery has a pair of motor brakes and a pair of machinery brakes. There are pier mounted eccentric end lifts at the rest piers and span mounted centering lock machinery. A total of four center wedges are located at the pivot pier. An electrical room and storage room flank the machinery room.

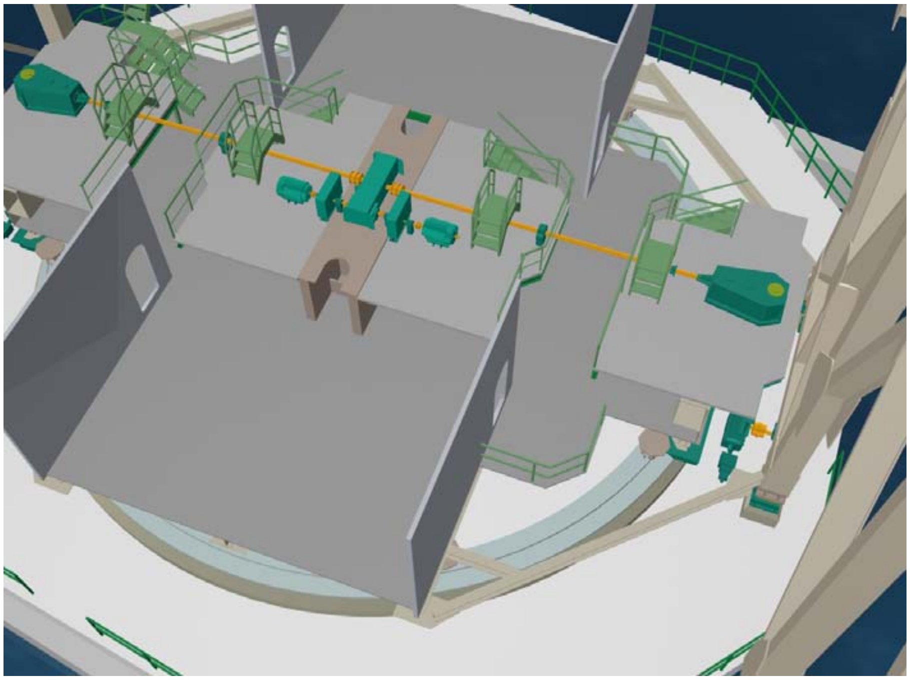

FIGURE 7: Operating Machinery Arrangement

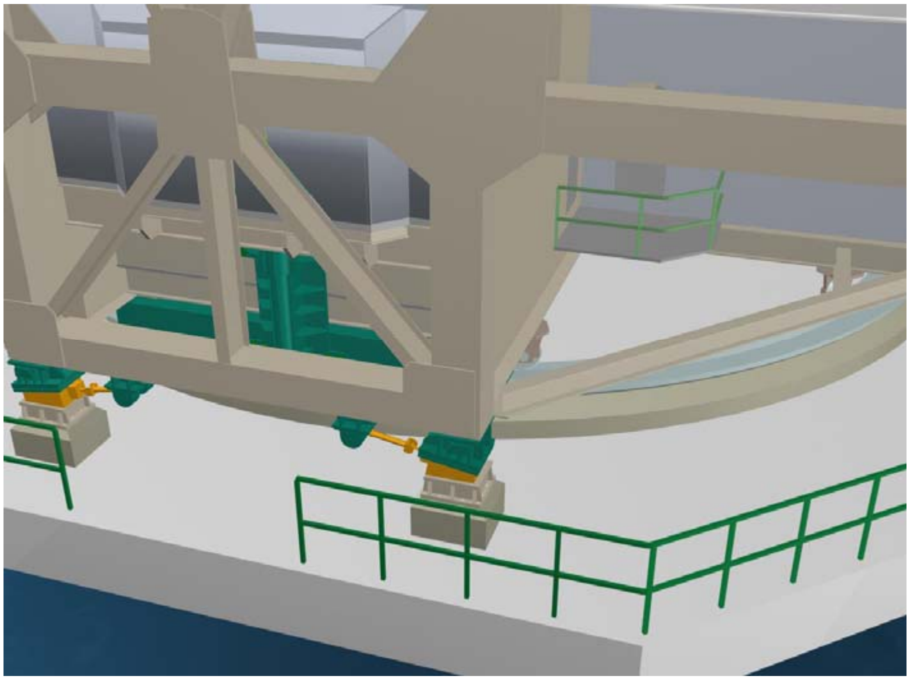

FIGURE 8: Four Center Wedges

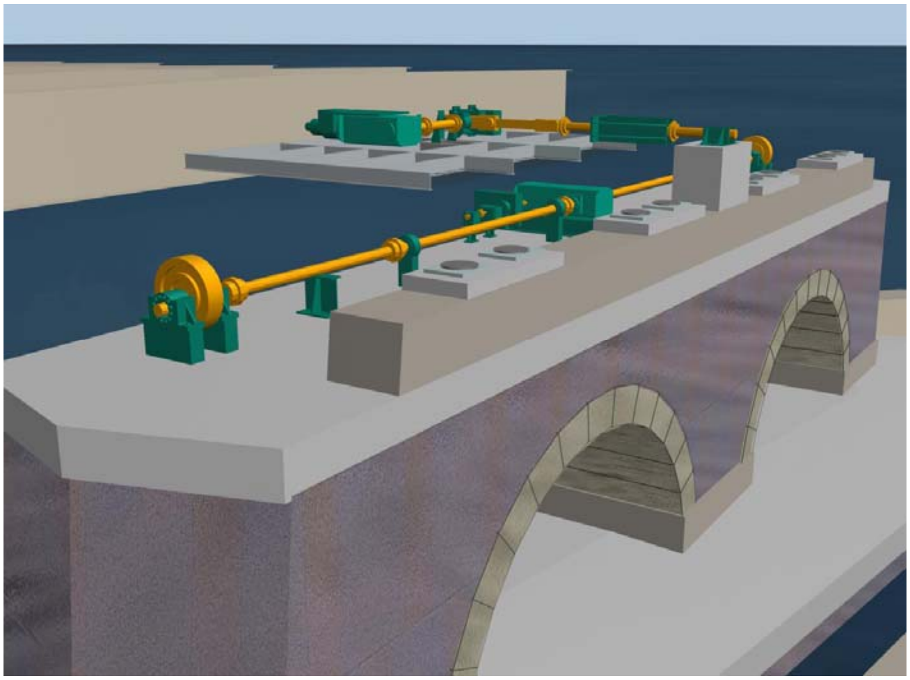

FIGURE 9: End Lifts and Center Locks

Electrical Systems

The bridge control house is located on the swing span above the roadway and houses the control console, CCTV and communication systems. The remaining major components of the bridge's electrical control system are located inside the swing span electrical room underneath the roadway. An auxiliary bridge operator's house is provided on the Manhattan approach which houses locker facilities for the bridge operators and an electric service vault. Electric Power for bridge operation will be supplied by Con Edison Power Company and be composed of two separate power feeders. One feeder will be provided at the Manhattan side and one feeder will be provided at the Bronx side. An Automatic Transfer Switch (ATS) located in the swing span electrical room will switch power feeders in case of electrical service interruption. In addition there is a diesel operated hydraulic power unit in the event of a power outage. Routing power and controls to the swing span is via flexible cables passing through the center pivot bearing. Submarine cables pass under each navigation channel and an intermediate voltage power feed is mounted to the structure over the railyard.

FIGURE 10: Control House

The swing span machinery will be driven by two fully redundant 112Kw (150HP) wound rotor motors. The span motors will be controlled by two AC Primary Thyristor (SCR) drives to provide closed loop speed control. The SCR drives will be interconnected to permit either drive to control either span motor. The span motors and drives will be arranged for automatic operation upon a single selector switch command. The SCR drives and primary resistors will be located inside the swing span electrical room. Operational logic and control functions are performed by a programmable logic controller with redundant central processing units. The second CPU is isolated and must be brought on line independent of the first, if required.

Squirrel-cage motors will be provided for end lifts, center wedges and centering locks operations. Soft-start controllers will control the end lift motors while full voltage reversing starters will control the center wedges and centering locks motors.

Control devices such as relays, starters, circuit breakers, etc. will be mounted in the Motor Control Center (MCC) located inside the swing span electrical room. Hand-Off-Auto (HOA) switches will be provided at the MCC for manual operation of starters.

The Control Console will be located in the control house and will include control switches, pushbuttons, meters and indicators to control and monitor traffic control devices and bridge operations. The console will also house a keypad and message display unit, and a printer for PLC interaction.

Control of the traffic signals, warning gates, barrier gates, end lifts, center wedges, centering locks and span drives will be interlocked such that the specified operation of the bridge will take place in the proper sequence. Key-operated bypass switches will be provided at the control console to permit bypassing an interlock in an emergency.

Two traffic warning gates and two barrier gates will be provided on each approach. The gates and barriers will be operated by the selector switches located on the Control Console or by the west and east gate control boxes. Each gate control box has its designated outlet located in the sidewalk area on the north side of the approaches adjacent to the barrier gates.

Approach Span Structures

The approach structures account for roughly 85 percent of the bridge deck area and 75 percent of the overall project cost. At the Manhattan end of the bridge, the FDR Ramp and the First Avenue approach merge just before the swing span. These spans include a combination of straight and curved girder spans some of which are supported on transverse steel cap beams straddling the Harlem River Drive. There are concrete cantilever retaining walls, abutments, wall type piers and multi-column piers as determined by project geometric and staging requirements. The FDR approach consists of eleven spans while the First Avenue Approach has five spans passing over a bus turnaround loop, the Harlem River Drive, the waterfront marginal street slated for a future park and the near shore area of the Harlem River. At the Bronx end of the swing span four steel tub girder spans pass over the Harlem River Yard including spans over five active railroad tracks plus a planned future track, access roads to a waste transfer facility, and access roads for a future intermodal transfer facility. The mainline bridge continues towards Willis Avenue where it straddles an existing roadway known as the Willis Avenue Extension.

As the bridge approaches Willis Avenue, a NYSDOT designed connector ramp to the Northbound Major Deegan Expressway diverges and crosses above the Bikeway/Walkway eliminating the conflict between pedestrians and the flow of traffic to the Major Deegan Expressway. Just east of the Railyard, the Bruckner Blvd Ramp splits off to the right curving past the site of the former Willis Avenue Station to connect with the existing ramp terminus adjacent to Pulaski Park. The superstructure at the Bronx end past the railyard includes two transverse steel box girders straddling roadways and but mostly steel straight and curved girders seated directly on the piers. The Bronx mainline includes eight spans while the Bruckner Blvd Ramp has four spans with a tight radius. Piers at the Bronx end includes column type piers supporting the transverse box cap beams as well as a series of arched piers with granite facing reminiscent of the existing historic piers at this end of the bridge. Abutments consist primarily of precast modular walls as well as some permanent soldier pile walls.

Foundation types vary throughout the site to accommodate diverse subsurface conditions and loadings.

The two most heavily loaded piers use 5-foot diameter drilled shaft foundations while twelve other piers and abutments plus the relieving platforms along the river use 4-foot diameter drilled shafts. There are a total of 271 drilled shafts on the job with lengths varing from 32 foot to 108 foot deep. There also are 12" diameter bored in piles, H-piles and spread footings each selected to best accommodate the wide range of subsurface conditions. Sections of bulkhead and relieving platforms will be replaced at both the Manhattan and Bronx waterfront.

The four river piers, including the pivot pier, two rest piers and a pier at the Manhattan bulkhead area are built on precast pier boxes elevated above the river bottom. The rest pier boxes are 117 foot long by 35 foot wide and the pivot pier box is 66 foot in diameter. The original plan was to float the boxes into position as a single piece. The contractor has opted to frabricate segmental boxes and lift them into place over the drilled shafts. The boxes are temporarily supported and filled with concrete to form a base for the pier shaft.

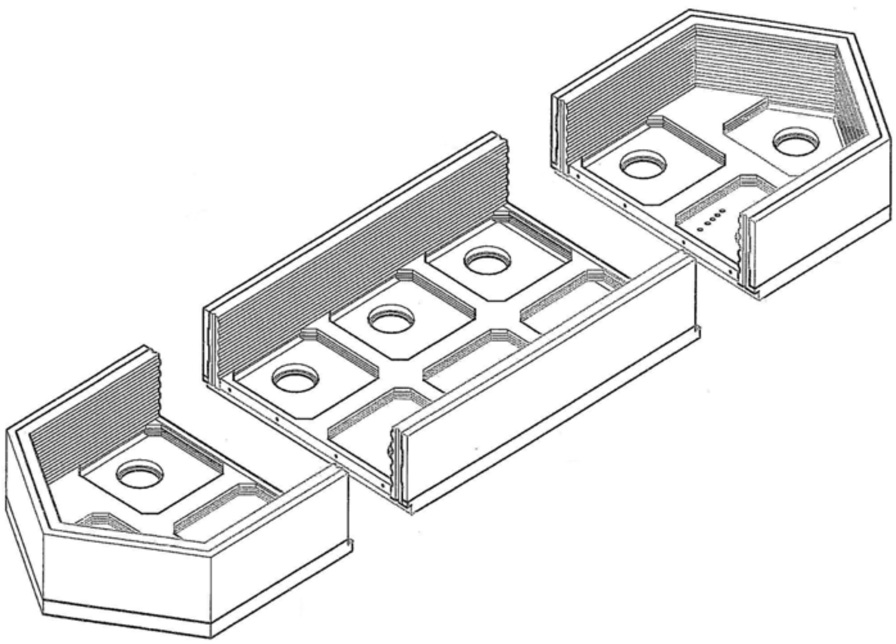

FIGURE 11: Segmental Precast Concrete Pier Box for Rest Pier

FIGURE 12: Drilled Shaft Installation Platform in Harlem River

Temporary structures are required to facilitate staging and at maintenance of traffic crossovers. A temporary loop ramp structure is required to divert traffic from the FDR Ramp so that two lanes of traffic are maintained at all times while replacing that ramp. Other work includes city street reconstruction and extensive associated utility work including municipal sewer and water as well as coordination of private utility work including electric, gas and telephone facilities. There is also landscaping, park restoration work, and historic preservation work.

The project required permits from the US Coast Guard, The Army Corps, New York State Department of Environmental Conservation, The NYC Parks Department, NYCDOT OCMC (Traffic), and CSXT Railroad, among others.

Upcoming Activities

Construction is just over one year into a five year schedule. Most site preparation work is complete including clearing utilities and establishing staging areas. Foundation work has commenced in all arteas of the project including in the railyard, in the river and in Manhattan. Work includes completing 21 percent of the drilled shafts and production of casings and reinforcing cages for numerous other shafts. Bored in pile installation has commenced in both Manhattan and the Bronx. The temporary loop[ramp construction is well underway and off-site fabrication of steel has commenced. Shop drawings and other submittals have been submitted for much of the work.

Foundation work will continue throughout the site for several years following a sequence which allows for maintaining traffic on either the existing or the new bridge. River work is sequenced to maintain navigation. The first rest pier drilled shafts are being constructed now, after which the contractor will move to the other river piers sequentially. The piers should be ready to accept the preassembled swing span in the summer of 2010. The swing span itself is being fabricated by PDM in Wisconsin, and assembled at a waterfront facility in Albany prior to float-in.

The overall completion of the project is scheduled for December 2012 including all approach tie-in work.