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Chapters 1-7

BRIDGE CONDITION AND ASSESSMENT REPORT

HIGH BRIDGE

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BOROUGHS OF MANHATTAN
AND THE BRONX, NEW YORK

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1.0 EXECUTIVE SUMMARY

This Bridge Condition and Assessment Report on High Bridge is presented to the New York City Department of Transportation as part of Contract HBMC039. This Report includes the results of the in-depth inspection, structure evaluation, load ratings, sampling and testing programs, topographic survey, underwater inspection of Pier 2, seismic analysis of the steel arch, soil borings, and a geologic evaluation of the masonry stones used in the construction of the gatehouses and the bridge.

High Bridge, which joins the boroughs of Manhattan and the Bronx in New York City, has been under the jurisdiction of the New York City Department of Parks and Recreation since 1960. Prior to that, the Department of Environmental Protection was responsible for the bridge's maintenance and repairs. As of 1974 High Bridge has been listed on the New York State and the National Register of Historic Places.

1.1 A BRIDGE TO THE PAST

High Bridge, the oldest standing bridge in New York, soars above the Harlem River, which is located approximately 100 feet below its steel arch. Its ten masonry arches span several ramps, busy highways, two local streets, and Metro-North Hudson Line. The original structure was completed in 1848 and at that time consisted of fourteen masonry arches that supported the Croton Aqueduct that for the first time brought fresh water to New York City. Its construction, predating the Civil War, was considered a great engineering feat. At one point during addition of the 90.5" water main, the Union authorities heard of a Confederate plot to burn several buildings in New York City and stationed a gunboat in the Harlem River to protect High Bridge from any possible sabotage[1].

The fresh water the Croton Aqueduct brought to Manhattan engendered a tremendous, and unanticipated, growth. The population increased so much, in fact, that only twelve years later, in 1860, a new 90.5" water main was added to the two 36" diameter existing pipes to increase the volume of the water delivery. That installation required the raising of the bridge walls and surface level. At the same time a brick-paved pedestrian walkway was constructed atop the bridge and it became a favorite destination for many New Yorkers and visitors alike.

In 1917, when United States entered World War I, the flow of water within High Bridge was shut down to remove the threat of sabotage. In 1927 it was shut down again when five of the stone arches that spanned Harlem River were replaced with a single steel span to allow river navigation by larger vessels.

The New York Landmarks Preservation Commission designated High Bridge a landmark in 1970. Shortly thereafter, the pedestrian walkway was closed as a result of danger posed to river and roadway traffic by items thrown off the bridge by irresponsible individuals. It is still closed at the present time.

[1] Liquid Assets A History of New York City's Water System by Diane Galusha Page 38

1.2 CONTRACT HBMC039

In the summer of 2002, New York City Department of Transportation-Roadway Bridges, contracted with Baker Engineering NY, Inc. to inspect and evaluate the present condition of High Bridge, as well as the condition of the two gatehouses and any underground chambers located at either end of the bridge. The limits of work were defined in the contract Addendum No. 1 as 100 feet north and South of the Gatehouse, 250 feet east of the end abutment up to the westerly curb line of University Avenue and up to the Water Tower on the west side of the structure. The results of the inspection of the various components are summarized below.

1.3 SUMMARY OF BRIDGE INSPECTION RESULTS

A. Stone Masonry

The in-depth inspection of the bridge elements revealed that the bridge structure is in fair condition. The masonry spans are level and plumb, and exhibit no differential settlement. They have, however, sustained a considerable loss of mortar in the joints between the stone blocks comprising the piers, arches, and outer spandrel walls. The losses extend up to 13" deep.

B. Pier 2 Base

The base of Pier 2, being subjected to wave action and water levels that fluctuate with tides, was found to have grout loss that varies from 1" to 17" deep. A Core taken in the pier base below the water line indicates although some chloride is present in the mortar and concrete the chloride penetration drops off significantly after the first 12”. The vertical core taken into the base of Pier 2 shows that the compressive strength of the concrete is 5030 psi.

C. "Attic"

The Attic is the area located above the masonry piers and is made of masonry walls, a concrete floor and a brick arch roof which serves as the support for the walkway. The Attic houses the water main in the masonry spans, is subject to water infiltration from both the gatehouses and from the bridge surface, especially in locations close to the gatehouses. Rainwater penetrates through the mortar gaps on the granite steps, along the roots of the shrubs that have sprouted at both sets of steps, and around the posts that support the wrought iron gates. There is frequently copious condensation clinging to the attic surfaces, and in the winter a thin sheet of ice coats the inner walls and brick arch areas. The moisture cycling causes salts to leach and mortar to erode from the brick walls. The longitudinal arches in both the north and south Attic walls in the Bronx approach have cracks and missing bricks. The condition is potentially dangerous and has been flagged. See drawing 2.3 for typical details and photos 5 and 13 in Chapter 2.

D. Tie-Rods

The wrought iron tie rods in the Attic's roof exhibit the greatest section losses where exposed to condensation, as opposed to areas where they are imbedded (and protected from moisture) in the arch itself. The tie-rods were examined both in-place and after the four sample rods were removed from the structure. The rods where then sent to Lehigh University where samples of the four rods were machined and tested in a Universal Testing Machine as well as being examined with a microscope. Lehigh University also performed an array of chemical analyses on the samples. The results of the tension tests yielded slightly lower then expected results. The yield strength of the tie rods ranged from 27.08 ksi to 28.37 ksi. The Tie-Rods were found to be a very high quality wrought iron but of a low strength.

E. Brick Arch

The brick arch that forms the Attic roof and supports the pedestrian walkway has several transverse cracks, tree roots, and moisture penetration. Bricks from the arch have been sampled in four locations and tested. The results of the compressive strength tests yielded slightly lower than expected results. The strength of the bricks ranges from 3,839 psi at span 6 to 4,940 psi at span 3. The lowest results occurred at locations where a significant amount of water is entering the attic space and would account for the deterioration of the arch.

F. Video Inspection of the Hance Walls

The hance walls, supporting the Attic floor, have been inspected with the aid of a video camera and the results have been recorded. The inspection revealed that the interiors of the piers are in good condition, no significant deterioration was found. The DVD’s of this inspection have been included with this report.

G. Steel Span

The steel span is in fair condition. The hinges located at each abutment and at the center of the span are functioning as designed, allowing the bridge to expand and contract with temperature changes. Typical deteriorations include moderate section losses in horizontal members where water tends to accumulate, crevice corrosion at junctures of gusset plates and columns, and losses of rivet heads in isolated locations, particularly on surfaces that are close to horizontal. More extensive section losses were found in the deck-supporting members, largely due to water leakage through the joints and several cracks in the coping plates.

H. Paint Removal Program

Paint and Pigeon Debris removal was necessary to accurately observe and measure the select samples of the steel span. The removal of the paint and pigeon debris was performed at panel points 4 and 8 and the results are detailed in the discussion of the steel span.

I. Foundations

After a significant amount of research it was determined that timber piles that are continuously submerged (the Highbridge piers are significantly below ground water) would remain in good condition, this conclusion was supported by the fact that survey and inspection found no indication of bridge settlement. As part of this contract, a permanent well-screen casing was installed to monitor the ground water level and setting of survey points on the piers was suggested for future monitoring. Also, four borings were taken to establish the bedrock location.

J. Seismic Analysis of the Steel Span

The steel span was analyzed for seismic loads and all the elements except for the column base connections meet the current seismic criteria, as set out in the December 30, 1998 New York City Department of Transportation Seismic Design Criteria Guidelines. For this structure to be seismically up to code it will be necessary to replace the rivets in the column base connection with High Strength A490 Bolts.

1.4 LOAD RATING RESULTS

Load ratings for the different elements of the bridge were based on the Allowable Stress Method. In addition to the wind and dead loads, all members were rated for pedestrian loads and for two typical Cushman vehicles, loads that may reasonably be expected to be carried by the bridge in the future. The As-built load ratings for most members met or exceeded the load rating criteria; with the exception of the tie-rods, which cannot carry the load even in the as-built condition, the remaining members will all support the current loadings. The Floor beams are the critical members on the steel span with a rating of 1.01 for the Cushman Live Load.

The As-inspected ratings were very similar to the as-built ratings except for two cases. The deterioration on most parts of the structure is minimal. The only elements that are critical and did not have a rating factor of 1 or better for the as-inspected condition are the floor beams, the brick arch walkway and the tie-rods. These elements will need significant modification and or replacement prior to opening the bridge to the public.

1.5 RECOMMENDATIONS

A. Railings

To rehabilitate this bridge and reopen it to the public there are a number of repairs required. It will be necessary to replace the railings with railings that meet today's standard of safety including being 4'-6" high and not having a clear opening between pickets greater then 4". It would also be advisable to install a barrier to prevent objects from falling or being thrown from the bridge onto the traffic (both vehicular and waterway) below.

B. Masonry Piers

To maintain the bridge the masonry piers should be cleaned and repointed.

C. Steel Span

The steel span of the structure should be cleaned and repainted on a regular schedule; this will increase the life of the structure significantly. Also, on the steel span all the rivets should be replaced with ¾" High strength A490 bolts. The A490 bolts are required instead of the standard A325 bolts to make the structure strong enough to withstand the design earthquake. Also, although currently functioning the pins at the bases and the crown of the arch should be oiled on a regularly scheduled basis. The deteriorated floorbeams should be repaired or placed. It is also recommended that some form of pigeon deterrent be installed to prevent pigeons from nesting inside the water main attic. Also, the navigation lights should be repaired as soon as possible.

D. Brick Arch, Walkway and Tie-Rods

The entire walkway should be removed and replaced with a walkway that meets the current standards for cross slopes. While the walkway surface is removed it is recommended that the waterproofing on the brick arch be replaced. Due to the condition of the tie-rods it is recommended that they be replaced. Of the four tie-rods removed all four were carrying loads and although these loads were carried by the stone walls upon removal of the tie-rods these rods were located a minimum of forty feet (8 rods) apart and there was never more then one removed at any given time. If too many consecutive rods were to deteriorate the side walls of the structure would not be capable of carrying the load from multiple tie-rods.

The posts that support the gates located at both ends of the bridge leak and allow moisture and vegetative growth to penetrate the bridge. It is recommended that these posts be sealed to prevent further deterioration.

It is also recommended that lighting be added to the walkway.

E. Approaches

The existing archway located under the southeast approach of the bridge exhibits several cracked and missing bricks as indicated in Appendix J. It is recommended that this arch be temporarily shored and then permanently repaired prior to opening the bridge.

1.6 SUMMARY OF GATEHOUSE INSPECTION RESULTS

Both the Manhattan and the Bronx Gatehouses exhibit a serious mortar loss from between the joints of the stone blocks that face their walls. The losses extend as much as 13 1/2" deep at the Bronx Gatehouse and up to 24" deep at the Manhattan Gatehouse. Some cornice stones have lost so much mortar that they have shifted and pose a falling hazard if pushed, should some individual want to cause mischief. The roofs are flat and have no (remaining) provisions for drainage; snow and rainwater penetrate the walls and contribute to the continuing deterioration of these structures. Cores had been taken in the roof of both gatehouse and show that the roofs are in poor condition. The brick samples taken from the Bronx Gatehouse show that the bricks are in good condition and are as strong as any of the other bricks sampled on the bridge, also it was noted that their saturation coefficient was no different then that of the bridge bricks even though it appears that there is a lot more moisture present inside the gate house. Bricks were not sampled from the Manhattan gatehouse due to the Flag Condition that was reported with regards to the roof of that structure. It was deemed unsafe to try to remove any bricks for fear that the removal operation may cause further damage to the roof.

The Manhattan Gatehouse is in much worse condition than the Bronx Gatehouse. In addition to the deteriorations noted above, the concrete roof of the Manhattan Gatehouse is cracked and sagging in the center. The brick arch supporting the roof exhibits a number of cracks, and a section of arch measuring roughly 2' x 6' has broken its bond with the rest of the arch and descended 2” below the other sections. The condition has been flagged.

The two underground chambers located at the Manhattan Gatehouse Plaza are both in a good condition. The smaller chamber houses two old water main valves that are no longer functional (neither are the water mains) and the larger chamber provides access to the Aqueduct. For pedestrian safety, both have been sealed with steel plates.

It is recommended that the roofs on both Gatehouses be replaced and that the Granite stones on the faces of the Gatehouses be cleaned and repointed.