Conservation Needs Assessment Report for

The Parthenon and Historic Concrete Structures at Centennial Park

Prepared for:
Metropolitan Historical Commission of Nashville
and
Centennial Park Conservancy

By
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&
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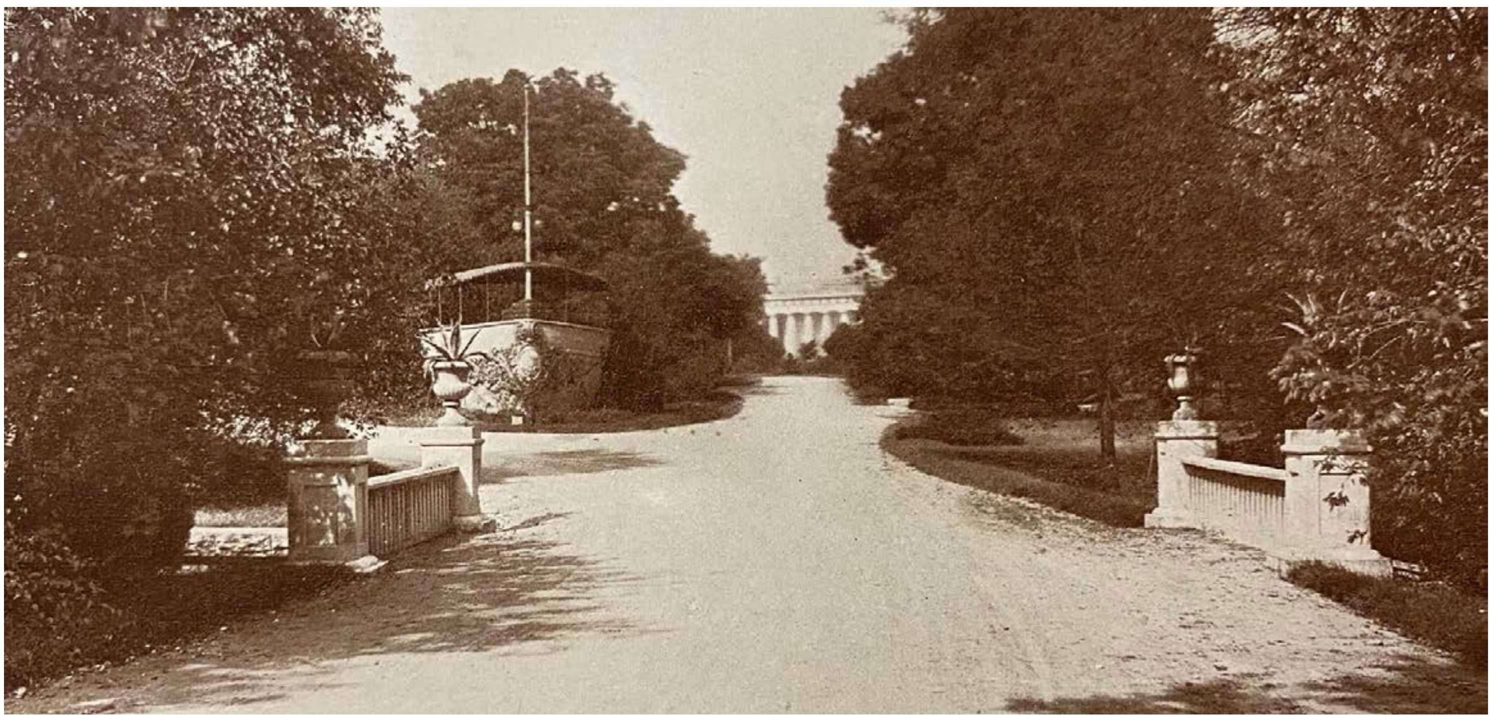


INTRODUCTION

Centennial Park is the site of the 1897 Centennial Exposition which celebrated the 100th anniversary of Tennessee's admission to the Union. The exposition director Major Eugene C. Lewis was responsible for the conception and planning of the fair, which included the building of an accurately scaled replica of the Parthenon in Athens, Greece. The exposition grounds were converted to a city park in the early 20th century and deeded to the city in 1902, making it a permanent space for community gatherings and recreation. Between 1906 and 1910 other structures, in addition to the Parthenon (the only remaining exposition building), were added to the park. Those included, in part: the Gunboat *Tennessee*, Shell Spring, Bridge at Lick Branch Sewer, and the 1910 Concrete Bridge by Lake Watauga. Due to disrepair, the Parthenon was reconstructed in concrete and completed in 1931.

Those five historic concrete structures are the focus of study in this initial needs assessment. The four smaller concrete structures are significant for their early use of reinforced concrete in the South, with architectural follies Shell Spring and Gunboat *Tennessee* employing unique construction techniques. The Parthenon is exemplary of John J. Earley's architectural concrete.

In June 2021 Cultural Heritage Conservation (CHC) was awarded the lead for a conditions assessment of the five structures in Centennial Park, the result of which is presented in this report.

Figure 1: Structures mapped on rendering by Nelson Byrd Woltz Landscape Architects. Approximate locations:1. Concrete Bridge. 2. Parthenon. 3. Gunboat Tennessee. 4. Lick Branch Bridge. 5. Shell Spring.

SCOPE OF WORK

Metro Historical Commission (MHC) undertook this assessment as a grant project with funding from the Historic Preservation Fund through the National Park Service and Tennessee Historical Commission, with additional funding provided by the Centennial Park Conservancy.

The Centennial Park Parthenon and Historic Concrete Structures Assessment Request for Qualifications outlined the scope of work as follows: For the historic concrete of the Bridge at Lick Branch Sewer, the 1910 Concrete Bridge, Shell Spring and Gunboat *Tennessee* Monument: completion of a conditions assessment, materials analyses to determine mix compositions, recommendations for maintenance and repair, priority list for repairs and any related findings, and cost estimates. The following assessment techniques were carried out in a limited capacity due to time and budget constraints: visual assessment of the four structures, hands-on investigations based on those findings, including drone photography, sounding, moisture meter readings, steel reinforcement locating, biofilm removal tests, and field measurements. The materials analyses were based on samples collected during the first site visit and submitted for petrographic analysis to determine mix compositions.

For the Parthenon exterior concrete, the scope of work consisted of a conditions assessment, priority list for repairs, recommendations for maintenance and repairs, and a cost estimate. Visual assessment of the Parthenon was in part to review the work completed in the 2001 major restoration campaign of the historic concrete to determine if it is still sound 20 years later. Visual assessment was conducted from the ground and by binoculars. Due to the alteration of the landscape around the Parthenon, hands-on access to the upper portions of the building was limited to the west elevation by bucket lift and the interior of the colonnade and the walls across from it by scissor lift on the stylobate. The Team completed a limited interior visual assessment of the foundation walls and columns, and underside of the slab, where access was possible.

CHC partnered with Silman for structural assessment of the historic concrete of all structures and Schnabel Conservation for petrographic analysis of the historic concrete from the two bridges and two follies, excluding the Parthenon. Cost estimates were provided by Allegrone Companies.

The report presents each structure as a chapter describing the structure, archival information that was provided by MHC to the Team, construction description, petrographic results, conditions assessments, and next step recommendations with associated cost estimates where applicable.

ARCHIVAL INFORMATION

MHC provided the following archival documents. The Parthenon archives are listed under its section.

- 2007 Sculpture Condition Survey of Shell Spring by Shelley Reisman Paine Conservation completed for Metro Parks
- 2008 Centennial Park National Register of Historic Places nomination
- relevant excerpts from the 2010 *Centennial Park Master Plan*
- 2015 Condition Report for Shell Spring by Tony Novak Studio
- 2017 *Metro-owned Artworks Conditions Assessment Report* which includes Shell Spring and Gunboat *Tennessee*
- Historical records and images from MHC files

CONCRETE OVERVIEW

Concrete at its most basic state consists of cement, sand, and aggregate, mixed with water. The cement is hydraulic meaning, it sets in water and gains strength quickly, reaching 90% of its total strength in 28 days though its hydration continues for several years. Reinforced concrete refers to embedded steel reinforcement in the concrete. Concrete is superior in compressive strength but lacking in tensile strength which the steel provides. Their coefficients of thermal expansion are comparable, making them compatible for construction. The disadvantage of the embedded steel is its susceptibility to corrosion, which in turn causes cracking and loss of concrete. When it is still alkaline (high pH), concrete provides a passivation layer on the steel, protecting it from corrosion – provided there are no cracks or loss that expose the steel to moisture. However, as concrete carbonates (becomes more neutral in pH), the steel is no longer protected and can begin to corrode. Concrete carbonates through exposure to water and air which is unavoidable in an outdoor environment. It can take many years for concrete to carbonate and often just carbonates superficially depending on the mix, its porosity, and other factors. The Team tested samples from the four historic structures for evidence of carbonation; results are provided under each structure's section.

The concrete and construction of the two bridges and two follies range in dates from 1906 to 1910. All structures are reinforced concrete making them very early examples of the technology. The general acceptance of reinforced concrete and its various uses and possibilities in the construction field was in 1900. The Shell Spring and Gunboat *Tennessee* are particularly unusual in their use of concrete as follies – or architectural structures that are more decorative than functional.

The Parthenon – the current reconstruction which was completed in 1931– is an architectural marvel, made more so because it is a remarkable example of John J. Earley's exposed aggregate concrete cladding. The Parthenon has been extensively researched, investigated, and surveyed resulting in many repair campaigns since its construction.

A note about new concrete mixes. It is very difficult to match new patch mixes to historic concrete. The latter alters over time, so knowing the composition of the historic mix is only a fraction of the process to achieve an aesthetically compatible mix. For every structure in this scope of work a significant amount of time and samples and mockups of new mixes should be allocated and approved before any implementation. Those costs are not included in the cost estimates.

A few terms and their definitions used in the following narrative:

Precast – refers to concrete forms that were cast/poured off site or not directly in situ. It is cast in molds and then moved and assembled on site.

Cast in place – refers to concrete that is poured on site in formwork built exactly where the concrete is to remain. This is largely the construction technique of the four historic structures and the structural concrete of the Parthenon.

Exposed aggregate finish – referred to as "finish" in this report; the Earley technique of applying the architectural concrete finish (at the Parthenon it has a pebble-dash appearance) onto the structural concrete similar to a stucco application only approximately 1-1/2" thick.

Anchorage – refers to metal attachments within concrete that may include dowels, pins, bars, etc. typically to attach decorative elements to the bulk of the concrete.

Rebar – refers to the ridged or smooth round or square bars used for steel reinforcement within structural concrete.

Parge or parging – similar to stucco or render, is a finer mix of cement (though it can be different binders) and sand applied over concrete (or other substrates) as a finished surface. There are several different campaigns of parges on the structures and it is unknown if any are original without further investigation not included in this scope of work.

Lift – refers to a continuous pour of concrete – typically at four-foot heights. If another lift/pour is added, a cold joint results between the two lifts. An example of this is evident at Gunboat *Tennessee* in what appears to be a large horizontal crack but is the joint between two pours.

GENERAL APPROACH TO HISTORIC CONCRETE PROJECTS

As two firms who have worked and continue to work on several historic concrete buildings and structures that are both in use and deteriorating, the need for a combination of testing, active monitoring, physical assessment, and regular inspections cannot be overstated. This involvement in several precedent projects has been viewed by owners and local building officials as a very effective method of ensuring on-going life safety for continued use of the site and facilities. This section provides guidance on how to approach many historic concrete structures for their continued preservation and public use. As with all historic concrete elements of national or local significance, this methodical approach would be most beneficial at the Parthenon and some of the other park structures reviewed for this project.

The approach usually begins with an initial site review to identify conditions that could be considered a potential life-safety concern. These could include obvious signs of structural instability or distress (large vertical cracking and spalling, shifting structural elements off their support, potential overhead spalls/fall hazards, etc.) or other low-level but still unsafe concerns (tripping hazards, uneven walkways, obstructions from general traffic, etc.). If the conditions noted are an immediate threat to the public, the team would notify the owners and propose measures to make the site safe until full repairs can be implemented. These measures could be fencing the structure or portions of the structure, temporary shoring, or having a contractor perform tactile review of the areas and remove all overhead hazards.

Once life-safety issues have been addressed (at least in the short-term), the remaining conditions are documented, and their sources of deterioration identified. Water ingress and environmental exposure, together with insufficient protection, are most often the cause of concrete degradation. However, there are other factors. Some could be of a structural nature such as inherent structural deficiencies, a change in the load distribution from the original design and construction, foundational shifts under the structure, disruption of structural support due to nearby or adjacent construction activities, inadequate rebar detailing and construction practices for reinforced concrete, etc. Others could be superficial/topical in nature such as poor execution or inadequate detailing of surface finishes to account for building behavior/movement, the application of incompatible finishes or coatings, etc. Understanding the source of the concrete degradation is key to detailing a repair that not only fixes the conditions noted but prevents them from continuing.

For structures exhibiting conditions relating to normal wear and tear and superficial/topical deficiencies, concrete repair treatments can follow a traditional conservation approach. Loose material must be removed back to sound concrete or stabilized. Any incompatible topical treatment previously installed such as parging, waterproofing, sealant, etc., that is a cause for any deterioration observed, should be removed as well. Once that is completed, the concrete can be fully assessed, and treatment recommendations made. Loss compensation, if it includes patching, depends on the size of the concrete patch to be installed and whether formwork and pours, or hand-troweled mortar-like installations, may be necessary. Protection of reinforcement and adherence of concrete to and around reinforcement is key to a properly executed patching campaign. Exposed rebar should be assessed to ensure it is salvageable; if rebar is beyond repair; it would need to be supplemented to ensure the structure behaves and supports loading as originally intended or as new demands require. If reinforcement is reparable, it should be scraped, primed, and coated with a corrosion inhibitor for maximum protection prior to being patched/covered with fresh concrete. The application of a suitable topical treatment (breathable water repellent, etc.) could be installed once all concrete elements are restored. Based on this review, that treatment scope is possible and appropriate for the 1910 Concrete Bridge, the Bridge at Lick Branch Sewer, and Gunboat *Tennessee* as noted in their respective sections.

For structures whose conditions are generated from structural issues or whose causes for conditions are not easily determined, a combination of testing, monitoring, physical assessment, and phased inspections is necessary. This level of investigation has the benefit of learning more about the building – in support of developing an over-arching repair campaign that makes effective use of funding – and carrying out the proper due diligence to ensure that the public is safe.

A program such as this would include sounding of the concrete structure to ensure all loose material is removed or stabilized (mitigating the risk of material falling off the structure without notice); active monitoring of significant cracks with digital crack gauges that can alert the engineering team and owner if cracks are opening and closing more actively than "normal"; regular hands-on inspections of specific areas of concern; sampling and testing concrete cores to identify decay mechanisms and their extent; high-definition photography of existing concrete to provide a baseline conditions map for future reference; and other real time digital monitoring equipment that allows the team to understand the building's response to seasonal variations, occupancy, etc. The conditions at the Parthenon warrant such an exercise.

As information is gathered, recommendations can be made to net or barricade areas if necessary and begin a more strategic approach to ensuring safety at the site. Though time-intensive and costly, it is a responsible approach to monitoring safety, a holistic approach to address causes of deterioration rather than just the conditions themselves, and better serves the long-term preservation of the cultural heritage.

COST ESTIMATES

The cost estimates were developed for the historic concrete only, with a few exceptions pertaining to some new casting of retaining walls and steel treatment. The costs are preliminary due to the nature of the survey as an initial needs assessment and issues of concealment due to parging, biogrowth, debris, old repairs, and subgrade elements such as foundations. For instance, the quantity of crack fills in the structural concrete that is covered by parging had to be wholly assumed.

Restoration work is an iterative process led by discovery phases which continually inform the scope of the interventions. In this phase the petrographic analysis conducted to determine the composition of the concrete mixes also determined that there were varied results on the depth of carbonation of the concrete, some of the samples contained salts in voids, and the aggregate, in minor part, consists of chert which can cause alkali-silica reaction - highly detrimental to concrete. This has led to the recommendation of additional cores and testing to determine service life issues with some of the structures.

The costs herein do not include the involvement of a Design Team, i.e., concrete conservator or structural engineer, which is critical to the implementation and success of the repairs and additional investigations.

For some tasks the cost estimate was based on a conservator specializing in concrete executing the repairs (outside of design services). Due to their unique structures, this particularly relates to the Gunboat *Tennessee* and Shell Spring. The costs do not assume Tennessee union labor costs.

The costs do not include access such as lifts, scaffolding, ladders, etc. The costs also do not include general conditions such as trash disposal, mobilization, site management, project management, enclosing the site to prevent public access, conditioning spaces such as heating, water access, runoff collection, etc.

The cost estimates are provided in tables at the end of each structure's section. They are presented by task, each of which gets an accompanying description, image (if relevant), quantity, priority, and cost estimate. In some cases, the tasks are presented with options based on the Secretary of Interior's Standards for the Treatment of Historic Properties – specifically, Preservation, Restoration, and/or Reconstruction.

Again, many of the quantities had to be grossly assumed because of concealed conditions or subgrade locations.

Some abbreviations for quantities referenced herein include:

- LF – linear feet
- SF – square feet
- CF – cubic feet
- CY – cubic yards

Priorities are based on a scale of 1 to 3, with 1 being the most urgent to implement or further investigate, and 3 being not urgent.

When a task in the cost estimate tables was not related to the historic concrete, and hence not in the scope of this project, it was given an "n/a" designation. That work includes further testing of subsurface materials and conditions by specialist consultants, such as steel location and corrosion, or drainage and site assessments, exploratory probes, crack monitoring, and the like.

THE PARTHENON

General Description

Originally built for the 1897 Tennessee Centennial Exhibition, the Parthenon is an accurately scaled replica of the original Grecian architectural marvel and was meant to celebrate Nashville, coined by locals as the "Athens of the South." Beloved by the city, a permanent structure was commissioned to replace the quickly deteriorating plaster-clad temporary structure. Artisan John J. Earley, rising to national recognition due to his decorative and durable techniques in the development of exposed aggregate concrete structures, was commissioned to clad the new concrete, steel, and masonry structure in the late 1920s. Earley employed several techniques to various architectural aspects of the structure, including polychromatic façades with sculptural elements within the pediments; thin precast paneling on the structural columns; and panelized exposed aggregate cladding at both the interior and exterior of the unreinforced brick masonry building walls and exterior steps and colonnade level.

A national and local landmark that exhibits experimental construction techniques, the Parthenon has been studied, assessed, and repaired numerous times. The building sits longitudinally east to west at the north end of Centennial Park and atop a large-infilled berm that tapers from approximately 10'-0" above grade on the east to at grade on the west. Grade slopes down at the north towards a surface parking lot and at the south towards the Great Lawn. In the late 1980s, a new entrance with a lobby, ticket booth, restrooms, and museum shop was installed adjacent to the east end of the building, where the original exterior steps ascending the berm to the east elevation entrance were located.

The building was one of the largest structures employing precast and cast in place concrete paneling at the time of construction, and some materiality and constructability issues emerged almost immediately. The site geometry, as well as construction techniques, appear to be sources for some of the conditions noted.

Figure 2: Parthenon south elevation.

Figure 3: Parthenon west elevation.

Construction

The Parthenon is a recreation of the original Grecian building, a rectangular structure approximately 72'-6" (north-south width) x 160'-0" (east-west length) and 60-0" high from the porch to the base of the roof cornice. There is a central, enclosed building with a perimeter elevated porch on all four sides. Entrance to the central building is at the east and west elevations, via 18'-0" x 72'-6" landings that are elevated 2'-8" above the walkway; this walkway extends 15'-6" from the north and south building walls and west and east entrance landings and is elevated above surrounding grade. Two levels of stereobates, 2'-8" H x 2'-5" H steps, allow visitors at grade to ascend to the perimeter porch around the main building. The roof covers the entire building, east and west entrance landings and perimeter porch; it is a low-pitch gable roof, sloping toward the north and south ends with a central height of about 20'-0". Exterior and interior columns, in addition to the four perimeter walls of the central building, support the roof structure.

The foundation of the original building is a series of continuous stone walls around the perimeter of the central building, the perimeter of the main porch, and beneath the east and west exterior columns at the edges of the entrance landings. A full height basement, separated into main event space, storage spaces and offices, is located within these stone foundation walls. The stone foundations are thickened into piers beneath the exterior columns around the perimeter porch; the exterior columns inside of the perimeter (at the edge of the entrance landings), are supported by 2'-0" wide stone walls reinforced with 2'-0" wide reinforced concrete buttresses. These buttresses may have been installed when the temporary Parthenon was reconstructed into the permanent building it is today, though there is no documentation supporting this hypothesis. The steps are structurally separate from the perimeter foundation wall and are founded on surrounding grade.

The porch, and most likely the interior first floor (though not confirmed), is a one-way reinforced concrete slab spanning to steel framing that is supported on the perimeter stone foundation walls and piers and finished with an exposed aggregate concrete coating that was cast against the reinforced concrete floor slab.

The exposed aggregate finish appears to be a 1-1/2" thick "skin" that was directly applied to most surfaces of the building, including the stereobates, the entrance landings, and the building walls and columns. The reinforced concrete columns are inside a two-part (thin reinforced concrete wall and exposed aggregate finish) castellated exterior concrete flute. The building perimeter walls are 5'-4" wide, composed of an inner and outer layer of exposed aggregate paneling encapsulating the unreinforced masonry brick structural walls. The roof over the main building is a reinforced concrete mesh slab spanning to steel trusses that create the gable frame; the truss ends are supported on brick pilasters built integrally with the rest of the perimeter brick walls. The roof beyond the central building is a reinforced concrete structure that spans between the building walls and the concrete columns around the porch.

Archival Information

Repairs have been implemented at different levels and stages of the building's history, and anecdotal information has indicated material conditions appeared soon after the building was constructed. The following reports and drawings were made available by MHC:

- 1928 Hart & Carter Drawing for the Restoration of the Parthenon
- 1928 Hart & Nevins Drawing for the Restoration of the Parthenon
- 1961 John Charles Wheeler Specification for the Restoration of the Parthenon
- 1981 Preservation Urban Design Inc. Summer Report of Interior and Exterior Cleaning Tests
- 1986 Law Engineering Testing Company Geotechnical Report for New East Entrance Construction
- 1986 Myrna Saxe Preliminary Inspection Report
- Circa 1990 Photos from "Parthenon Foundation Repair"
- Circa 1990 Harris Drafting Floor Plan
- Circa 1990 East Addition Basement Floor Plan
- 1991 Gresham, Smith and Partners Preliminary Findings
- 1991 Western Waterproofing Company Inc. Conditions Report
- 1992 Myrna Saxe Review of Western Waterproofing Proposal
- 1994 Quinn Evans Exterior Restoration Study of The Parthenon
- 1994 Gresham, Smith and Partners Roof Restoration Drawings (Set of 8)
- 1995 Gresham, Smith and Partners Phase One Restoration Drawings (Set of 9)
- 1995 Gresham, Smith and Partners Phase One Restoration Specifications (Volume I of II)
- 1995 Young Sales Corporation Phase I Extra Antefix Molds CO
- 1996 Western Waterproofing Phase I Concrete Restoration CO
- 1997 Western Waterproofing East Elevation Drawing
- 1997 Orion Building Corporation Phase II Investigations Change Order
- 1998 Young Sales Corporation Parthenon Roof Replacement Accounts Payable Invoice
- 1999 Quinn Evans The Parthenon: Pediments, Entablatures, Metopes, and Prototype Repairs
- 1999 The Parthenon Phase II East Elevation Pediment and Entablature Restoration Construction Drawings and Specifications (hard copies located in Ann Arbor, MI)
- 2000 The Parthenon Phase II West Elevation Pediment and West and South Entablature Restoration Construction Drawings and Specifications (hard copies located in Ann Arbor, MI)
- 2001 The Parthenon Phase II Naos Walls, Steps and Plaza Repair Construction Drawings and Specifications (hard copies located in Ann Arbor, MI)
- 2004 *APT Bulletin* Article "Replicating the John J. Earley Concrete Mix to Restore the Nashville Parthenon"
- 2008 Centennial Park National Register of Historic Places nomination
- 2020 GHP Environmental + Architecture NESHAP Asbestos-Containing Materials Survey Report
- 2020 GHP Environmental + Architecture NESHAP Hazardous Materials Survey Report
- Circa 2004-2011 Quinn Evans NTHP Field Session on the Nashville Parthenon Restoration

<u>1961 Repair Information</u>

The earliest documented restoration work conducted on the Parthenon structure dates to November 1961. (Note: The 1928 drawings entitled "The Restoration of the Parthenon" pertain to the reconstruction work that turned the temporary structure into a permanent, durable one.) Architect John Wheeler Charles developed the specifications for repairs to the following concrete areas:

- cleaning the exterior of the building.
- repairing cracking and spalling.
- resetting settled steps around the perimeter of the building.

- replacing the west entrance wood steps with new concrete steps.
- waterproofing the exterior.
- caulking open joints in the concrete.

Other repairs included patching the plaster ceiling; painting the doors; adding bird guards; and refinishing the bronze doors.

The specifications noted that "existing caulking in wall cracks and step joints shall be removed prior to general surface cleaning," which indicates that cracks had already developed in the building walls and possibly between steps before the 1960s. The specifications go on to indicate that most of the cracking seen around the building exterior is due to thermal expansion and contraction of the back-up material and lack of jointing in the applied concrete exterior coating to allow for such movements, but that "severe cracking" alongside the entrances has occurred "as a result of settlement of the building." Caulking the bases of columns and at all joints between steps around the building with an elastic waterproof Thiokol compound, tinted to match the color of the adjacent surfaces was also recommended. This most likely is not the current pinkish caulk seen at these locations since the service life of caulk is typically not more than 10 years; most likely the current caulking is from the 2001 Phase II restoration campaign.

Expansion joints were specified to be treated with grout, while settlement cracks required complete removal and replacement of the exterior concrete finish around the cracking. It is unknown to what extent, if any, these repairs were implemented.

There was major cracking noted in the east entrance walkway that was to be removed and replaced; it is unclear if this walkway was outside of the building footprint or if this walkway was removed when the east lower entrance was installed. It was further noted that there were multiple spalls and abrasions at the east end of the building, specifically the northeast corner, possibly due to that area being the most heavily trafficked. The specifications called for these concrete areas, as well as all pediment statuary and frieze figures, to be repaired and restored though specific extents are not documented. Therefore, it is unknown what was done at the time.

The specifications described settlement of the base steps along the east elevation and the eastern ends of both the north and south elevations; the corrective measures included raising the steps using grout pumps to jack up the settled steps or build up the top elevation of the steps. It does not appear as though either of these measures were ever performed as "settlement concerns" at the steps continued to be noted in subsequent assessments.

The specifications recommended that a silicone waterproofing, like "Thompson's Water Seal," be applied to all exposed concrete surfaces once repaired, but it is not known whether that was completed.

<u>1980s Repair Information</u>

The next document in sequential order and reviewed was Preservation Urban Design Inc.'s (PUD) cleaning tests performed in 1981 on the interior and exterior walls and columns and on the interior ceiling of the building. PUD's report notes that the exterior of the building was cleaned 15 years prior, around 1965. This may have been part of John Wheeler Charles' scope of work performed in the 1960s.

ProSoCo, Inc. representatives tested several different cleaning materials and methods, and recommended the following:

- Interior walls and columns be cleaned in a two-step system using ProSoCo 585 Liquid Marble Cleaning and lightly scrubbed and then apply ProSoCo Interior Stone Cleaner. A gentler paint stripper, ProSoCo 509 Paint Stripper, could be used on areas with thickened residue.
- Interior ceilings be cleaned with a water or mild solution of water and oil soap. Glass panels shall be cleaned with a soapless or water-soluble cleaner.
- Exterior walls and columns be cleaned in a two-step system using ProSoCo T-534 and a diluted acidic cleaner.

In 1982, Western Waterproofing Company, Inc. tested steam cleaning on the interior walls and columns, as well as one-step and two-step cleaning processes. They found that steam cleaning was appropriate for interior areas above 12'-0" in height and the two-step process originally specified in the 1981 testing was appropriate for all cleaning below 12'-0" in height.

Toward the latter half of the 1980s, plans were being developed to remove the existing stairs and porch at the east elevation to install a new, below grade entrance to the Parthenon. As part of this design work, Law Engineering Testing Company completed site borings and test pits and prepared a geotechnical report to document recommendations for the installation of the new structure adjacent to the existing building foundations. The report indicates that the existing basement floor level was between (absolute, sea level) 531' and 532.5' and that the new entrance would be at a finish floor of about 526' (6'-0" below the existing basement level). Therefore, they recommended the entire east elevation to be underpinned down to the limestone bedrock layer below the foundation soils.

They found that bedrock is approximately 11'-0" below exterior grade, which correlates to 3'-0" to 4'-6" below bottom of existing foundations. However, given the geology of the area, this bedrock could vary. The foundations exposed were found to be supported on residual stiff brown silty clay soil, though fill consisting of a variety of soils and other materials (brick, concrete, stone, etc.) were encountered along the east foundation wall below the estimated foundation depths. Therefore, the actual substrate under the entire building could vary significantly across the building's footprint.

The geotechnical report also noted that the center foundation is reinforced by 24"-wide concrete buttresses; these buttresses can be seen along the east and west elevations of the central building foundation wall within the basement spaces around the building. News articles and other secondhand literature indicated these reinforcements were put in when the temporary structure was made permanent in the late 1920s, though that has not been confirmed.

The report noted that there are "some early vertical and diagonal cracks […] observed on the exterior walls. The cracks are closed, and the main structure appears to be generally in good condition." It continued to state that "significant cracks were observed at the connection of the steps to the platform area and between different components of the steps. The cracks were generally largest […] along the east end of the structure [which] corresponds to the deepest fill places around the building. The cracks have been previously caulked and have subsequently experienced additional movement. The steps were generally free of significant cracking on the west end of the structure corresponding to locations constructed near original grade."

MHC provided photographs labeled "Parthenon Foundation Repair" (dated 1990 and sourced from Metro Archives). These photographs show the removal of the east stairs and openings through the east stone foundation wall and into the eastern most basement storage room. They depict a construction team working adjacent (or on) the concrete buttresses along the foundation wall below the east building elevation. Not much more is known from these photographs, but the photos do confirm that the perimeter steps around the building are not integrally connected to or supported by the building stone foundation walls. The base two steps appear to bear on surrounding grade, while the foundation stone walls go down to a continuous foundation 7' to 8' below grade.

Figure 4: View of east foundation looking south.

Prior to the installation of the new east entrance, conservation and architecture firm, Myrna Saxe, prepared a conditions report to determine what stabilization efforts would be needed due to the current state of the concrete, as well as what measures would be needed prior to construction being conducted adjacent to the building. They note "from the date of completion until the present time, several repairs were executed on the exterior decorations by various craftsmen. In 1960 the entire exterior was treated by application of a waterproofing chemical."

After their review, they identified the northwest column abacus as a life safety condition that required immediate attention and localized decorative elements within the east and west pediments requiring further review. The widespread cracking in the porch floor had led to water leaks within the basement. Recommended treatments included application of a wicking fabric between the underside of the concrete slab and basement ceiling and injections of highly elastic epoxy into cracks. They noted the base steps around the building had shifted and appeared to be an active settlement due to a loose fill base. They recommended the steps be removed and re-founded on properly consolidated subgrade.

They also recorded the cracks in the building wall but cite more analysis and discussion was necessary to recommend a suitable treatment. They noted the large cracks on either side of the east and west doors and provided images of map cracking on the north and south elevations. They cite a possible cause of the cracks is "sinking of foundation in places where the foundation curvature was corrected in the 1920's reconstruction. Possibly with relative loose soil. Crack shape somewhat follows corrected fill areas indicated on Drawings by

Russell E. Hart – George D. Nevins, Foundation Level Corrections, S & E Elevations dated March 25, 1921, and N & W Elevations, dated May 2, 1923." They recommended crack monitors be installed to determine whether the cracking is active, as well as subsurface investigations to determine any possible continued settlement of the foundation.

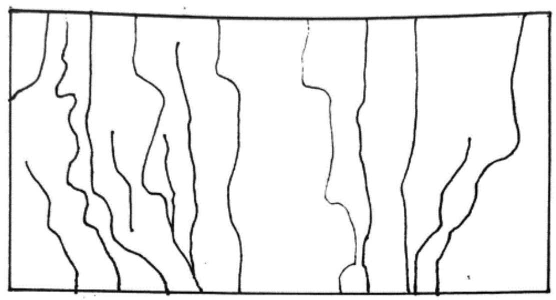


FIG. 3: WALL - NORTH ELEVATION - GENERAL CRACK PATTERN

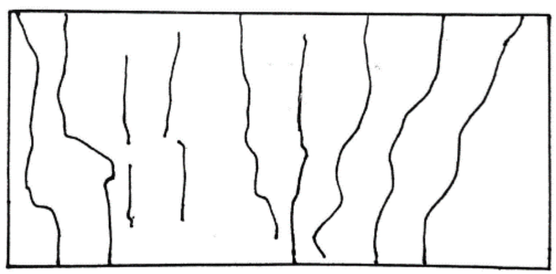


FIG. 4: WALL - SOUTH ELEVATION - GENERAL CRACK PATTERN

Figure 5: Myrna Saxe Crack Mapping, 1986.

1990s Repair Information

By 1990, the site needed to be fenced off due to the deleterious state of the building, specifically due to roofline spalls that became a life safety concern. In 1991, Gresham, Smith, and Partners (GSP) and Western Waterproofing Company, Inc. (WWC) provided preliminary conditions assessments.

GSP did a visual review of the building and with WWC removed the most damaged and unsafe portions of concrete and roof tile above. They provided estimated amounts of damage at the roof, pediment, cornice, frieze, and architrave, and marked up five column capitals that had extensive spalling and damaged steps at the northwest and southwest corners of the building. WWC recommended that a half cell potential survey be done to ensure all deteriorated concrete and reinforcement were removed during the repair program. They recommended all column cracking to be epoxied. They noted the extensive vertical and diagonal cracking on all building wall elevations but noted that the cracks did not translate to the interior face of the walls. They also noted that the cracking was full height that continued at a 90-degree angle at the base of the wall between the building walls and the exterior columns. They surmised the cracking was "most probably caused by thermal movement," and recommended full depth removal and replacement of the concrete paneling for the extents of the cracking. They noted the extensive cracking and movement of the perimeter steps as well and recommended that all the steps should be removed and reset on new foundations to prevent further foundation settlement or movement below grade. The consultants also recommended that a prototype area be completed to determine the best approach and suitability of repairs.

In 1994, Quinn Evans was added to the GSP and WWC team as historic preservation specialists, and they conducted their own on-site visual review of the building. Their primary focus was on all elements above the column capitals and offered the Metro Parks a range of restoration options. These recommendations led to the first phase of restoration, Phase I, which was 100% replacement of the roof tiles and restoration of all concrete elements (roof slab, raking, cornice, antefix, etc.) needed to be repaired prior to reinstalling the new roof system.

Quinn Evans elaborated on their assessment and recommendations in their 1999 report, with more elaborate conditions mapping of the east and west pediments, including all statuary figures, and the north, south, east, and west entablatures, architraves, and abaci. They noted areas to be removed and replaced versus patching and completed a crack mapping of the entablatures and abaci between and above the columns. This work became Phase II and included complete restoration of the east and west pediments, from the roof down to the metopes and localized patching of the entablatures and abaci. Work on these phases culminated on New Year's Eve 2001 with the lifting of the last recast gryphon in place.

Review of the construction documents shows that in addition to the extensive work done above the architraves, Quinn Evans documented the cracks along the architraves face and underside, as well as areas of the column abaci that required attention. These drawings identify that every architrave soffit (the junction of the element's vertical face and horizontal underside toward the exterior) was to be pinned with eight 6mm stainless steel helical wall ties that went through the depth of the exposed aggregate finish to the structural concrete. At cracks on the underside of the architraves, 6mm stainless steel Helifix anchors were to be installed on either side of the cracked concrete, every 16" along the length of the cracks.

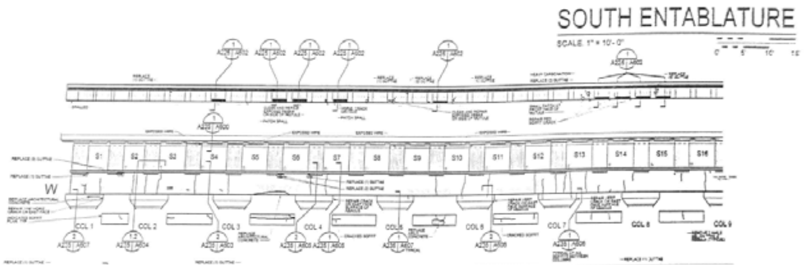


Figure 6: Crack mapping of part of south entablature by Quinn Evans, 1999.

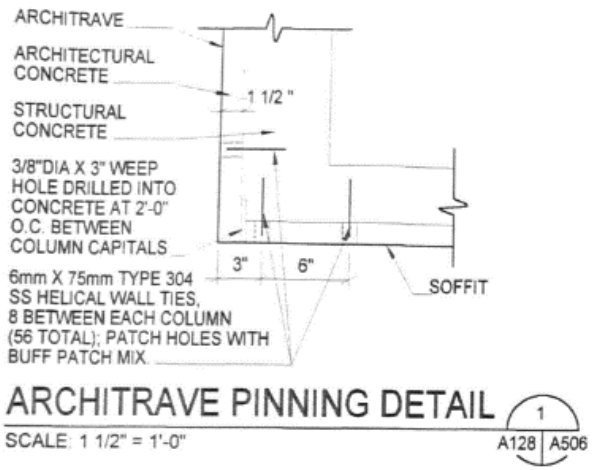


Figure 7: Pinning detail that was to be installed at every architrave, 1999.

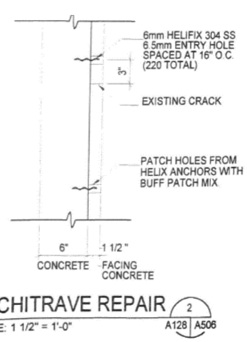


Figure 8: Pinning section detail that was to be installed at every architrave crack, 1999.

The drawings indicated that the tops of all concrete abaci were to be sounded, patched, and coated with Sikafloor 450/455 membrane. Full coating thickness and depth removal and patching was detailed at the southeast abacus on two sides (east and south), the southwest abacus on three sides (north, south, and west), the northwest abacus (on the west and north), and the third abacus from the south along the west elevation (west face). The north elevation was missing from the drawing set but based on site review, it appears patching of the abaci at the northeast and northwest corners were also completed.

The 2001 construction drawings show four vertical cracks on the north elevation toward the middle of the building, one crack on the east elevation on the north side of the entrance doorway, two cracks on the west elevation, one on either side of the entrance doorway, and five cracks on the south elevation (one toward the west end and four toward the east end) to be repaired by means of removing and patching the full depth of the finish on either side of the crack. Based on comparison to Myrna Saxe's crack map in 1986, the cracks identified on these drawings correspond only to the largest cracks that Quinn Evans recommended repairing with a patch. It is unknown whether the other cracks were repaired.

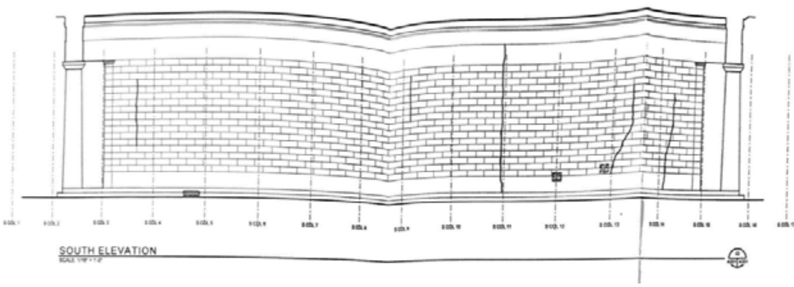


Figure 9: South elevation map cracking of most extensive cracks, 1999.

The finish of the northeast corner and portion of the southeast corner steps were removed and recast, and the structural concrete steps were assessed and pinned where needed prior to applying a new finish. New sealant was installed in the porch joints. Where sealant was previously used for crack repairs, aggregate was added to the sealant to better blend with the surrounding mix. Twelve localized areas of coating spalls were patched, and approximately eighteen cracks were identified to be repaired by means of crack injection with "Micro Capsule Engineering epoxy injection system". The scope of work does not show any work done to the cracking throughout the porch, though the caulking at the steps appears similar to that at the porch and base of the columns.

Figure 10: Northeast corner step pinned and recast, 2001.

Figure 11: Southern steps toward east end recast, 2001.

The 1999-2001 drawings note that all exterior concrete was to be cleaned with a mildly acidic product and then coated with a water repellent, Weather Seal Siloxane WB Concentrate.

Quinn Evans also identified areas of repair at the east plaza over the below-grade entrance. They identified the entire northern half as requiring a new topping with new 1/8" wide control joints and note that 1/2" thick expansion joint was to be installed between existing steps and new topping.

Conditions Assessment

Overall Description & Findings

Roof to Guttae

The building was found to be in generally good condition. Roof and pediment restoration work completed in the 1990s appears to be faring well. There are localized areas of rusting at the underside of the guttae, most likely due to rusting of the interior anchors. These were seen at discrete locations along the west elevation and were not extensive around the remainder of the building. Repairs between the guttae and the roof sima, Phases I and II of the work completed from 1997-2001, are in generally good condition with no obvious signs of distress.

Figure 12: Roof to guttae.

Architrave to Column Capitals

Below the guttae, cracks were identified along the face and underside of the architraves. Many cracks were observed from grade and wide enough to be seen without the use of binoculars. In addition, lift survey at the west elevation and the west end of the north elevation identified many hairline cracks upon closer review. Given the textured surface of the exposed aggregate finish, the depth of these cracks, whether they are hairline, through the full depth of the finish, or through the finish and the structural concrete behind it, could not be determined. These cracks do appear to be some of the same cracks identified in Quinn Evans' 1999 conditions report. It is unclear if the cracks not identified in the original assessment were hairline, unseen, or whether they did not exist at that time, but it does appear that some of the same cracks noted by Quinn Evans have continued to increase over the years.

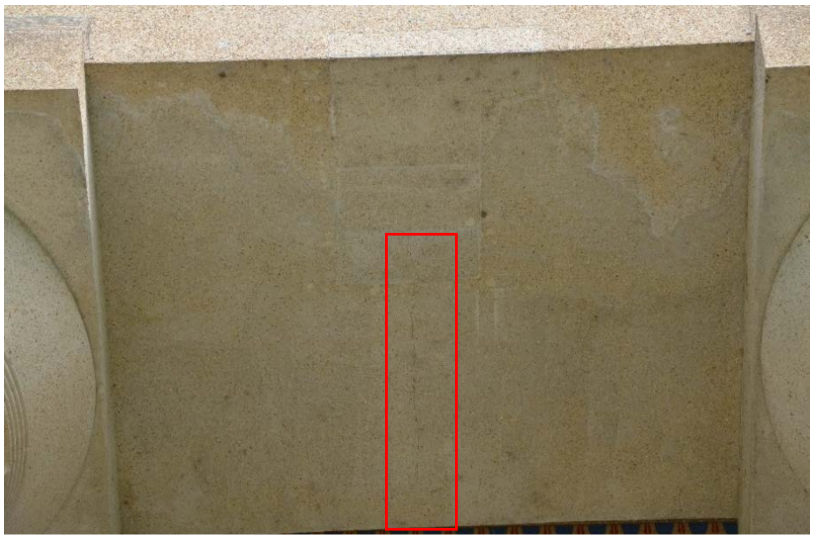


Figure 13: Underside of architrave on south elevation with crack through part of the patch and into original concrete.

Some cracking, most notably at the four corner columns, has formed network cracking that appears to be developing into areas that could spall. The most significant cracking and imminent spalling can be seen from grade at the west elevation column abaci. The west and north faces of the northwest corner abacus were already patched in the 1999 scope of work, and that repair is faring well; however, cracks are continuing to develop along the south and southeast corner of this abacus. It appears that this area was pinned together during the 1999 repairs, but it is not known whether the large cracking and spalling have grown since then.

Figure 14: Underside of architrave on south elevation with crack in the middle.

Up-close review of the remaining west faces of the west elevation column abaci showed varying degrees of cracking, the most concerning happening at the second, third and fourth columns from the south. It appears that the portion of the abaci that projects beyond the architrave is susceptible to exterior rain and runoff, and to shed water off and away from it, the projections were previously capped with a triangular concrete drip edge. These caps are cracked and failing, leading to water getting into the abacus from above. Cracks are forming on the north and south ends of the west projection as well as at the underside of the west projection, leading to thick efflorescent crusting and potential spalling.

At the southeast corner abacus, a large crack is developing along the west elevation, continuing south. A patch was installed at the north elevation which is faring well. The same is true of the southwest corner abacus, where a patch is in good condition along the east elevation but cracking and efflorescence are developing on the south and west corners.

Comparing Quinn Evans' crack mapping and repair details at the architraves and abaci have shown that while many of the cracks at the abacus soffits were existing, there are several new cracks that have formed. Some are extensions of cracks previously identified and some appear to be new ones. At grade, review of the soffits did not reveal any anchorage of the soffits as shown in the contract documents; it is unknown whether these repairs were installed.

Figure 15: Northeast corner of southwest abacus showing potential spall.

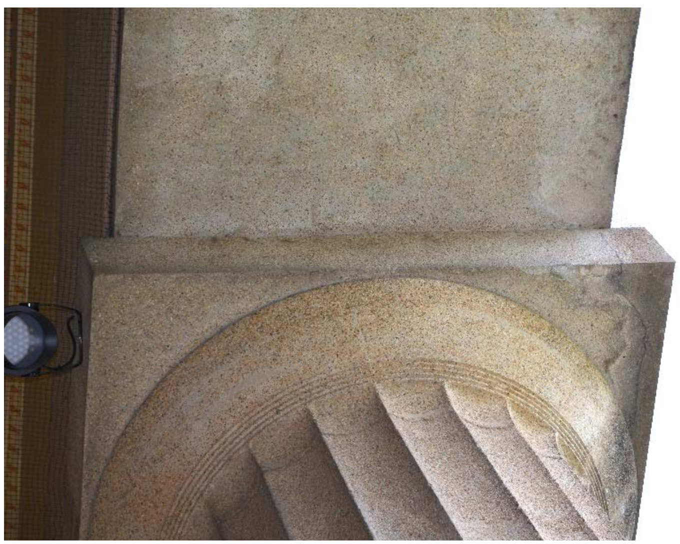


Figure 16: West column abacus showing cracking.

It also appears as though some of the cracks have widened since the 2001 work. There is a crack noted as 1/16" wide along the west elevation of the southeast abacus. Today, the crack appears dark with heavy staining and is easily spotted from grade. Up-close review of this crack was not possible so could not be measured with a crack comparator.

Figure 17: West column abacus showing cracking.

Figure 18: Southeast corner abacus.

The 2001 patches at the abaci are easily identifiable and faring well though it is unknown whether all areas were patched as shown in the drawings. This is true of the west elevation abacus, third from the south. This abacus appears to have the most areas of cracking, efflorescence, and potential spalling.

Building (Cella or Naos) Walls
The main issue noted above the porch are the large vertical cracks that are evident on all four cella walls. Based on archival information, vertical cracking on the cella walls has been documented and potentially repaired before the 1960s. In the 1960s, John Wheeler Charles called for these cracks to be repaired though it is unknown if that work was completed.

Comparing the crack mapping performed in 1986 by Myrna Saxe and the 2001 crack patching performed by Quinn Evans with this on-site review conducted in August 2021, it appears Quinn Evans' recommendations have led to the repair of the twelve widest cracks, but it is unclear if they injected the remaining cracks identified by Myrna Saxe.

The Myrna Saxe cracks not identified on Quinn Evans' documents have widened and numerous new cracks have developed. Similarly, more cracks have developed on the east and west elevations, outboard of the large cracks previously repaired in 2001. Large vertical cracking, noted by its dark staining and discoloration, appears to be in the center of the north elevation and toward the west and central areas of the south elevation. It appears that there are hairline cracks over most of these elevations, approximately every 26"-28", between wider cracks.

The continuation of crack development may be the result of one or more of the following:

1. Settlement of the building was and still is an issue.
2. The previous repairs of cracks, 2001 or otherwise, may not be providing the necessary space to allow for the thermal movement of the base material behind the finish and the base wall is finding other avenues to alleviate the pressure caused by thermal expansion and contraction.
3. Despite the previous crack repairs to allow for thermal movement, there is still not enough regular jointing in the finish to alleviate the pressure exerted on the finish when the base wall wants to seasonally expand and contract.

Figure 19: Crack comparator to measure width of wall crack, in inches.

Figure 20: Several cracks in the north wall at east end.

Figure 21: Large cracks on the south wall east end.

Below the Columns to Grade

The base of the building has the most conditions to note as the porch and entrance landings have large networks of caulked cracks, the caulk appears to be past its service life. The caulking is extensive and, in most areas, no longer properly adhered to the building substrate. The cracking at the porch is throughout and tends to be at the discontinuities in, or lack of, cold joints in the exposed aggregate finish. At the steps, the most extensive network of horizontal cracking appears to be along the south elevation, south ends of the east and west elevations and the northwest corner steps.

Figure 22: Southern steps, up close.

The bed joints between stylobate porch and stereobate and the head joints between stereobate units have the same pinkish caulk around the entire building. Most of this caulking is no longer adhered to the finish. The bed joints between the porch and stereobate steps show some signs of movement in the caulk, but it is unclear whether that is thermal expansion and breakdown of adhesion between the caulk and the finish or if the steps have moved due to ongoing settlement. This downward movement can occur because the stereobate foundation is on grade while the porch and building are on stone foundation walls.

There are signs of differential movement between steps. Some appear to have been historic movements since the caulking, although no longer adhered to the concrete, does not appear to have moved differentially across joints. This is evident at the northeast and northwest corner steps and the eastern third length of the south elevation. At the northern steps between the third and fifth easternmost exterior columns, however, the caulking has been torn, indicative of movement occurring after the caulking was placed. There is one spall at the northeast corner of the east elevation that could be a potential tripping hazard for visitors; this spall should be removed and repaired in the first phase of work.

Figure 23: Southeast corner step looking east.

At some caulked joints, the cracks are extending beyond the caulking, indicating that the thermal expansion and movement of the base material is not alleviated through the existing caulked jointing. At head joints between stone units, cracks are forming at both the horizontal and vertical faces of the finish. The cracking varies from hairline thickness to larger crack networks that have developed into spalled areas of finish.

The porch and building foundation walls and the underside of the porch slab within the basement storage spaces were also reviewed. As was expected, the foundation and slab show the most deterioration at areas where the caulked cracking of the porch and nearby steps are extensive. The cracking in the finish above is allowing water to migrate to and through the concrete slab and the foundation walls. Stalactites are found in through-slab cracks, most notably at the east end of the north and south elevations. In addition, there is a recurring leak beneath the west entrance landing above the offices in the basement. The slab underside could not be reviewed as the original formwork (wood slats) was still in place. This area will require further investigation to alleviate the known leaking affecting the office space.

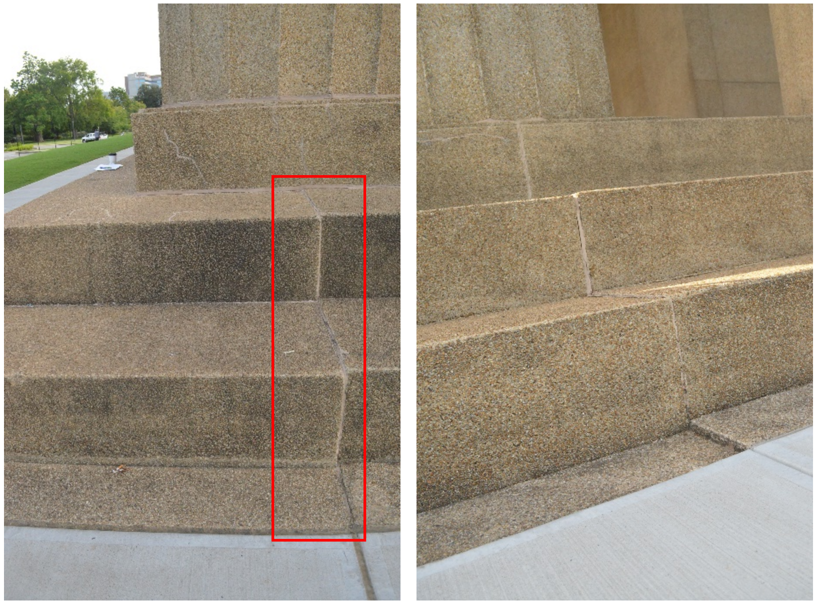


Figure 24: Northwest and northeast corner step misalignment.

Figure 25: Incipient spall at east elevation, north end.

The damaged areas at the underside of the porch slab have not deteriorated the steel framing to the point where stabilization is needed, but continued moisture egress through the finish could lead to potential slab and steel framing failures.

Figure 26: North wall of basement toward the east end showing through cracks and stalactites.

Figure 27: Concrete slab and beam intersected by steel beam.

Recommendations for Repair

Roof to Guttae

Overall, the roof and pediments look to be in good condition. There are five gutter tiles that have displaced at the south elevation near the edge that should be realigned. The localized areas of guttae that appear rusted should be reviewed up-close and possibly repaired (patched or removed and replaced to insert a new stainless-steel pin). The guttae at the regula are not within the netting at the cornice so are a public safety hazard if they fall. One guttae on a mutulus at the south elevation has fallen and was caught in the netting. We recommend regular monitoring of these elements to ensure continued success.

Figure 28: South side of roof has misaligned tile.

Architrave to Column Capitals

Quinn Evans' repair program to anchor every architrave soffit back to the structural concrete is a suitable recommendation to re-support the cracked finish. However, it is currently unknown whether that portion of the project was completed. Furthermore, the cracking has elongated and widened, and new cracks have formed. Therefore, the architraves should be sounded to ensure the anchors were installed and are properly supporting the finish, and additional anchors may be required around fresh cracks.

It is unclear right now whether the cracks that are developing are forming due to thermal expansion and contraction or whether there is a more serious structural issue. Therefore, the installation of an electronic crack monitoring system at select architrave cracks is recommended.

The system will continually monitor and record the crack movement to help gain an understanding of the fluctuations or progressions of the cracking. Progressive movement would be indicative of an internal concern or material failure and cyclic movement would be indicative of temperature shifts. This data would inform repair designs. These systems need at least one year of data (ideally three years) to help determine the source of the cracking.

Should the cracks be indicative of temperature variations, they may need to be injected with suitable material to prevent moisture ingress, which requires intentionally widening the cracks. Consideration should be given to whether some of these cracks become permanent control joints, which allow for the thermal movement of the structural concrete backup.

At the column abaci, the patching appears to be in good condition, but there are new cracks that can lead to spalls. Immediate attention should be given to the southern half of the west elevation abaci and the southeast abacus, which are exhibiting the most aggressive cracking, efflorescence, and spalling. The remaining abaci should be regularly monitored to ensure conditions have not worsened.

Building (Cella or Naos) Walls

The patching of the twelve widest cracks in 2001 is in generally good condition. Where patch jointing does not align, smaller cracks have developed which is most likely a result of thermal expansion of the finish. The smaller cracks appear to have widened and new cracks have been noted. These cracks appear to be through the finish and are most likely due to the inability of the exposed aggregate finish to move when the masonry back up wall wants to thermally expand or contract.

The cracks are most likely the finish's attempt to alleviate the pressure build-up from this thermal movement. However, due to the variable and unknown nature of the building foundation, settlement cannot yet be ruled out. Further investigation is needed to determine the source of the cracking and how active it is. An electronic crack monitoring system at these wall cracks should be installed.

The monitoring system will continually document the wall movement and record data to understand the fluctuations or progressions of the cracking. Progressive movement would be indicative of settlement issues, which could inform any foundation retrofitting that would need be developed. Cyclic movement would be indicative of temperature shifts which would require a different repair approach. These systems, as mentioned above, need at least one year of data (ideally three years) to help determine the source of the cracking

Sixty years of documentation by experts in the field of architecture, engineering and preservation have stated the cracking is either due to settlement and/or temperature variations without resolution. Therefore, it is the recommendation of this Team that all relevant information be gathered to determine the decay mechanism and source of cracking. Once the source is identified, it can be properly addressed, and repairs can be developed that will ensure the longevity and durability of the building.

Below the Columns to Grade

The caulking at the porch and two lower stereobates is past its service life. As a priority, the north end of the east elevation where there is a significant spall and tripping hazard at the top stereobate should be removed and patched.

For the remaining areas at the porch, there are several options that could be recommended:

1. 100% removal and replacement of the current caulking.
   - This would be the most cost-effective fix that could be implemented immediately.
   - This would be a short-term repair that will require continued maintenance over the years, (as it has had over the past sixty years) given the service life of typical caulking products.
   - This would not address the damage of the concrete slab underneath the porch, which has areas of leaks that need to be investigated and evaluated further.

2. Partial removal and replacement of the most damaged areas.
   - This approach would identify the areas that have the maximum porch slab damage and maximum finish cracking for replacement of the finish.
   - This is a moderate approach that addresses those areas that are most damaged or deteriorated. Further time on site would be needed to develop a tiered list of slab conditions but for this cost exercise assume 25% of the top side of concrete slabs should be removed and replaced.
   - Depending upon the severity of the concrete slab condition (through cracking, spalls, saturation, and carbonation levels), some concrete slabs would be replaced with new concrete on metal deck. Further time on site would be needed to develop a tiered list of slab conditions but for this cost exercise assume12% of the perimeter concrete slabs should be replaced.
   - The remaining concrete slabs would be patched from topside (where finishes are removed) or underside (where finishes have not been removed). Further time on site would be needed to develop a tiered list of slab conditions but for this cost exercise assume that 12% of the perimeter concrete slabs would need some level of repair (crack injection, infills, patching, etc.).
   - Some areas of finish would be completely removed and replaced. When removed, the top side of the concrete slab would be assessed and reviewed in tandem with the conditions noted at the slab underside within the basement.
   - As part of this program, the remaining areas would be regularly monitored and maintained and if deterioration is progressing faster in some areas, those slabs and finish would be replaced in a subsequent repair program.
   - This will reduce the amount of future caulking of cracked jointing since areas will be replaced with new finish and new control joints to account for thermal expansion and contraction.

3. The third tier of repairs would be to remove and replace all areas where cracking is found and install a new finish with control joint spacing that will allow proper movement between the materials.
   - This approach would be built-upon the second option to include more finish removal and possibly more concrete slab replacement. For the purposes of this cost estimate assume that 75%-100% of the slab finish would be removed and that 50% of the slabs would require repair or replacement.
   - It would not only address the major areas of cracking but moderate areas as well, which would account for a majority of the top side to be removed and replaced.
   - This will reduce the amount of future caulking of cracked jointing since areas will be replaced with fresh finish and new control joints to account for thermal expansion and contraction.

To accompany all these repair options, the underside of the slab and steel framing should be documented and repaired where needed. The existing steel framing should be cleaned and coated, the concrete slab should be patched and its reinforcement cleaned and coated, and any loss in the foundation walls be compensated. Further time on site would be needed to fully document the steel and slab conditions and a possible exploratory program through areas concealed by finishes at the office space, southern storage room and kitchen would be warranted.

Due to the known leak occurring in the west basement office space, water testing is recommended of the west entrance landing above this area and exploratory probes through the ceiling space and underside of the slab to identify the source of the leaking and document the full scope of damage to remediate the situation. The ceiling should be removed, as well as original wood formwork obscuring the underside of the slab, in obvious water damaged areas. Once that is removed, water testing should take place above and monitored above and below to track the flow of water into the space. This will require partial relocation of staff and materials to properly executive this investigation. Other areas can be water tested as well to understand the extent of water infiltration into the basement and to qualify some noted cracking and deterioration of the concrete slab underside. Areas that could be part of this phase or a second phase of testing would include the east end of the north elevation and the southeast corner.

For the stereobate steps, several options could be recommended:

1. 100% removal and replacement of the current caulking:
   - This would be the most cost-effective repair that could be implemented immediately.
   - This would be a short-term repair that will require continued maintenance over the years, (as it has had over the past sixty years) given the service life of typical caulking products.
   - This would not address the differential settlement of the steps that has been noted in all the conditions reports over the past 60 years.
   - This would not address the differential levels between stereobate steps so pedestrians would still need to be cautious when traversing across these areas.
2. The second level of repair would be to locally remove and replace the finish on steps that have aggressive network cracking and spalls:
   - This would be a continuation of Quinn Evans' efforts and include about 15-20 steps (20% of the stereobate area).
   - This will reduce the amount of future caulking of cracks and joints since areas will be replaced with new finish and new control joints would be installed to account for thermal expansion and contraction.
   - This would not address the differential settlement of the steps since this would be pinning the concrete in its current state and providing a new finish over the steps.
3. The third tier of repairs would be to remove and reset all the steps on a new foundation. Steps that are beyond repair should be replaced.
   - This will reduce the amount of (or eliminate) future caulking of cracks and joints since areas will be replaced with new finish and new control joints would be installed to account for thermal expansion and contraction.
   - This would address the differential settlement of the steps around the building and between individual unit steps.

Monitoring

To maintain the life safety of the structure and increase longevity of service life it is recommended to implement a monitoring and investigation program so that a holistic repair approach can be designed:

1. Conduct a hands-on review and sounding of all areas that have seen the continued propagation of cracking. This may include removal of existing loose concrete.
2. If necessary, install temporary protection at locations where the volume of repair work is clustered together and spalled, cracked, or deteriorated concrete is more at risk to fall.
3. Implement a more rigorous monitoring program as outlined below.
4. Perform an inspection, at a predetermined intervals established by the engineer of record and MHC (it is recommended to be on a quarterly basis for the first year at a minimum, in conjunction with monitoring) to determine if additional, immediate repair work or temporary shoring is required.

Monitoring Program

The previous assessments to date have provided little insight into obtaining a comprehensive understanding about how the building is moving daily, seasonally, and annually. A more robust monitoring program is critical to the success of any short- or long-term repair or restoration effort. The program should include the following:

- Laser Scan Survey of the building that will produce a point cloud to develop a three-dimensional model and produce accurate two-dimensional as-built drawings. The models can be used to observe behavior with software-applied stresses and the study establishes a baseline understanding of the building. The drawings could also be used by MHC and consultants for all future restoration efforts.

- Robotic Optical Surveying to continuously (on an hourly basis) record building movement laterally, radially, and vertically. This can be accomplished by setting strategically located instruments around the Parthenon and setting target survey points, as many as desirable within line of sight of the instrument. This will aid in determining exactly how the building is moving, whether the patterns are cyclical in nature (indicative of temperature or seasonal movement) or if movement is consistent in one direction or another (indicative of settlement or precursor of a bigger stability-related issue).

- **Bi-Axial Tilt Sensors** to detect plumbness, or lack thereof, in two directions of vertical load bearing elements, such as the building walls or columns, over time. Radial forces pushing against the perimeter line of framing would cause the perimeter to tilt.

- **Extensometer or Crack Monitors** to measure the differential movement across an existing crack. This is critical to determining whether a crack is dormant or active, whether it is cyclical (expanding and contracting) or progressive (increasingly expanding). The crack monitors also have temperature gauges to record the temperature at the time of each reading. Data is logged on a continuous basis and reports are generated automatically.

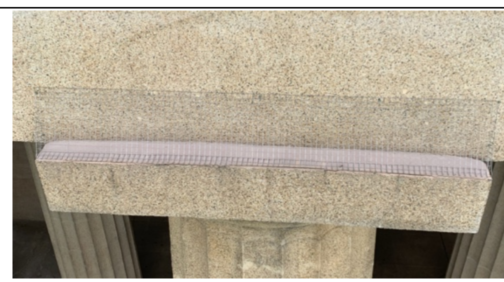
- **Vibration Monitors** to measure the frequency of the existing structure. The structure can vibrate on account of occupancy, nearby construction activity, a natural event, etc. Vibration can induce spalling of concrete or generate cracks. Given the nearby construction at Vanderbilt University, this may be an appropriate data point to measure how much the Parthenon structure absorbs and responds to nearby construction activity.

All monitors can electronically transmit data remotely to a data logger and the information distributed to MHC and the Design Team at set intervals. Thresholds for movement can also be established to trigger a report and notification if substantial movement is detected.

Twelve to eighteen months of data is recommended so that there is overlap with typical seasonally induced building movements. Over that time, movement patterns will become apparent. This will allow the Design Team to better pinpoint the causes for movement and the way the structure is moving and, ultimately, for development of a tailored solution as an appropriate response to the actual building movement which will extend the life span of the structure. Depending on the conclusions informed by the data analysis, additional investigations may be warranted. For example, should settlement be determined a cause for crack propagation, test pits would need to be performed to understand the foundation.

The monitoring program recommendations are not included in the cost estimates as they require additional work by the Design Team and other specialists to design the testing programs.

PARTHENON					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
ROOF TO GUTTAE					
Roof vertical cap realignment	Reset vertical cap so roof tile edges are no longer exposed.		5 units	1	$1,000
Guttae survey & repair	Drill into each gutta with corrosion to clean steel. Apply corrosion inhibitor. Patch guttae to match adjacent. Excludes close-up survey of every guttae.		36 units	1	$6,000
ARCHITRAVE TO COLUMN CAPITALS					
Sounding architrave, soffits, abaci	Hands-on review, including sounding of the underside of the architraves to determine presence and condition of anchors installed and soundness of concrete exterior at new cracks. Assume engineer on site for two weeks, excludes lift, etc.		276 units	1	$20,000
Crack monitoring	Installation of crack monitors on underside of architrave, two on east/west, four on north/south; one centralized system.		1 system, 12 nodes	1	n/a
Anchor architrave soffits	Assume 4-6 stainless steel helical anchors per soffit (assumption pre-detailed survey). Cover each hole with matching mortar repair.		276 units	2	$60,000
Water repellent	Apply water repellent to each crack at soffits and architrave; assume Weather Seal Siloxane WB.	-	150 LF	2	$6,000
Anchor architrave	This is determined by sounding – use stainless steel helical anchors.	-	300 units	1	$66,000

PARTHENON					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Control joints	Introduction of control joints: assume 1-1/2" deep by 1/2" wide; filled with sealant and matching river stones embedded in surface to blend.	-	24 LF	2	$4,000
Anchor abaci	Assume one to two stainless steel helical anchors per abaci elevation. Cover each hole with matching mortar repair.		60 units	1	$12,000
Patching abaci	Patch with mortar repair. Assume stainless steel pin embedded in patch.		28 SF	1	$8,400
Capping abaci	Remove and reapply sloped waterproofing and bird protection.		15 units	2	$6,000
BUILDNG WALLS					
Crack Monitoring	Installation of electronic crack monitors on walls, 2 on east/west and 4 on north/south; one centralized system already identified	-	12 nodes	1	n/a

PARTHENON					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
PORCH/STYLOBATE					
Option1	Remove and replace caulking (750 LF) Refill joints at steps (1400 LF) Cut unrepaired cracks and install caulk (100 LF)		see notes	1	$45,000
Option 2	Repair select areas that exhibit more damage and cracks: Assume 6 locations Repair concrete slab – 90 CF Clean and coat steel– 50 LF Finish replacement – 1-1/2" thick at 840 SF		see notes	2	$80,000
Option 3	Remove and replace entire stylobate: Repair concrete slab – 2000 CF Clean and coat steel– 1000 LF Finish replacement – 1-1/2" thick at 5280 SF 88 control joints (1 at every column corner) – 3 ft long x ½" wide		see notes	2	$690,000
STEPS/STEREOBATE					
Option 1	Re-caulk bed joints between steps (1400 LF) Re-caulk head joints at steps (1200 LF) Cut install caulk at previous and new cracking. (500 LF)		see notes	1	$62,000
Option 2	Replace the finish on steps exhibiting the most cracking/damage (20 steps). Pin backup concrete as needed. Re-caulk bed joints between steps (1400 LF) Re-caulk head joints at steps (1200 LF) Cut, install caulk at previous and new cracking. (500 LF)		see notes	2	$275,000
Option 3	Remove and reset stereobates (100 steps). Replace concrete bases that are damaged/cannot be reset (Recast 30 steps). Replace finish on all steps that have cracking (40 steps).		see notes	2	$1,750,000

BASEMENT					
Investigate and document steel and concrete slab	Develop full conditions mapping of the underside of the slab and steel and review exploratory probes performed: two days on site, development of conditions mapping, developing prioritized area plan. Assume removal of storage and other materials for proper access to underside of slab.		1 unit	2	n/a
Exploratory Probes (1)	Open ceiling in back-of-house areas to observe steel and concrete slab framing; Assume six to ten probes through ceiling.	-	6-10 probes	3	n/a
Exploratory Probes (2)	Open ceiling above west office space with known leaks; remove existing formwork to expose slab underside; assume one to two probes in this area.	 	1-2 probes	1	n/a
Water Testing	Perform water testing on porch to identify movement of water and source of leaks.	-	3 locations	1	n/a
Steel Framing	Scrape and clean all exposed steel.	-	n/a	3	n/a
Concrete Slabs	Replace significantly damaged concrete slabs Repair concrete slabs.	-	n/a	2	n/a

THE GUNBOAT *TENNESSEE*

General Description

The Gunboat *Tennessee* (Gunboat) is a concrete monument that was built to display a bronze figurehead in 1910. It is located in Centennial Park at 25th Avenue North near West End Avenue along a path heading north into the park. The monument is shaped like the prow of a ship and truncated at the backside creating a flat elevation. It is a hollow vessel and has a top and parapet similar to a boat's deck and railings. It is approximately 9-1/2' tall including the parapet, 6-1/2' without it, with a steel staircase at the back for access to the top. It is 22-1/2' at its longest and 18-1/3' at its widest – the configuration of it tapers in length and width. The prow comes to a point at the front, but the center crest of the bronze figurehead is 3' wide.

Archival Information

In a newspaper article dated in the early 2000s it was stated that the Gunboat and the other historic concrete structures in this scope were spearheaded by Major E.C. Lewis. Lewis was board chairman of the Nashville, Chattanooga & St. Louis Railroad, and director general of the 1897 Centennial Exposition at the park with an interest in reinforced concrete. The bronze figurehead of the Gunboat was discovered at the Seattle Exposition of 1909 by Nashville native Captain Albert Gleaves who spoke with Major E.C. Lewis about obtaining the piece for the city. The figurehead required a way to display it once acquired by the City of Nashville and this effort was overseen by Lewis who directed the fabrication of the concrete prow in January 1910. The figurehead was the original cast used to make the piece for the United States cruiser *Tennessee* in the period of the 1898 Spanish-American War. [1]

The monument sits near the location where the original main entrance to the park used to be – off Elliston Place. It was situated against trees and bushes, so its truncated back was integrated into the plantings within the park's landscape.[2]

Images of historic Centennial Park postcards provided by MHC suggest the figurehead was gold or yellow, perhaps gilt with gold leaf originally, but no evidence of that can be observed today.[3] The postcard has a white border around the image which dates the card to 1915-1930.[4] The *Metro-Owned Artworks Conditions Assessment Report* also states it was originally painted a golden color.[5]

The oldest photograph of the Gunboat provided by MHC shows large chain-links on either side of the monument from two portholes, presumably attached to, or suggest the presence of, anchors, but that is not discernible in the image. The photograph also shows a post coming from the top of the prow with two light fixtures halfway up the post, a flag near the top, and a bird (likely an eagle) at the very top of the pole. There was a canopy over the monument supported by a framework with posts inserted into the top ledge of the concrete.[6]

In a 1948 photograph printed in the newspaper article referenced above, the Gunboat no longer has the canopy, posts, flagpole, or chains attached to the monument. In a 1980 article in the *Tennessean*, the short steel railing observed today at the top of the monument is extant.[7] This railing was inserted into the holes that were already present for the canopy support. The monument has fewer plantings at its backside in the 1980 article and today has none except for a tree nearby.

Construction

The Gunboat is a concrete structure believed to be cast-in-place in lifts with regularly spaced cold joints throughout the construction. It is a hollow construction, so observations of the interior were possible. The interior does not have the parging as seen on the exterior so the formwork marks and pour lifts are readily visible. It appears as if the walls were poured in two lifts and then formwork was designed at the interior for the pour of the top slab ("roof") and sides ("parapet"). There are two I-beams, 3-1/2" wide and 6" tall, running longitudinally across the ceiling of the interior (roof) that are not encased in concrete except at their ends which are (were) engaged with the wall and somewhat embedded in the concrete. There is concrete at the back and front of the monument in the interior that looks like original fill between the walls and the roof perhaps to fill in the irregularities there. Those fills encapsulate the ends of the I-beams which are otherwise free of any cement or concrete. One I-beam has detached from the back wall and the void remaining suggests that perhaps the I-beams were placed after the completion of the walls.

[1] "Centennial Park's concrete landmarks have stories to tell", *Tennessean*, by George Zepp, March 17, 2004.
[2] Ibid.
[3] Centennial Park postcards on file at MHC.
[4] *Stamped Cards and Postcards*, United States Postal Service, September 2014.
[5] *Metro-Owned Artworks Conditions Assessment Report*, by Metro Arts, 2017.
[6] Image c. 1910 from Metro Archives.
[7] Stroll in Park Walk in Past, *Tennessean*, Hugh Walker, Dec. 28, 1980.

Figure 29: Gunboat Tennessee, undated but believed to be shortly after construction in 1910. Note flagpole with flag and light fixtures, canopy, and anchor chains coming from portholes that are all not extant today, and since at least 1980.

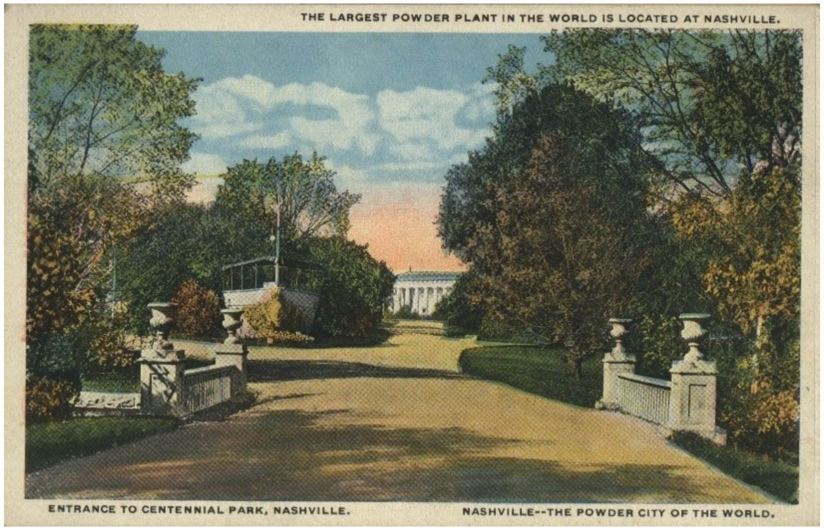


Figure 30: Historic postcard likely from 1915-1930 depicting the figurehead as gold/yellow.

Figure 31: Gunboat Tennessee in 1980.

The concrete is reinforced with 1" square ribbed steel bars. At the interior ceiling most of the bars are visible due to areas of loss of concrete at their underside and vary in their spacing from 13" to 24" on center.

The figurehead is bolted into the concrete with steel bolts that are sheared off at the bronze surface and backed by a steel nut and washer at the interior. Some of the bolt heads at the exterior face have cementitious material covering them, presumably to inhibit corrosion.

The exterior of the Gunboat consists of a parging on top of the concrete. Where parging is missing, the cold joints between pours of concrete can be observed. The roof has built-in down spouts for drainage off the back of the monument. A steel railing atop the parapet appears to be inserted into holes for the original canopy posts. A steel staircase is engaged with the monument at west edge of the roof.

Where it could be measured, the concrete is approximately 6" at its most narrow near the top of the parapet and 12" thick at one of the lower portholes. At the east (prow) of the monument's interior the concrete does not come to a point as the exterior might suggest, so there is a substantial amount of concrete at the prow to support the figurehead. Rough measurements of the interior length are about 16' and the overall length of the monument at the bottom exterior (its greatest length) is 22-1/2', suggesting the concrete at the prow is about 6' thick when accounting for the thickness of the west wall.

Figure 32: South elevation of Gunboat Tennessee.

Figure 33: North elevation.

Figure 34: East elevation which is predominantly the figurehead.

Figure 35: West elevation.

Figure 36: Interior of Gunboat.

Petrographic Analysis

A sample of the Gunboat was obtained from the interior of the monument. Due to the construction and condition of the concrete based on preliminary review, a core was not taken from the monument but a piece that had fallen from the interior ceiling was collected.

The sample from the Gunboat is a single large fragment from the interior of the structure at the underside of the deck. The originally exposed, finished surface of the sample is smooth with a surface zone approximately 1/8" thick containing no aggregate. The opposite, interior surface is rough. The sample is extremely friable, with pieces easily broken off from the edges and the interior surface. Individual aggregate grains are fairly easily removed from the interior surface. The smooth surface sounds hollow when tapped, and there is cracking sub-parallel to the finished face that goes around the aggregate. Small pieces that have broken off of the sample can be broken by hand with some difficulty, with the aggregate popping smoothly away from the matrix (paste).

The coarse aggregate in the sample provided included one large piece (1-1/2" maximum diameter), though the concrete contains more aggregate of this size and larger, but it is not well distributed. The next largest size aggregate in the sample is 5/8" on its longest dimension, with 3/8" being a median size. The coarse aggregate is crushed stone, and the angular, comparatively well-graded material has a slight orientation of the flat faces parallel to the finished surface.

The matrix is evenly distributed and of generally uniform color (Munsell 5Y 8.5/1) though there are areas on the interior face that are distinctly browner, possibly from dirt or rust staining. The matrix is rather chalky and granular in texture. Voids are typically unfilled, irregular in shape, and often the size of the larger fine aggregate. The voids are well distributed and seem to form less than 3% of the total volume.

At low magnification, two types of stone are distinguishable in the crushed stone aggregate: a rare, smooth, cryptocrystalline type and a more common microcrystalline type. Both are pale greenish gray in color, and limestone based on reaction to acid. The aggregate is evenly distributed. Large residual cement grains are readily visible throughout the matrix. In addition to the larger voids, there are also smaller, more spherical voids but the total volume does not exceed 3% of the whole. The voids have no lining or filling.

The finished surface is revealed to be irregular and map-cracked at low magnification. In cross-section the surface material is thicker than normal surface laitance typical of formed and poured concrete, but it may be that because this was the bottom of a poured section, there was simply a heavier accumulation of paste.

Viewed in cross section, the matrix at the inner and outer margins of the sample is degraded and there are fractures that go around the aggregate that are sub-parallel to those surfaces. Some of the dense aggregates are internally fractured, but this internal fracture does not extend into the matrix. Testing the pH with phenolphthalein reveals that the sample is fully carbonated, which may partly explain the degradation of the sample. A deeper core into the concrete where visibly sound may prove the material is not fully carbonated. A small diameter core is recommended to be extracted in a next phase for a phenolphthalein test and drill powders extracted for chloride content. The fine aggregate includes both crushed stone of a similar type to the large aggregate and some mono-mineralic sand-sized grains.

Observed in thin-section, the majority of the crushed stone aggregate is identified as a dolomitic limestone. The stone is a matrix of anhedral microcrystalline carbonate containing fossil fragments and larger, rhombic crystals of dolomite (biomicrite) grading through biomicrosparite (more coarsely crystalline matrix with fossils and dolomite rhombs) to biosparite (coarsely crystalline matrix with fossils and dolomite rhombs). The coarse aggregate that appeared cryptocrystalline and fractured at low magnification appears to be chert which seems to have been a component of the limestone based on aggregate grains that contain both materials. However, there is no evidence of alkali-aggregate reaction. The sparse fossil fragments (allochems) are recrystallized, and include mollusks, echinoderm plates, and bryozoans, but the extent of recrystallization and the fragmentary nature of the fossils makes positive identification difficult. The fine aggregate consists of fragments of each of these grades of stone, along with individual grains of calcite and dolomite, and single allochems.

The matrix consists of cryptocrystalline calcium carbonate with abundant, large fully hydrated residual cement grains. The complete carbonation of the cement paste suggests prolonged exposure to moisture containing carbon dioxide; microporosity of the biomicrite aggregate may have played a role in the carbonation process. The matrix is extensively fractured both parallel and perpendicular to the original orientation of the concrete. The ratio of matrix to aggregate is estimated visually at 1:2.5.

Figure 37: Location of Gunboat sample (interior) prior to falling off ceiling.

Figure 38: Exposed surface (the visible ceiling) of the sample for petrography.

Figure 39: Unevenly distributed large aggregate in wall.

Figure 40: Map cracking of surface with mm scale.

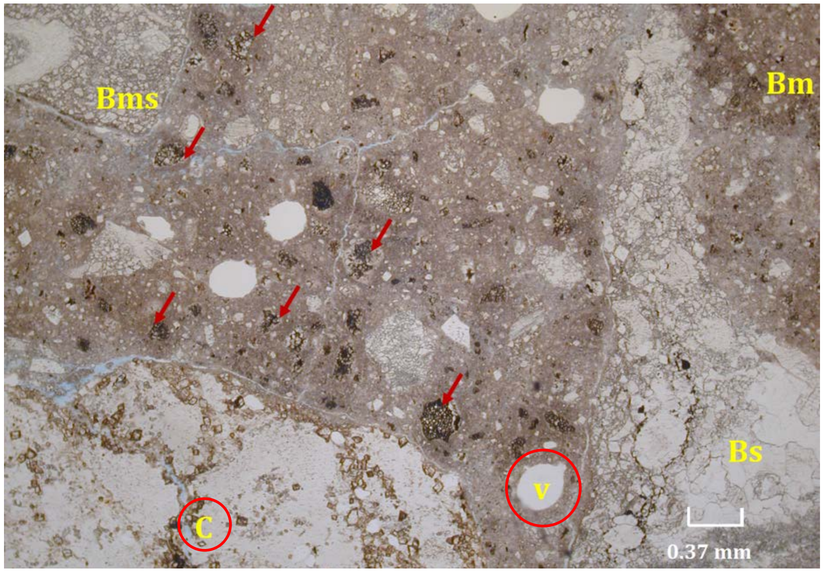


Figure 41: View of thin section from Gunboat, 40x magnification in plan polarized light. C is chert; the other coarse aggregate grains show the gradation of texture of the limestone from biomicrite (Bm) through biomicrosparite (Bms) to biosparite (Bs). The fine aggregate consists of fragments of each of these stone textures and individual rhombs of dolomite and fragments of calcite. The matrix (tan) is fully carbonated, and contains abundant, large residual cement grains consisting of alite, belite, and dark greenish brown ferrite (red arrows). Voids and cracks are filled with blue epoxy, or white where the resin did not penetrate (v).

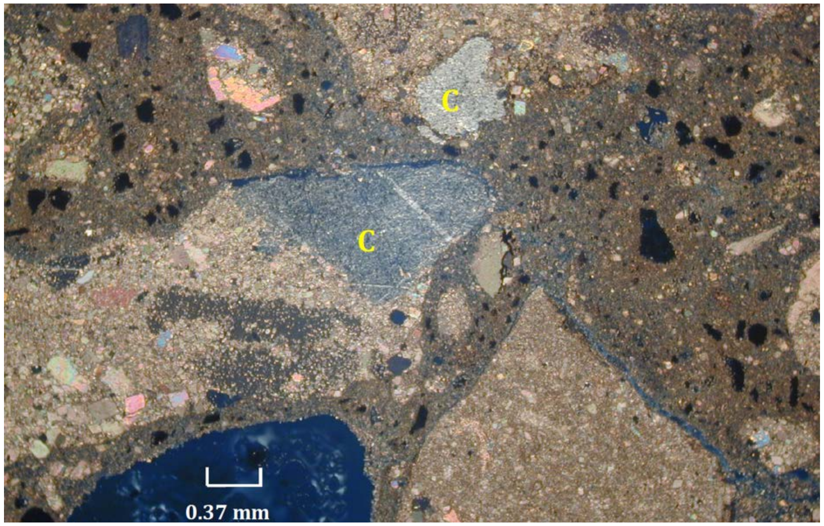


Figure 42: Thin section in cross polarized light. The upper and left aggregate grains contain chert (C).

Conditions Assessment & Repair Recommendations

The Gunboat is a concrete structure over 100 years old that has been exposed to the elements on a site that allows runoff to flow over and around it unprotected and whose base is in direct contact with the ground leading to rising damp. For a structure of that size and materiality, it has fared well over its lifetime. However, it is in an advanced state of deterioration, so repair is necessary. There is substantial structure remaining so typical restoration techniques for historic concrete structures can be implemented.

To assess and repair the full extent of the historic concrete, the figurehead must be removed and stored in a safe location until such a time that it can be reinstalled; it should be cleaned and restored off-site prior to its reinstallation. The exterior parging over the structure, which has been delaminating and falling off for some time, must be removed; if it is found that it is still well adhered to areas of the concrete walls such that removing it would potentially harm the concrete structure, then those areas shall remain. The parapet though seemingly intact exhibits network cracking and salts and is believed to be a later parging; it is likely incompatible with the historic concrete so it should also be removed unless very well adhered.

It is recommended that the roof slab be investigated more to understand the thickness and reinforcing (rebar is 13" to 24" apart laterally across the ceiling as viewed due to concrete loss), which will help determine its inherent capacity and whether the steel beams found within the space were installed as a temporary (i.e., shoring/formwork support) or permanent support for the roof slab. If it is determined that the steel beams are needed for support of the roof slab, the roof should be immediately shored until the deteriorated steel can be removed and replaced with new steel. New steel beams should be installed tight to the underside of the roof slab. Additional cores should be taken to investigate carbonation and salts in the concrete to determine its ability to protect the steel reinforcement. If it no longer provides the proper environment, cathodic protection is a possibility, or the interior can be considered for additional support such as a steel structure of welded cross beams and posts (like an exoskeleton, but in the interior space).

Once the decorative exterior parging is removed and the structure shored (if necessary), the entire concrete structure (walls and roof) can be sounded from the interior and exterior. During this process, all loose material less than1-1/2" thick should be removed down to sound concrete. Loose material more than 1-1/2" thick should be injection grouted with a conservation grout to reconsolidate. Rebar that is currently exposed or becomes exposed during the removal process should be prepared for treatment; this involves removing concrete all around the reinforcement and cleaning the rebar such that it is free of all rust and deleterious material. A corrosion inhibitor such as Rust Reformer should be applied to the rebar. Concrete cracks must be grout-injected and areas of concrete loss should be patched.

It is unclear whether the Gunboat originally was parged. The interior surface has a smooth finish of 1/8" thick but that could have been from troweling after the formwork was removed or gravity drawing more cement paste to the bottom of the formwork. Further investigation of the current parging and surfaces is required to determine original construction. The parging on the roof and parapet is not original, but below that layer there are other campaigns one of which may be original. Nonetheless, the exterior surface was not as aggregated originally as it is currently, so a surface treatment, such as (re-)parging, is necessary to re-establish that aesthetic and more critically provide protection to the structural concrete. The petrographic analysis identified the aggregate as limestone so both the cementitious binder and the aggregate of the concrete are acid soluble. This means there is little resistance to acid rain exposure and a parging that matches the original, if extant, is recommended. The parging binder however should not be composed solely of portland cement since current cements are too impermeable and brittle compared to historic concrete. A mixture of portland cement with lime would be recommended.

Lastly, the bronze figurehead – once cleaned and restored – can be reinstalled via new anchors with plate washers anchoring the pieces to the inside face of the concrete walls.

Preservation projects are often aided by determining a period of significance for the structure. In the case of Gunboat this would mostly apply to the decorative elements depicted in the 1912 photograph: the canopy, flagpole, and chains. This report assumes there is not the intention of reintroducing those elements; however, a consideration might be to reintroduce the canopy as it would provide some protection to the concrete below it. The concrete at the underside of the steel reinforcement under the roof slab was fully carbonated so no longer provides protection of the steel at the underside. If the canopy is not reintroduced, a roofing membrane could be considered depending on whether the staircase remains. Lastly an option would be the application of water repellents applied to the concrete to afford some protection; these would need to be re-applied every 5 years.

If the intent is to retain the extant metal railing along the parapet, it should be primed and recoated, including the steel anchor points if significant dimension still exists. If not, the railing anchors would require new stainless steel posts be attached. Where the posts were anchored into the concrete the previous patches should be removed, any steel routed out, the railing reset, and the concrete re-patched with an appropriate mix. Another option is to remove the staircase at the west side of the folly to prevent public access to the roof in the future. However, that would alter the original intent of engagement with the structure. There are no known images of the original staircase if a more historically accurate design was to be reconstructed. Additionally, the screens over the lower portholes should be removed, cleaned, painted with an epoxy-based coating as corrosion inhibitor, and reinstalled with stainless steel anchors if there is no intention to reintroduce the chains observed in the historic photographs.

To encourage the long-term preservation of the Gunboat *Tennessee* some intervention with the surrounding site is recommended. One suggestion is to install drainage around the base of the structure. Moisture meter readings were taken at select locations and were all approximately 25% wet.

Regular monitoring and maintenance of the concrete as it continues to be exposed to the elements is necessary to maintain the integrity and aesthetics of the structure.

Figure 43: South side depicting loss of the majority of the parging; large cracks, the horizontal one is a cold joint between concrete pours during construction but there is debris and concrete fragments within it, network cracking is apparent on the parapet, and there is loss of concrete on the bullnose detail.

Figure 44: Detail of parge loss, disaggregated concrete, missing concrete, and cracks.

Figure 45: Roof of Gunboat. Note horizontal cracking indicated by red arrows which is likely lined up with and due to corroded rebar within the roof slab (see image below). Due to the potential structural instability of the roof slab the Gunboat should not be accessible to the public.

Figure 46: Exposed rebar at the underside of the roof slab. Note deteriorated concrete above it.

Figure 47: Inside Gunboat looking out. Note the right steel beam has corroded so extensively it has fractured and spalled the concrete around it (red circle). At the left side the beam has fallen from its concrete pocket (yellow arrow). It is not known whether the beams were to support the formwork for construction or serve as structural support to the roof slab which is why the monument should be fenced off.

Figure 48: Similar condition of handrail posts to stair rail connection: corrosion is causing cracking and loss. Handrail must be removed, concrete repaired, rail restored and reinserted if it will be reused.

Figure 49: Steel bolts viewed from the interior that support the figurehead are corroding and should be replaced with stainless steel when the figurehead is reinstalled.

Figure 50: Exterior view looking north from the southwest corner showing the crack in the structural concrete that wraps around to the west in the parging – it is likely a cold joint.

Figure 51: North elevation detail; similar to the preceding image, the crack is likely a cold joint that should receive grout; the red outline (detail below) indicates a surface possibly indicating the original appearance of the concrete or the surface of the concrete prior to an original parge that is not known if it is extant anywhere on the folly. The left yellow arrow shows a rusted steel anchor head in the bronze and the right yellow arrow shows one that has been covered by cementitious material.

Figure 52: Possible original finish of Gunboat.

Figure 53: Top of stairs are anchored into the roof slab possibly corroding and causing cracking and spalls. The top layer of concrete is a newer parge but the layer below it may be original suggested by aggregate appearance. Stairs must be removed and concrete repaired and stairs either eliminated or cleaned, restored and reinstalled.

Figure 54: Detail of delamination parging – debris gets in the cracks and separations and pushes the parge coat out of plane making preservation of parging difficult.

GUNBOAT *TENNESSEE*					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Fencing	Immediate action: Fencing of the structure to prohibit public access is recommended due to unknown condition of the roof slab and interior beams and embedded steel reinforcement.		1 unit	1	n/a
Temporary shoring of interior	Temporary shoring is needed to support the top of the structure while steel is being removed and work is being done. One steel beam has fallen at the interior south of the monument and the north beam is heavily corroded. It is unknown if the beams were for the formwork during construction or if they were intended to support the roof; if the latter, they are no longer structurally contributing.		1 unit	1	$3,200
Figurehead	Removal of the figurehead so concrete work can be executed. The figurehead should be protected, cleaned, and restored. The current pins are corroding steel which so removal must be done carefully; some anchor heads have been covered with patch mixes which also need to be removed. At the completion of the concrete work the figurehead should be reinstalled using newly fabricated stainless steel pins.		1 unit	1	n/a
Parge Removal	The failing exterior parge needs to be removed so the structural concrete can be assessed and repaired. At the parapet the parging is better adhered and may be a different parge campaign but areas of it exhibit map cracking and salts so removal should be investigated to determine if too much historic concrete is removed in the process.		750 SF	1	$6,000

GUNBOAT *TENNESSEE*					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Handrail removal	The extant handrail should be removed, it can either be primed and painted for reuse with new stainless steel anchors and the insertion points in the concrete prepped for reinstallation. This scope could instead include reintroduction of the historic posts and canopy, or no installation of steel if the staircase is removed.		1 unit	1	n/a
Probes & cores	One probe should be cut to determine rebar size and spacing, depth of carbonation and a core 4" in diameter should be extracted during that time for service life investigation; cost should include patching probe and core areas.		1 unit	1	$9,000
Removal & replacement of deteriorated steel beams	Remove two steel beams at the ceiling and replace with a structural support assuming galvanized steel that will be post-installed and supported on two posts with footings in the ground below the frost line. Include two cross beams – one near the door and one toward the front.		6 units	1	n/a
Concrete sounding	Sounding of interior and exterior concrete to determine condition once parge is removed. This work to be executed by Design Team – should be done in conjunction with roof probe and wall core.	-	1650 SF	1	$6,000
Concrete removal	Remove loose concrete as determined by sounding and remove concrete around corroded steel. Assume 30% of total square footage; cost to include cleaning concrete so that its surface is prepped for a patch. Assume 3" depth around rebar.		500 SF 30 CF	1	$12,000

GUNBOAT *TENNESSEE*					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Steel prep	Clean steel so that thick scaling corrosion is removed; apply corrosion inhibitor to all cleaned exposed areas.		150 LF	1	$5,000
Steel Protection	If concrete is totally carbonated cathodic protection or another system may be necessary.	-	1 unit	2	n/a
Crack injection	Grout injection of wall cracks on interior & exterior and roof slab cracking from above and below.		200 LF	1	$8,000
Concrete patching	Patch concrete that has been removed and requires building up prior to parging. A compatible patch mix is imperative. Cost should include development of mix.		500 SF	2	$15,000
Interior parge	Apply a mesh reinforced cementitious coating on the interior surfaces of the Gunboat.	-	750 SF	2	$10,000
Exterior parge	Apply new compatible parge on entire exterior surface where former parging was removed. A parge coat will provide some protection to the historic concrete. The mix should consist of a blend of portland cement and hydrated lime to ensure a softer more breathable coating system is applied to the historic concrete.	-	750 SF	2	$20,000

GUNBOAT *TENNESSEE*					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Door	A new door and door frame should be installed that is visually coherent with the exterior of the Gunboat and one that prevents public access. The current assembly should be removed. There are no archival images of the original door's appearance.		1 unit	3	n/a
Stairs	Remove and repair (clean, coat, re-anchor) stairs. Alternate: replace with new stair on new concrete pier footings at base. There are no images of the historic stair but if found a replica could be fabricated.		1 unit	3	n/a
Porthole screens	The screens covering the lower portholes should be removed, cleaned, primed, painted and reinstalled with new stainless steel anchors.		1 unit	3	n/a
Site Considerations	Introduce landscaping measures that draw water away from the base of the concrete structure. A French drain should be considered to redirect water runoff away from the monument. The area at the base of the Gunboat could be gravel for drainage and allow for mowing without damage to the concrete.	-	n/a	1	n/a

THE SHELL SPRING

GENERAL DESCRIPTION

The Shell Spring is a concrete folly that was built over a spring in1906. It is in Centennial Park also near 25th Avenue North near West End Avenue but nestled in trees and set back from the path that used to be the main entrance from Elliston Place. The folly is designed to look like a partially opened scalloped clamshell at the base of which is a spring. The base of the spring sits on tiered limestone and adjacent to that are benches, both for visitors to sit alongside the spring water. The interior area of the shell is sunken which creates a grotto-like construction. It is currently fenced off due to public safety hazards.

Figure 55: Partial view of Shell Spring.

ARCHIVAL INFORMATION

The Shell Spring, also commissioned by Major E. C. Lewis, is reportedly based on a shell he found on a beach in Florida.[8] An archival photograph from the Board of Park Commissioners Twelfth Annual Report of 1912 depicts the folly as it was shortly after construction. The folly today is similar in its extant elements but there is significant loss of form and some features such as retaining wall capstones, planters, and minor decorative elements. The image suggests there was another structure, perhaps wood, to the west of the spring and possible additional seating in front at the south.

A condition survey was done of the folly in 1988, 2006 and 2007 by Shelley Reisman Paine Conservation. The report indicates major sections of delaminating concrete were removed at that time and the fencing was erected around then to prohibit public access due to its deteriorative state. In 1988 there was little loss on the top of the clamshell but the 2007 report depicts the significant lacunae seen today. In the same report much of the clamshell scalloped edge is intact though the area of exposed rebar extant today is already exposed in 2007. There is more definition in 2007 to all of the concrete corners and edges which today are highly eroded.

The report states the presence of a thin mortar surface on the underside of the clamshell that is delaminating. Today some of the underside coating appears elastomeric so it is unclear if more coatings were applied since 2007. The flanking retaining walls have a bluish gray elastomeric coating on them that is currently extensively failing but one image in the 2007 report depicts it present and largely intact (and graffitied), so it is believed to have been applied earlier than 2007. It is unknown if that coating is the same era as the one on the underside of the clamshell.

Figure 56: Shell Spring circa 1912.

[8] Metro-Owned Artworks Conditions Assessment Report, by Metro Arts, 2017.

Figure 57: Screen shot provided by MHC, date unknown; the clamshell is largely intact though exhibiting cracks and a cold joint distinguishing concrete pours, and overall significantly less erosion.

Figure 58: In this image the clamshell still retains much of its scalloped edge which is mostly gone today; date unknown.

Construction

The Shell Spring is reinforced concrete though the concrete observed mostly appears to be more similar to mortar due to the lack of large aggregate typical in concrete. There is some exposed steel reinforcement at the clamshell construction which revealed it to be 1" square bars running the length of the clamshell. A Zircon MT7 Metalliscanner was used on the underside of the clamshell where accessible which indicated steel reinforcement within each scallop of the clamshell (in addition to that already exposed). There is also an exposed 1-1/2" diameter circular rod running the width of the clamshell near the outermost edge. It does not appear to have any ridges in it which compromises adhesion of the concrete. This type of reinforcement was also observed in the front retaining wall, but it is unknown if this type of reinforcement is elsewhere in the construction.

The clamshell top terminates in the ground, so it is unknown what the construction is subgrade and how the shell is structurally supported. There are two posts on either side of the shell that are steel reinforced as determined by scanning, and they, in part, support the cantilever. The posts sit atop flanking retaining walls that have earth on one side and bench seating on the inboard side. The shell spans this construction which is approximately 20' across.

The clamshell appears in part to have been poured in two lifts. The front of the clamshell is 6" thick and appears to taper to 4" thick behind the posts but there is an apparent cold joint on top of the clamshell. However, where one lift ends and the other starts is indiscernible. The top front scalloping may be one lift. There is a partial lateral crack seen on the underside of the clamshell that may be a cold joint. This would suggest the front at the sides and top scalloping is one pour and the other pour may be the middle and underside. This is not known for certain. There are two pieces of concrete scalloping that are separated and displaced from the clamshell suggesting those were additional pours to complete the decorative back scalloping.

The interior base of the shell sits on a tiered limestone formation which in turn sits on a tiered rectilinear concrete floor. The top tier of the concrete floor is 108" from the limestone edge to the retaining wall. The spring appears to still run below the lowest concrete level.

The front of the folly has a low retaining wall approximately 28' across, 8" thick, and 47" high at the inboard side (18" at the outboard side) that creates a grotto-like alcove with stairs leading down into the grotto at both sides of the retaining wall. Exposed steel reinforcement revealed a circular rod running the length of the front retaining wall. The stairs leading to the interior of the folly are flanked by retaining walls. The stairs are 52" wide at the bottom and 56" wide at the top.

Front to back (south to north) the folly is approximately 18'. The shell has remnants of lighting fixtures that used to light the grotto.

Figure 59: View to north: The complete retaining walls and stairs are not in the photo. The clamshell cantilevers (supported with the two short posts on either side at red arrows) over the grotto-like space where the spring flowed at the base. The shell sits on a tiered bed of limestone (yellow arrow) and is scalloped. The shell has conduit in it for now defunct lighting.

Figure 61: View to south: The clamshell has a scalloped form like the underside, but portions of the scalloping are missing (red outline). The bottom third of the scalloping may have been two separate concrete pours as seen in historic photos depicting what is likely a cold joint. These panels are displaced and have lost fragments (red arrows).

Figure 60: This is a view of the interior space looking west. Stairs lead down to the spring and a bench was built into the side retaining wall. Several attempts at coating the concrete have been made but are incompatible to the historic substrate and are failing themselves.

Figure 62: This is a view of the interior space looking east. Stairs lead down to the spring and a bench was built into the side retaining wall. There is a lot of debris within the folly much of which is pieces of concrete fallen from the cantilevered shell.

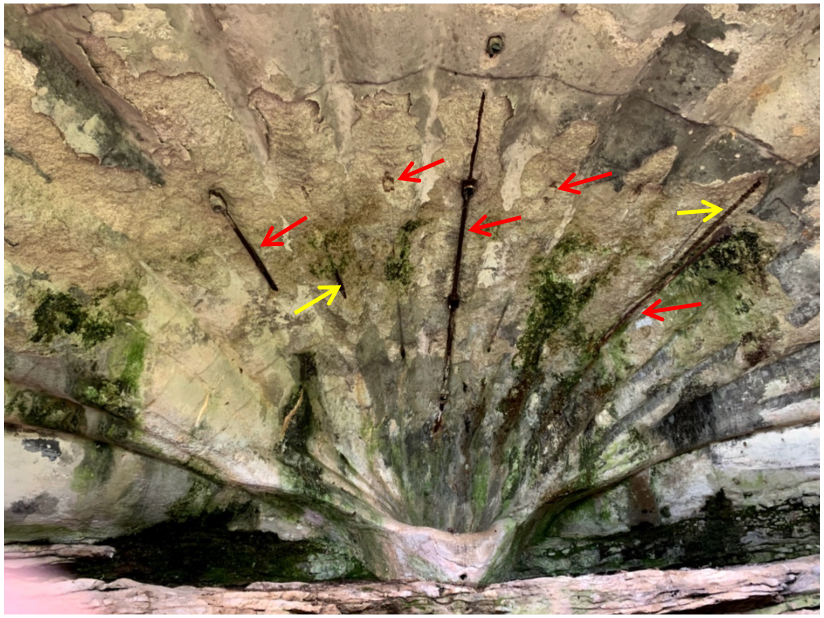


Figure 63: Interior lower portion of the shell. Red arrows indicate old conduit for lighting and yellow arrows indicate exposed steel reinforcement.

Figure 64: Base of Shell Spring. The spring flows under the grate and plywood box. Removal of debris around the entire slab is recommended for better assessment of the concrete.

Figure 65: End of 1" square steel reinforcement bar (rebar) in red circle. Historically rebar could be square, or round, though today round ridged bars are typical. The square bars appear to be ridged as viewed from exposed rebar at the underside of the shell, but the outer rim of the shell and front retaining wall have exposed smooth round steel bars.

Figure 66: Example of the smooth round steel reinforcement – exposed at the front retaining wall where a large piece of the top of the wall is missing.

Petrographic Analysis

A sample of the Shell Spring was collected from the edge of the scalloping at its western side. The sample from Shell Spring is a single, rather thick fragment which retains two original exposed surfaces: one the top or skyward facing surface, and one the face or lip of the shell. The other surfaces included a weathered downward-facing surface without the original finish (bottom), the broken faces at either end, and the interior surface, opposite the face. The sample was attached to the shell at sampling but there is a band of green biological growth on the bottom near the face indicating a fracture. The top and face of the sample were heavily covered with biological growth. All the surfaces are rough.

On the unwashed sample the character of the coarse aggregate is only visible on the bottom surface; it is crushed stone similar to that observed in the Gunboat sample, only not as large. The largest aggregate is 1/2" on its longest dimension; most are 1/4" on their longest dimension. Thin white films were noted on some of the aggregate and the ends and bottom that look like reprecipitated calcite from prolonged wetting and drying. The lack of such deposits on the original exposed surfaces suggests they may have developed due to water migration through cracks. The matrix is not clearly distinguishable. On the interior surface a series of voids was noted both subparallel and elongated parallel to the top surface. These are irregularly shaped, and typically 1/8" long. Similar voids were noted on the ends of the sample, and also the bottom surface. Void volume seems low in the unwashed sample.

After washing to remove dirt and biological growth, the top and face surfaces were found to be eroded with the matrix recessed between the aggregate. At these eroded surfaces, the large voids are accentuated. The larger voids are irregularly shaped, the smaller voids are more spherical. Examination of the cleaned interior face suggests that dirt was filling the voids and the volume is higher than initially perceived. The concrete has fine fractures on the bottom and inner faces that do not go through the aggregate. The color of the matrix is Munsell 10YR 8/1, a bit browner than that of the Gunboat, perhaps because of the exposure of the sample.

At low magnification on a cut face, the crushed stone aggregate appears as elongated, bladed shapes with the long, flatter faces roughly parallel to the finished face. The fine aggregate is crushed stone with some carbonate mineral grains; in addition, one large grain of pyrite and one large piece of slag were noted. The aggregate stone types are the same as the Gunboat concrete. The aggregate appears well graded and well distributed. The void volume is estimated at 10% as both large, irregularly shaped voids and smaller, more spherical voids that have no evidence of linings or fillings. The matrix is more sound and less granular than that of the Gunboat overall, and particularly near the broken and finished faces, though there is some erosion and granularity near the bottom face. The ratio of matrix to aggregate is estimated visually at 1:3.

Figure 67: Shell Spring sample near location at top of the clamshell.

Figure 68: Exterior surface of scalloped edge.

Figure 69: Skyward facing surface.

Figure 70: Cross-section of the sample after cutting - still wet. Note the small size of the aggregate throughout the sample. This was observed to be typical for the historic concrete at the Shell Spring. This would be deemed more similar to mortar than concrete.

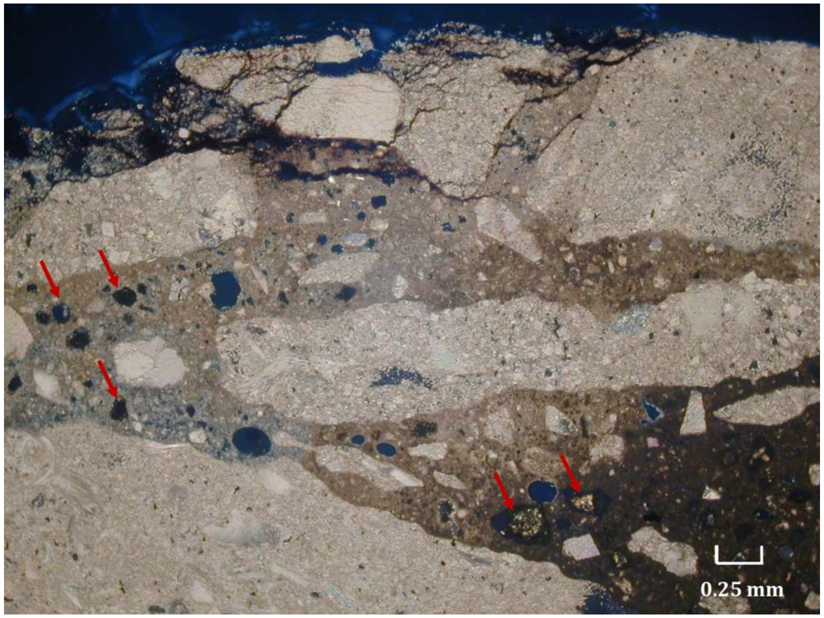


Figure 71: Shell Spring sample in thin section, 40x, xpl. The top face of the sample is at the top of the image. The matrix in this part of the sample shows partial carbonation; the carbonated paste is tan to light brown, and the uncarbonated paste is black. Voids are rounded to irregular and appear dark blue; some have linings of microcrystalline calcite or (more rarely) ettringite. The paste also contains partially- to fully hydrated cement grains (red arrows), some of which are very large. The aggregate is limestone, typically biosparite but also biomicrosparite to biomicrite. Note the fractures in the outermost aggregate and the paste, parallel to the surface; there are also small fractures in the aggregate deeper in and also in the paste parallel to the surface.

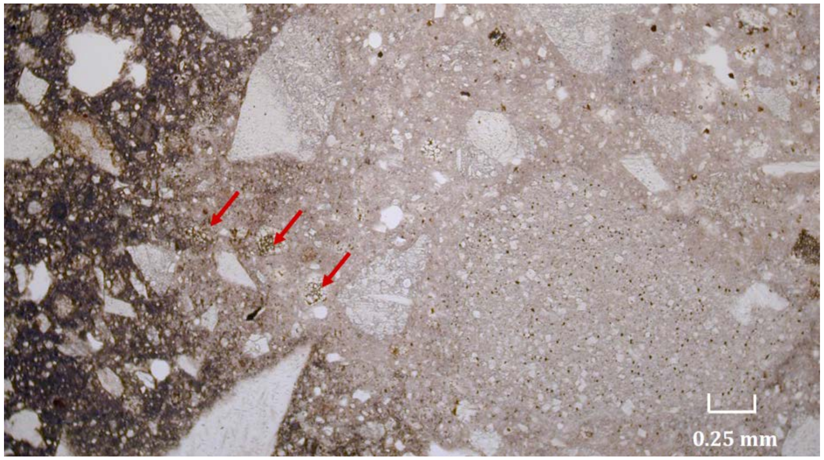


Figure 72: View of the Shell Spring sample near the interior face showing the extent of carbonation. 40x, ppl. Note the distinctive residual cement grains in the carbonated paste near the boundary between the carbonated and uncarbonated paste (red arrows).

CONDITIONS ASSESSMENT & REPAIR RECOMMENDATIONS

Like the Gunboat, the Shell Spring is a concrete structure over 100 years old that has been left exposed to the elements on a site that allows runoff to flow over and around it unprotected. Due to the Shell Spring's geometry and materiality, it has not fared well over its lifetime. However, there is still a considerable amount of historic concrete present that can be preserved and fortunately the clamshell is still extant. The level of erosion and loss noted at this time has left the structure in an advanced state of deterioration such that repair is critical. There is substantial structure remaining such that repairs can implement typical restoration techniques for historic concrete structures. However, additional investigation is needed to determine how best to treat the structure and arrest its sources of deterioration.

Site observations and petrographic analysis determined the concrete does not contain large aggregate unless it is extant at the subgrade foundation. This may be due to the thinness of the construction and experimentation with the form. The larger typical aggregate would make a stiffer mix that would be more difficult to flow into the curves of the clamshell formwork. However, the mix did contain many voids suggesting a high water content to also aid flow. Concrete is more porous when it contains many voids allowing water to reach the steel reinforcement. Depending on the ratio of voids, the concrete could be highly susceptible to freeze/thaw damage. The concrete mix contains chert as a minor portion of its aggregate. Chert is known to cause alkali-silica reaction (ASR, or alkali-aggregate reaction) which occurs from a silica gel that forms in reaction to the alkaline cement, swells and creates an expansive pressure within the concrete causes cracking and loss. It is recommended that an additional sample be extracted and tested for ASR and salt content.

The subgrade construction of the Shell Spring is currently unknown. All previous assessments, including this current one, have been of visible portions of the structure above grade. However, it is necessary to understand the foundation base of the shell structure to understand how the cantilevered shell construction is anchored. The Design Team recommends test pits at the back of the structure, and along the adjoining retaining walls, to determine concrete base configuration and condition. Most likely, the retaining walls, which have noted areas of moisture damage and movement, are not waterproofed against their retention side, allowing groundwater to attack the concrete.

Any foundation damage found during the test pits should be addressed with typical repair techniques: crack injection, concrete patching, etc. However, if more significant deterioration is found during the exploratory work, the installation of new reinforced concrete supports may be necessary.

Similarly, if the test pits around the retaining walls find that foundation support needs to be re-established, then new reinforced concrete foundations should be installed. This could entail subgrade buttresses to the outboard sides of the retaining walls so they do not visually alter the appearance of the folly but may also require demolishing and rebuilding all or select walls if they are not salvageable. Waterproofing should be applied, drainage installed, and fill/landscaping placed back over and around it.

The base slab is in relatively good condition, but settlement issues may be ongoing and the surface was largely covered by debris and fallen concrete. One option is to retain the slab and execute repairs to it such as crack filling. These may be short-term repairs depending on subsurface soil movement. A long-term repair would be replacement of the slab. The slab is, arguably, of less historic significance than the remainder of the structure so has less impact on the preservation of the whole, if replacement is pursued. However, its removal affects adjacent historic concrete. The center of the slab where the spring is believed to flow should have the garbage removed.

Similarly, the stairs which are more deteriorated than the slab can be either repaired or replaced. Again, the success of the repairs would be determined by an understanding of the soil and settling.

The limestone was difficult to assess due to the amount of soiling on it. An assumption can be made as a placeholder for repairs to injection grout interior voids to ensure it is solid. This would allow for continuous bearing support by the limestone's stacked configuration.

The shell overhang itself appears to be in varying states of deterioration so non-destructive testing, such as linear polarization resistance (LPR), half-cell potential, and core extraction for additional carbonation testing, shall be conducted to determine whether the sound concrete that is remaining is undamaged and determine the condition of the steel reinforcement. To execute this work the extant coatings need to be removed. The shell underside and interior side walls have been coated with impermeable elastomeric coatings that are peeling off the surface but also trapping moisture within the concrete. The removal of these coatings should be done with plastic and wood tools, such as scrapers, avoiding metal to prevent damage to the underlying concrete. Their removal will allow for the tests to be done and the concrete to be assessed and sounded. The sounding will reveal, if extant, shallow delaminations and voids within the historic concrete.

Once the foundational support, steel condition, and concrete condition beneath the coatings are determined, repairs can be developed and implemented. The repairs recommended are based on what was visible during the site visits so excludes material below coatings, below grade, under biogrowth, and within the concrete or based on assumptions. Hence, not all the repairs can be captured in this phase.

The work on the Shell Spring above grade can either entail a preservation approach which would stabilize it, sustaining its existing form, or a restoration approach which would repair existing concrete and rebuild and patch lost fragments to reflect its appearance at the time of construction, or other determined date. In some cases, the standard for reconstruction may apply, if for instance, for structural purposes and public engagement, the retaining walls need to be rebuilt. The preservation approach would maintain, in part, its appearance as a ruin and the restoration approach would reintroduce some of its form that has since eroded or fallen/been removed. There is a gradation between the two in what elements to restore or stabilize. It is recommended by the Design Team to preserve as much historic fabric as possible, while recasting some pieces such as the clamshell's scalloped edge and top.

There are what appear to be two separate pieces of the clamshell back/top that might be displaced but that have lost their edges and other fragments. They are delineated by what is believed to be a cold joint but there is plant growth in that joint, so it is unknown how many fragments are missing and if the pieces have slid down the clamshell. If they are detached and moveable they should be carefully removed, cleaned, repaired, and protected. This would also allow for assessment of the base concrete. All remaining concrete should be cleaned of biological growth and other soiling. The thick growth can be gently scraped with wood shims and remaining biogrowth can be cleaned with D2 Biological Solution. It should be spray applied on a dry surface, allowed to dwell for 10 minutes, scrubbed with a natural bristle brush, and rinsed. Pressure washing should be less than 300 psi.

Site issues, such as improper/lack of drainage and the presence of sink holes/pits around the site, should be addressed. It appears the site is differentially settling in areas, causing shifts in the foundational support of the retaining walls, concrete base and stairs. The site should be reviewed to determine the best way to prevent the soils from shifting the retaining walls or stairs again.

Depending upon the findings of the invasive and non-invasive testing, the concrete shell repairs could be standard patching repairs or could involve the installation of a system that would continually protect the structure. For example, if carbonation tests show the concrete is no longer capable of protecting the reinforcement within the shell and/or half-cell potential and LPR tests determine a high rate of corrosion, then the use of a passive cathodic protection system may be a suitable means of ensuring the durability of the structure. With a cathodic protection system, the embedded steel would be protected from the elements so long as the system is functioning. Cathodic protection systems have service lives up to 50-70 years. Other options as discussed, such as partial reconstruction, could also be considered depending upon the severity of the findings.

In summary, the next immediate steps should include:

- Temporarily shore the clamshell since its structural support and the condition of the support is unknown.
- Cleaning the site of debris, garbage, dirt, and clean the concrete of biological growth for better assessment of the concrete.
- Removing coatings and parging to assess the above grade concrete.
- Executing test pits to determine structural condition.
- Extracting cores for testing to determine service life issues such as alkali-silica reaction, carbonation, chloride attack, and other deleterious effects.
- Conducting a steel and corrosion study employing surface-penetrating radar and linear polarization resistance and/or half-cell potential.

Once those initial tasks are completed, a far better understanding of the Shell Spring can be achieved and its necessary repairs recommended. The following repair table only provides a general idea of possible repairs – further investigation is necessary before any repair can be definitive or implemented.

Figure 73: Shell Spring east end; red is lacunae and yellow is cracking.

Figure 74: A fragment of concrete from the top of the shell near the front edge was removed and a crack observed under it; this crack may run most of the length of the front edge of the shell as it was also observed on the underside; significant loss is imminent and must be addressed immediately. The more original material extant at the time of intervention the more beneficial for its preservation and/or using it to recreate the front edge with a new casting to complete the form. This image also depicts the thick biogrowth that conceals the concrete from proper assessment.

Figure 75: Exposed steel reinforcement at front edge of clamshell.

Figure 76: Underside of clamshell at west end; the same steel reinforcement in the preceding image can be seen here at the yellow arrow; numerous cracks are extant throughout approximately the first 12" of the clamshell from the front edge; while there is far less biogrowth on the top surface of the clamshell there are thick, possibly elastomeric, coatings concealing a significant portion of the underside of the shell that need to be removed so the underlying concrete can be assessed and repairs determined in conjunction with additional testing recommended above.

Figure 77: Top west of clamshell – triangles indicate cracked fragments that may be loose and large enough to remove, clean, stabilize and reattach; additional testing may determine they should be recast to better preserve the whole.

Figure 78: Back bottom of clamshell depicting cracked fragments that may be too small or disaggregated to preserve or additional testing will determine it is more beneficial to fill with a new casting or patch. The leaves seen at the left are collected in the separation between what is believed to be a cold join between two different concrete lifts. That debris needs to be removed for better assessment of the substrate.

SHELL SPRING					
Scope	Notes		Quantity	Priority	Cost Estimate
Temporary shoring of shell	Temporary shoring is needed to support shell during repair and investigations. The shoring is necessary since the subsurface construction and condition is unknown. Repairs will also cause vibrations, and stress so shoring will provide stability during all work.		1 unit	1	$4,000
Test Pits	Test pits should be dug to uncover the subsurface base of the shell; assume (4) 4'x4' openings at locations designated by the engineer; assume shoring boxes at back of shell are needed as base may exceed 6' OSHA safety depth.		4 units	1	$6,000
Parge/Coating Removal	In order for much of the work outlined below to be executed the incompatible coatings on the retaining walls and shell need to be removed. Much of it appears to be failing so simple mechanical means are assumed for this task. The coatings conceal the concrete from assessment and are disruptive to sounding techniques and other non-destructive evaluation methods, so it is one of the first tasks to be completed.		500 SF	1	$6,000
Cleaning	The biological growth needs to be removed from the concrete to allow for assessment and treatment; the growth also holds moisture to the concrete surface accelerating decay; it is particularly heavy on the top but is also extant beneath failing coatings, on the walls, the limestone and underside of the shell.		1805 SF	1	$10,000

SHELL SPRING					
Scope	Notes		Quantity	Priority	Cost Estimate
Debris Removal	There is excessive debris on the slab, limestone, benches, and stairs. The fallen concrete pieces should be collected but the rest of the debris can be disposed. This can be done by Parks staff; specialists are not required, but metal such as shovels should be limited in use to not scrape or damage concrete. The debris concealed many surfaces so once removed, the structure can be better assessed.		600 SF	I	n/a
Non-Destructive Evaluation	Surface penetrating radar, linear polarization resistance, and half-cell potential testing should be done for the clamshell to determine rebar location and depth, concrete cover, and corrosion rate; quantity includes entire shell and assumed amount for back span. The Design Team can recommend specialists.		500 SF	I	n/a
Testing	Small cores should be extracted for testing carbonation under the direction of the conservator who will test on site with phenolphthalein to determine pH. An additional 4" diameter core should be extracted to test for service life question such as alkali-silica reaction, salts, and void analysis. Cost includes testing.		4 units	I	$9,800
Steel Protection	If concrete is totally carbonated as determined by the testing described above rebar protection will need to be designed. One system that would be considered is cathodic protection.	-	1 unit	I	n/a

SHELL SPRING

Scope	Notes	Image	Quantity	Priority	Cost Estimate
WALLS					
Option 1: Preserve	To preserve the extant historic concrete at the retaining walls, excavate the backsides, waterproof, and pour subgrade buttresses – 390 CF At the visible historic surfaces: Patch concrete only at exposed rebar – 5 CF Inject cracks with conservation grout – 80 LF Parge coat visible areas with compatible mix – 400 SF		See notes	1	$60,000
Option 2: Restore	Cast new pieces for large lacuna including coping details – 250 CF Build up front wall to receive coping		See notes		$55,000
Option 3: Rebuild	Demolish and repour all retaining walls, waterproof backsides.		5 walls		$150,000
SHELL – assumes preservation of the shell					
Waterproofing Foundation	100% waterproof backside of shell foundation after excavation and repair.	-	90 SF	1	$4,000
Crack Injection at Foundation	Assumed at foundations of shell; this quantity cannot be known until excavation.	-	n/a	1	n/a
Patching Foundation	Assumes 30% of buried foundation of shell.	-	30 SF	1	$6,000
Concrete Sounding	100% concrete sounding on top and underside of shell to determine if voids are extant; requires access.	-	660 SF	1	$5,000
Concrete Removal	Remove loose concrete that is visible and those areas determined by sounding; in addition remove concrete around rebar that is deteriorated.		30 CF		$7,400

SHELL SPRING					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Steel prep	Where the steel is exposed after concrete removal it should be cleaned and a corrosion inhibitor should be applied. The biggest threat to concrete is corroded steel so where accessible it must be treated.		100 LF	1	$10,000
Remove exposed conduits	Cut back exposed conduits, do not replace, patch as needed. This assumes there will be no reintroduction of lighting employing the same conduit channels. However, lighting should be considered as a part of the restoration for public safety and to prevent vandalism. A lighting specialist should be retained.		5 units	1	n/a
Crack Injection	Inject cracks with conservation grout to stabilize.		40 LF	1	$6,000
Patching Shell	This work includes patching of the shell underside. Quantity is assumed since current coatings conceal condition.	-	40 SF	2	$8,000

SHELL SPRING					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Forming and pouring scalloped edge	The associated condition with this scope is lacunae at the scalloped edge of the clamshell. The extant concrete at this location is also in poor condition: it is fractured, not consolidated, has exposed steel reinforcement, and is heavily eroded. To attain the scalloped shape the loss compensation should be a recast piece which is anchored with steel dowels into sound concrete. The fractured concrete should be removed, the extant sound concrete chemically consolidated, the steel removed. Then the piece can be attached, and edges filled.		20 CF	1	$30,000
Reattach shell fragments	Large decorative fragments have displaced. To preserve the pieces, they should be carefully removed, access to all faces should be allowed for cleaning and chemical consolidation of fragments and shell structure, and the fragments should be blind pinned back in place. Loss compensation at edges and cold joints should be done.		45 SF	1	$15,000
Casting pieces to fill lacuna	This lacuna is located at the right backside of the shell. Some pieces may have fallen off and be buried adjacent to the shell so careful excavation should be done first. The pieces determined to be still missing will need to be re-cast – due to their decorative surface they cannot be hand patched. After cleaning the shell, the old and newly cast pieces should be attached with steel anchors blind pinned into the shell top for attachment. All edges should be filled with compatible mortar to reintegrate.		40 SF	3	$22,000
Parge	Parge underside of shell with a mechanically and aesthetically compatible mix to provide some protection to the historic concrete and homogeneity to the surface. The mix should consist of a blend of portland cement and hydrated lime to ensure a softer more breathable coating system is applied to the historic concrete.	-	300 SF	2	$12,000

SHELL SPRING					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
SLAB & STAIRS					
Option1	Slab remains, cleaned, cracks filled. Stairs remain, clean, grout voids adjacent to retaining walls, fill cracks, patch concrete, caulk joints. This may be a short-term repair if there is ongoing settlement.		400 SF	1	$9,000
Option 2	Demolish and repour reinforced slab and stairs at east and west ends of folly. May require temporary support of surrounding retaining walls.		400 SF		$45,000
Removal of stair at east	The stairs at the east though historic do not significantly contribute to the site. One option, assumed here for cost, is to remove them and only replace with earthen fill. Another option is to stabilize them – there are large voids beneath them and no foundation so excavation is required, and footings would need to be poured.		1 unit	2	$8,000
Removal of sidewalk	The sidewalk leading to the stairs is broken into several fragments. This assumes it is saw cut near the top tread, demolished since it does not contribute to the site's significance and is re-poured. It is a high priority due to tripping hazards so needs to be addressed.		36 SF	1	$10,000
Water repellent	Chemical treatment to provide water repellency on all historic concrete such as SL40<600 by Prosoco. These treatments protect the concrete by inhibiting water absorption at the surface. They are clear and penetrating but should be tested to determine that they do not alter the appearance of the concrete. They need to be reapplied approximately every 5 years.	-	1505 SF	1	$15,000

SHELL SPRING					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Limestone	Potentially injection grout to create a solid mass to support public usage and bearing support.		60 SF	3	$12,000
Site Considerations	Introduce landscaping measures that draw water away from the base of the concrete structure; this may include re-grading or French drains; appropriate consultants should be retained to conduct a study.	-	n/a	2	n/a

1910 CONCRETE BRIDGE

General Description

The 1910 Concrete Bridge, designed by Wilbur Creighton, Sr. of Foster and Creighton Company, is in the north section of Centennial Park, along the west end of Lake Watauga and is believed to be one of the company's first reinforced concrete bridges in the state of Tennessee. Predominantly used by pedestrians as part of the northeast loop of Centennial Park Walking Trail, the bridge is wide enough for vehicular traffic, though it should be confirmed with the Parks what level of vehicles, if any, are allowed access to this pathway, especially since 27th Avenue North is immediately to the west of this trail and follows the same general path in this area of the park.

Approximately 40' long and 25' wide between concrete piers supporting concrete planters, the bridge is a reinforced concrete arch structure topped with asphalt pavement. The arch is a "filled spandrel arch" bridge, which means the area between the curving arch and the flat deck is solid. The edges of the bridge are sided with solid concrete walls/rails running the length of the bridge; each wall terminates at a large concrete end post at each end. The outboard side walls and end posts are incised with a repetitive rectangular pattern and parged with a thin cementitious coating. The walls are inset from the arch edges approximately 10-1/2", creating a horizontal ledge at the top of the deck at both exterior faces of the bridge.

The bridge currently spans over a landing that begins at the western edge of the bridge and extends approximately 10' beyond the eastern edge; the landing is a few feet above Lake Watauga's water level and several feet below the bridge deck/Centennial Park walking level. The landing extends the full length of the bridge and is currently covered with soil and plantings. A stone wall is built along the western edge of the lake and supports the eastern edge of this landing; it appears the western edge of this landing is built against a short retaining wall that forms the edge of the Sunken Garden, whose grade is higher than the landing's.

Archival Information

The bridge was originally constructed for the Centennial Exposition in 1897, was composed of wood, and spanned over a riverway that linked Lake Watauga on the east and Lily Lake on the west. The bridge was rebuilt out of concrete in 1906; however, archival information indicates that Lily Lake was first converted into the Japanese Water Garden in 1922 and then into today's Sunken Garden around 1950. Therefore, it appears that this concrete bridge was originally designed to span over waterway that no longer exists. It is unknown when the landing under and towards the east of the bridge was installed, but this landing obstructs full review of the foundational base of the bridge.

There is little other archival information on the 1910 Concrete Bridge with the exception of four archival photographs provided by MHC. One image is from shortly after construction and was included in the Board of Park Commissioners Twelfth Annual Report of 1912. It is mostly informative about the landscape than the bridge itself. The second image states on the backside it is of William Foster Creighton Jr. standing in front of the bridge that his father designed in 1906 and claims it is the first reinforced concrete bridge in Tennessee. The image is dated July 26,1974. It depicts the bridge much as it is today but in far less disrepair, and a very different landscape around it. The view of the bridge is of the east side. Lastly, there are two color photos, undated, but are likely after 1974 as the east side of the bridge appears to be in slightly worse condition, though quite good condition than it is presently.

Though narratives of the bridge have been completed for its inclusion in the 2008 National Register nomination and for periodic reviews, no extensive work on the bridge has been documented since its original construction in 1906. Images were taken in January 2020 for this project's RFP, but without descriptions or recommendations on repair. Discussed in more detail in the following section, it appears a brownish patch has been applied at the top of the east railing, but it is not known when these repairs were applied nor is it known if other repair work was completed over the lifetime of the bridge.

Figure 79: Concrete Bridge in 1912.


Figure 80: Handwritten on the backside of the image: "Wilbur Foster Creighton, Jr. stands beside bridge that his father designed in 1906. First reinforced concrete bridge in TN." Dated 7/26/74.


Figure 81: East elevation, undated.

Construction

The bridge extends 39'-6" longitudinally (north-south) from outer edges of the railing end posts and 25'-0" across (east-west). The arch peaks approximately 2'-10" above the grade on the landing underneath the bridge and the deck, including asphalt pavement, is approximately 1'-3" thick. The underside of the bridge shows reinforcement, approximately ½" ridged square bars spaced 6" on center, running along the arch span.

The side walls appear to be monolithically cast with no signs of construction joints along their lengths; the walls are 2'-10" high and 8" thick with a 13" wide x 3-1/4" thick, continuous arched top rail. The end posts are 2'-0" x 2'-0" sections that are 4'-5" above the bridge pavement. The four end posts appear to sit over the top ledge of east-west running stone site walls that were most likely the original northernmost and southernmost edges of the lake prior to the area under the bridge being infilled.

The west end of the bridge abuts grade that is elevated 2'-10" above the landing beneath the bridge; a small site wall retains the high grade. This site wall does not extend up the full height of the arch and daylight can be seen through the west end at the top of the arch. The grade is covered with large rocks that transition to plantings the farther west you move away from the bridge.

The bridge and underside of the arch is parged.


Figure 82: 1910 Concrete Bridge looking north.

Figure 83: West side of west railing depicting the mostly covered arch.

Figure 85: East side of east railing.

Figure 84: West side of east railing at the south end.

Figure 86: The northeast post, west face; note loss, cracking and salts in the parging.

Petrographic Analysis

A sample from the 1910 Concrete Bridge is a single long piece with faces labeled bottom (the horizontal surface facing the ground) outer (the vertical face of the bridge) and inner (the fractured face where the sample was attached to the underlying concrete). The surface labeled as the bottom is partially covered with a thin (1/8"), dark gray parge; the outer surface is rough and eroded and does not have any remnant of the original finished surface.

The coarse and fine aggregate is crushed stone similar in character to that in the Gunboat. The largest coarse grain in the sample is 1" on its longest dimension; 3/8" to 5/8" coarse aggregate is common in the sample provided. Larger coarse aggregate is clearly visible in the site images. The coarse aggregate appears fairly well distributed, with a slight orientation of the long faces to the outer surface. However, at the top of the inner surface there are large voids around the coarsest piece of aggregate in the sample, and honeycombing is clearly visible in the site image. When removed from the bridge, the sample fractured at the aggregate-matrix interface.

At low magnification the outer face appears to be covered with a thin layer of reprecipitated calcium carbonate, indicating water saturated with calcium is flowing over the surface. The bottom face has some of this material as well. The parging on the bottom surface looks like a cement-sand mixture with a topcoat of a white cement slurry. The fine aggregate appears well graded and well distributed. Void volume in the sample is greater than 3%; perhaps 10% or even 15% in the form of irregularly shaped entrapped air voids the size of the coarse aggregate and small, more spherical voids the size of the smaller aggregate. Aside from the large void at the top of the inner face which is filled with loose brown material that is likely dirt, the voids appear unfilled and unlined. In cross-section the matrix color appears uniform (Munsell 10YR 9/1), and the matrix is evenly distributed. Large residual portland cement grains are visible. The matrix appears to be only slightly carbonated at the bottom face.

The thin section from the concrete bridge sample was cut from a cross section through the piece and included all the faces and the parge on the bottom surface. The coarse and fine aggregate are the same as those observed in the Gunboat *Tennessee* sample; biomicrite and biomicrosparite predominate. The matrix is also similar, with large, hydrated residual cement grains. Void volume in the sample is estimated at 10%, primarily as spherical voids the size of the fine aggregate. The concrete is carbonated to a depth of approximately 1/4" from the bottom surface; the balance of the concrete is leached, with some carbonation. Cracking was noted in the concrete immediately adjacent to the parging and also adjacent to the inner face. The cracks extend through the aggregate. The cracks are believed to be partly from moisture-related deterioration and partly due to damage during sample preparation. The ratio of matrix to aggregate is estimated visually at 1:2.5 to 3.

There two layers of parging on the bottom that are distinctly different from the concrete and from each other. The parge in direct contact with the concrete is a gray portland cement-quartz sand mixture. The cement matrix consists of abundant residual cement grains that are only partly hydrated in a limited amount of fully hydrated cement. The character of the mix suggests it did not contain sufficient water, or there was water loss during the application preventing hydration. There sand is primarily angular quartz with some chert; proportions of the cement to sand are approximately 1:2. There are irregularly shaped voids in the parge that are elongated relative to the bottom surface of the concrete. These voids are lined with microcrystalline calcite, and there is slight carbonation of the parge around the voids. Void volume is low, less than 3%. The outer parge is also cement and sand with a similar aggregate but is completely carbonated. The extent of alteration is such that the original composition of the binder is difficult to determine; chemical analysis of the material would likely be needed for positive binder identification.

Figure 87: Sample just after removal at corner of bridge bottom at the west elevation.

Figure 88: Sample location before extraction.

Figure 89: Outer surfaces of the sample.

Figure 90: Interior surface of the sample.

Figure 91: View of a cross section through the parge on the bottom surface showing the two layers of cementitious coating material. 12x, reflected light. Also note the character of the fine aggregate and the small, spherical voids in the binder.

Figure 92: View of a fresh cross section of the 1910 Concrete Bridge sample, treated with phenolphthalein. The bottom of the sample is at the bottom of the image. The depth of carbonation from the bottom is approximately 1/8".

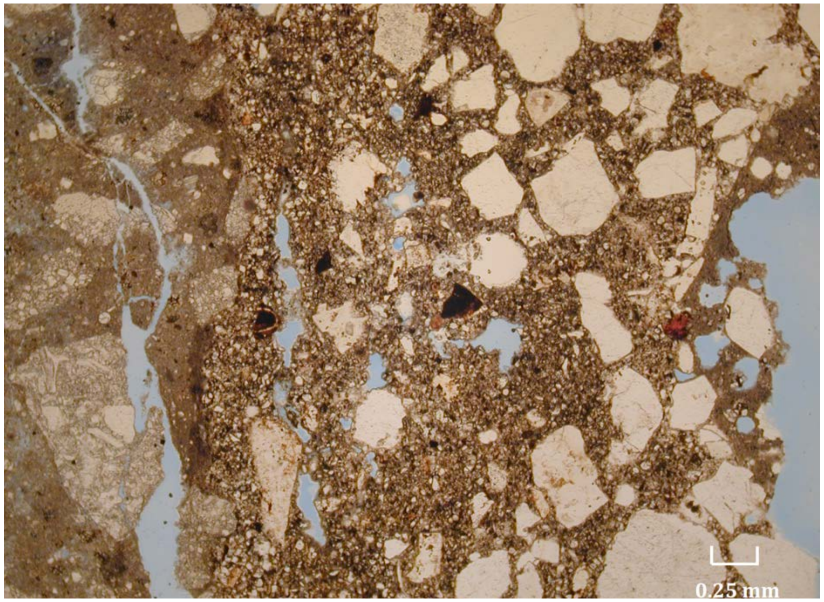


Figure 93: The texture of the parge is due to the abundance of unhydrated cement residuals, ppl.

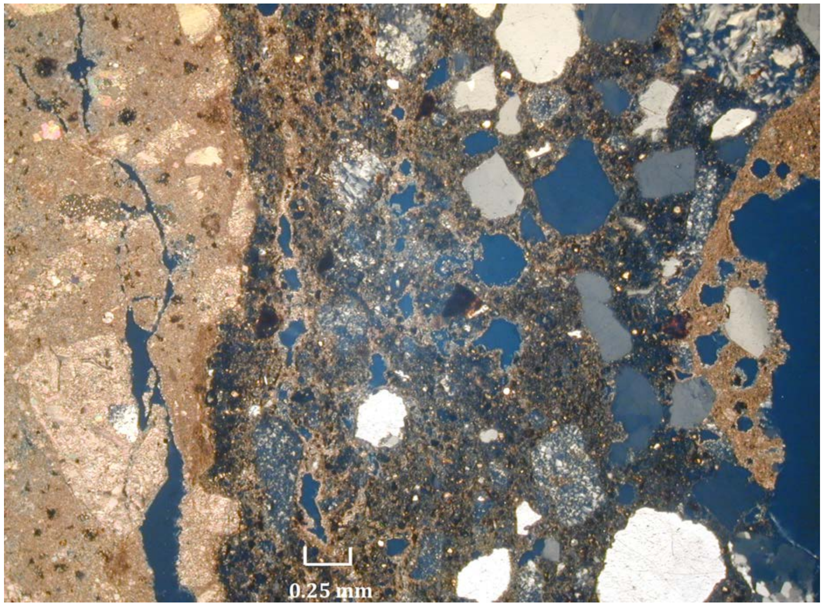


Figure 94: Concrete Bridge in thin section, 40x. The image shows the bottom of the sample to the right with two separate layers of parging on top of fully carbonated concrete. This is the same view as above but in cross-polarized light.

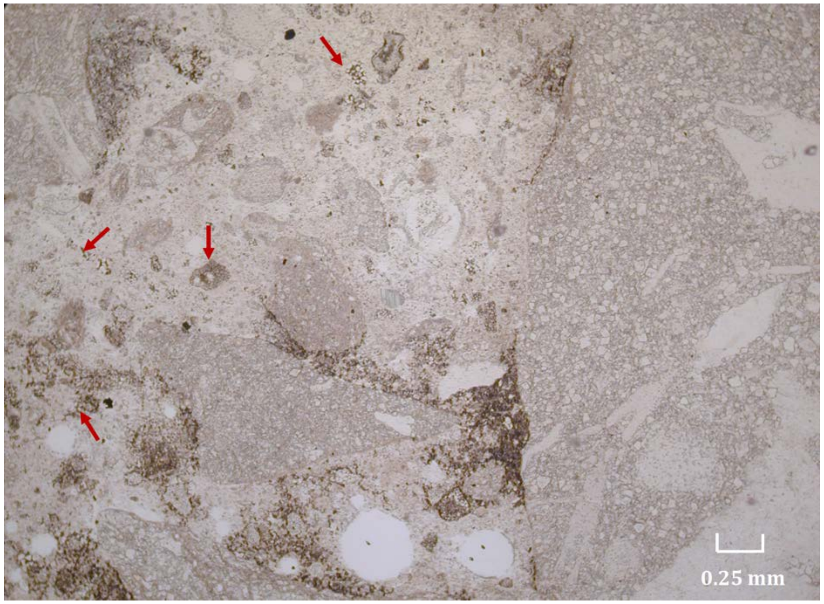


Figure 95: Residual cement grains (red arrows) are similar to the other concrete samples; ppl.

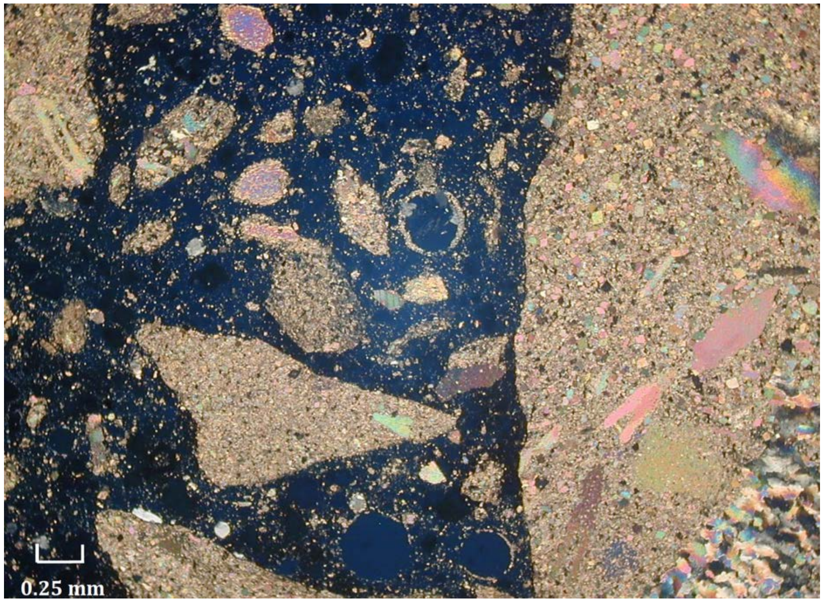


Figure 96: Showing the character of the paste. Note the spherical void at the upper center lined with salts; the voids near the bottom of the image have thin rims of microcrystalline calcite. 40x; same view as above in cross-polarized light.

CONDITIONS ASSESSMENT & REPAIR RECOMMENDATIONS

The deterioration observed at the 1910 Concrete Bridge stems predominantly from moisture issues that are typical of an historic concrete structure left exposed to the elements for over 100 years. Deterioration is exacerbated by drainage issues on and around the bridge, site retention failure at the west end of the bridge, failed patches and a parge coating that appears to be trapping moisture, leading to loss.

It is difficult to fully assess the condition of the 1910 Concrete Bridge due to the parge coat covering much of the structural concrete. Sounding was executed with a customized tool on all surfaces which determined many voids are behind the parge coat. This condition can be from poor construction techniques, differential thermal expansion between materials, and water ingress in the assembly through cracks. It is not known whether the parge coat is original to the bridge. Determining that is beyond the scope of this project but may define the treatment that is implemented. If the parging is original there may be the desire to preserve as much as possible which would involve drilling small portholes for injection grouting a conservation-grade grout into the voids to stabilize it. The grout could also help consolidate the structural concrete behind it, but otherwise the concrete's condition would be unknown if the parge remains. To note, by injecting the parging and filling in losses a somewhat uneven surface might be created because any out-of-plane parging cannot be pushed into plane. Often when there's delamination in parging debris and deteriorated material get caught behind it causing bulges which cannot be corrected if the voids are filled. The parge, original or not, can also be removed everywhere it is delaminated, the underlying concrete repaired and new parge applied. This is the recommended approach since much of the west railing can be preserved.

The underside of the structural arch shows several areas of concrete delamination and potential spalling. Two major areas of spalls can be seen toward the north end of the span, where six to eight reinforcing bars are exposed with visible rust, and along the east exterior arch edge, where a large spall has exposed a 1/2" diameter reinforcement bar. There are many other areas of the underside that show concrete cracking and delamination, which should be assessed and patched. Widespread cracking along the western edge has led to spalls of the parging along the bridge elevation, as well as at its abutments. The loss of the parging has left the structural concrete exposed, which has begun to erode, with loss of the cementitious material. Large concrete spalls along this edge have led to small plant growth sprouting within the cavities. The 10-1/2" wide ledge beyond the railings has cracking running along its length and is visibly eroded.

The entire underside of the concrete arch should be sounded to determine locations and execute removal of deteriorated parging and concrete. This will have to include the removal of the earth and debris under the bridge. Any reinforcement that becomes exposed during this process or was previously exposed should be prepped for repair, which involves removing a certain amount of concrete around the rebar so that it can be properly cleaned and coated, and a concrete patch can encase the full section of the reinforcement. Since many of the exposed rebar are toward the base of the arch, some of the grade under the bridge will need to be removed to locate the full extent of rebar and concrete deterioration as it terminates into the landing. Partial coating and patching of corroded steel reinforcement without addressing all the damage will not arrest the conditions. Once the area is prepped and the reinforcement is cleaned and coated, the concrete at the underside can be patched.

The site wall at the west end of the bridge appears to have failed toward the north end, leaving the east end of the site unretained/unsupported.

The west elevation of the west railing is in the best condition, with minimal spalls or cracking; however, there is a continuous horizontal crack running the span of the arch at the base of the side rail. Sounding at the west railing determined there is only roughly 100SF of delaminated parging.

The east elevation of this west railing has some loss of the exterior parge, revealing sound concrete underneath. The decorative ledge on the outside and base of the railing on the inside have eroded due to its contact with surface runoff and other elemental exposure.

The east railing is in worse condition than the west, with several areas of parge loss predominantly toward the bridge's southern half on both the east and west sides. At the east railing sounding determined that all the parge coat is delaminated from the concrete. The exception is some areas of the posts which still had well-adhered parging.

The southwest post is fractured at the base resulting in dimensional loss and the northeast post has a network of microcracking on each of the faces that has led to efflorescence in the cracking and spalling in the parging. The other three end posts, while not as damaged, still all have areas of microcracking and spalls, most evident at the base and at decorative transitions (ledges). It is recommended to patch the areas of loss to bring definition back to the details and protect the historic concrete at the base.

The surfaces should be cleaned of the biological growth so that they can be better assessed, and treatments can be executed and visually matched. The growth is quite heavy throughout and can conceal cracks and other conditions and features. Cleaning tests were conducted with chemical cleaners compatible with concrete: D2 Biological Solution and All Surface Cleaner diluted to one part product to three parts water. Both cleaners were effective at removing some of the biogrowth, but additional applications and a pressure washer (at 500 psi) would be required for complete removal to allow for concrete/parge assessment.

If the parging is removed the concrete should be assessed. It was observed at the arch of the east face of the east railing that the concrete contained rock pockets – also called honeycombing – at the bottom edge where there is extant loss of parging and concrete. This condition means there are many voids in an area where the cement binder and fine sand have not been able to fill in between the aggregate, formwork, and rebar. This can be typical at corners, detailed areas, and around rebar where the concrete may not have been flowable enough to reach those crevices, the aggregate was too large or poorly integrated to fully consolidate those tight spaces, and/or the concrete was not vibrated within the formwork during construction to ensure the cement and sand moved to those spaces. The rock pockets are most detrimental to the rebar because they create voids around the steel for water and air to collect and hasten corrosion. The rock pockets if revealed after parge removal should be injection grouted and filled with patch repair mortar to consolidate the aggregate. Wherever rebar is revealed it should be cleaned; if there is not enough dimension remaining in the rebar it should be replaced, all steel should be coated with a corrosion inhibitor and patched around it.

The scaling concrete can be tooled to sound concrete and any loss can be patched. If loss is larger such as at the footings of the posts, those areas should be re-cast instead of patched for a longer-term repair.

There are several cracks that run over the tops of the railings and some traverse down the sides. These should be injected with a mechanically compatible grout and filled at the top with a visually appropriate mix.

There is a later repair campaign that is failing at the east railing top. It appears as if the railing was originally poured with a shallow slope on top and the repair effort re-created an arched top to shed water. The repair is largely failing, which will aid its removal, because the historic concrete was not properly prepared to receive a successful topping. Once the repair is removed it should be assessed on how to proceed – whether to reintroduce the topping or leave it be. The west railing has retained the original profile and appears to be performing well.

The repair material in other areas may be too impermeable for the historic concrete. Where the repair material is on the posts there is adjacent cracking so it should be removed.

Finally, the areas where parging was removed or loss require the application of a new compatible parge.

The pavement over the bridge is cracked in multiple directions and the current drainage pattern is for runoff to run toward and along the base of the side railings. The railings have observed moisture damage along their bases, as do the four end posts, with areas of cracking and spalling due to moisture ingress and freeze thaw. The pavement also encases some portions of the footing of the bridge railings and posts. This is detrimental to the long-term preservation of the bridge. Drainage should be assessed and designed so water does not get directed to the historic concrete.

Figure 97: West side of west railing – the footing is the part of the railing in worst condition, detail shown here of loss, disaggregation, cracking, and biogrowth; this condition spans the length of the railing. Towards the bottom of the image the top of the arch is just visible.

Figure 98: There are several large cracks on the top of the east railing; the cracks allow water ingress which at the Concrete Bridge means it gets behind the parging coat, accelerates the decay of the structural concrete, and eventually causes loss of parging, exposing the eroded decayed concrete; similar to the following image this results in a significant amount of surface loss over the years.

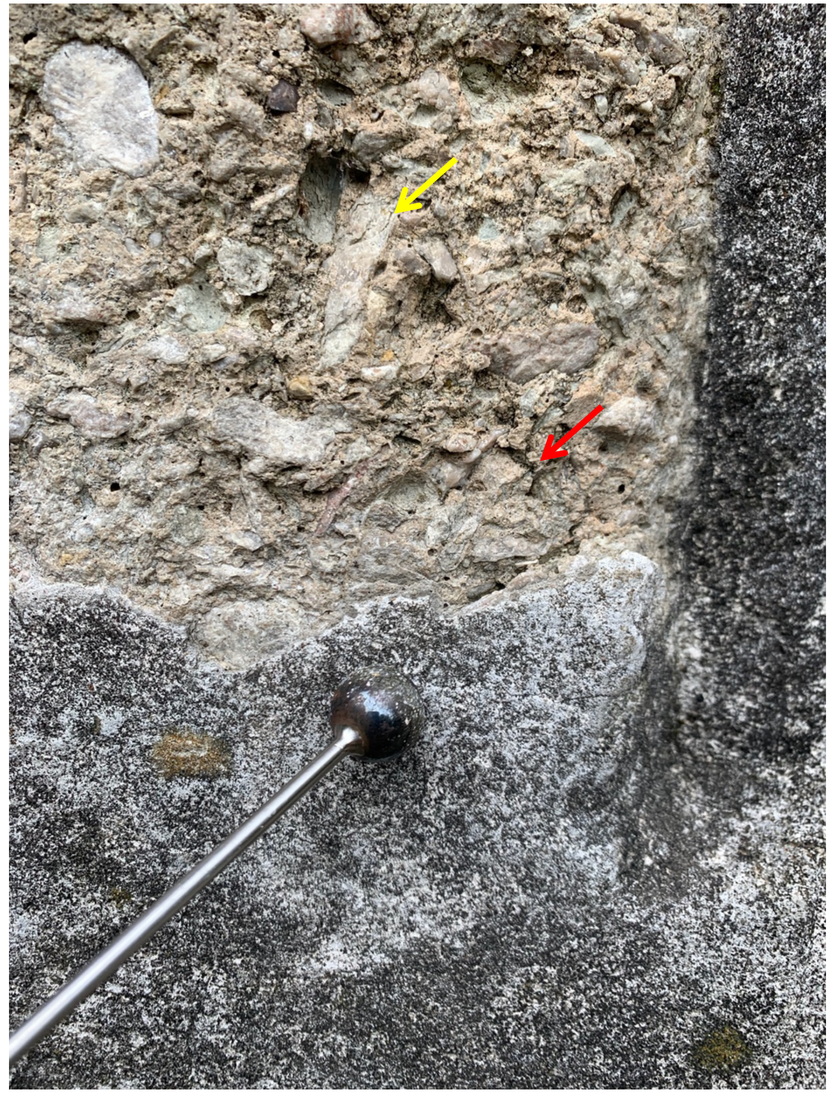
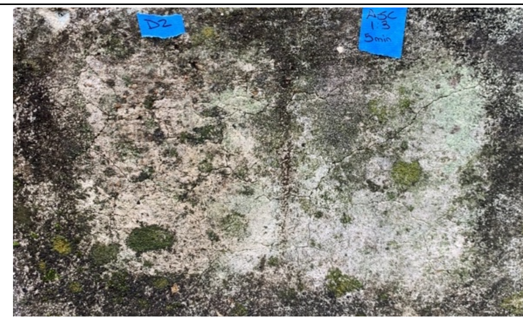


Figure 99: Detail at loss of parging – sounding tool is used to tap on parging and detect delamination which was almost 100% of the east railing's parging; note cracks in the concrete substrate that are in the cement matrix (red arrow) as well as through aggregate (yellow arrow). The aggregated surface typical of the exposed areas of concrete is not the original appearance which would have been much smoother due to pouring the concrete against formwork – this condition suggests a significant amount of surface loss over the last 110 years.

1910 CONCRETE BRIDGE

Scope	Notes	Image	Quantity	Priority	Cost Estimate
Concrete Sounding	The entire underside of the concrete arch should be sounded which will require cleaning a significant amount of fill from beneath and the ends of the bridge. Cost does not include fill removal. Sounding would be done by the engineers and conservator.		600 SF	1	$6,000
Cleaning	Removal of biogrowth; assessment of the condition of the parging and concrete is somewhat obscured by the biogrowth so cleaning is recommended. Tests were conducted to some success but multiple applications and a low-pressure washer should be used. Cost for railings and posts only.		1100 SF	2	$6,000
Concrete removal around steel and steel prep	Prep concrete around reinforcement, clean steel and apply corrosion inhibitor; assume 3" depth of concrete removal; sounding will determine extents.		25 CF	1	$10,000

1910 CONCRETE BRIDGE					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Concrete removal and patch	Removal of loose concrete determined from sounding; this is in addition to the concrete removal to clean the steel; square footage was assumed.		200 SF	1	$15,000
Parge Sounding and Removal	Sounding of the west railing and all posts to mark locations of removal (east railing wall is 100% removal). Removal should be done in conjunction with the sounding so concrete assessment can occur directly after. Removal should be done carefully to not damage concrete beneath it.		600 SF	1	$9,000
Remove large concrete incipient loss and patch	Remove large incipient loss at base of end posts and along west elevation and patch using stainless steel pins if thicker than 2".		40 CF	2	$8,000

1910 CONCRETE BRIDGE					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Parge	Apply a new compatible parge coat over the entire east railing and all other areas of removal. This includes the entire ledge on the west face of the west railing which is highly aggregated.		850 SF	1	$34,000
Remove top rail previous patch	70% of east top rail has a failing patch that needs to be removed. Reinstalling a patch should be considered to shed water but might require scarifying the historic concrete to get a mechanical key for the topping that is currently lacking and inducing failures. The top should be assessed after repair removal.		25 LF	2	$2,000
Site Prep around deteriorated concrete	Temporary removal of soil adjacent to concrete for rebar that needs treatment; north and south edges of underside of arch base need to be cleared to chase deterioration back to sound concrete/rebar.		80 LF	1	n/a

1910 CONCRETE BRIDGE					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Site Prep around deteriorated concrete	Temporary removal of soil adjacent to west side of bridge; entire length of exterior west elevation of bridge.		40 LF	I	n/a
Site retaining wall repair	Repair retention wall and high grade at west side of bridge; entire length of exterior west elevation of bridge.		40 LF	I	n/a
Site Drainage	Assess movement of water on bridge pavement and along west elevation adjacent to high grade to avoid continued base deterioration.		n/a	I	n/a

BRIDGE AT LICK BRANCH SEWER

General Description

The Bridge at Lick Branch Sewer is located near the original entrance to the park off Elliston Place. It spans the road and leads to the Gunboat with the Parthenon in the distance. It is believed to have been constructed in 1907 similar to Shell Spring and prior to Gunboat and 1910 Concrete Bridge. The bridge has two railings – east and west – consisting of balusters and end posts. The posts, as with the 1910 Concrete Bridge, are plinths for planters with decorative recessed panels; however, the bridge railings are balusters unlike the solid spandrel arch of the Concrete Bridge.

The bridge is approximately 23' long, made up of 24 balusters 6" wide by 6.5" deep, punctuated with 24" wide by 50" tall posts (excluding the planters) at the four ends.

Grade appears to have been filled in around and under the bridge at some point in the bridge's lifetime as evidenced by the presence of stone retention walls that used to retain the higher grade, between which, the waterway led to a spring. These walls provided perimeter ends for the waterway, but now grasses and soil elevations match the tops of these walls.

The traffic is limited to park and construction vehicles, but it was observed during the site visits that the public still drives down the road occasionally.

Archival Information

A bridge was originally constructed for the Centennial Exposition in 1897, and based on historic maps of the park, it spanned over a small waterway in the southeast section of the park that led to a natural spring (where the Shell Spring was constructed). The current concrete bridge is believed to have been constructed in 1907, designed by Wilbur Creighton, Sr. of Foster and Creighton Company (same builders of the 1910 Concrete Bridge). The construction date contradicts the National Register of Historic Places nomination which suggests it is 1910. Through review of photo archives with Caroline Eller of the Metropolitan Historical Commission, a partially mislabeled historic image places the bridge, clearly the Bridge at Lick Branch Sewer due to the defining balusters, by Lake Watauga, but correctly dates the image to 1907. This is reinforced by the NRHP nomination stating the bridge is Creighton Company's "first experience" with reinforced concrete bridge construction whereas the 1910 Concrete Bridge is "one of" the company's first reinforced concrete bridges.

Though there are a few archival photographs, there is otherwise limited archival information on the Bridge at Lick Branch Sewer. One image is from shortly after construction, 1907, and one from the Board of Park Commissioners Twelfth Annual Report of 1912. The latter is from a distance so does not provide much information. The 1907 image depicts the arch of the bridge that is now buried, and adjacent stone retaining walls. There are two color photographs that are undated. These images depict the bridge railings as ill-defined due to a later parge coat and the site is altered to fill beneath the bridge and a large pipe directing the flow of the spring.

There have been no drawings found nor repairs on the bridge documented since its original construction in 1907. Most recently there were photographs taken of the bridge in January 2020 for the Request for Qualifications for this project but did not include descriptions or recommendations on repair.

Figure 100: Bridge at Lick Branch Sever, looking east, shortly after construction.

Figure 101: Undated image depicting context of bridge, looking east.

Figure 102: Undated image; note more recent parging on concrete and lack of planters on the posts.

Construction

An historic photograph shows the original bridge to be a concrete arch spanning over a waterway. The bridge is completely buried below grade at both the east and west walls so the existing structure could not be reviewed. Based on archival information, the bridge is composed of reinforced concrete.

The bridge was elevated above grade so much that the balustrades and side rails were completed exposed; Currently the bottom rail and end post bases are partially hidden below grade. The bridge extents are sided with concrete railings composed of 6" square balusters, spaced 1'-0" center to center, 2'-0" above grade and capped with a continuous 13" wide x 3-1/4" thick top rail. The railings terminate with end posts that are 2'-0" x 2'-0" and 4'-0" above grade. These end posts support concrete urn planters. The side walls and end posts are parged with a cementitious coating.

Figure 103: Bridge at Lick Branch Sewer looking east.

Figure 104: Bridge at Lick Branch Sewer looking west.

Figure 105: Bridge at Lick Branch Sewer looking north; same view as image on title page approx. 110 years later.

Petrographic Analysis

The sample from Lick Branch Bridge is one large piece from the outside corner of one of the bridge balusters. The sample is almost entirely repair material with a small inner rim of original concrete. The exterior surface was heavily coated with biological growth and the interior with some dirt, especially at the top end.

The two outer surfaces are distinctly different - one appears to have been coated with a slurry of some kind as distinct brush strokes are visible. After water washing to remove the surface debris and biological growth, the differences are even more distinctive, with three different surface materials visible, indicating that this portion of the bridge has been repaired multiple times.

Based on the limited amount of concrete attached to the surface parging, the material is similar to the Gunboat *Tennessee* and the Concrete Bridge in composition and character. The coarse and fine aggregate are crushed stone; assessment of the aggregate grading and distribution at the macro level is difficult due to the limited amount of original concrete in the sample. Similarly, the character of the void volume is difficult to distinguish. The concrete is fractured along the length of the sample with both large and fine cracks that typically go around the aggregate. Viewed in cross-section the concrete is observed also to be extensively cracked subparallel to the surface parging; these cracks go through the aggregate. There seem to be at least two layers of parging. Testing with phenolphthalein reveals that the concrete is apparently carbonated, but the parge is still alkaline.

In thin section the appearance of the concrete is similar to that of the Gunboat *Tennessee* and the Concrete Bridge. The coarse and fine aggregate is primarily biomicrosparite and biomicrite. The matrix is fully carbonated throughout, with large hydrated residual cement grains. Void volume is approximately 10% in the form of irregular and spherical voids, some of which are partially lined with salts or microcrystalline calcite. The ratio of matrix to aggregate is estimated visually at 1:2.5 to 3.

Three separate layers of parging were observed in the thin section. The outer two layers resemble those on the concrete bridge; the inner layer is different. The inner parge is also portland cement-quartz sand, but the cement is fully hydrated. Voids in the inner layer are filled with salts, principally ettringite.

Figure 106: Sample location detail.

Figure 107: Sample location, overall.

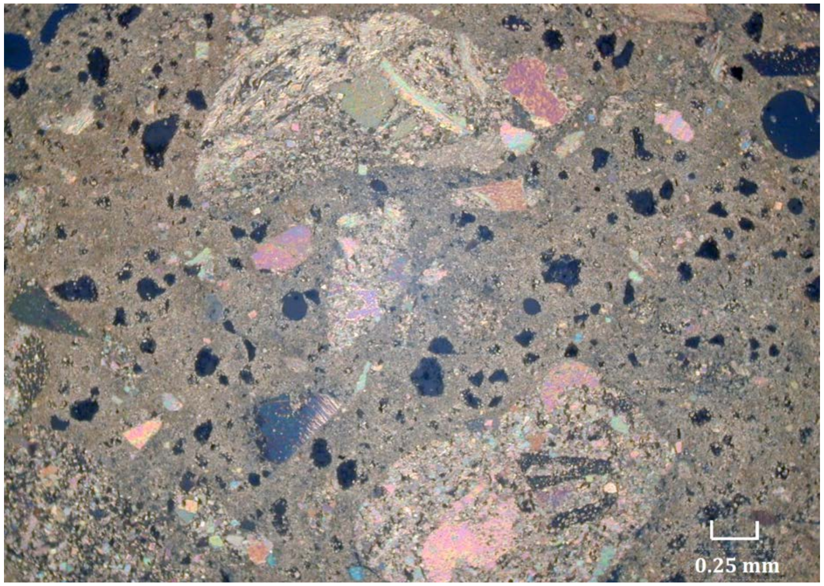


Figure 111: The concrete (not the surface parging) in thin section, 40x, xpl. The matrix is fully carbonated with large, hydrated residual portland cement grains.

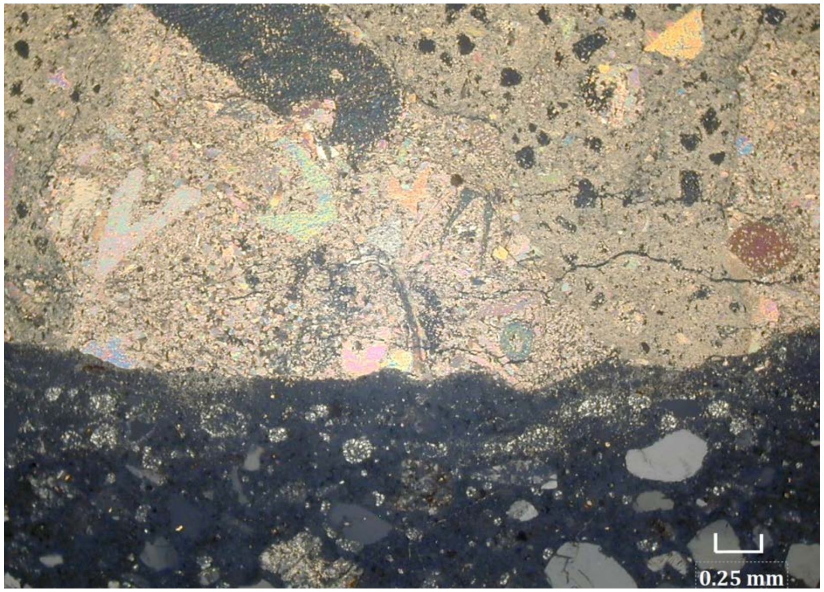


Figure 112: View of the boundary between the thick, outer surface parge and the inner concrete of the Lick Branch Bridge sample in thin section, 40x, xpl. Note the cracking in the concrete that extends through the aggregate. There is a zone of salt-filled voids in the parge immediately adjacent to the concrete.

Figure 108: Sample outer surfaces; note multiple parge coats indicating different repair campaigns.

Figure 109: Sample interior surface.

Figure 110: Left: Fresh cross section of the sample. The inner, white material is the original concrete; the outer, gray-brown material is a later repair. Note the fracturing in the concrete subparallel to the surface parging. Right: sample treated with phenolphthalein: original concrete is colorless.

Conditions Assessment

The Bridge at Lick Branch Sewer is in fair condition overall. Since grade has been filled under and around the bridge, the structure is at grade and no longer spanning; the portion of the bridge structure below grade could not be reviewed.

The structure that remains above grade, the railings and end posts, are in good to fair condition. The most notable concern is at the west railing's north end, toward the Gunboat, where several balusters have loss of parging, heavily eroded concrete and widespread cracking. Cracking in this area continues up to the top rail with large visible cracks running perpendicular to the balustrade. The end post in this corner has scattered areas of spalls and large horizontal cracking through the parge up the height of the post. The east railing is in good condition with the exception of the posts.

The bridge is heavily covered in biological growth so other conditions could be concealed, and it was not possible to discern if any original material is visible/at the surface except where the newer parging has exposed the historic concrete. Cleaning tests were done on the bridge but had almost no effect so either multiple applications with the use of a pressure washer or tests with other products are needed.

There is a newer parge coat over the majority, if not all, of the historic concrete and/or over a possible historic/original parge coat. It is failing in several places such as on all the posts and on 13 balusters. In locations where the historic concrete is visible it is scaling, cracked, disaggregated, and exhibits dimensional loss. Some of the concerns are whether this newer parging is too dense for the historic concrete beneath it or if it is contributing to the preservation of the historic concrete. Petrographic analysis revealed the surface of the historic concrete is carbonated but the parging is not which offers protection to any steel reinforcement within the historic concrete. As discovered by sampling, the parging, in places, is well-adhered to the historic concrete and its removal will also remove original concrete.

A conservative approach to the preservation of the bridge is to clean and repair the parging and original concrete where accessible. Another option is to remove the parging on the most damaged balusters which can be used as probes to determine substrate condition, steel location, and adhesion of parging. Depending on findings the remainder of the balusters can be restored or dismantled and replicated as required for structural purposes. The restoration of the balusters would entail injection grouting into cracks, removing displaced pieces or incipient spalls within the parging, and patching the parging. Lastly, if the historic concrete appears to be deteriorating in part because of the parging, then it would be recommended that all of the parging be removed, the historic concrete restored and a new more compatible parging re-applied.

It is recommended that the majority of the posts have the parging removed, concrete restored and new parging applied. During the survey and sounding with ball peen tool, it was observed that some sides need 100% removal of parging, others 75% and 50%, indicating a significant amount of work should be executed on the posts. In these areas all detached parging should be chipped off, the underlying concrete restored by injection grouting, select tooling of surfaces, patching, and re-parging with a compatible mix.

The top of the west railing has 14 cracks across it that should also be filled if the parging is to be retained. This will prevent water ingress into the assembly. The east railing is in much better condition, so it is possible its parging campaign is a later edition than the west.

As a first step, it is recommended the bridge get cleaned with appropriate materials and methods. This will allow for work to be executed and for future monitoring depending on the preservation approach implemented.

The area around the base of the railing should also be cleared of dirt and debris and drainage should be considered. The east side of the west railing at the north end has the majority of the disrepair and it appears after a rainstorm that area pools water so the wicking of the moisture accelerates the deterioration of the concrete. In winter this can become freeze/thaw which also accelerates the decay of concrete.

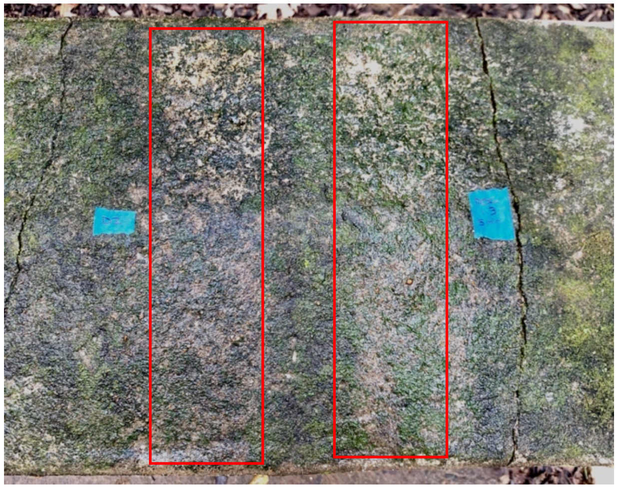


Figure 113: After cleaning tests across top of west railing. The results were not satisfactory though these cleaners can improve after a couple weeks of exposure. More testing should be done.

Figure 114: West side of west railing. Note cracks in parging at red arrows, cracks in structural concrete at yellow arrow, loss of parging in outlines.

Figure 115: East face of east railing. Note the better condition of this railing which is true for the whole railing compared to the west railing. The parge coating may also be a later campaign than the west.

Figure 116: The north post of the east railing is in the worst surface condition of all the posts with the most parge loss, concrete cracks, and disaggregation.

BRIDGE AT LICK BRANCH SEWER					
Scope	Notes	Image	Quantity	Priority	Cost Estimate
Cleaning	The biogrowth is obscuring the surface so it is difficult to discern conditions; biogrowth also holds moisture to the surface which accelerates deterioration. Testing had limited results but the use of a pressure washer and multiple applications or different products can be tested.		350 SF	1	$15,000
BALUSTERS					
Option 1: Repair 14 balusters	Repair 14 balusters Injection grout Fill cracks Patch Select removal & re-parge		14 units	1	$20,000
Option 2: Remove and replace 11 balusters	Remove and replace 14 balusters; on west and one on east.		40 CF		$25,000

POSTS					
Concrete & parge removal	Removing loose concrete and parging. Should also include cleaning concrete so that its surface is prepped for a patch.		200 SF	1	$8,000
Patch structural concrete	Includes the prep/any cut back needed for suitable patch		50 SF	1	$6,000
Injection grout & Patch parge	Grout the cracks and apply parging where removed.		100 SF	1	$8,000
SITE					
Site Drainage Considerations	removal of soil and asphalt adjacent to base of railings for concrete work and to avoid continued base deterioration		n/a	3	n/a

DISCUSSION

The expectation, in our experience, would be for the Design Team and the Park stakeholders to formally establish a program that demonstrates a set of thresholds so that clear expectations about data extraction, life safety monitoring, and conclusions/deliverables are agreed upon by all parties.

At the Parthenon, continued cracking at areas including the architraves, entablatures, building walls, porch and stereobate steps, indicate an active material movement the cause of which is still elusive. Sixty years of experts have reiterated the continued cracking could either be from thermal expansion and contraction of differing building materials or foundational settlement (particularly and continually noted at the building walls) without a conclusive statement as to which is the source of the conditions, why such conditions are continuing to occur, and how to arrest the conditions from furthering.

At the Shell Spring, concrete deterioration is evident. Its level of deterioration is, however, still unknown. That level of deterioration can vary from erosion and loss of surface concrete to complete degradation of the material's integrity and chemical composition. The former results in exposed rebar, surface spalls, and minor cracking; the latter results in structural instability of the concrete mass, a potential life safety issue for surrounding visitors.

The petrographic analysis revealed the concrete appears to be the same between the four structures: Gunboat *Tennessee*, Shell Spring, 1910 Concrete Bridge and Bridge at Lick Branch Sewer. The exception is Shell Spring which lacks the large aggregate so is more comparable to a mortar than concrete. However, its smaller aggregate and cement paste are similar to the other structures. The matrix consists of portland cement, the cement residuals all samples have a similar size and appearance suggesting a single source, and the coarse and fine aggregate is crushed dolomitic limestone. The coarse aggregate contains rare chert and the fine aggregate also contains carbonate mineral grains and rare individual fossil fragments. They all contain relatively large residual cement grains which is typical for early 20th century concrete. The limestone as the primary aggregate means the concrete in its entirety consists of acid soluble materials. Often concrete aggregate is silica based which provides some acid resistance for concrete, but this is not the case for these four structures. The concrete is exposed to acid though rainwater and pollutants and becomes eroded upon exposure, however microscopically.

The concrete though may be somewhat protected by the parging coat that is partially extant on the Gunboat, 1910 Concrete Bridge and Bridge at Lick Branch Sewer The analysis of the parging coats was not included in this project's scope so it is uncertain if its composition is similar. That is complicated by the fact that it is unclear if original parge coats exist. There are obvious repair parge coats in some locations, certainly Bridge at Lick Branch Sewer, but the other structures are difficult to discern with the biogrowth and methodical sampling and analysis would be necessary to discern parge campaigns.

As presented in the sections above, it is recommended to clean the parging and concrete so a better understanding of the condition and materials on the structures can be attained. The one exception is Gunboat which requires removal of the exterior parging to treat the underlying concrete and remove and treat the figurehead. The latter should be done by a metals conservator.

The Design Team recommends the preservation of as much historic fabric as possible is pursued in the future interventions because each feature is a significant contributing asset to the Centennial Park's collection of structures.

With any preservation project, a phased approach is imperative and this report records the completion of an initial needs assessment which is critical to begin to understand future phases and those scopes for the recommendation of successful repairs that protect the cultural heritage for the long term.

CONCRETE MAINTENANCE

Each concrete structure and/or building presents its own unique geometry, materials, conditions, siting, form, and function. It is therefore difficult to give a one-size-fits-all recommendation on their maintenance and care, however, some basic good practices are the following:

Ensure all records to pertaining to each structure are gathered in known locations. This includes drawings such as original, as-built, restoration, and detail drawings, archival photographs, original construction specifications, notes, receipts, etc., previous reports written on their construction or conditions or repair recommendations, any record of repairs that were implemented, specifications, field reports, change orders, etc.

Regular inspections should be conducted on the historic concrete so changes over time can be observed and interventions can be executed before deterioration conditions result in loss or the need for more aggressive repairs. The inspections should be done by consultants with specialization in historic concrete and can include conservators, engineers, architects.

Regular maintenance should be executed based on the inspections, and under the direction of specialists, so the issues can be addressed immediately before they worsen.

Maintain whatever systems are in place to help shed water from the concrete be it roofs, coatings, drainage systems, etc. Note, coatings should not be applied without a conservator's approval because typical film-forming coatings that advertise waterproofing or repelling, trap moisture in the concrete, accelerating its decay.

Under the direction of a conservator, remove coatings that are trapping moisture against the concrete.

Under the direction of a conservator, clean concrete of biogrowth, which holds moisture to the concrete surface and accelerates its decay.

Minimize the use of deicing salts which greatly accelerate concrete decay.

Install waterproofing under the guidance of professionals sensitive to historic cultural heritage and knowledgeable in various systems available.

Understand the concrete service life issues. This can be pertinent to historic concrete so that a baseline is understood of the depth of carbonation of the concrete, whether alkali-silica reaction is extant, and if chlorides are in the concrete – either from early uses of original admixtures in the concrete that are now known to accelerate decay, or from deicing salts, or other sources. These parameters can also help determine the concrete environment for the protection or corrosion of steel reinforcement. This work is less about maintenance, but a program could be implemented that begins to catalogue the condition of historic concrete of Nashville's parks to help prioritize which structures need attention and strategically approach their preservation and restoration.