Arlington Memorial Bridge
Adjacent to the base of the Lincoln Memorial, spanning
the Potomac River to Arlington Cemetery, VA.
Washington
District of Columbia

HAER No. DC-7

HAER,
DC,
WASH,
563-

PHOTOGRAPHS
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Department of the Interior
Washington, DC 20013-7127

HAER
DC,
WASH,
563-

HISTORIC AMERICAN ENGINEERING RECORD

ARLINGTON MEMORIAL BRIDGE

HAER No. DC-7

Location:	Adjacent to the base of the Lincoln Memorial, Washington, D.C., spanning the Potomac River to Arlington Cemetery, Arlington, VA. UTM: 18/321680/4306600 Quad.: Washington West
Date of Construction:	Designed 1929, Completed 1932
Architects:	McKim, Mead and White, New York, New York; William Mitchell Kendall, Designer
Engineer:	John L. Nagle, W.J. Douglas, Consulting Engineer, Joseph P. Strauss, Bascule Span Engineer
Contractor:	Forty contractors under the supervision of the Arlington Bridge Commission
Present Owner:	National Capital Region National Park Service Department of the Interior
Present Use:	Vehicular and pedestrian bridge
Significance:	As the final link in the chain of monuments which start at the Capitol building, the Arlington Memorial Bridge connects the Mall in Washington, D.C. with Arlington National Cemetery in Virginia. Designed to connect, both physically and symbolically, the North and the South, this bridge, as designed in the Neoclassical style, complements the other monumental buildings in Washington such as the White House, the Lincoln Memorial, and the Jefferson Memorial. Memorial Bridge was designed by William Mitchell Kendall while in the employ of McKim, Mead and White, a prominent architectural firm based in New York City. Although designed and built almost thirty years after the McMillan Commission had been disbanded, this structure reflects the original intention of the Commission which was to build a memorial bridge on this site which would join the North and South.
Historian:	Elizabeth M. Nolin, 1988

The idea of a bridge over the Potomac spans 150 years. The idea was first conceived during President Andrew Jackson's term in office, March 1829 - March 1837. An act passed on July 14, 1832 provided for the purchase of land, the site of the bridge crossing with various acts and executive documents following in 1833, 1834 and 1836. On January 4, 1836, the Washington Globe reported that Congress had passed an act to build a bridge across the Potomac.[1] This action is most likely linked to the fact that during Jackson's second term in office, he laid the cornerstone for a community, Jackson City, on the Virginia shore of the Potomac. With the laying of the cornerstone came a large parade and much excitement regarding the soon thriving suburb of Washington. Bureaucracy plodded along, even in the 1830s. A bridge was never built despite congressional acts and executive orders. Without a bridge, Jackson City was not easily accessible to Washingtonians and within a short time, Jackson City was again a swampy grassland.[2]

There appears to be no further action taken on the bridge until 1851. On July fourth of that year, Daniel Webster addressed a crowd and spoke of President Jackson's dream, perhaps romanticizing it slightly. Webster describes the structure as a bridge with arches of granite stretching across the Potomac from Washington to Virginia, physically and symbolically uniting the North and South.[3] Several subsequent presidents also endorsed plans for a memorial bridge. Studies for a bridge were made, design competitions were held and various factors were scrutinized, but again, no action was taken.[4] Another movement that had also been going forward during this time period was one to beautify Washington. It was strongly influenced by the change in aesthetics that resulted from the 1876 Centennial Exhibition in Philadelphia, the 1890 Centennial of the founding of the City of Washington and the 1893 Columbian Worlds Fair in Chicago.[5]

---

[1] David Hoth, The Andrew Jackson Papers, Knoxville, TN. Telephone communication.

[2] Robert V. Remini, Andrew Jackson and the Course of American Democracy, 1833-1845. (New York: Harper and Row, Publishers, 1984), 399.

[3] Bridges - Arlington Memorial 1895-1918, file, Martin Luther King Jr. Public Library, Washingtoniana Room.

[4] Donald Beekman Myer, Bridges and the City of Washington, (Washington: U.S. Commission of Fine Arts, 1974), 17.

[5] Connie Foley, River Port and Capital: The Architectural and Natural Landmarks of Washington, (Department of the Interior: 1965), 13.

A direct result of this wave of interest was the formation of the Senate Park Commission also known as the McMillan Commission.[6] This Commission was established by Senator James McMillan of Michigan, Chairman of the Park Commission on the District of Columbia. Four men were selected by McMillan and assigned to study and report on the present condition of the District's parks.[7] The four men were Frederick Law Olmsted, Jr., Daniel Burnham, Charles McKim, and Augustus St. Gaudens. To better understand the ideas of Pierre L'Enfant, city planner of Washington, and many of the great European designers, the men of the McMillan Commission traveled to Europe. Many of the impressive landscapes such as Villa d'Este, Hadrian's Villa, Piazza San Marco, Versaille, and Hampton Court were studied.[8]

"In effect, the Senate Park Commission Plan of 1901, as it came to be known, was an exact revival of L'Enfant's plan of 1791."[9] The models and drawings of the 1901 plan included a bridge and other supporting architectural elements where the Arlington Memorial Bridge and other structures came to be built.[10] Upon McMillans death in 1902, the Park Commission ceased to exist.[11] In 1910, President Taft established a similar Commission through Congress, the National Commission of Fine Arts. Comprised of seven men, the Commission consisted of three architects, a landscape architect, a painter, a sculptor and an art historian/critic.[12]

The Fine Arts Commission acted as executors of the 1901 plan[13] and in 1916 the idea of a memorial bridge came up in their meetings, but it was not until the Armistice Day celebration and dedication of the Tomb of the Unknown Soldier in 1921 that plans actually went ahead for a bridge from Washington to Virginia. Due to an unprecedented traffic jam stretching from Washington to Arlington Cemetery in Virginia, a trip that normally took twenty minutes stretched out to an hour and a half. On this day, President Harding was traveling to the cemetery with some of the members of the Commission of Fine Arts. The day following this fiasco, the Commission decided to act upon this problem by asking Congress for appropriations for a bridge in the vicinity of

---

6 Norman T. Newton, Design on the Land, (Cambridge, Massachusetts: Belnap/Harvard Press, 1971), 420.

7 Foley, 13.

8 Newton, 405.

9 ibid, 407.

10 ibid, pp. 407, 409, 410; figs. 256, 260, 261.

11 ibid, 410.

12 ibid, 411.

13 Foley, 13.

Arlington Cemetery.[14] There were arguments presented that the bridge should be in line with New York Avenue extended but a final determination was made in 1922 when President Harding and the Commission visited the two proposed sites.[15] The bridge was, according to the 1901 plan, to span the Potomac from the west end of the Mall at the base of the Lincoln Memorial to Arlington Cemetery.[16]

The Commission, rather than hold a competition to decide on the design team, chose the firm by direct selection. The architecture firm of McKim, Mead and White of New York City was specified to design the bridge with William Mitchell Kendall submitting a preliminary design in May of 1923. The bridge was neoclassical in style, keeping with the Lincoln Memorial and other monumental architecture in Washington. The design was well received by the Commission and work went ahead on the bridge. On May 27, 1927, Kendall submitted drawings for the Washington side of the bridge which included the parkway approach, seawall and watergate (see HAER #DC-7A); and at the same time included drawings depicting the Virginia terminus including the formal avenue from the bridge to Arlington Cemetery and the Boundary Channel extension of the Arlington Memorial Bridge (see HAER #DC-7B). Many complications regarding both termini arose, mostly concerning traffic demands but costs and aesthetics were also factors. The design for the Washington terminus was finally settled on March 15, 1928 and on the Virginia side as late as 1940.

The Arlington Memorial Bridge consists of nine arches which include a double leaf bascule span in the center with four masonry arches on either side plus two smaller spans over low level roadways which carry traffic through the abutments at each end of the bridge. The superstructure of the bridge rests on four abutments, one at each shore line and one on either side of the draw span with six piers in between the masonry arches. Between the pylons at each terminus the bridge measures 2,138 feet. The bridge deck width is ninety feet with sidewalks measuring fifteen feet and the roadway sixty feet.[17] A total of forty contractors worked on the construction of the bridge, all under the supervision of the Arlington Bridge Commission. The bridge foundation was built by H.P. Converse and Company, with the superstructure by the Hunkin-

---

[14] Sue A. Kohler, The Commission of Fine Arts: A Brief History 1910-1984, (Washington, D.C.: Commission of Fine Arts, 1984), 16.

[15] Kohler, 16.

[16] ibid, 18.

[17] John L. Nagle, "The Arlington Memorial Bridge," The Military Engineer. (1928): 155.

Conkey Construction Company.[18] To obtain greater quality control, the granite for the bridge was purchased by the government and supplied to the contractor free.[19] The ring stones in the arch are load bearing, all other granite is used as veneer or ornamentation. The bridge is white in color to match the Lincoln Memorial and has a bush-hammered finish. The granite below the spring line is from the Stone Mountain Quarry in Georgia with all other granite coming from the Mount Airy Quarry in North Carolina. Most of the ornamentation on the bridge is made of granite. At each arch, except the bascule, there are bas relief eagles which face into each arch and are surrounded with a wave border. These discs measure twelve feet across and have fasces on each side. The keystone in each arch which is over water, not including the bascule span, is a six foot bison head. At the Arlington terminus of the bridge are two pair of pylons with eight foot eagles on top. The sculptor for all of this ornamentation was Paul C. Jennewein.

The bascule span was designed to blend with the style of the bridge. The fascia is built of ornamental pressed metal and, until recently was painted to match the granite; creating the illusion that the draw span did not exist. Out of six companies who entered into a design competition for the bascule span, Strauss Engineering Corporation was selected to design the structure with the Phoenix Bridge Company as builder.[20] The span is 216 feet long, with each of the counterweights weighing 5,000 tons.[21] Due to space constraints in the interior of the bridge, the counterweights could not be made of ordinary concrete. The weight of the concrete was raised to 271 pounds per cubic foot, which was done by adding steel punchings and swedish iron ore to the concrete mixture.[22] The span was able to open in sixty to ninety seconds.[23] Due to decreased shipping traffic on the Potomac, and the later down river construction of a fixed, low-clearance bridge, the bascule span has been permanently fastened in the closed position.

Most of the decisions regarding the bridge, design and otherwise, went smoothly. However, the lighting of the bridge was one of the topics that remained undecided for a period of almost four years. Aesthetics and engineering were in conflict over the subject of light standards for the

---

[18] Commission of Fine Arts, Arlington Memorial Bridge, Parkway Approach, Inscription for First Panel. Drawing Number 2A3-15.

[19] Drawing, 2E3-19

[20] Nagle, 156.

[21] D.H. Gillette, "The Arlington Memorial Bridge," American Civic Annual, 83.

[22] C.C. Keyser, "Designing Concrete for Weight of 271 Pounds Per Cubic Foot," Journal of the American Concrete Institute, Volume 3, April 1932.

[23] Myer, 20.

bridge. Many different styles and heights of light posts were tried but between the architect, the engineer, and the Commission a common decision could not be made. William Kendall had designed a lighting standard but due to economic conditions at the time these were never constructed. Kendall's design came amidst several other suggestions and proposals regarding the lighting on the bridge; with the subject of neon being brought up twice! As a temporary measure it was decided to use light standards that were typical to the streets of Washington to light the bridge. Although temporary, these lights, designed by Frances D. Millet still light the Memorial bridge today.[24]

The Washington terminus of the Arlington Bridge is concluded with a pair of statues designed by Leo Friedlander which depict the Arts of War, namely Valor and Sacrifice. Coordinating with this pair are the Arts of Peace which punctuate the Rock Creek and Potomac Parkway at the Memorial Circle. Originally to be carved of granite, then of marble, these four statues were cast in Italy of bronze and then flame gilded with mercury and gold. Standing nineteen feet high these statues were set atop pedestals ornamented with carved wreaths and thirty six stars which represent the states of the Union at the end of the Civil War. These statues cost two hundred thousand dollars and were presented to the United States by the people of Italy. Their dedication on September 26, 1951 brought work on the Memorial Bridge to a conclusion.

[24] Kress-Cox Associates, P.C., Historic Structures Report Arlington Memorial Bridge, (Washington, D.C.: 1986), 119-126.

Bibliography

Borman, Henry H. Bridges. New York: McMillan Publishing Co., 1934. Located at Martin Luther King Public Library (MLK), Washingtoniana Room (WR), Washington, D.C.

Commission of Fine Arts. Drawings for Arlington Memorial Bridge. Located at National Capital Region Park Headquarters, Washington, D.C. Also located at the National Archives, Cartographic Division.

Department of Highways. Washington Bridges Historic and Modern. March, 1956. Located at MLK, WR.

Foley, Connie. River Port and Capital: The Architectural and Natural Landmarks of Washington. U.S. Department of the Interior, 1965.

Gillette, D.H. "The Arlington Memorial Bridge." American Civic Annual. (1932): 81-83. Located at MLK, WR, in file: Bridges, Arlington Memorial, 1895-1918.

"Government Engineers Incorporate Unique Features in Design of Creosoted Fender System for Arlington Memorial Bridge." Wood Preserving News. Volume IX Number 4, (April 1931): 42-44.

Heine, Cornelius W. A History of the National Capital Parks. U.S. Department of the Interior, 1953. Located at MLK, WR.

Keyser, C.C. "Designing Concrete for Weight of 271 Pounds per Cubic Foot." Journal of the American Concrete Institute. Volume 3 Number 8, (April 1932): 525-529.

Kohler, Sue A. The Commission of Fine Arts: A Brief History 1910-1984. Washington, D.C.: The Commission of Fine Arts, 1984.

Kress-Cox Associates, P.C. Historic Structures Report Arlington Memorial Bridge. Washington, D.C.: Kress-Cox Associates, 1986. Located at George Washington Memorial Parkway Headquarters, Turkey Run, Virginia.

Myer, Donald Beekman. Bridges and the City of Washington. Washington, D.C.: The Commission of Fine Arts, 1974.

Nagle, John L. "Draw Span of Arlington Memorial Bridge." The Military Engineer. Volume XXII Number 126, (November-December 1930): 518-522.

______. "The Arlington Memorial Bridge." The Military Engineer. Volume XX Number 110, (March-April 1928): 154-160.

Newton, Norman T. Design on the Land. Cambridge, Massachusetts:

Belnap/Harvard Press, 1971.

Schuyler, Montgomery. "'Monumental' Engineering." The Architectural Record. (October, 1901): 615-640.

Templeman, Eleanor Lee. Arlington Heritage. Privately published by the author, 1959.

"The Memorial Bridge Competition." The Engineering Record. Volume XLI Number 16, (April 21, 1900): 361-369.

"The Modified Design for the Memorial Bridge over the Potomac at Washington." The Engineering Record. (October 13, 1900): 339.

U.S. Department of Transportation. Final Construction Report, District of Columbia Bridge Repair. Federal Highway Administration Project No. 15A2, 1977. Located at U.S. Department of Federal Highways (Fed. Hwys.), Arlington, VA.

U.S. Department of Transportation. Final Construction Report, Arlington Memorial Bridge and Approach Repairs, Painting of Bascule Span and Fascia Plates. Federal Highway Administration Project No. 15A3, 1977. Located at Fed. Hwys.

Washington Evening Star. Located at MLK, WR.

Washington Post. Located at MLK, WR.

Washington Sunday Star. Located at MLK, WR.

Whitney, Charles S. "Plain and Reinforced Concrete Arches." Report of Committee 312 Journal of the American Concrete Institute. Volume 12 Number 1, (September 1940): 1-26.

Addendum To
ARLINGTON MEMORIAL BRIDGE
(Memorial Bridge)
Spanning Potomac River between
Lincoln Memorial and Arlington
Cemetery
Washington
District of Columbia

HAER No. DC-7

HAER
DC
WASH,
563-

PHOTOGRAPHS

Historic American Engineering Record
National Park Service
Department of the Interior
P.O. Box 37127
Washington, D.C. 20013-7127

ADDENDUM TO:
ARLINGTON MEMORIAL BRIDGE
(Memorial Bridge)
George Washington Memorial Parkway
Spanning Potomac River between Lincoln Memorial & Arlington National Cemetery
Washington
District of Columbia County
District of Columbia

HAER No. DC-7

HAER
DC
WASH,
563-

PHOTOGRAPHS

PAPER COPIES OF COLOR TRANSPARENCIES

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C St. NW
Washington, DC 20240

ADDENDUM TO:
ARLINGTON MEMORIAL BRIDGE
(Memorial Bridge)
George Washington Memorial Parkway
Spanning Potomac River between Lincoln Memorial & Arlington
National Cemetery
Washington
District of Columbia

HAER DC-7
HAER DC,WASH,563-

COLOR TRANSPARENCIES

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

ADDENDUM TO:
ARLINGTON MEMORIAL BRIDGE
(Memorial Bridge)
George Washington Memorial Parkway
Spanning Potomac River between Lincoln Memorial & Arlington
National Cemetery
Washington
District of Columbia

HAER DC-7
HAER DC,WASH,563-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001

ADDENDUM TO:

HISTORIC AMERICAN ENGINEERING RECORD

ARLINGTON MEMORIAL BRIDGE
(Memorial Bridge)

HAER No. DC-7

This is an addendum to an 8-page report previously transmitted to the Library of Congress in 2009.

Location:	Spanning Potomac River between Lincoln Memorial and Arlington National Cemetery, Washington, District of Columbia Arlington Memorial Bridge is located at latitude: 38.88743700, longitude: -77.055185. The point represents the center of the span. It was obtained in 2014 using Google Earth. There is no restriction on its release to the public.
Dates of Construction:	1926 – 1927, Design 1927 – 1932, Construction 1949 – 1951, *Arts of War* statues
Architects:	McKim, Mead & White, New York, NY; William Mitchell Kendall, Designer
Engineers:	John L. Nagel Walter J. Douglas, Consulting Engineer Joseph B. Strauss, Bascule Span Engineer
Sculptors:	Leo Friedlander, *Arts of War* statues C. Paul Jennewein, Eagle statues and bas-relief medallions Alexander Phimister Proctor, Bison-head keystones
Contractor:	Forty contractors under the supervision of the Arlington Memorial Bridge Commission
Present Owner:	National Capital Region National Park Service Department of the Interior
Present Use:	Vehicular and pedestrian bridge
Significance:	As the western link in the chain of monuments that starts at the Capitol Building, the Arlington Memorial Bridge connects the

National Mall in Washington, DC, to Arlington National Cemetery in Arlington, Virginia. Intended to connect, both physically and symbolically, the North and the South, this bridge, designed in the Neoclassical style, complements the other monumental buildings in Washington, such as the Capitol, White House, Lincoln Memorial, and Jefferson Memorial. William Mitchell Kendall designed the bridge while in the employ of McKim, Mead & White, a prominent architectural firm based in New York, and Joseph B. Strauss designed the Chicago-type bascule span to compliment the bridge's granite-faced masonry spans. It was one of the largest and heaviest Chicago-type bascule spans when built, and, unlike most such bridges, its novel design located all structural elements and mechanical equipment completely below the deck so not to mar the monumental aesthetics of the bridge.

Historians: Elizabeth M. Nolin, 1986
J. Lawrence Lee, Ph.D., P.E., 2014

Project Information: This project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. The Heritage Documentation Programs of the National Park Service, U.S. Department of the Interior, administers the HAER program.

A historic structure report, brief report, and photographs of the Arlington Memorial Bridge were completed during 1986-88. This phase of the recording project, conducted during 2013-14, brings the historical report up to date and adds measured drawings of the bridge, along with additional photographs. It was conducted under the general direction of Richard O'Connor (Chief, Heritage Documentation Programs and Acting Chief, HAER). J. Lawrence Lee (HAER Engineer-Historian) supervised the project. The recording team consisted of Brianna Kraft and Julia Rine, assisted by Ashley Walker and Pavel Gorokhov (HAER Architect Interns). Paul Davidson, Dana Lockett and Jason McNatt performed LIDAR scanning. Jet Lowe and Todd Croteau (HAER Photographers) produced the large-format photographs. This project was sponsored by the George Washington Memorial Parkway, National Capital Region, National Park Service; and funded by the Federal Highway Administration.

Contents

Introduction

The Arlington Memorial Bridge, begun in 1926 and opened for traffic on January 18, 1932, is a major element of the system of public buildings, parks, memorials, bridges, and streets that constitutes the monumental core of Washington, DC, and that gives unity and focus to what has become a large metropolitan area. Although less well-known as an individual symbol of the city than the White House, Capitol Building, Washington Monument, or Lincoln Memorial, the Arlington Memorial Bridge is nevertheless an integral component of the complex of sites and vistas—of classic monuments in green parks—that is the national and international image of the capital city of the United States of America.

A now-indispensable part of the modern transportation system of the National Capital Region traversed daily by thousands of local residents and visitors, the Arlington Memorial Bridge is so suited to its site that it seems to have always been where it is, uniting the equally timeless Lincoln Memorial and great lawn of the National Mall with Arlington National Cemetery and the historically rich landscape of Virginia. In both physical and visual dimensions, the bridge extends the grandeur and processional qualities of the Mall across the Potomac River to the historic site of Arlington National Cemetery. A sense of permanence and appropriateness for the site is at the heart of the bridge's success as both a monument and a functional structure. From the day it was opened for traffic, the Arlington Memorial Bridge became both a statement of the growth of a metropolitan city and a link that enabled and encouraged extensive, region-wide development.

The Arlington Memorial Bridge was but one part of a larger project to construct a formal connection and entrance to Arlington National Cemetery, a connection to the Mount Vernon (now George Washington) Memorial Parkway, an attractive Washington shoreline with a formal entrance to the Rock Creek and Potomac Parkway, and a Watergate for formal entry to the city from a vessel. Almost all of these elements originated with what was known as the McMillan Plan of 1902, and the Arlington Memorial Bridge Commission (AMBC) faithfully executed it three decades later. While all of this construction and extensive landscaping was integrated into a unified whole, this report is solely concerned with the Arlington Memorial Bridge. Other documents, including Elizabeth Nolin's 1986 *Historic Structure Report: Arlington Memorial*

Bridge, and other sources cited herein contain information on other structures and landscaping built as part of the larger project.

To fully understand the decision-making process and how it changed during the bridge's design and construction period, it must be remembered that the economic conditions in the United States changed drastically after the October 1929 stock market crash that initiated the Great Depression. The Arlington Memorial Bridge, which had taken so long to come to fruition, began amid a spirit of exuberant optimism, but the project was completed as the economy steadily worsened between 1929 and 1932. After 1929, every expenditure was re-examined, adding yet another layer of complexity to an already complex endeavor. It is a tribute to its dedicated proponents that the project continued without interruption through this difficult time.

Significance

To a casual viewer who sees only the deck of the Arlington Memorial Bridge while driving, riding, or walking across it, this may seem to be little, if anything, other than a utilitarian urban structure, but this perception is far from accurate. This bridge holds particular significance in both cultural history and engineering history arenas in ways that apply to no other bridges in the National Capital Region.

The Arlington Memorial Bridge is commonly cited as "Washington's best-looking bridge," or some phrase to that effect. While the Francis Scott Key Bridge between Georgetown and Rosslyn is an aesthetically pleasing structure thanks to a very attractive design concept and satisfying proportions, it features none of the memorial embellishments or the engineering finesse exhibited by the Arlington Memorial Bridge. This should not be seen as a criticism of the Key Bridge, which was—and remains—an excellent bridge for its site, but rather as praise for the additional decorative and engineering achievements needed to produce a bridge that would not only be a practical crossing of a navigable river, but also be a fitting extension of the National Mall from the revered Lincoln Memorial to the poignant grounds of the Arlington National Cemetery.

William Mitchell Kendall's design achieved these goals, and he included an abundance of symbolic details that memorialize the United States and the legions of men and women who have taken up arms to defend the nation and its central principles. The location of the bridge

between Washington and Virginia forms a symbolic and physical link of reconciliation between the states of the Union and Confederacy following a horrendous war. The Arlington Memorial Bridge is perhaps the most appropriate memorial to that conflict, since few nations so bitterly divided have ever reunited and moved forward increasingly as one. While there are scores of monuments at battle sites recognizing those conflicts and the services of individual units, no other memorial to the Civil War inherently commemorates its ultimate *resolution* in such a grand fashion.

In both the nature and placement of the bridge's ornamentation, Mitchell, with strong input from several interested parties, accomplished a design where the abundance of ornamental details in no way marred the graceful appearance of the structure. Like the Key Bridge, the Arlington Memorial Bridge is an inherently beautiful structure that enhances its site rather than detracts from it. Always desirable in a prominent bridge, this may seem to be a deceptively easy task to the uninitiated, but the relatively few bridges that achieved this level of aesthetic excellence over the centuries furnish ample evidence to the contrary.[1]

The sculptural ornamentation of the bridge, much of which can only be appreciated from the river or along its shores, consists of intrinsically American elements that were designed by American artists. Eagles are found alongside the Columbia Island entrance and on the sides of each river pier and abutment. The eagles carved on the piers are each flanked by a pair of *fasces*, a classical symbol of strength constructed from many small components and epitomizing the nation's motto, *E Pluribus Unum*—out of many, one. The outward facing of each blade forms a reaffirmation that America's strength would be used to defend the whole nation from outside and not to again focus that strength internally. All of the eagle statues are arranged in pairs. On the piers their heads are turned to face each other, and those on the western pylons face outward. Both postures represent mutual guardianship and cooperation.

The Arlington Memorial Bridge was built as one portion of a grand plan to not only link the Mall and Arlington Cemetery, but also to formalize the Washington shoreline, provide

[1] While an excellent architect, on his own Kendall likely would not have been so successful. His original design included statues above the balustrades at each pier and massive towers beside each entrance. Initially, he felt that the statues could hold open torches to illuminate the bridge at night, and he continued to argue for some of these features throughout the project. Fortunately, saner heads and economic considerations eliminated such overt architectural statements that, viewed in retrospect, would probably have been garish at best!

connections to the new Mount Vernon Memorial and Rock Creek and Potomac parkways, and develop man-made Columbia Island into an appropriate park. All of this was built to coordinate with, but not eclipse, the existing monuments, particularly the Lincoln Memorial. Accordingly, a low-level design was essential, even though that introduced the very-difficult problem of maintaining navigation through to Georgetown. Equally essential was a surface finish that complemented the existing memorials; as a result, most visible surfaces of the Arlington Memorial Bridge are faced with ashlar granite.

In and of itself, the bridge is a memorial, but it has also been a vital part of countless funeral processions that have conveyed honored American service- and statespersons to their final resting places in Arlington National Cemetery. Most are unknown to the general population, but a few, including assassinated President John F. Kennedy, garnered nation- and worldwide attention. One convoluted procession fraught with problems and delays served as the catalyst that initiated the bridge's funding and construction, and it is now difficult to imagine a processional from the Capitol to Arlington across any other bridge.

In addition to its unique cultural heritage, the Arlington Memorial Bridge possesses similarly unique engineering significance in at least two areas. Though finished in granite, the masonry portions of the bridge have a structure of reinforced concrete. While Kendall favored an all-granite bridge, the cost would have been prohibitive, even if a sufficient quantity of stone could have been found. Thus, the engineers decided to employ a concrete core. The technology was known at the time, but analysis of the open-spandrel design revealed that the interaction between the deck, cross walls, and arch of each span was more efficient structurally than had been predicted. The structure actually could have been somewhat lighter in weight with no compromise in strength. With construction underway, no major changes were made to the design, but the results influenced the design of many subsequent bridges.

Support and anchorage of the ashlar granite covering the sides of the spans was a crucial element, and the engineers used an innovative method of accomplishing this. The weight of the stones on each span is not born by the concrete core, but rather by a true arch of granite *voussoirs* along the arch intrados. Concrete backing walls were poured after the granite was in place, but they only furnish lateral stability. The *voussoirs* arches convey the weight of the granite directly to the foundations. Few bridges have been driven by aesthetic requirements as much as the

Arlington Memorial Bridge and seemingly minor aspects such as this made its construction a practical and reasonably economical endeavor.

Nowhere did the aesthetic demands of this bridge affect the design more than in the design of the bascule span. Draw bridges of any type have rarely been recognized as notably attractive structures. With a large, heavy moving span and widely varying live loads when opened or closed, design engineers sought reliability and practicality. Ornamentation meant additional weight, and the type of movable span, i.e. vertical lift, bascule, or swing, selected largely dictated how its structure and mechanism would look. Almost all large movable spans were some form of utilitarian truss structure. All of the early concepts for the Arlington Memorial Bridge featured towers that hid the machinery, but the massive towers were unacceptable visual intrusions, as were the truss structures.

Noted bridge engineer Joseph B. Strauss adapted a type of bascule bridge he had designed primarily for the City of Chicago into a draw span that blended with the masonry portions of the bridge in a very unobtrusive manner. The Arlington Memorial Bridge required a draw span that was unusually long and wide, and this, along with the structural adaptations needed, made it quite heavy as well. Strauss chose to use two mirror-image leaves to optimize weight, but they were still subjected to high forces from wind when open. Strauss's design was much more complicated than his earlier Chicago-type bascules, but he succeeded in getting all of the span's structure, its drive machinery, counterweights, and even its control house completely below the bridge's deck. The span's steel structure formed an arch that emulated the masonry arches, and he designed a fascia that enclosed each side and concealed the truss. The final product, painted to match the granite, complimented the masonry spans well.

Several innovations were needed to make this a success. No previous Chicago-type bridge had *all* of its structure below deck level, and accomplishing that involved significant alterations to the basic truss design in both the main arches and in the lateral braces. The limited space available within the abutments limited the size of the counterweights, even though they were among the heaviest built to that point. A special mix of concrete, steel punchings, and—uniquely—finely ground iron ore was developed to obtain the required density. The counterweights also had to be articulated to the truss in order to move properly within the abutments, an uncommon, but not unique, complication. The need to conceal the operator's

house, typically located on a tower above the deck to provide clear views of the waterway, required more complex controls than usual, as well as a pair of semi-concealed cabins integrated into the railing for deck-level personnel. With ordinary traffic warning fixtures unacceptable to the Commission of Fine Arts, who governed on aesthetic matters, a unique arrangement of warning lamps on pickets rose vertically from the deck to warn traffic to stop. These were flush and virtually invisible when recessed.

Almost all of the engineers involved in the bridge's design strongly favored a bridge with no draw span at all, believing that navigation to Georgetown was declining. However, once the decision to include a draw span was made, Strauss produced a cutting-edge design that, while unique, could be built using standard techniques and materials of the era. The Arlington Memorial Bridge's bascule span survives today as a rare example of engineering design to satisfy unique specifications with techniques that were, by today's standards, quite limited.

Description

The Arlington Memorial Bridge is a Neoclassical, multi-span, deck-arch, vehicle-and-pedestrian bridge. The main portion across the Potomac River consists of nine arches—a double-leaf, steel bascule span in the center with four granite-faced concrete arches on either side. The approaches at each end include smaller masonry-arch spans over roadways along the riverbanks. Except for minor differences between the shore abutments, the bridge is symmetrical about its center. The masonry superstructure of the over-water portion of the bridge is supported by an abutment on each shore, six piers—three per side—and two abutments between the masonry and bascule spans. Each of the two mid-river abutments bears all of the dead and live loads of one bascule leaf and those from one end of the adjacent masonry span. Two gilded-bronze equestrian statues entitled *The Arts of War: Sacrifice* and *Valor*, by American sculptor Leo Friedlander, are mounted on matching pedestals that flank the Washington entrance. The Columbia Island entrance passes between two matching 30'- $8^1/_2$"-high granite pylons capped with 5'- 7"-tall granite eagles by American sculptor C. Paul Jennewein. Each of the piers and central abutments feature sculpted granite, bas-relief eagle and *fasces* ornamentation, also executed by Jennewein, on both sides. Each masonry arch keystone is decorated with an

approximately 6'-foot-tall bison head sculpted by noted American *animalier* Alexander Phimister Proctor. The height varies to suit each arch.

The bascule span has a two-piece (one per leaf), steel fascia on each side that encloses the span's steel truss structure. It repeats the arch form, but does not attempt to replicate the ashlar granite. It is instead decorated with ribs, coffers, and raised details that complement the masonry arches in an unobtrusive manner. Except for two small, recessed guard cabins that are integrated into the north-side balustrade, no portion of the bascule structure or mechanism is visible above the deck when the span is closed. Even the traffic warning lights for the draw span descended vertically into the deck and out of sight when not in use, illustrating the great degree to which aesthetics influenced the bridge's design.

Including the pedestals and pylons at its entrances, the Arlington Memorial Bridge measures 2,138' in length. The total width of its deck is 90', consisting of a 60'-wide, six-lane roadway flanked by 15'-wide sidewalks. The roadway follows a parabolic vertical curve from an elevation of 34' above the mean low water (m.l.w.)[2] level at the shorelines to 45' at its center, giving the bridge a graceful camber. All arches over the water are similarly proportioned, but they increase in width from 166' adjacent each shore to 184' for the central, bascule span. Thus, they remain in proportion to their increasing height. The spring line for all of the arches is 10' above m.l.w.[3]

As with the arches, all piers are similar in design, but vary slightly in dimension to maintain the bridge's aesthetic proportions. They rest on concrete foundations, or substructures that, in turn, rest on bedrock approximately 40' below m.l.w. The upstream (north) end of each pier's cutwater is a curved wedge, while the downstream end is semi-circular, giving each pier a boat-shaped plan. The cutwaters extend beyond the width of the bridge faces by approximately 20' on the north side and 15' on the south, varying slightly to suit the proportions of each pier. The two bascule abutments are similar in appearance to the piers, but are more massive and rest on correspondingly larger foundations. Their internal configuration, each of which

[2] Mean low water is considered to be the 0'- 0" reference elevation for the bridge.
[3] A variety of sources report dimensions that vary somewhat, and any correlation of these minor variations would be difficult at best. Unless otherwise noted, dimensions and structural/mechanical details of the bridge herein were gleaned from Arlington Memorial Bridge Commission (AMBC) construction drawings. Copies are maintained by the National Archives and Records Administration (NARA) at College Park, MD, in Record Group (RG) 79, filed by the AMBC drawing numbers. A box of index cards listing them is filed as RG 79.6.7. Specific drawings are herein identified by drawing title and AMBC drawing number.

accommodates the support structure and machinery for one bascule leaf, is entirely different from that of the piers; however, the two abutments are essentially mirror images that differ only in interior details. The bascule abutment foundations, including cutwaters, are 136' long (north-south) and 47' wide at the top, widening to 60' at the bases, and the intermediate piers measure approximately 130' by 40', increasing slightly in width toward mid span.

Each of the bridge's main spans consists of a reinforced-concrete barrel arch with side spandrel walls that are faced with ashlar granite. The thickness of this arch decreases from 6' - 0" at each end to 2' - 3" at its center, and it is reinforced with 1"-square steel rods. Eighteen concrete cross walls that vary between 1' - 6" and 2' - 0" in thickness support the deck above the arch. Each span was poured in keyed segments so that it would function as an integral structure when complete. The ends of each arch bear on matching faces of its supporting piers (or abutments), thus transferring the span's dead and live loads to the piers and foundations.[4] The interface angles were designed to ensure that the horizontal dead load on one side of a pier balances that on the other, even though the two spans have slightly different sizes and weights. Expansion joints at each pier-span interface provide the flexibility needed to accommodate thermal expansion and contraction.

Since the bridge has 11' of overall camber, the arches are asymmetrical with one end higher than the other. Thus, the cross walls of one end of each arch are taller than their counterparts on the other end. To closely equalize cross wall weights on each side, the taller walls have openings to reduce their volume of concrete and, therefore, compensate for their additional height. An opening along the center line of every cross wall provides access to all interior arch areas and surfaces, and two small, diamond-shaped openings near their upper corners furnish a pathway for electrical cables.[5]

Each of the piers consists of 2'-thick reinforced-concrete outer walls faced with cut granite stones and four, 2'-square, inverted-**V**, reinforced-concrete internal braces. These braces are parallel and oriented in the bridge's longitudinal direction. Abutments 1 and 4 (at the east and west shores, respectively) feature two panels of similar design. Access to the interiors of the piers and masonry spans is via rectangular manways set in the sidewalks at each pier. Beneath

[4] The term "dead load" refers to a constant force due to the weight of the structure itself. A "live load" is any external, variable force on the bridge, such as forces due to traffic, wind, river flow, and ice.
[5] The specific arrangement of each cross wall is shown on "Cross Walls and Spandrel Walls," AMBC Drawing No. 2E5-3.

each of the steel cover plates, a ladder affixed to the internal sidewall extends down to the top of the pier's foundation. The interior spaces of the adjacent arches can be accessed for inspection and maintenance from there through the cross wall openings. Cast-iron drain pipes in the arch and pier interiors route storm water from catch basins along the curbs to the river. Electrical wiring also extends through these interior areas to supply power to the bascule span machinery (from the east side) and to distribute power to the lampposts and warning signals. Recent inspections have revealed other wiring of unknown origin and function in the interior spaces as well.

In June 1985, the Federal Aviation Administration installed a unique "Guidance Light System" on four Potomac River bridges (Key, Roosevelt, Memorial, and 14th Street/Mason) to provide reference points for pilots on landing approach to Ronald Reagan Washington National Airport from the north, where they are required to closely follow the river's path. This system is distinct from the 2,400' approach light system between Gravely Point and the end of Runway 19. The strobe lights on the bridges are normally off, but flash as needed when visibility is limited, so this system remains energized.[6]

The approach spans, which include the roadway overpasses for Ohio Drive and the northbound George Washington Memorial Parkway, have arch proportions and an internal design that differs from that of the main spans. The internal construction of the roadway spans utilizes steel-and-concrete arches as the primary structural form. Because of their smaller size, higher spring-line elevation, and roadway clearance requirements, these arches have a shallower rise-to-run ratio than the river spans. Internally, steel Warren arch-trusses bolster the concrete arches. Concrete cross walls—thicker deck slabs are adequate in the central portions—above the arches support the deck, and the arch intrados of each is faced with concrete blocks cast to resemble cut stones that present an attractive appearance to motorists passing below. The approach panels adjacent to the roadway arch spans—three panels on the east end; one full and one short panel on the west end—have essentially the same structural design as the river piers, with vertical concrete walls and parallel, inverted-**V**, reinforced-concrete braces.

All of the above structures support transverse, reinforced-concrete deck beams spaced 6'-6" to 15' on-centers (most are 8'). These deck beams are cast integrally with the deck sections so

[6] Richard Brock, Federal Aviation Administration Service Center Manager, who is responsible for maintaining this system, conversation with author, Feb. 19, 2014.

that the total depth of the 1'-thick deck and beams measures 3'- 7" at most places. (The design at the center of the two roadway arches is different to accommodate the limited space between the arch and the deck in those areas.) The current pavement is asphalt with numerous repair patches and worn areas that have not been repaired. The nominal thickness of this wear layer is not known, but a $3^1/_2$"-thick wear layer was originally specified for the roadway, along with bronze castings at the toe and heel joints. The existing pavement was applied across the heel joints of the bascule span such that they are no longer visible. The toe joint where the leaves meet remains intact. The sidewalks are paved with an exposed-pebble aggregate of unknown thickness. (The original specification was 4" of wear surface over the $1^1/_2$" deck.) The heel joints and toe joint remain visible across the sidewalks, but concerns about the deteriorated sidewalk support structure in these areas led to the National Park Service (NPS) installing pedestrian bridges across the four heel-joint locations that remove live loads from the worst areas as a safety precaution. For storm-water drainage, the roadway has an 8" crown, and the sidewalks slope down $2^3/_4$" toward the curbs. Catch basins with slotted covers along the curbs collect the run-off and route it to the river via 4" cast-iron pipes, although some of these are damaged or have been removed. Each river span has four catch basins along each curb, while the approach spans have three.[7]

To give the Arlington Memorial Bridge the desired monumental appearance, designer William Mitchell Kendall applied a facing of ashlar granite stones, some of them carved in appropriate motifs, to the sides of the bridge's arches and piers, and he used granite for the ornate balustrades, pylons, and pedestals. (For structural reasons, the bascule span's balustrade consists of aluminum balusters, bases, and railings shaped to match those of granite on the fixed spans.) Across the piers, solid panels and inward-facing granite benches break the balustrades on both sides. The eight large arches have granite *voussoirs* dovetailed with the concrete barrel along the intrados at each face. The two roadway arches have similar *voussoirs* attached to their structures. These *voussoirs* are load bearing, and form the main support for the granite facing above, which consists of ashlar stone laid up in mortar with some anchored to the concrete spandrel walls and others keyed to them. A $2^1/_2$" wide x $2^1/_2$" deep carved channel outlines each stone. Most stones have this channel on two of four sides, with channels in adjacent stones

[7] The current conditions of the drainage system and other components of the bridge are discussed in the Present Condition portion of this report.

completing the perimeter. On the main spans, the outer edges of the arch intrados are also faced with ashlar granite, while the remainder is smooth, but otherwise unfinished, concrete.

The pier and central abutment cutwaters are also faced with ashlar granite above the -3' elevation, including their top surfaces.[8] Above this, the granite-faced sides of each pier and Abutments 2 and 3 feature a multi-piece circular medallion with a *guilloche*-like motif around a bas-relief eagle. These are approximately 20' in diameter, and the eagles' heads are turned to alternately face right and left. This medallion is flanked by outward-facing *fasces* that extend almost the full height of the pier. The background for this ornamentation consists of ashlar blocks laid up in mortar. All of these details appear alike, but they have minor dimensional differences to suit each pier/abutment. Each side of the shore abutments has a raised, rectangular detail with no embellishment, although inscribed text was in the original plan.[9] Like the main spans, the approach spans and panels are faced with ashlar granite laid up in mortar.

The concrete used for the roadway and sidewalk deck slabs as well as the roof slabs of the machinery rooms and auxiliary generator rooms was "Class AA" concrete. Known as a "ten-bag" mix, it used ten bags of cement per cubic yard of concrete in approximate 1: 1: 2 proportions of cement, sand, and coarse aggregate and had a minimum compressive strength of 5,000 psi. A "six-bag" mix with a minimum compressive strength of 3,000 psi was used for the remaining concrete, except for the counterweight, which was constructed with a unique, high-density mix that will be discussed below.

The steel-truss bascule span's external appearance complements the masonry spans. This was achieved by facing the trusses on both sides with an ornamental fascia fabricated from $^{3}/_{16}$" rust-proof steel plates and pressed shapes. The panels so formed are fitted with decorative stars, buttons, and an ornamental cartouche at the center of the bascule span, all of which are cast aluminum. The balustrade and moldings are cast aluminum as well. This fixed-trunnion, underneath-counterweight, or "Chicago-type," double-leaf bascule span was designed by the Strauss Engineering Company of Chicago, Illinois, founded by prominent civil engineer Joseph B. Strauss, and fabricated by the Phoenix Bridge Company of Phoenixville, Pennsylvania. While similar in concept to other Chicago-type bascule bridges, all of which feature fixed

---

[8] Abutments 2 and 3 were protected from vessel collisions by timber fenders until sometime after the bascule span was fixed in place. Since they are no longer extant, they will be discussed in the History portion of this report.
[9] "Granite Facing, Pylon to Center of Arch No. 1," AMBC Drawing No.2A3-6, shows these panels were intended to have "appropriate inscriptions to be determined later," but none was ever inscribed.

trunnions and counterweights below the deck level, the Arlington Memorial Bridge's span is one of the largest and heaviest ever built, and it incorporates several novel features to meet the bridge's overall aesthetic requirements without sacrificing functional reliability**.**

This is one of the few Chicago-type bridges to have all members of its truss structure concealed below the deck. Most examples have fully exposed trusses and at least a portion of their top chords visible above the deck level. Early examples feature exposed rack teeth that extend well above the deck level on a quarter-circular structure at the heel end of each truss. This allowed their main trusses to have a simpler shape than the more-complex trusses needed for the Arlington Memorial Bridge.

While the closed span appears to be one arch span, each bascule leaf is actually a balanced cantilever structure that originally rotated about a pair of co-axial trunnions. The weight of the over-water portion of the leaf on one side of its trunnions is balanced by a concrete counterweight on the other. The primary structural elements of each leaf are two, half-arch trusses located beneath the roadway curbs (each 33' from the bridge's longitudinal centerline), with each truss having eight panels. Seven panels extend from the main trunnion out over the river, while an eighth panel, on the opposite side of the main trunnion, carries one end of the counterweight via a second trunnion. Three panels at the toe end (center of bridge) are doubled plate-girder panels, while the remaining five panels use the Warren plan. Transverse floor beams and members between the bottom chords connect the main arches. The posts, diagonals, and bottom chord are braced with diagonal members for transverse rigidity. Steel stringers bear the deck and live loads to the floor beams and, thence, the main arch-trusses. These stringers are 18" deep **CB** sections in the four panels closest to the toe, while the panel adjacent to the abutment end features 12"-deep **CB** stringers braced with Warren trusses.[10] The deck originally consisted of a $6^1/_2$"-thick concrete roadway reinforced with wire mesh, granite curbs, and $3^1/_2$"-thick concrete sidewalks with transverse reinforcing wire. The concrete was poured around transverse bulb-**L** members that secure it to the stringers. A granite step and the aluminum balustrade along each outboard edge complete the deck. A similar floor beam-deck assembly spans the open top of Abutments 2 and 3 to join the masonry deck and the heel end of the movable leaf. Two pairs

[10] A CB (Carnegie Beam) section is a historic structural-steel shape similar to a modern W (Wide flange) shape, but with slightly different dimensions. Introduced in 1927, it was produced by Carnegie Steel Co., part of the United States Steel Co. See Kurt Gustafson, "Evaluation of Existing Structures," *Modern Steel Construction* "SteelWise" column (Feb. 2007); and *Carnegie Beam Sections,* 1st ed. (Pittsburgh, PA: Carnegie Steel Co., 1927), 8-30.

of steel trunnion posts support each leaf. Each main truss bears on the center of a 31"-diameter, 8' - 9"-long trunnion, the ends of which rotated in phosphor bronze bearings supported by a pair of trunnion posts. Each trunnion post consists of a vertical member on the trunnion's vertical centerline and a brace angled 19 degrees from vertical that together form an asymmetrical ***A***. The two members of each trunnion post are secured to a common base that bears on concrete reinforced with steel, **I**-section grillages at the top of the abutment's foundation (10' - 0" elevation). To maintain alignment across the bridge, the inner trunnion posts are connected by a lateral Warren truss that also supports one end of the abutment deck stringers. The trunnion posts support the trunnion bearings with their common centerline 30' above the abutment floor (40' - 0" elevation). Each leaf's dead load of approximately 3,800 tons, including the 2,400-ton counterweight, is borne by these two trunnions and the four trunnion posts.[11] Whenever the span was not in its closed position, any live load from wind was also borne by them. With the span fully closed, the live loads—primarily from vehicle traffic—generate a moment about the trunnions. This is borne by two live-load supports at the base of the trunnion posts, 11' - 11" from the trunnions' centerline. Cast-steel bearing blocks fixed to the lower chords of the movable span bear on mating blocks that, in turn, bear on a steel pedestal and grillage set into the concrete foundation. A pair of pneumatic dampers at the base of each main truss served as a final cushion as the leaf reached its fully closed position. A second pair of pneumatic dampers under the abutment's deck cushioned and stabilized the counterweight as it reached its upper (bridge closed) position.

The counterweights—one for each leaf—are attached to the heel ends of the trusses in an uncommon manner. Unlike most Chicago-type bridges, which have a counterweight fixed to the heel end of each leaf, the Arlington Memorial Bridge required a more complex articulated design. The aesthetic requirements demanded that each counterweight fit and move completely within its abutment and remain out of sight, but the size, weight, and proportion of each leaf required a counterweight almost four times the weight typically needed in Chicago-type bridges. Earlier bascule bridges generally employed iron counterweights, but Strauss had developed a

---

[11] Frank Maguire, *Report on Bascule Span for Arlington Memorial Bridge* (Washington: David Volkert and Associates, Dec. 19, 1985). This report was prepared for Nassaux-Hemsley, Inc., and portions are quoted in Elizabeth M. Nolin, *Historic Structure Report: Arlington Memorial Bridge, Washington, D.C.* (Washington: KressCox Associates, P.C., May 2, 1986).

design for large counterweights using heavily reinforced concrete poured around a central steel frame. In the Arlington Memorial Bridge, 18"-diameter pins engage a pair of steel counterweight hangers at each end of the counterweight frame, a transverse steel truss through the counterweight's center of mass. These hangers suspend the counterweight like a pendulum from one end of the two main trusses via 17"-diameter counterweight trunnions. Opening the bascule leaf caused rotation of the counterweight trunnions about the main trunnions such that the former moved down and toward the bridge's center. While the counterweight remained suspended directly below its trunnions, it moved 10' vertically and 6' - 6" horizontally. The horizontal shift kept the leaf properly balanced throughout the opening/closing motion, as the truss's center of mass also shifted horizontally, but in the opposite direction from the counterweight. Two steel links pinned to the bottom of the counterweight frame and the trunnion post's transverse bracing completed a four-bar linkage that ensured the counterweight's orientation and stability as it moved.[12]

The space available for these counterweights was not large enough to allow them to be made of concrete with a density typical for the time (approximately 150 lb./cu. ft.); they would have been too large to fit. Accordingly, these counterweights used concrete mixed with scrap from steel punching processes and iron ore. While the former was a known technique, the large volume of steel scrap needed would have been very difficult to procure, and it would have resulted in concrete that lacked strength and durability. The addition of finely milled iron ore to the mix allowed fewer steel punchings to be used and solved the quality problems. The resulting concrete densities were 262 lb./cu.ft. for the west counterweight and 271 lb./cu.ft. for the east one. The greater density, thus weight, was needed to compensate for the weight of the two center-lock mechanisms at the toe of the east leaf, equipment not needed on the west leaf.[13]

To precisely match the weight of each leaf, each counterweight was cast with four 5' x 7' x 9' pockets. These pockets could collectively hold up to 1,960 concrete adjustment blocks that measured 1' on each side and weighed 255 lbs. As the leaf was constructed, the

---

[12] Counterweight and connection details are shown on the following drawings: "Longitudinal Section," AMBC Drawing No. 2E6-6; "Counterweight Frame," AMBC Drawing No. 2E6-33; "Outline of Counterweight," AMBC Drawing No. 2E6-34; "Counterweight Reinforcing," AMBC Drawing No. 2E6-35; and "Counterweight Trunnion and Bearing," AMBC Drawing No. 2E6-38.
[13] C.C. Keyser, "Designing Concrete for Weight of 271 Pounds Per Cubic Foot," *Journal of the American Concrete Institute* 3 (April 1932).

contractor added adjustment blocks as needed to keep the assembly in balance. Further adjustments were made at leaf completion to achieve the required balance accuracy, as well as equalize the numbers of blocks in the four pockets.[14]

All of the arch-truss, trunnion post, counterweight frame, and deck members are riveted fabrications assembled from multiple pieces of plate, **L**-section, and flat-bar steel. Although the overall design of this bridge is unique, it was designed around the most common structural components of the era, and hot rivets were the standard means of steel fabrication. In this regard, the Arlington Memorial Bridge evidences how such standard components and techniques were readily and successfully adapted to unusual structures. The various members exhibit a variety of designs and sizes that suit their specific functions within the bridge. Those with large compressive loads, like the trunnion posts and lower chords, must resist buckling, and they have large cross sections with plates and **L**s assembled into deep **I**-sections that are paired to create a member with a cross section resembling a hollow rectangle. They are typically joined with flat bars arranged in a series of **X**s known as lacing, or lattice. The lacing is riveted to the **L**-sections and to each other where they cross. Lighter-weight members were fabricated in the same fashion, but with fewer, usually lighter, components. Each member was individually designed to carry its specific loads, which vary throughout the structure.[15] Some of these members use alternating diagonal lacing bars rather than intersecting **X**s. Certain members, notably some of the transverse members between the trusses that support the deck stringers, are plate girders fabricated from plates and **L**s. The ends of the truss members are connected using pieces of plate known as gussets that are shaped to suit each particular location. At high-stress locations, as many as five layers of gusset plates were used per side, with long rivets connecting them to each other and the members meeting at that point. Assembled, the members form a set of triangles throughout the truss that give it strength and rigidity without excessive weight. The trunnion posts and counterweight frames, components with heavy stresses and size constraints, were fabricated from a high-strength, low-alloy steel that was termed "silicon steel" at the time.[16]

[14] "Outline of Counterweight," AMBC No. 2E6-34.
[15] The stresses in each main member calculated by Strauss for the original design conditions, including added impact loads where appropriate, are shown on "Stress Sheet – Diagrams," AMBC Drawing No. 2E6-4.
[16] "Silicon steel" as used here, refers to steel meeting American Society for Testing and Materials (ASTM) "Specification for High Strength Structural Steel A94," with a silicon content of no more than 0.9 percent, along with manganese, carbon, and smaller amounts of phosphorus and sulfur. ASTM withdrew A94 in 1966, and this

To meet the aesthetic requirements for the bridge, which precluded open trusses that would contrast with the masonry spans, the bascule span leaves have solid fascia panels on their sides to conceal their truss structures from most viewing angles. (The bottom sides of the leaves were not covered, and the truss structure is clearly visible from a boat passing under the span.) Fabricated from $^{3}/_{16}$" “rust-proof”[17] pressed steel plates, and fitted with cast aluminum details, these fascia panels did not attempt to duplicate the granite-block exterior of the fixed spans, but instead provided the bridge’s central span with a design that harmonized with them. Each fascia panel is one half of the 184' arch, and its proportions match those of the masonry spans. Each features thirty-four rectangles arranged radially along the intrados, a series of squares and parallelograms that border the remaining area, and vertical ribs through that area. These shapes and ribs are formed steel sections that stand proud of the plate surface. Most of these ribs feature aluminum cloverleaf button detailing. The squares and parallelograms each frame an eight-point, stylized star medallion, and the intrados rectangles frame similar diamond medallions. A cast aluminum key block with shield and flower details is attached to both sides of the west leaf’s toe such that they overlap the east leaf when closed to conceal the joint between the two leaves. The fascia panels adjacent to the key block on each side contain the red-and-green-light navigation fixtures that marked the toe of each leaf and governed ship movement through the span. The bascule span balustrade forms the top portion of the fascia. This balustrade matches the design of the granite balustrade on the masonry portions of the bridge, but its components were cast in aluminum and internally anchored to the fascia structure to survive repeated opening and closing of the bascule span.

The fascia and balustrades were painted, and have been repainted several times, in a shade of light gray intended to resemble the granite facing on the fixed arches. There does not, however, appear to be an official color specification for it. Instead, the color has always been selected by the National Park Service (NPS), and it has likely changed somewhat over the years to suit hue changes in the granite, not to mention the color sense of different individuals

---

should not be confused with modern “silicon steel,” also known as “silicon-iron electrical steel” (ASTM A876), which contains about 3.5 percent silicon and much less carbon. Electrical steel is primarily used to form laminated cores for motors, transformers, and other electrical devices, not as structural steel.

[17] The term “rust-proof” is ambiguous, but “Rust Proof Steel” is the only specification shown on “Fascia and Balustrades,” AMBC Drawing No. 2E6-26. It likely refers to a steel alloy containing 10 - 15 percent molybdenum and other corrosion-resistant elements such as chromium. “Metal Details,” an unnumbered AMBC drawing of the fascia’s as-built configuration, has no steel specification.

responsible for selecting the color. Though no quantitative study has been done, the existing shade of gray appears lighter than the surrounding granite, though that may well be due to weathering of the granite.

These fascia panels are attached to half-arch, Warren trusses located outboard of, and parallel to, the main trusses. Although these are much simpler and lighter than the main trusses, they were fabricated from similar materials using the same techniques. Each fascia truss is supported from the corresponding main truss by the same cantilever struts that support the sidewalks, stabilized by nine panels of **X** braces between the two trusses along the intrados. **L**-section girts running parallel to the intrados and top chord provide attachment points for the fascia panels, which were attached with spot welds to avoid marring the surface with rivets.

Although the bascule span has not been opened since February 1961, its operating machinery remains intact, but not energized. This machinery, located on the lowest floor (13' - 0" elevation and a pit at 10' - 0" elevation) of Abutments 2 and 3, resembles that found in many bascule bridges, but its controls and operating procedure differed in several respects to suit the uniqueness of this bridge. The machinery for each leaf is the same.

Each leaf was moved by two 80-horsepower Westinghouse direct-current electric motors through a common, two-stage, speed-reducing gearbox. A differential fitted to the output shaft gear maintained the same torque to both shafts while accommodating minor variations between the two that might otherwise overstress the shafts or gearbox. The output shaft from each side of the gearbox extends approximately 24' horizontally to a 14-tooth, $16^{23}/_{32}$"-diameter (pitch diameter) gear that meshes with a 48-tooth, $57^{19}/_{64}$"-diameter gear for a third stage of speed reduction. This 48-tooth gear turned the pinion shaft and its 14-tooth, $22^{1}/_{4}$"-diameter pinion. Bolted flanges with elastic inserts connect the shaft sections and accommodate minor angular misalignments. The shafts on each side are supported by six phosphor bronze bearings. Each of the pinions meshes with a 77-tooth operating rack mounted on the centerline of one of the span's main trusses. The teeth of both the pinion and rack are 14" wide. With a radius of 24' - $4^{1}/_{2}$" from the trunnion centerline, these racks rotated the span up to 71 degrees (fully open) when turned by the pinions. As with other large rack-and-pinion applications, the faces of each pinion tooth have a compound curve that meshes with the flat faces of the rack teeth. This

configuration allows the teeth to roll past one another without sliding to minimize wear and obtain the greatest efficiency. All of this equipment is extant.[18]

The use of direct-current motors controlled by a Ward-Leonard system allowed the operator to vary the speed of the operation. The operator used a much-slower speed near the fully open and fully closed positions than for most of the operation to avoid shock from an abrupt stop. The drive was capable of raising or lowering the leaf within 90 seconds, but slowing the motion at each end of the rotation and operating the center locks and the roadway warning lights extended the typical time to about 120 seconds.[19] Limit switches caused an immediate stop at each end of the rotation if the operator were to lose control for any reason. The dead load of each leaf was well balanced by its counterweight, but live loads due to opening/closing and wind were primarily borne by the racks and pinions and conveyed via the shafts to the bearings and drive/brake mechanism. Though no longer used, all of this equipment remains in place.

In the closed position, a pair of center locks was extended from the toe of the east leaf into mating sockets in the toe of the west leaf. Each lock consists of two articulated jaws that expanded vertically to meet panels in the socket. Located at the toe of each main truss, each was driven by a $7^1/_2$-horsepower, direct-current motor through a gearbox that rotated a crankshaft 188 degrees. The crankshaft moved a horizontal rod that extended or retracted the lock's jaws, causing them to engage or disengage the mating socket. When engaged with the bridge closed and the locks properly adjusted, they prevented no more than $^1/_{32}$" of relative motion due to changes in the live load between the toes of the two leaves, thus preventing curb-like bumps for heavy vehicles and unnecessary shock loads on the bridge. A crank was provided to manually actuate each lock if needed. One three-position rotary switch on the operator panel controlled both center locks.[20]

Two machinery rooms, one for each leaf, are located on the lowest floor (13' - 0" elevation) of the abutments. In an unusual and rather impractical accommodation to aesthetics,

---

[18] For details of the drive, see "Operating Machinery," AMBC Drawing No. 2E6-39; "Operating Rack and Buffer," AMBC Drawing No. 2E6-40; and "Herringbone Speed Reducing Unit," AMBC Drawing No. 2E6-42

[19] C.O. Sherill to McKim, Mead & White, July 3, 1923, NARA RG 72.

[20] The jaw-type center lock was a device invented by Joseph Strauss in an attempt to improve on the reliability of the tapered-bar interlock in common use at the time, particularly in long-span bridges. It proved to be expensive to maintain, and the tapered-bar device remained the preferred choice for movable-bridge designers. See "Center Lock," AMBC Drawing No. 2E6-44 and "Center Lock Machinery," AMBC Drawing No. 2E6-45.

the control room is adjacent to the east side machinery room, rather than in a tower above the deck. While it cannot be seen from most exterior vantage points, the location denied the operator the usual, unobstructed view to both sides of the bridge available from an elevated tower. Thus, he had to rely on two other persons, known as overseer and guard, who were stationed in small cabins integrated into the north balustrade and recessed approximately 3' below the sidewalk level, much like a baseball dugout. The overseer's cabin is on Abutment 2, and the guard's cabin is situated on Abutment 3. Both measure 4' - 5" x 12' - 0" inside. Two small, bronze-framed windows in each cabin furnished a limited view up the river and across the roadway in the downstream direction. A similar third window in the bronze access door was more for decoration than function, as the view through it encompassed little more than a portion of the sidewalk. Where this arrangement required at least three people to operate the bridge, many movable bridges needed only one. Even so, the overseer had to step outside the cabin to get a clear view of any approaching boat that had sounded its whistle three times, the standard signal to request the opening of a drawbridge.

The overseer and guard control panels are still in place in their respective cabins, and most of their controls remain intact. The guard's panel has only one rotary switch to cause an emergency stop of the draw spans' motion and an intercom handset (no longer extant). The overseer's panel includes an emergency stop switch, the warning light rotary switch, two selsyns that indicated the opening angles of the leaves, four indicator lights and an intercom handset (no longer extant).[21] Each of these panels originally featured two permanently-mounted brass lamps with green glass shades that illuminated the panel and cabin, but only a portion of the mounting fixtures for these remain. An electric resistance heater on one side of each panel heated the cabin during winter.

A steel spiral staircase descends from each cabin level to a floor at the 33' - 8" elevation. A toilet room is located at this level in Abutment 2 only. Straight staircases with steel frames and wooden treads descend from there to the 22' - 4" and 13' - 0" elevations of both abutments,

[21] A "selsyn" (a portmanteau of "self" and "synchronizing") is an electrical system that causes the rotational motion of one device to be replicated on one, or more, remote devices. In this instance, opening the bridge rotated the armature of a rotary transformer. This rotation generated electric currents in its Y-connected windings that varied with the armature's position. A similar receiving device connected to the transmitter used these currents to identically rotate its armature and an attached pointer. Thus, the pointer moved in unison with the bridge leaf. The Arlington Memorial Bridge had a separate selsyn system for each leaf, with their transmitters mounted at the northeast and southwest outer trunnion bearings.

and a second short staircase from the 33' - 8" elevation of each goes down to a network of steel walkways that provide access to the trunnions, center locks, and various electrical switches for one leaf. Two of these walkways are located between the main and fascia trusses on each side, and they are connected by a transverse walkway having sections mounted on both the moving and fixed structures. Short extensions provide access to specific points for inspection and maintenance. A separate walkway is located above and parallel to the transverse walkway, but offset from it by about 3'. A later addition to provide access to the heel break gutter, it has a welded steel frame and wooden treads. It has no permanent means of access and was likely reached via a portable ladder.

In another nod to aesthetics, the Arlington Memorial Bridge featured a unique system to warn motorists when the draw span was to open. Rather than the typical, but architecturally unacceptable, arrangement of gates with flashing lights that rotated from a vertical to a horizontal position to stop traffic, this bridge employed lights mounted atop pickets that rose out of the pavement. One was located in the center of each lane on both sides of the bascule span. When inactive, the only indications of their existence were small iron disks flush with the surface. Controlled by the overseer, these pickets rose 3' when activated, and two red lamps at the top of each one alternately flashed to warn motorists that the draw span was about to be opened. They were raised in groups of three, with those in the on-coming lanes on each side raised first, and the ones in the off-going lanes raised only after all traffic had cleared the bascule span. A switch on the overseer’s panel controlled all twelve of these lights, plus a pair of fixed red lights and a gong mounted on a lamppost on each side’s on-coming sidewalk. A motor-driven rotary contactor timed the flashing of the lights. Activating the warning lights also caused a gong to sound in the operator’s control room to alert him that an opening was imminent. The earliest drawings of the bridge indicate that these warning lights were to be raised and lowered manually by the overseer on one side and the guard on the other using a pair of handles located in a well recessed into the sidewalk. Each person would open a cover and pull one handle up to raise the on-coming-lane pickets, and then pull a second handle up to raise the off-going-lane pickets after all traffic had cleared the bascule span. They lowered these handles to retract the pickets after the bridge returned to its closed position. A 1938 drawing details a modification to add electric motors, gearboxes, and vertical racks to raise and lower the warning light pickets,

but the lack of any drawing title or number and the lack of any control panel switch to activate the motors suggests that the modification may never have been made, though it certainly would have made the overseer and guard's jobs easier.[22] In any event, the sole remaining remnant of this system is one badly deteriorated handle that has survived in its well. No other components are known to exist.

These pickets did not provide a strong physical barrier that would prevent a vehicle from going through and beyond them. They only identified the safe limit for vehicle travel, but one intrinsic feature of the bridge did furnish just such a barrier. The heel end of each bascule leaf was located 6' - $2^1/_2$" from the trunnion toward the center of the bridge. This resulted in the leaf's heel moving up and back over the fixed deck when the span opened so that the leaf itself formed a solid barrier. Had the heel been on the shore side of the trunnion, as is the case for most Chicago-type bridges, it would have moved down instead and left an unattractive, possibly dangerous, pit with the span open.

The bridge's opening and closing operations were controlled from a control room in Abutment 2 at the 13' - 0" elevation. This control room and its adjacent machinery room have windows that furnish a clear view of the area under the bascule span, but neither has windows that offer useful views up- or down-stream. Two rotary drum controls on the operator panel, one for each leaf, served as the operator's main control of the opening and closing process. A six-circuit rotary switch rotated by a large handle, each controller actuated that leaf's dual drive motors and their respective service brakes. Each controller has a center, "off" position and five detented positions to each side. Turning the handle clockwise from center opened the leaf, with an increasing speed at each successive notch. Counter-clockwise rotation from center lowered the leaf in the same manner. In the "off" position, a pair of solenoid-released service brakes, one on each motor shaft, stopped that leaf's motion. Normally engaged (applied) by springs, these brakes, known as solenoid brakes, were released by energizing their solenoids, making them either fully "on" or fully "off." A second, smaller rotary switch for each leaf controlled four similar but larger emergency brakes on extensions of the reduction gear's intermediate shaft. Each has an "off" position and four detented positions that sequentially applied emergency brakes A, B, C, and D as selected by the operator. While each was either "on" or "off," the

[22] An unnumbered, untitled drawing of such a modification marked "W.S.S. 6/6/32," with views labeled "Assembly of Roadway Warning Lights" and "Operating Unit" is available in NARA, RG 79.

operator could use the emergency brake and motor controller together to achieve fine control over the leaf's speed, giving him some ability to account for differences in wind velocity. Turning an emergency stop switch on any control panel engaged all emergency brakes and stopped the motors immediately.[23] This panel remains *in situ*, although some components are missing.

In addition to its two large rotary switches that control the leaf drive mechanisms, the panel includes dual selsyns that displayed the opening angles of each leaf; switches for various lights, navigation signals, motor-generator set, and emergency generator; a rotary switch for the center locks; a rotary emergency stop switch for each leaf; and fifteen indicator lights. A wall-mounted electric resistance heater furnished heat. An intercom handset mounted on the panel's right side provided communication with the overseer and guard when needed, but the normal operating sequence was adequately communicated with a gong and indicator lights on the panels. The cover and handset are missing from the operator's intercom set, but nothing of the intercom sets remain at the other two panels.[24]

A floor-mounted panel to the operator's left holds volt and amp meters that indicate the condition of the electrical system and adjustment knobs to set the precise DC voltage from the motor-generator. The selsyns on the panel were backed up by two wall-mounted mechanical indicators. An extension of the pinion north-side shaft of each leaf turned the input shaft of a 20.8 to 1 right-angle gear reducer, which, in turn, rotated a pair of shafts via a second right-angle gear box to actuate a pointer. The 2' - 3"-long east-leaf pointer was mounted against a quarter-circular scale on the inside of the control room's west wall, above and to the right of the operator's panel. It rotated 90 degrees counterclockwise from vertically down to horizontal as the east leaf rotated through 71 degrees. The scale had seven marks at key points where the operator might need to make adjustments to the speed. The west-leaf indicator was similar, except that its indicator was mounted on the outside of the machinery room's east wall, where it could be seen easily by the operator on the other side. To enable night-time visibility, its pointer was actually an enclosure around four 60-watt lamps. Fixed, single-lamp fixtures were mounted

[23] "Wiring Diagram," AMBC Drawing No. 2E6-47, and "Control Desks," AMBC Drawing No. 2E6-48. An inspection by the author revealed that some secondary controls and circuits were added or modified over the years, but the primary controls do not appear to have been altered.
[24] "Control Desks," AMBC Drawing No. 2E6-48.

at the ends of the 90-degree stroke. The west-leaf mechanical indicator no longer exists, though most of its drive remains in place.[25]

Abutment 2 contains electrical equipment and spaces that are not duplicated in Abutment 3. Commercial alternating current (AC) electric power (4,000 volt, 3 phase, 60 hertz) was furnished from the bridge's east end via wiring through the masonry spans. The service terminated at a main panel located on an intermediate level (22' - 4" elevation) of Abutment 2's north side. Typical for the era, this panel features vertical, stone panels with surface-mounted blade switches, along with an assortment of relays, contactors, and indicators that controlled electrical power distribution throughout the bridge. Since these devices have exposed components that were energized, the panel is located within a cage to prevent accidental contact and electric shock. Cables from this panel were routed to Abutment 3 via two channels in the river bottom that were dug and backfilled after cables had been laid between the two abutments. The second channel and cables were installed as a back-up, but they were never used. A Westinghouse motor-generator set located in its own room on the north side of the lowest level (13' - 0" elevation) has a 300-horsepower induction motor that turned two 100 kilowatt, 500 volt, direct current (DC) generators and a 25 kilowatt, 125 volt exciter. Direct current, with easily varied voltage, enabled the operator to control the speed of the bridge's opening and closing. A similar room on the same level of the south side houses a Westinghouse 100 kilowatt, 500 volt, DC generator powered by an eight-cylinder Sterling GRC-8 "Dolphin" gasoline engine that could be run to operate the bridge in the event of a utility power outage. Its fuel was supplied by gravity from a steel tank located on the generator room's roof.[26]

The roadway and sidewalks are illuminated at night by forty electric street lamps, four on each river span and two on each roadway span. Mounted across from one another along each curb, they appear to be evenly spaced, but the spacing actually varies in proportion to the length of each span. The present lampposts are replicas of the original ones, which were a standard design by Francis D. Millet that is extensively used throughout Washington. It features a tapered, fluted column with three capital and base ring details and an etched-glass, urn-shaped globe. Each post measures 15' high and is painted black. At an unknown time, a pair of flag

[25] "Mechanical Indicator," AMBC Drawing No. 2E6-46.
[26] While diesel fuel is less volatile than gasoline and remains stable in a storage tank for longer periods of time, diesel engines of the era were frequently difficult to start, particularly in cold weather. The need for rapid, reliable starting under all conditions outweighed the storage advantages of diesel fuel.

holders was added to each post approximately 2' below the globe using a circumferential band. Flags are installed by NPS crews on special occasions. A few posts feature standard traffic signs, which photos show have changed over the years. Each of the lampposts contained a single incandescent light bulb for many years. These were changed at least once to high-pressure sodium lamps—possibly when the original lampposts were replaced with new duplicates in 1986—and those lamps were exchanged for light-emitting-diode lamps to further reduce energy consumption. NPS crews made the latest change in July 2013.[27]

Two pylons that flank the Arlington entrance are 36' - 7" tall and 13' - 6" square. Each rests on a three-tiered base that, in turn, rests on a foundation that also forms the end of the balustrade. Each has a five-tiered cap featuring a frieze with dentil and star ornamentation on all four sides. A 7'-high granite eagle statue sits atop each pylon. They are identical, except that their heads are turned to face outward from the bridge. Each pylon has a hollow concrete core faced with cut granite, some of which includes carved details. Each corner is fashioned as a pilaster, and the four sides have bas-relief wreaths just below the frieze. Adjacent manholes and short tunnels provide interior access to the pylons, though it is rarely needed.

Careful inspection reveals a wire stretched between the eagles. It is one part of the *eruv* that marks the limit of the Washington Domain for orthodox Jews. In accordance with a strict understanding of Jewish law regarding rest on the *Shabbat*, a Jew may not, in simplest terms, carry burdens across this line in either direction between sundown Friday and sundown Saturday, or on *Yom Kippur*.

Each of the twin pedestals for the *Arts of War* equestrian statues that flank the Washington entrance to the bridge measures 17' - 6" x 8' - 9" at its base and 12' - 6" high. Slightly tapered inward toward the top, each rests on a two-tiered foundation measuring 22' -6" x 14' - 6" x approximately 5' high. (This height above the roadway varies slightly at each end to achieve a level top surface matching the top of the balustrade.) Each consists of finished granite stone with no concrete core and has spartan ornamentation compared to the west-entrance pylons. Their hollow interiors can be accessed via manholes and short tunnels. The four sides are flat and smooth, except for square, raised panels, two on each side and one on the front and back. Near the top, each side has thirteen bronze stars in a horizontal row, complimented by a

[27] This work was observed by the author on July 24, 2013.

row of five stars on each end. The total of thirty-six stars represents the thirty-six states that existed when the North and South were reunited after the Civil War. The front (outward) end of each has a bas-relief wreath under its stars. Carved stone panels on the front sides of the statue pedestals read as follows:

North statue:

S A C R I F I C E

LEO FRIEDLANDER SCULPTOR

CAST IN BRONZE FLORENCE 1950

A GIFT FROM THE PEOPLE OF ITALY

TO THE PEOPLE OF THE UNITED STATES OF AMERICA

South statue:

V A L O R

LEO FRIEDLANDER SCULPTOR

CAST IN BRONZE MILAN 1950

A GIFT FROM THE PEOPLE OF ITALY

TO THE PEOPLE OF THE UNITED STATES OF AMERICA

The two statues are in a late Art Deco style. Each features a stocky, bearded, nude male figure on horseback with a nude female alongside, each on the side facing the roadway. *Sacrifice* also places a child in the rider's arms. The male and female figures of the two statues appear to be the same, but their postures are different. Each horse has one forefoot placed atop a cannonball, and each statue includes a bronze base slightly smaller than the top of its pedestal. These statues were erected in place by bolting together individual pieces that were cast in bronze using the *cire-perdue* (lost-wax) method and gilded using a traditional process known as wash-gilding, or fire-gilding, where a gold-mercury amalgam was applied to the bronze surface. The material was then heated to approximately 675 Fahrenheit to evaporate most of the mercury while leaving the gold in place. After cooling, the gold plating was finished using one of several

techniques. Due to the toxicity of mercury vapor, fire gilding is now rarely done anywhere in the world.[28]

The statues' current gold finish is not the original one. An inspection in 1970 revealed significant deterioration of the bronze and flaking of the gilding in multiple locations. A rehabilitation project removed the original plating; repaired holes, cracks, and large pits in the bronze; and re-plated the surface using a multi-layer brush electroplating process sealed with Incralac, a lacquer coating formulated for bronze.[29]

Present Condition

Completed and opened to traffic in 1932, the Arlington Memorial Bridge has endured over eight-one years of weather, Potomac River flow, ever-increasing traffic volumes, de-icing salts, vehicle collisions, and one significant earthquake. Maintenance and repair projects during its life have kept the bridge in serviceable condition, but the years have taken their toll. Recent inspections have exposed numerous locations and types of deterioration throughout the masonry and bascule structures, and the NPS, in conjunction with the Federal Highway Administration (FHWA), is currently studying options for a thorough rehabilitation of the bridge. It will be the bridge's first complete rehabilitation since its opening.

The masonry spans, piers and abutments have numerous cracks in their concrete and many areas of spalling. Most are minor, but a good number of spalled areas are large and deep enough to expose internal reinforcing rods. These exposed rods have rusted to varying degrees, depending on their time of exposure, and some have sections that have lost a significant amount of their cross-sectional area and, thus, strength.[30] When steel rusts, it expands and exerts internal

---

[28] For details, see "Fire-Gilding" chapter of Erhard Brepohl, *Theory and Practice of Goldsmithing* (Brunswick, ME: Brynmorgen Press, 2003). An excerpt is available at The Ganoskin Project, http://www.ganoksin.com/borisat/nenam/fire_gilding-9-3.htm (Accessed Sept. 24, 2013).

[29] Fielding Ogburn, Elio Passaglia, Harry C. Burnett, Jerome Kruger, and Marion L. Pickelsimer, "Restoration of Large Gilded Statues Using Various Electrochemical and Metallurgical Techniques," in *Corrosion and Metal Artifacts: A Dialogue Between Conservators and Archaeologists and Corrosion Scientists*, National Bureau of Standards Special Publication 479, eds. Benjamin Floyd Brown, et al. (Washington: U.S. Government Printing Office), 1977, 168-177.

[30] In simplest terms, rusting is a chemical reaction between iron and oxygen in the presence of water, either as a liquid or as moisture in humid air. The result is iron oxide that is similar to iron ore from which the iron or steel was made. The water provides oxygen and serves as the medium for electron exchange from the iron to the oxygen, the basic process of the reaction. The addition of electrolytes, such as de-icing salts, to the water accelerates the process. Rust occupies two to four times the volume of the iron that formed it, so it exerts outward pressure on any solid material surrounding it, which often includes concrete, paint, or adjacent steel parts. Rust has no structural

pressure on the surrounding concrete, often causing pieces to break off (spall), aggravating the condition still further. Ice formation in cold weather can have the same effect, particularly when it forms adjacent to previously spalled areas. Many patches to replace spalled sections are visible evidence of repair work over the years.

Underwater visual inspections by divers have revealed external cracks in some of the piers and abutments, but the degree of penetration and compromise of the load-carrying ability of the affected structures is not known at this time. As this is written, no additional testing has been performed to further define this damage. For Abutments 2 and 3, this damage does not appear to be the result of vessel collisions, even though their original timber fenders are no longer extant.

The granite facing is in generally good condition, but there are places with deteriorated or missing stones, and many of the stones along the edges of the arch intrados show evidence of significant water efflorescence. Some of the mortar exhibits deterioration that is likely due to this efflorescence as well, though much of the damage may be the result of ice forming in cracks during winter months. The granite curbs and balustrades, while in generally good condition, have cracks, spalls, and other damage or deterioration at numerous locations. A vehicle collision on February 24, 2013, destroyed a 20' section of the south balustrade about 300' from the west end of the bridge. As of this writing, a temporary railing is installed in its place strictly to meet the functional requirements. It bears no resemblance to the original structure, and plans for a proper reconstruction are uncertain.[31]

The current wearing surfaces of the sidewalks and roadway exhibit the normal wear expected after almost four decades of service. The roadway has numerous cracks and repair patches, and the sidewalks, which consist of 4' x 4' sections, have sections displaced to varying degrees, cracks, and missing pieces. Some of the manhole covers and frames are broken or otherwise damaged, and some of the ladders under them for access into the piers exhibit deterioration. At least one of these has become detached from the wall at its upper end. The covers for the manual traffic warning-light handles are in place, but their frames and hinges are

---

strength, however, so its formation reduces the cross-sectional area of any steel member, thereby reducing its load-carrying ability.

[31] Martin Weil, "Memorial Bridge reopened after crash that left vehicle in Potomac River," *Washington Post*, Feb. 25, 2013.

damaged and the internal panel is heavily rusted. One heavily rusted actuating handle remains in place, however, most of its length is no longer extant.

The current condition of the bascule leaves and supporting structure varies widely by component. While all of the steel structure exhibits paint that is well beyond its useful life as a protective coating, most of the structure appears to be in reasonably good condition. Large areas of surface rust are evident throughout the structure, but most major members do not show evidence of significant section loss. There are, however, some members that exhibit serious deterioration and substantial loss of section. Twelve locations, six on each leaf, have the most serious deterioration:

<u>East leaf</u>

- Lower portion of both inside trunnion posts, particularly the angled members.
- Cantilever structure supporting the sidewalk near the heel breaks on both sides.
- Fasciae and attachments to fascia trusses at numerous locations.

<u>West leaf</u>

- Lower portion of both inside trunnion posts, particularly the angled members.
- Cantilever structure supporting the sidewalk near the heel breaks on both sides.
- Fasciae and attachments to fascia trusses at numerous locations.

These areas have very significant rusting and section loss. In some places, portions of members have completely rusted away. The inside trunnion posts exhibit serious section loss due to rust at their bases, and major rust streaks are readily visible along the length of all four angled inside trunnion post columns. Although the outside trunnion posts do not have the major rust streaks or a similar level of deterioration, they do exhibit significant rusting at their bases. The design and fabrication of the trunnion posts created pockets at the base of each column that could retain water that drained into them. Their drainage openings were small and easily choked with dirt and debris. A reduction in maintenance activities following the permanent closure of the bascule span in 1965 likely resulted in reduced awareness of any drain fouling and water collection. The heel breaks were originally fitted with gutters and downspouts to collect storm water—including de-icing salt during winter—and route it safely away from the steel structure, but the seal welding and other modifications to the heel breaks during the 1976 repair project

appear to have altered the storm water flow patterns, with the result being a significant amount of water flowing to the granite curbs, where it was intended to be drained by the catch basins. Unfortunately, the joints between the bituminous pavement and the granite curb blocks provide an avenue for water infiltration, and the curbs are directly above the inside trunnion posts. Thus, the water has had a clear path to flow down the inside trunnion posts—indicated by large streaks of rust—and collect at their bases for many years. This caused rusting to begin anywhere the paint had failed, and it ultimately involved the entire lower area. Since this storm water does not flow directly onto the outside trunnion posts, rusting at their bases, while significant, is not as severe as that observed on the inside trunnion posts.[32]

The high amount of serious rust damage under the sidewalks near the heel breaks likely was also fueled by improperly drained storm water, since the worst deterioration is of members located under the curbs. These members are much smaller than the trunnion post columns, so the extent of their damage is proportionately greater in most cases. Some members have rusted in two and now contribute nothing to the structural strength, while others have only 5 to 20 percent of their original cross-sectional area. Several repairs have been made to sections of the sidewalks in recent decades, but none of this work addressed the underlying structural problems.

Biannual inspections of bridges are legally mandated, and these inspections have documented the extent of the bridge's deterioration over the years and recommended short- and long-term corrective actions. While immediate concerns have been addressed, and the bridge continues to be rated for its design loads, budgetary constraints, traffic demands, and the long process necessary to get a major rehabilitation project planned, approved by all involved, and funded have frustrated efforts to accomplish the long-term goals. Two temporary repairs that are readily visible on the deck are the previously mentioned crash damage to the south balustrade and four sidewalk bridges across the heel-break areas at each corner of the bascule span to remove live loads from the most deteriorated part of the structure and ensure pedestrian and biker safety.

[32] Details of this work are shown on "Plans for Proposed Project 15A3, Repair of Bridge and Approaches, Arlington Memorial Bridge," U.S. NPS, 1976, sheets 6-8. Recent inspection reports that indicate the bridge's condition, particularly that of the trunnion posts, include "In-depth Inspection of Structure 3300-016P, Arlington Memorial Bridge," (Norfolk, VA: Clark-Nexsen Architecture & Engineering, 2011); and "Arlington Memorial Bridge Trunnion Post Inspection," (Leesburg, VA: Fuchs Consulting, Inc., 2011). Copies are maintained by the Federal Highway Administration, Eastern Federal Lands Highway Division, Sterling, Virginia.

The bascule mechanism and controls were deactivated in 1965, but the equipment was left in place, and it remains in place as of early 2014. One main control handle is missing from the operator's panel, along with the selsyn receivers, intercom sets, and desk lamps on all three panels. Several indicator lamp lenses are also missing, but the remainder of the switches, gauges, and label plates are essentially intact. Much of the copper wiring was removed at an unknown time. While the control panels remain in place and retain most of their fittings, all three of them exhibit superficial deterioration from years of neglect and non-use. Since the bascule span was deactivated, the center locks have apparently loosened or worn, since 3" to 4" of relative motion between the two leaves can now be observed when a heavy vehicle crosses.[33]

The compartments inside the abutments exhibit a similar level of superficial deterioration. Some of the wooden stair treads and doors are missing or damaged, and the lighting system no longer functions. Assorted debris and boxes of small parts, primarily electrical items, occupy some of the compartments. Drive system machinery appears to be fully intact, except for one or two missing cover plates, but the external paint on these components is peeling and in generally poor condition. Nevertheless, the component surfaces do not exhibit serious deterioration. Their internal conditions are not known. This description also applies to the motor-generator and emergency-generator equipment. The main electrical panel and its numerous fixtures are largely intact and appear to be in good condition. As noted elsewhere, much of the bridge's wiring has been removed. The Federal Aviation Administration lighting system remains operable.

An intriguing addition to the bridge since the 1960s is a set of four steel columns. Two of these were installed between the bottom of each counterweight and the floor of its pit. Neither the date of their installation nor their purpose is certain. They may have been intended as a mechanical stop to prevent anyone from opening the draw span after closure, but before it was de-energized, or a minimal response to the trunnion post deterioration problems that was intended to take at least part of the weight of the counterweight in the event of a trunnion post failure, hopefully preventing a total collapse of the leaf into the pit. These exhibit significant rust at their bases.

---

[33] Inspection by author, June 9, 2013.

Several locations, particularly floors and horizontal joint surfaces at the lower levels of the bridge, have significant build-up of bird guano, some of which is between 1" and 6" deep. In an attempt to prevent birds, primarily pigeons, from roosting on the bridge structure and leaving these deposits, the 1976 repair project included installation of a chain-link fabric "pigeon barrier," as the project termed it, along the arch intrados of both leaves. Breaks in it are currently visible, but the bird population within appears to be very low.[34]

Although it is not readily apparent to the casual viewer, the *Arts of War* statues at the east end also suffer from deterioration, including cracks in the bronze and weathering of their gold plating. Park personnel have known this for a number of years, but budget constraints have prevented corrective action beyond essential repairs. The granite eagles at the west end seem to have fared better over the years and exhibit little, if any, deterioration.[35]

History

From conception to opening day, a century was needed to plan and build the Arlington Memorial Bridge that exists today. The monumental bridge over the Potomac River to connect Washington's Mall to Arlington National Cemetery opened on January 18, 1932, but the idea for a river crossing first came to light during President Andrew Jackson's term in office (March 1829 - March 1837), when the District of Columbia included land on both sides of the river.[36] Congress passed an act on July 14, 1832, that funded the purchase of land for the bridge's approaches. Subsequent acts and executive documents between 1833 and 1836 set the site of the bridge and additional details. On January 4, 1836, the Washington *Globe* reported that Congress had passed an act to build a bridge across the Potomac. President Jackson, having laid the cornerstone for a new community, Jackson City, on the Virginia shore during his second term, promoted a bridge as well. In spite of great celebration and excitement regarding the soon-thriving suburb, bureaucracy plodded along, and despite congressional acts and executive orders

[34] Details of this work are shown on "Plans for Proposed Project 15A3, Repair of Bridge and Approaches, Arlington Memorial Bridge," Drawing No. 850/41905, U.S. NPS, 1976, sheets 17-19, NARA RG 79.
[35] Gregory Anderson, Cultural Resources Specialist, George Washington Memorial Parkway, conversation with author, July 10, 2013.
[36] The Residence Act of 1790, as amended in 1791, defined the original District of Columbia, but specified that the public buildings were to be built on the Maryland side of the river. With no evident need for the western portion, Congress finally retroceded it to Virginia in 1846. The Virginia legislature accepted it the following year and incorporated both the county and city of Alexandria in the area. In 1920, the legislature changed the county name to Arlington to minimize confusion between the city and county.

the bridge was never built. Without a bridge, Jackson City was not easily accessible to Washington, and it soon withered and died, leaving the Virginia shore to revert to swampy grassland.[37]

The idea of a bridge lay dormant until July 4, 1851, when Daniel Webster addressed a crowd and spoke of President Jackson's dream in glowing terms, describing a bridge with arches of granite stretching across the Potomac from Washington to Virginia, physically and symbolically uniting the North and South, which at that time were already in serious disagreement over the issue of slavery.[38] Several subsequent presidents endorsed plans for a memorial bridge, especially after the Civil War. Studies were done and design competitions were held over the next half-century, but none resulted in construction of a bridge.[39]

No small reason for the failure to build a bridge from the core of Washington across the river to Virginia was the changing character of the Potomac's eastern shore throughout the nineteenth century. Even without the growth of Washington, this alone made it difficult for engineers, much less Congress, to specify a specific location for a bridge that would be both practical for construction and useful for the foreseeable future. A brief review of these changes and the city's early attempts to deal with them is vital to understanding these challenges.

Washington and the Potomac River

From the time of their first settlements, the design and development of Georgetown, Maryland; Alexandria, Virginia; and Washington were, like most towns and cities, heavily influenced by local geography. For the national capital area, the dominant geographical feature was, and remains, the Potomac River, which more or less bisected the original District of Columbia from north to south and now forms the district's western boundary. The character of the river changed dramatically as it entered the district from the northwest near Georgetown. Above and through Georgetown, the Potomac followed a relatively narrow channel formed by palisades on both banks, but where Rock Creek joined it on the eastern edge of Georgetown, the

---

[37] Robert V. Remini, *Andrew Jackson and the Course of American Democracy, 1833-1845* (New York: Harper and Row, 1934), 399.

[38] "Bridges - Arlington Memorial, 1895-1918" file, Martin Luther King Jr. Public Library, Washingtoniana Room, Washington, DC.

[39] Donald Beekman Myer, *Bridges and the City of Washington*, (Washington: U.S. Commission of Fine Arts, 1974), 17.

river turned south and flowed into a broad, sedimentary valley that became the site of Washington. At this point, the river became at least twice as wide and considerably shallower than it was upstream, and it retained this character for the remainder of its length across the coastal plain to the Chesapeake Bay. The river's mean elevation changed so little over the coastal plain that it was tidal as far upstream as Little Falls, located above Georgetown, and the river was navigable by oceangoing ships to Alexandria and Georgetown.

Both Georgetown and Alexandria grew into moderately successful ports during the eighteenth century, and the new federal city between them was conceived as a commercial center as well as a seat of government. No one involved with its founding believed that Washington would thrive solely as a place of government business. The plan of Washington reflected the city's orientation to the Potomac and Anacostia rivers, and the course of early real estate speculation and development reflected the generally held belief that the city would grow first along the waterfront. The Washington Canal Company, in an attempt to foster local commercial development as well as carry out a major element of Pierre L'Enfant's plan for the city, commissioned noted engineer Benjamin Henry Latrobe in 1802 to superintend construction of a canal connecting the two rivers. Although the Anacostia joined the Potomac on the south side of the city, storms and frequent freshets could make the Potomac dangerous, and it was thought that a canal through the heart of the city would provide safe haven for ships and promote a business center along the Pennsylvania Avenue corridor.

Unfortunately, the Potomac River failed to cooperate. Its condition as a shipping route continually deteriorated as the silt carried from its 14,700-sq. mi. watershed began settling out as the river widened and its current slowed south of Georgetown. Seriously deteriorating in the late-eighteenth century, "[b]y the 1820's the Potomac River's channels had become so silted and impassable that neither Georgetown nor Alexandria could survive on river navigation alone. The two port cities looked to a large canal scheme." [40]

In 1806 the upper end of the Virginia Channel of the Potomac—the naturally widest and deepest of the several channels then in the river at Washington—was closed off by the construction of a causeway—actually a dam—between Analostan (now Theodore Roosevelt) Island and the Virginia shore. The intention in constructing the causeway was to force the

[40] Frederick Gutheim, *Worthy of the Nation: The History of Planning for the National Capital* (Washington: Smithsonian Institution Press, 1977), 48.

channel toward, and to deepen it along, the Georgetown waterfront, but its promoters had little knowledge of hydraulics or possible consequences of the causeway. It accelerated the already serious silting in the Washington Canal. By 1818, it was useless except at high tide, and Congress had to authorize funds for the City of Washington to complete its purchase of the Washington Canal Company. But silting continued, and it created a large marshy area in the "dead water" below the island. The so-called Washington Channel, which followed the city's original shoreline from the mouth of Rock Creek to the junction with the Anacostia River, was largely filled by 1834.[41]

Throughout most of the nineteenth century, the Potomac River's eastern bank was a continually shifting, ill-defined line as the shallow, tidal water merged with the low-lying valley to form a marshy area known as the Potomac Flats that covered much of the area west and south of where the Washington Monument now stands. Tides covered and uncovered it twice daily, and the river was prone to floods that inundated the area, particularly during spring. During the warm summer months, the perennially soggy marsh became a foul-smelling swamp and a fertile mosquito breeding ground.

This fetid marsh situation was aggravated by the Washington Canal. Though Congress and the city funded several improvements between 1831 and 1849, including a connection to the Chesapeake and Ohio Canal at Georgetown, the canal fell into disuse by the mid-1850s. By then it had become the discharge site of numerous storm and sanitary sewers, and its western portion was nothing more than an open sewer by 1862, which only aggravated the sanitation and aroma problems stemming from the adjacent marsh. Congress ignored the problem, so the city began building an underground sewer and filling in the western portion of the canal in 1871.[42] (The U.S. Army Corps of Engineers assumed responsibility for this project in 1874.) The southern portions survived into the 1880s, but they were ultimately filled as well.[43]

Though numerous studies of filling in the Potomac Flats were conducted following the Civil War, Congress took no action to implement any of their recommendations until a major flood inundated the Mall and Pennsylvania Avenue in 1881. After yet another study combined

---

[41] Peter C. Hains, "Reclamation of the Potomac Flats at Washington, D.C." *Transactions of the American Society of Civil Engineers* 31 (1894): 55-57.
[42] This is the current location of Constitution Avenue between 6th and 17th streets.
[43] Cornelius W. Heine, "The Washington City Canal," *Records of the Columbia Historical Society of Washington, D.C.*, vol. 53/56 (1958), 1–27.

the best elements of earlier proposals, Congress finally appropriated $400,000 to raise the flats and stabilize the river channels for navigation the following year. Over the next eleven years, the Corps of Engineers, led by Washington District Engineer, Lt. Col. Peter C. Hains, dredged the river to improve its navigation channels and "reclaim" the flats with some 9,000,000 cu. yd. of dirt dredged from the river bottom. By 1891, "about 620 acres of malignant swamp had been transformed into healthful dry land."[44]

Hains' successors, Maj. Charles E.L.B. Davis and Lt. Col. Charles J. Allen, completed the initial reclamation project over the next year, and additional land-building projects continued through 1913. Following an 1897 proposal by banker Charles C. Glover, Congress set the reclaimed land aside for a public park, much of which is now Potomac Park. To maintain the Washington Channel, which was dredged northward to obtain the reclaim soil, Hains installed four artificial lakes just north of the channel's termination. This novel "tidal reservoir" employed gates to hold high-tide water from the Virginia Channel and release it through the Washington Channel as the tide receded so that the flow would flush the latter channel and prevent it from silting up. The Tidal Basin has since been consolidated, enlarged, and modified, but it continues to perform as intended.[45]

The northern part of this reclaimed land became the western portion of the Mall. Today's World War II Memorial, Reflecting Pool, Vietnam Veterans Memorial, Korean War Veterans Memorial, and Lincoln Memorial all stand on this reclaimed land. The Jefferson Memorial, located on the south side of the Tidal Basin, likewise owes its location to the reclamation project, as do memorials for John Ericsson, Franklin D. Roosevelt, and Martin Luther King, Jr. Washington's famous flowering cherry trees, gifts from Japan, flourish in the reclaimed soil around the Tidal Basin and throughout Potomac Park, and recreational facilities and trails provide convenient respites from congested urban life for area residents and visitors alike.

Changes in the Urban Aesthetic

As the topography of the District's western area changed, the cultural sense of Washington began to change, too, as improved transportation made it easier for its citizens—at

[44] "Memoirs of Peter Conover Hains," *Transactions of the American Society of Civil Engineers* 85 (1922): 1682-3.
[45] Pamela Scott, *Capital Engineers: The U.S. Army Corps of Engineers in the Development of Washington, D.C., 1790-2004* (Alexandria, VA: U.S. Army Corps of Engineers History Office, 2007), 125-28, 177-80.

least the wealthier ones—to experience other American cities, and many of them were well versed in European ideas as well. Two particular events outside Washington during the post-bellum nineteenth century exerted a strong influence on Washingtonians to see the capital city in a new light, one that emphasized both natural and man-made beauty to make the city a source of pride, not only for its residents, but for the nation as a whole. The first of these events was the 1876 Centennial Exhibition in Philadelphia that celebrated the country's first century. There, exhibits from a dozen countries and twenty-six states were displayed in grand, although mostly temporary, buildings, including the two largest buildings in the world at the time. Even industrial machinery was presented in an attractive, even monumental, setting that awed the many visitors. Two decades later, the 1893 Columbian Exposition in Chicago celebrated all things modern at the time, including electric lighting designed to enhance the grand architecture of the White City along Lake Michigan. Both events, while specifically designed as exhibitions, revealed just what was possible. (Washington had vied to host the 1893 World's Fair, but its bid was not successful.)

The centennial of the founding of the City of Washington in 1890 provided influential Washingtonians and Congressmen an opportunity to reflect on the evolving urban aesthetic and how it might be employed to improve the city and guide its future development. One direct result of this wave of interest was the formation of the Senate Park Commission, more commonly known as the McMillan Commission after its originator, Senator James McMillan of Michigan, Chairman of the Park Commission of the District of Columbia. McMillan selected four respected architects and landscape architects and assigned them to study and report on the present condition of the District's parks. The four men were Frederick Law Olmsted, Jr., Daniel Burnham, Charles McKim, and Augustus St. Gaudens. To better understand the ideas of Pierre L'Enfant, who originally planned the City of Washington, and many of the great European designers, Olmsted, Burnham, and McKim, along with Charles Moore, clerk of the Senate Committee on the District of Columbia, traveled to Europe in 1901 to study such classic landscapes as Villa d'Este, Hadrian's Villa, Piazza San Marco, Versailles, and Hampton Court. Due to ill health, St. Gaudens could not make the trip.[46]

---

[46] Norman T. Newton, *Design on the Land* (Cambridge, MA: Belnap/Harvard Press, 1971), 405, 420; Connie Foley, *River Port and Capital: The Architectural and Natural Landmarks of Washington*, (Washington: U.S. Department of the Interior, 1965), 13.

The trip and discussions during it proved to be seminal in the evolution of the master plan ultimately adopted for the Mall. The McMillan Commission determined early in its deliberations that there were five major elements guiding planning for the monumental core of Washington, DC: the U.S. Capitol, the White House, the Washington Monument, and proposed memorials to Lincoln and Grant. These unbuilt memorials could be used to extend the axis of the Mall into the new public grounds west of the Washington Monument, where the Mall would be linked to new parkways through Rock Creek Park and, via a bridge, to Mount Vernon, and Great Falls, Virginia. They also saw the bridge as an integral component that would directly connect the Mall and Arlington Cemetery and decided that, "the Memorial Bridge should be a low structure on a line from the site of the Lincoln Memorial to the Arlington Mansion—a monumental rather than a traffic bridge, but a significant element in an extensive park scheme." [47]

The Senate Park Commission Plan of 1901, as it came to be known, was essentially a revival and confirmation of L'Enfant's 1791 plan. The models and renderings of the 1901 plan, displayed at the new Corcoran Gallery of Art during January 1902, included a memorial bridge and supporting architectural elements where the Arlington Memorial Bridge and other structures came to be built. Lavish praise for the plan was immediate from politicians and civic leaders alike. President Theodore Roosevelt applauded the "greatness of the conception itself." [48]

While the beauty and appropriateness of a low-level bridge connecting the Lincoln Memorial to Arlington Cemetery was readily apparent, such a design raised what became the most controversial aspect of the entire project: whether to include a draw span that would allow continued navigation to Georgetown. In 1897, Lt. Col. Charles J. Allen of the Army Corps of Engineers conducted a study of river traffic. Using the existing Long Bridge, with a vertical clearance of 10' - 4" above the water when closed, as his model, Allen found that about 12,500 vessels per year required the Long Bridge to be opened for their passage—an average of almost thirty-five per day. Though more than one ship could often be accommodated during a single opening, the bridge was opened an average of seventeen times per day, and as many as twenty-five times during the heaviest navigation season. Almost all of these ships called at Georgetown, and almost half of them were sailing ships. The ocean-going sailing ships typically had masts

---

[47] Charles Moore Papers, General Correspondence, n.d., Manuscript Division, Library of Congress, Washington, DC.

[48] Quoted in Gutheim. *Worthy of the Nation*, 125.

between 140' and 155' tall. Most of these ships could reduce this 40'-50' by lowering their topmasts, but that was "… by many regarded as a hardship."[49] Allen estimated that a memorial bridge with at least 35' of clearance when closed at high tide would need to open only five or six times per day.

By the early 1920s, when the bridge was again under serious consideration, the number of ships requiring a draw span had decreased considerably since the turn of the century, but it was still significant. According to Lt. Col. Clarence O. Sherrill, Director of Public Buildings and Parks, the Corps of Engineers had ascertained that 98 percent of vessels passing the bridge site, carrying 80 - 85 percent of the tonnage, required a vertical clearance of less than 40 feet. The bascule span specifications, published in 1928, but probably using earlier shipping data, listed an average of twenty ships passing per day. This would total about 7,300 ships per year, and if only 2 percent of them used the draw, it would be opened twelve times per month, compared with the five or six times a day estimated in 1900. Still, this 2 percent represented 10 to 15 percent of the tonnage shipped to and from Georgetown.

The Army engineers emphatically did *not* want a drawbridge, nor did the Park Commission members, but for different reasons. The Army preferred to build a high-level bridge that would clear the tall ships, even if they would have to lower their topmasts, arguing that the construction, operation and maintenance costs of a draw span would be high. In addition, they noted that the number of large vessels going to and from Georgetown was slowly declining, so the draw span would be unneeded at some future date. The members of the Park Commission did not, based on the first round of design competition submittals in 1900, believe that a draw span could be built without massive towers that would destroy the aesthetics of the low-level concept and lead to an ugly monstrosity. The citizens and merchants of Georgetown were equally emphatic that their port not be permanently cut off from the world. They had no objection to a monumental bridge of high- or low-level design, so long as it did not impede navigation to their city. Although three decades were to elapse before the Arlington Memorial

---

[49] "The Memorial Bridge Across the Potomac," *The Engineering Record* 41, no. 16 (April 21, 1900): 362.

Bridge opened, debates over low- versus high-level designs, and whether the former would have to include a draw span, continued throughout the entire time.[50]

Upon McMillan's death in 1902, the Senate Park Commission ceased to exist. In 1910, President Taft established a similar Commission through Congress, the National Commission of Fine Arts (CFA). Comprised of seven men, the commission consisted of three architects, a landscape architect, a painter, a sculptor and an art historian/critic. The CFA acted as executors of the 1901 plan. Congress established the Arlington Memorial Bridge Commission (AMBC) to oversee planning and construction of a bridge in 1913, and concepts of how it could be both a practical and a memorial bridge soon came up in meetings, as it did in Commission of Fine Arts meetings. Ideas and concepts were discussed for almost a decade, but Congress appropriated no money for actually building a bridge. It was not until the Armistice Day (now Memorial Day) celebration and dedication of the Tomb of the Unknown Soldier in 1921 that plans actually went ahead for a bridge from Washington to Virginia.

With patriotic fervor high in the years immediately following World War I, a large crowd attended the celebration. The highlight of the day was a long automobile procession that followed the casket of the Unknown Soldier, who had been brought home from France aboard the U.S.S. *Olympia*, from the Capitol across Aqueduct Bridge to Arlington Cemetery for burial, but it unexpectedly produced a traffic jam so extensive and unmanageable that even President Warren G. Harding came close to missing the internment ceremonies. All traffic had to be funneled into Virginia's narrow roads by way of the 14th Street Highway Bridge or the Aqueduct Bridge. This unprecedented traffic jam stretching from Washington to Arlington Cemetery stretched a trip that normally took twenty minutes into an hour and a half or more. President Harding, traveling to the cemetery with some members of the CFA, arrived about two hours late, and many dignitaries never made it at all.[51]

The day's traffic problems highlighted a growing trend that was not well understood or appreciated by many of the public officials who would be forced to deal with it. To an ever-greater degree, the demands of private automobiles were re-shaping Washington, as they were other American cities. With the introduction of vehicle registration laws that furnished reliable

[50] The long saga of this debate is a recurring part of the project's history in Nolin, *Historic Structure Report*, from page 74 to page 206. She mentions at least eight significant proposals or exchanges during the period, with the final decision coming in 1928, several months *after* substructure construction had begun.
[51] "Officials Miss Ceremonies; Traffic Jam Blocks Roads to Arlington," *Washington Post*, November 12, 1921.

quantities, it became clear that the number of automobiles was not only increasing, but doing so at an ever-increasing rate. By 1930, automobile registrations in the District of Columbia alone numbered almost 175,000, and by that date, less than 35 percent of Washington workers still used public transit to reach both work and play sites.[52] The Arlington Memorial Bridge would not only be a desirable monument; it had also become a practical necessity.

Getting Serious about the Bridge

The day following the Armistice Day fiasco, the CFA decided to act upon this problem by asking Congress to appropriate funds for a bridge in the vicinity of Arlington Cemetery. The dedication of the Lincoln Memorial on May 30, 1922, highlighted the logic and beauty of the Senate Park Commission's intended bridge across the Potomac River from the memorial to the cemetery's main entrance. In June 1922, Congress finally released the $25,000 appropriated for the use of the AMBC nine years earlier. Although the location seemed to be set at last, Lieutenant Colonel Sherrill of the Army Corps of Engineers made one last appeal for the high-level bridge in line with New York Avenue that the Engineers had long favored. His concept received unanimous approval from a meeting of the bridge commission at the White House on June 29, and he was directed to seek the advice of the CFA with respect to the architectural and landscape features of the proposed bridge. This re-opened the seemingly settled matter of the bridge's location, and Charles Moore was alarmed at another attempted departure from the McMillan Commission plan. Moore alerted Frederick Law Olmsted, Jr—the only other survivor of the McMillan Commission—and assembled the opinions of the CFA members: John Russell Pope, James L. Greenleaf, James E. Fraser, Louis Ayres, Henry Bacon, and H. Siddons Mowbray.[53] One of the more understated views in opposition to the proposed change of location was that of sculptor James Fraser, who thought that a New York Avenue bridge would be "exceedingly unsightly and misplaced."[54]

Moore circulated the CFA's report on the Memorial Bridge to the press and members of Congress friendly to the Senate Park Commission plan. The *Evening Star* carried a front-page story on the CFA's objections to the New York Avenue traffic bridge in its issue of September

---

[52] Constance McLaughlin Green, *Washington: Capital City, 1879-1950* (Princeton, NJ: Princeton University Press, 1962, 281).
[53] Report of the Commission of Fine Arts on the Memorial Bridge, September 7, 1922, NARA RG 66.
[54] James E. Fraser to Charles Moore, July 24, 1922, NARA RG 66.

12. While this tactic successfully pressed that commission's position, it angered not only Sherrill, but also President Harding, the unconsulted chairman of the AMBC. The genial President, however, was soon mollified. Before a subsequent joint meeting of the CFA and the AMBC on December 18, 1922, the members made automobile visits to several possible bridge sites. The views of Moore and his colleagues prevailed when all sat down to discuss the matter: a decision in favor of a low bridge on the line connecting the Lincoln Memorial and Arlington House was reached in "less than half an hour." [55]

Regardless of this decision, Sherrill could not see how a draw bridge of any kind could satisfy the artistic requirements that had been agreed upon. He claimed that a clearance of about 41'- 6" was adequate, and that the bridge should be built without a draw span. John L. Nagle, assistant engineer for the bridge commission, supported Sherrill, but all other parties present at the hearing, including the Board of Trade and Georgetown Citizens' Association—all non-engineers—favored the draw and vowed to fight against construction of a low bridge without one. Commercial, military, and artistic interests trumped the engineers' concerns, and the following month the AMBC issued a memorandum to the press stating its intention to design a bridge consisting of a series of "flat graceful arches" with a central bascule draw.[56]

Sherrill had no choice but to accept the decision, but not without another statement of his position in a July 3, 1923, letter to McKim, Mead & White:

> The question of the draw ... has always been one of much annoyance. This office has held from the beginning that the draw should be eliminated from this bridge and has gone to no little trouble to secure the elimination. Its view has not, however, prevailed either with the public interests or with the War Department in control of these matters, and it is now definitely established that the draw opening will be required for the present ... it is possible and even probable that at some future date the draw will be abandoned and a masonry span built in its Place....[57]

In December 1922, Sherrill asked Charles Moore for the CFA's recommendations regarding architects for the bridge, and Moore responded by suggesting three firms: Charles A. Platt, Paul P. Cret, and McKim, Mead & White. The commission felt it wise to avoid another competition and advised direct selection of the architect. With the approval of the president,

[55] Joanna S. Zangrando, "Monumental Bridge Design in Washington, D.C. as a Reflection of American Culture, 1886 to 1932," Ph.D. diss., George Washington University, 1974, 363.
[56] AMBC, Memorandum for the Press, February 17, 1923, NARA RG 42.
[57] C.O. Sherrill to McKim, Mead & White, July 3, 1923, NARA, RG 42.

Sherrill began discussions with Bert Fenner of McKim, Mead & White in March 1923, and the firm was appointed by the 13th. McKim, Mead & White agreed to furnish architectural services at much less than their normal rate—an act of patriotism for which they were thanked by the AMBC.[58]

Moore and the CFA members were naturally delighted with the selection of McKim, Mead & White and further reassured when William Mitchell Kendall—who, as McKim's assistant, had been associated with Moore since the days of the Senate Park Commission's work—took responsibility for the design. Moore relied on the old friendship to foster his own views and help preserve the McMillan Commission concepts, especially in the early development of the bridge design. In fact, Kendall was invited to appear at a meeting of the CFA May 25, where he presented his initial ideas. The bridge would have a low rise and consist of seven parabolic arches. It would be Neoclassical in style, keeping with the Lincoln Memorial and other monumental architecture in Washington.

The bridge design was well received by the commission and preliminary design work went ahead on it, but debate immediately ensued over the architectural and landscaping treatment at the Virginia terminus, where the Senate Park Commission had planned a circle large enough to accommodate a memorial to Robert E. Lee. Moore, however, had an alternate vision in mind, and he hoped to gain greater design control for the Virginia end of the bridge through an enlargement of the cemetery grounds.[59] Many complications regarding both termini arose during the design phase, mostly concerning traffic demands, but costs and aesthetics were also factors. The design for the Washington terminus was settled on March 15, 1928, but details of the Virginia approach remained in limbo until 1940, eight years after the bridge opened. A traffic circle with connections to and from Arlington Cemetery and the Mount Vernon Memorial Highway was constructed, but without a Lee memorial.[60]

As a practical matter, Kendall soon changed the number of spans from seven to nine. The arches remained relatively flat, but shortening each one gave them sufficient curvature for standard masonry construction and long-term reliability. While Kendall had originally intended

[58] Zangrando, "Monumental Bridge Design," 371 (note).
[59] Commission of Fine Arts, Minutes of the Meeting of May 25, 1923, NARA, RG 66.
[60] The Mount Vernon Memorial Highway, completed in 1932, is now the southern portion of the George Washington Memorial Parkway, which was constructed north of the bridge to the Capital Beltway in stages between 1930 and 1970. It is currently accessible from the bridge in both directions via the Columbia Island traffic circle.

the arch soffits to be faced with granite to match the sides, Sherrill had already informed him that economic considerations dictated that the arch soffits be concrete instead, and that a draw span would be required.[61] As instructed, Kendall placed a double-leaf bascule span in the center of the bridge with four masonry arches on either side, plus two smaller spans in the abutments over low-level roadways at each end of the bridge. Except for minor details at the shore abutments, this yielded a symmetrical structure with a graceful parabolic curve as its top line. The superstructure of the bridge would rest on four abutments, one at each shoreline and one on either side of the bascule span, and six piers in between the masonry arches. As crowning details, the architect proposed a bronze railing interrupted by masonry pedestals. The pedestals between the arch spans were to support sculptured figures, with the allegorical figures bearing torches to illuminate the roadway. Tall pylons crowned by eagles would mark both ends of the bridge.

The CFA took issue with some aspects of Kendall's design. Reacting to criticism from its members in July 1923, Kendall agreed to return with a design for an eleven-span bridge—which proved unnecessary and less attractive than his nine-arch design—and to abandon the idea of lighting incorporated in the sculptural figures. He was, however, unwilling to give up the sculptural figures and felt that the commission members' ideas for a solid parapet and sculptura1 groups on pedestals at the ends of the bridge, rather than tall pylons, required further study. Henry Bacon, in particular, opposed the pylons and the statues along the bridge, which in his opinion overwhelmed the Lincoln Memorial. The bridge was generally supposed by the commission to be "subordinate" to the Lincoln Memorial—a choice of word that caused Kendall to bristle and become defensive. He reminded James Greenleaf, landscape architect and vice-chairman of the commission, that Congress and the Senate Park Commission intended the bridge to symbolize the union of North and South and serve as a "monument to American valor"—hardly a subordinate role.[62]

By late summer 1923, Lt. Col. Sherrill regarded the preliminary scheme for the bridge as sufficiently complete to justify presentation to Congress. Anxious to secure funding, and convinced that the presently robust economy wou1d encourage favorable action, Sherrill urged Kendall to proceed with his design work. He also assured Kendall that the members of the

[61] Zangrando, "Monumental Bridge Design," 375, 377.
[62] William M. Kendall to James L. Greenleaf, August 3, 1923, NARA, RG 66.

Arlington Memorial Bridge Commission had complete trust in the architect's ability, and that they did not have to give unqualified acceptance to the views of the CFA.

James Greenleaf—acting for Charles Moore, who was out of the country—called a meeting of the CFA on September 26, 1923. Bacon's opposition to the overall scale and other features of the bridge continued, but the commission accepted Kendall's presentation and drawings, suggesting only minor changes. Sherrill then prepared a report and asked for a meeting of the AMBC. That meeting took place on December 20, with President Calvin Coolidge presiding. Sherrill may have expected the meeting to be little more than an approval of his plans, but Coolidge was distracted by other, more-pressing concerns. He had only been in office since the death of Warren G. Harding on August 2, and he was preoccupied with repairing the damage done to the image of the presidency during Harding's administration. Accordingly, the bridge commission reviewed Kendall's plans, but decided to delay approval until they were considered further.

Kendall's and Sherrill's reports to the bridge commission, which included a draft of enabling legislation written by Sherrill and estimates of costs, formed the substance of the Report of the AMBC that Coolidge finally approved on April 22, 1924, and forwarded to Congress along with drawings of the proposed bridge. The document emphasized the role of the bridge as a monumental symbol of the established federal union of North and South, and described the style of the bridge to be "as simple and severe as possible."[63]

The proposed bridge would consist of nine spans: four masonry spans on either side of a central, double-leaf bascule span. The length of the bascule span was to be 184', and the flanking granite-faced arch spans would increase in length from 166' to 180' as one moved from either shore toward the center section of the bridge. This increase in length corresponded to their increase in height from 34' to 45' (top of roadway) to achieve the parabolic line across the river appropriate for its Neoclassical style. The total length of the bridge was to be 2,138', and it would carry a roadway 60' wide and two sidewalks, each 15' wide. The reinforced-concrete arches would be faced with ashlar granite chosen to harmonize with the color of the white marble on the Lincoln Memorial.

---

[63] Published as *Report of the Arlington Memorial Bridge Commission*, Senate Doc. No. 95, 68th Cong., 1st sess. (Washington: Government Printing Office, 1924). The report illustrates all principal features of the McKim, Mead & White design as modified through the end of 1923.

The design included sculptural groups bracketing pairs of 40'-tall pylons surmounted by eagles at the Washington and Virginia ends of the bridge, as well as at the entrance to the adjacent shoreline road on the Washington side. Kendall maintained the pairs of allegorical sculptures along the parapets—one pair on the up-river side and one pair on the down-river side of each pier—to symbolize achievements in the arts and sciences. Into the granite facing of the pier walls below these sculptures were incorporated bas reliefs of eagles on round medallions bordered by a *guilloche*-like motif and bracketed by *fasces*.

The decision to build a reinforced concrete structure faced with granite hearkened back to the Burr-Casey scheme of 1899-1900.[64] The bridge plaza and the proposed watergate—a broad flight of steps from behind the Lincoln Memorial to level of the river—came directly from the McMillan Commission plan. The report called for the widening of B Street, NW (now Constitution Avenue) and its extension eastward to the Capitol, which would result in a boulevard reminiscent of the Centennial Avenue proposed in 1900. Columbia Island—created below Analostan Island by the continued dredging operations of the Corps of Engineers since about 1915—was to be developed as a park area, and two columns 166' high were to be constructed at the crossing of the bridge axis and the axis of the island as symbols of the North and the South. A connection to Lee Boulevard (no longer extant, but now approximated by Arlington Boulevard) was to bring that artery across the boundary channel separating Columbia Island from the Virginia shore.

The report of the AMBC recommended an appropriation of $14,750,000, to be made over a period of a decade. Of this amount the bridge itself would require $7,250,000. The legislation drafted by Sherrill would authorize the existing bridge commission to direct construction, and it permitted the President to use the Corps of Engineers in the work of erecting the bridge.

Sen. Bert Fernald of Maine introduced S. 3173 on April 24, 1923, two days after the bridge commission report was transmitted to Congress, and Rep. Frederick Gillett of Massachusetts introduced H. R. 8916 on April 26. Both bills were identical to Sherrill's draft and were supported by the CFA. By the end of January 1925, after lengthy and "sometimes

[64] Kendall, Nagle, Sherrill, and most others involved realized that the bascule span would have to be constructed of steel. Similarly sized existing spans had visible steel trusses, but Kendall's rendering of the bridge showed an arched bascule span that appeared to be much like the masonry arches. Since how this would be accomplished was as yet unknown, they did not delve into those details at this stage of the project, leaving them to the future engineer of that span.

comical" hearings, the Public Buildings and Grounds Committees of both Houses of Congress had recommended passage of S. 3173.[65] In the spirit of compromise, and to counter one of the most persistent arguments against passage of the bill—that the District of Columbia was the primary beneficiary, but paid nothing of the costs involved—Rep. Louis Cramton offered an amendment allowing Congress to determine the District's fair share of costs for the bridge and associated street improvements in the City of Washington. The amended bill, entitled "An Act To provide for the construction of a memorial bridge across the Potomac River from a point near the Lincoln Memorial in the City of Washington to an appropriate point in the State of Virginia, and for other purposes," passed the House by a vote of 204 to 125, and became Public Law No. 463 when signed by President Coolidge on February 24, 1925.

Final Design and Construction

An initial construction appropriation of $400,000 was also voted by the 68th Congress. Since substantial site-preparation work had to be accomplished before bridge construction could begin, Sherrill proposed using funds available to the Washington District Engineer and the money voted by Congress to begin necessary dredging and construction of one or two piers by the end of 1925.[66]

The river bore a significant volume of commerce at the time, with an average of twenty commercial ship passages across the bridge site per day. The majority of these vessels (87 percent) were sand and gravel tugs and scows with an average draft of six to eight feet. Ten percent of the ships, including canal boats, barges, and schooners with cargoes of coal, wood, and other materials had drafts of six to fourteen feet. The remaining three per cent were large vessels with drafts greater than thirteen feet. The Corps of Engineers maintained a 20' depth in the so-called Virginia Channel—by then actually located along the Washington shore—to accommodate them. Since the symmetry of the bridge was an aesthetic requirement, it precluded placement of the draw span over the existing Virginia Channel.

The Washington Engineer District, under the direction of Lt. Col. Brehon B. Somervell, began dredging to relocate the navigation channel so that it would pass beneath the draw span in July 1925, and this continued through June 1927. Some difficulty was encountered when

[65] An informative account of the hearings is given in Zangrando, "Monumental Bridge Design," 391-399.
[66] Commission of Fine Arts, Minutes of the Meeting of March 27, 1925, NARA, RG 66.

pinnacles of solid rock were discovered in the area of the new channel that had to be removed. At the same time the river's prism was widened by dredging away a strip of Columbia Island to allow the same volume of flow to pass at the same rate after the piers and abutments were built. Columbia Island itself was originally a man-made tidal flat that flooded at high tide. The first deposits placed in this area were from the 1915 dredging of the Virginia Channel. Each time the river was re-dredged, the spoil was deposited behind dikes and levees. By 1925, the island had been built up to a level 7' to 12' above m.l.w. through the placement of this uncompacted material. The new material dredged from 1925 to 1927 was used to build the island up to an elevation of about 20' above m.l.w.

At the same time the Army Engineers were getting started on the channel relocation, Sherrill shifted the focus of the Arlington Memorial Bridge Project from architectural design to engineering and construction matters. Despite the fact that the firm of McKim Mead & White had received a net fee of only $1,288.98 for architectural design services rendered so far in the bridge project, Sherrill sought to minimize the scope of further architectural services required to preserve as much money as possible for the complicated engineering work which was to come.[67] The agreement reached with McKim, Mead &White on July 29, 1925, provided that Kendall would henceforth be consulting, rather than designing, architect. The following month Sherrill signed a contract with Walter J. Douglas, principal in the firm of Parsons, Klapp, Brinckerhoff and Douglas. Douglas was to be consulting engineer during construction, and he was no doubt chosen because of his experience in, and contributions to, the theory of, arch design.

Having set the stage for actual construction of the bridge, Lt. Col. Clarence O. Sherrill resigned his commission on December 31, 1925, to become the first city manager for Cincinnati, Ohio, concluding a very successful career with the Army Corps of Engineers, including admirable service as Officer of Public Buildings and Grounds and Executive Officer of the AMBC. Possibly better known for directing the Lincoln Memorial and Rock Creek and Potomac Parkway projects, his achievement in bringing to the point of realization the almost-forty-year-old project to connect Washington and Arlington Cemetery with a memorial bridge was in itself a monumental endeavor.

[67] Zangrando, "Monumental Bridge Design," 384.

Sherrill's successor was Maj. (later Lt. Col.) Ulysses S. Grant, III, a West Point graduate and grandson of the U.S. President whose memory played such a part in the Arlington Memorial Bridge story. Grant was the personal choice of President Coolidge to head the Office of Public Buildings and Public Parks of the National Capital, which had assumed the functions of the Office of Public Buildings and Grounds under a reorganization of February 26, 1925. Under the provisions of the Arlington Memorial Bridge legislation, Grant also became Executive and Disbursing Officer of the AMBC. In April 1926, when Congress formally established the National Capital Park and Planning Commission by passage of the Capper-Gibson Act and gave it authority to plan for the growth of Washington, Grant became that commission's executive officer. Until 1933, he was not only the chief administrator of these three agencies, but executive officer of the Rock Creek and Potomac Parkway Commission as well. Grant plunged into the Arlington Memorial Bridge project with characteristic energy, a desire for quick decisions, and an appreciation for the bridge as one element—an *essential* element—of any comprehensive and coordinated plan for the nation's capital.

Grant authorized a March 1926 date for commencement of construction, and he organized the job of erecting the bridge into two logical segments: piers and abutments, and the bridge superstructure. He further divided these segments into specific, well-defined tasks for which individual contracts could be advertised and awarded. Ultimately, a total of forty contractors worked on the construction of the bridge, all under the supervision of the AMBC.

Engineering Design, Techniques, and Construction

Substructure

The substructure of the bridge includes the two end-abutments on the river's edge, between the river and the highway underpasses at each end; the two bascule-span abutments, and the six intermediate piers, three on each side of the bascule, up to the spring line of the arches, 10' above m.l.w. The superstructure of the bridge, consisting of the masonry arches and deck, would be built on those foundations under a separate contract, and the bascule span would be fabricated and erected under a third major contract. Before any construction work could begin, though, the precise nature of the Potomac River bottom had to be determined.

Soil and Bedrock Investigations

John L. Nagle and his office (Corps of Engineers) performed the initial soil investigations and designed the substructure before letting the contract for bid. Although the theory of soil mechanics and soil investigation for foundations in soil *above* bedrock was primitive in the mid-1920s, this investigation, for the purpose of locating sound bedrock in which to found the piers, was reasonably well understood and comparable to what might be performed today given the same problem. Beginning in April 1925, about eighteen water-jet probes per pier or abutment, were made to locate the top of the bedrock.[68] This technique entailed forcing a $1^1/_2$"-diameter pipe through the bottom soil to the rock surface using a jet of water pumped through the pipe at 45 psi. The water displaced soil and pebbles, allowing the pipe to descend through the unconsolidated sediment until it reached solid rock. Once the general rock location was determined, wash borings were made through the sediment in at least two locations per pier to determine its stratification. Core borings with a $2^1/_2$"-diameter calyx, or shot, drill, which used metal shot as its cutting element to bore an annular hole around a core sample, continued 10 - 15' into the bedrock. (Similar drills in use today employ industrial diamonds instead of shot.) These core borings brought up a relatively undisturbed rock sample showing the rock's composition and condition.[69] The investigation revealed hard, gneiss bedrock, irregular and weathered on top, between about 30' and 40' below m.l.w. This rock was overlain with mud consisting of silt

---

[68] "First Work is Done on Memorial Bridge," *Washington Post*, March 12, 1925.
[69] Walter J. Douglas, "Foundations and Earthwork," in *American Civil Engineers Handbook*, *5th Ed.*, ed. Thaddeus Merriman (New York: John Wiley and Sons, 1930), 708-709.

and fine sand to an average depth of about 20' below m.l.w. in the navigation channel area, and considerably thicker toward the shores.

Substructure Design and Specifications

The structural design and stability calculations for various loading combinations, including vertical loads imposed by the bridge and horizontal loads from water, ice, and wind were done by Nagle's engineers. The shape of the piers and draw span abutments is similar to that of a ship's hull. The "cutwater" caps are pointed upstream, and rounded downstream. The pier below the cap is of concrete poured in place. From bedrock to 3' below m.l.w., a "five-bag" concrete mix consisting of cement, sand, and gravel or broken stone in 1: 3: 5 proportions, using five bags of Portland cement per cubic yard, which cured to a compressive strength of 2,000 – 2,500 psi. Above this level, a 1: 2: 4, "six-bag" mix was specified with a compressive strength of approximately 3,000 psi. From 3' below m.l.w. to the arch spring lines at 10' above m.l.w., the piers are faced in ashlar Stone Mountain granite for appearance and wear-resistance. Concerned about water-penetration and appearance problems, the engineers specified "non-staining cement mortar," composed of one part Portland cement, two parts non-staining sand, and a waterproofing compound. The face joints were then pointed to a depth of 1" with a mortar of one part Portland cement to one part sand. As an additional protection against staining, the back, or pier side, of the mortar joints were coated with a waterproofing paint to prevent internal moisture from seeping through. Each stone is connected to the backing by at least two cemented brass anchors, and the stones in the upstream cutwater points and the headers on the corners of the river piers and abutments also have at least two brass cramps. Cast-iron 10"-diameter drain pipes extend downward from the super-structure through each abutment and pier, opening to the river out several feet below the m.l.w. level.

Management Issues

On January 6, 1926, one day before the AMBC was to let the contract to construct the substructure, an unexpected—and serious—problem arose when Comptroller General John R. McCarl announced that the AMBC's contracts with McKim, Mead & White and J.W. Douglas were unlawful. McCarl pointed to a federal law which barred the government from hiring

a general contractor. The AMBC, he said, must make the architect and the consulting engineer federal employees. As it did not fall under McCarl's general contractor ban, the Bridge Commission decided to go ahead and award the first major construction contract on January 28, 1926.

The AMBC then met in special session on February 17, 1926, to fully examine its options. The members believed that minor amendments to the contracts would satisfy McCarl, but he was adamant. The issue required congressional action to change the civil service law. The Senate was sympathetic to the AMBC's predicament and passed legislation exempting the AMBC from the civil service hiring requirement on March 9, 1926, but the House balked. Ultimately, an amendment to an Independent Offices appropriations bill added the necessary language. It passed both houses and was finally signed into law almost a year after McCarl first raised the issue.[70]

In spite of McCarl's objection and any congressional action to satisfy it, the AMBC wanted work to begin as soon as possible. Interestingly, even though it had not resolved the general contractor issue, Congress did appropriate $2.5 million in fiscal year 1927 construction funds for the bridge in February 1926.[71] With this appropriation, actual construction work could begin, even with the general contractor issue in limbo.

The AMBC ultimately dealt with the general contractor issue in way that improved every facet of the project. Originally, the AMBC used general contractors, such as McKim, Mead & White and J.W. Douglas, for the major portions of the work, and it had wanted to award very few, large contracts to equally large companies. That way, the general contractor would be responsible for identifying and managing what would essentially be subcontractors, even though their contracts were with the AMBC. McCarl's ruling made that impossible, but it proved to be a blessing in disguise. In 1927, the AMBC changed this management scheme into one where it became the project coordinator, thus eliminating the need for a hired general contractor. This

---

[70] This saga is described in a series of articles in the *Washington Post*, specifically, "Memorial Bridge Bids will be Let, Ignoring M'Carl," Jan. 7, 1926; "Bridge Commission to Study Contract for Memorial Span," Feb. 17, 1926; "Amendment Aids Arlington Bridge," Mar. 9, 1926; "House backs M'Carl's Memorial Bridge Ruling," Apr. 16, 1926; "Arlington Bridge Delay Threatened By Ruling in House," Jan. 12, 1927; "House Action Fails to Halt Bridge Work," Jan. 14, 1927; and "Independent Offices Bill Passes House," Jan. 15, 1927.

[71] "$2,500,000 Provided to Continue Work on Memorial Span," *Washington Post*, February 16, 1926.

change prompted the Bridge Commission to divide the work into smaller, specialized contracts, which meant that smaller firms could effectively compete for them. With more firms bidding, many bids came in lower than expected. Financing costs were also reduced, and the cost-plus contract of the general contractor eliminated. An added bonus was that the speed of work also increased, which led to still lower costs over the long run.[72]

Substructure (Pier and Abutment Foundations) Construction

On January 28, 1926, the AMBC selected the H.P. Converse Company for the $1.3 million substructure contract, in large part because of its considerable experience with bridge foundations, and the Bridge Commission wisely left the construction method entirely up to the company. By mid-March 1926, Converse had begun work by setting up a field-operations office and blacksmith shop near the site of the Washington end of the bridge. Converse elected to build the bridge from the Washington shore toward Columbia Island. With most of its work in mid-river, the company erected a concrete mixing plant, cement storage house, and a derrick on barges that were easily moved to the different locations as needed. Once the job site and equipment were ready, work on the substructure could begin, and it was well underway in April. By June 30, the cofferdams were in place for Abutment 1 and piers 1 and 2, and excavation was in progress for Abutment 1 and Pier 1. The company poured the bridge's first concrete on September 23, 1926.[73]

H.P. Converse chose to construct open-top, single-wall, braced cofferdams, "of unusual size," as George Follett, an engineer for the company noted.[74] The cofferdam was built with interlocking steel piling. Steel sheet piles were customarily used when the water depth was greater than 20' or if a piling had to be driven into soft rock or other material to get a toe-hold. In this case, however, "the rock was usually a hard gneiss and the overlying material of little value either for a toe-hold or as a waterstop," which meant that the sheet piling had to be otherwise braced and the gaps plugged.[75]

[72] *Office of Public Buildings and Public Parks of the National Capital, Annual Report of the Director of Public Buildings and Public Parks of the National Capital* (Washington, DC: Government Printing Office, 1928), 49-40.
[73] "Bridge Commission Accepts Boston Bid," *Washington Post*, February 5, 1926; *Office of Public Buildings and Public Parks of the National Capital, Annual Report of the Director of Public Buildings and Public Parks of the National Capital* (Washington, DC: Government Printing Office, 1927), 19.
[74] George A. Follett, "The Construction of a Cofferdam," *The Military Engineer* 20, no. 109 (Jan-Feb 1928): 29.
[75] Walter J. Douglas, "Foundations and Earthwork," 746.

To construct the cofferdams, two ranges (rows of wooden piles) connected by two lines of wales, were driven 200' and 300' upstream from and parallel to the bridge axis. Working from these, a steam pile driver on a barge drove wooden piles spaced 8' apart in the rectangular outline of the cofferdam slightly outside the sheeting line. The outline piles were connected by three lines of wales against which the sheet piles were placed, each interlocking with the next, around the rectangle, and driven to rock. A horizontal bracing timber frame was then built floating inside the cofferdam, close to the inside face of the sheeting, to keep the sheet piles from caving inward. As excavation of mud inside the cofferdam began, vertical posts were added to the first level of bracing timber and another rectangular frame built above that, sinking the first frame below water. The process continued, tier upon tier, until the frame hit the bedrock. As long as the sheet piling had been driven plumb, the frames all fit. The pile diver then placed the final bracing posts at the bottom.

Derricks with clamshell buckets excavated the mud to reach the rock, which, as the investigation had indicated, was quite uneven and jagged, leaving gaping holes where the sheet piles met it. Since these had to be plugged to de-water the cofferdam, the workers pumped grout into the spaces. Once pumping began, the water pressure on the outside pushed the sheet piles inward to close the joints. Anywhere leaks were detected, they poured cinders outside the cofferdam that were sucked into the cracks to complete the seal. With a relatively dry work surface, laborers shoveled out the remaining mud, broke off loose and jagged rock, cut and covered channels and sumps for the remaining seepage, thoroughly cleaned the rock surface, and poured the first layer of concrete to establish the foundation. After this layer had cured, they removed the interior bracing in 11' x 11' sections and poured the next layer of concrete. To insure that all of the concrete cured properly, the engineers specified a certain sequence for pouring it. This prevented undue shrinkage stresses and cracks. It also allowed the heat generated during curing to dissipate easily and avoided the pouring of additional concrete on top of any that had not adequately cured.[76] Above the -3' elevation, the granite courses were laid and waterproofed first, after which the concrete core was poured and the granite cutwater tops applied.

[76] "Pouring Diagram, Abutment No. 2," AMBC Drawing No. 2E3-16, is typical of these drawings. A drawing was done for each abutment and pier because the amount of concrete varied due to the dimensional differences.

The work proceeded at a good pace, even though H.P. Converse suffered one embarrassing setback. In an effort to accelerate its progress, the company quietly began requiring its workers to report to work two hours before the official start time. At the end of July, the government learned of this. Grant reprimanded the firm and enforced the federal eight-hour day law carefully from that point on.[77] Converse continued to make good progress and completed its work in January 1928.

Masonry Superstructure

When Clarence Sherrill decided that the Arlington Memorial Bridge would have a concrete structure faced with ashlar granite, he did so with confidence based on several decades of successful use of the material in bridges, particularly arch bridges. In 1871, John C. Goodridge designed the first concrete bridge built in the United States, the Cleft Ridge Span, an un-reinforced concrete arch in Brooklyn's Prospect Park. The Alvord Lake Bridge in San Francisco, designed by Ernest l. Ransome and completed in 1889, became the nation's first steel-reinforced concrete arch bridge. Both remain in service, and they served as prototypes for many other concrete arch bridges built during the ensuing four decades. During this time, various bridge engineers favored different methods of stress analysis for arches. Fortunately, they were conservative, generally reliable, and resulted in safe bridges, even though they were not fully understood. In 1925, Charles S. Whitney presented a comprehensive analytical method for symmetrical arch design that was theoretically sound, and it led to greater computational standardization.[78] Thus, by 1926, most bridge engineers were familiar with concrete arch theory and practice, even though competing computational methodologies remained in use for a decade or more.[79]

Largely because of its overall camber, the Arlington Memorial Bridge presented some unusual arch design problems. John l. Nagle, the design engineer, described the arch design and construction in the March-April 1928 issue of *The Military Engineer*, and that thorough explanation is herein allowed to speak for itself.

[77] "8-Hour Labor Day Enforced On Bridge," *Washington Post*, Aug. 9, 1927.
[78] Charles S. Whitney, "Design of Symmetrical Concrete Arches," *Transactions of the American Society of Civil Engineers* 86 (1925): 931-1103.
[79] Clyde T. Morris et al., "Concrete and Reinforced Concrete Arches: Final Report of the Special Committee," *Transactions of the American Society of Civil Engineers* 100 (1935): 1429-1581.

Structural Design

Arch Construction: With the few minor exceptions arising in the underpass arches and approaches, which vary slightly from each other because of special local conditions, the bridge structure is symmetrical about the middle of the draw span. The four masonry arches on each side, counting from the shore toward the draw span, have lengths of 166', 172' - 8", 177' - 4", and 180', respectively. The elevation of the grade line of the roadway at the middle of the draw span is 45' above mean low water, and the gradient of the roadway is downward toward each shore on inverted parabolic curves to an elevation of 34' at the entrance pylons, making a total amount of 11' of longitudinal camber in the bridge.

The rise-ratios of the steel arches were proportioned to maintain, so far as possible, the same visible sizes and shapes of the arches in order to eliminate any undue effect of the camber of the longitudinal profile. A further consideration in the proportioning of the rise-ratios was the equalization of the horizontal thrusts of the arches on the inside of the intermediate piers. As finally adopted, the arches adjacent to the shore, although somewhat shorter than those adjacent to the draw span, have a flatter rise-ratio than the latter, in consequence of which the resulting horizontal thrusts of these arches are practically the same. The same equalization of thrust was also effective in the intermediate arches, so that little, if any, unbalanced dead-load thrust is applied to any of the intermediate piers.

The arches are of the full-barrel type, and are of reinforced concrete except for a ring of granite *voussoirs* dovetailed with the concrete barrel at each face. The thickness of the arch barrel at the crown is 2' - 3", and at the skewbacks is 6', the thickness of the arch barrel between the crown and the springs varying in such a manner as to maintain approximately the same critical stresses along the length of the arch. The dimensions just given apply to all four of the arches, regardless of their different span lengths. Also, the four arch barrels have the same thickness at all points whose distance from the crown, expressed as a fraction of the span length, is the same.

Contrary to the procedure followed in most arches, the shape of the intrados curve alone was fixed by a formula. This was done in order that precise dimensions could be furnished for the cutting of the granite *voussoirs*. On the other hand, the shape of the neutral axis was not defined analytically, but was derived indirectly from the intrados curve by laying off on the normal to the latter curve the half-thicknesses of the arch barrel as computed by the thickness formula. As finally shaped, the neutral axis of the arches coincides almost exactly with the dead-load pressure line.

The arch barrels were analyzed by the ordinary elastic theories and presented no unusual difficulties. Originally, it was intended to eliminate tension in the arch barrel altogether, and to keep maximum allowable compressive stress within 650 psi. Actually, it was found that these requirements were unduly restrictive, and tensile stress to the extent of some 50 psi in the concrete (about 800 psi in the steel) was found to exist. As this tension was occasioned by a very unlikely and infrequent condition of loading and temperature, it was considered

warrantable to accept it. Further, the highest compressive stress in concrete was found to amount to 675 psi but, as this was occasioned only by the same unusual conditions, it also was accepted. For the purposes of computing temperature stresses, the normal temperature was assumed to be 55°F. Assumed variations were taken from 25° above and 35° below the normal; that is, 80°F and 20°F, respectively.

The specifications for the concrete of the arch barrels (and for that matter all other concrete of the structure) call for six bags of Portland cement per cubic yard of concrete in place, with a maximum slump of 6". It is expected, however, that actual slumps will be somewhat less than the maximum allowed; and, by extensive tests which were carried out prior to the writing of the concrete specifications, it was demonstrated that the ultimate compressive strength of such concrete, even with the maximum slump, will not be less than 3,000 psi.

The concrete arch barrels are reinforced longitudinally both at the intrados and extrados by 1"-square bars spaced 8" center to center, the clear concrete protection for the steel being 2". To avoid undue shrinkage stresses and consequent cracks in the arch barrels, the latter will be poured in four longitudinal sections, each of a width of approximately one-fourth of the width of the arch barrel face to face, with longitudinal keys 3' in width between them. Each longitudinal section will be poured in four blocks, about 45' in length, with transverse key blocks at the crown, at the skewbacks, and at the quarter points. The longitudinal steel is not continuous across the transverse keys, but the steel for the adjacent blocks is lapped out but not wired together, so that any relative deformation of the arch centers during the pouring of the barrels will cause no initial stress on the steel.

The arch centers will consist of steel ribs hinged at the crown and at the abutments, each center being wide enough to carry one of the longitudinal sections of the arch. The centers will be shifted transversely as the successive longitudinal sections are finished. The two inside longitudinal sections will be completed first, in order that all benefit and advantage of the study of the behavior of the centers under load can be taken in the construction of the outside longitudinal sections which are faced with the granite. It is desired that the granite rings be set as truly as practicable so as not to disturb the jointing of the ashlar masonry carried on the granite *voussoirs*. The centers will be so manipulated that the unbalanced thrust during the pointing of the arch barrels on any of the intermediate piers will not amount to more than that due to one longitudinal section of an arch. The specifications provide that the decentering shall not be done until twenty-one days after the last concrete has been placed. After the arch was constructed, the steel centers were removed.

<u>Cross Walls and Spandrel Walls:</u> The deck of the bridge is carried by solid walls built upon the back of the arches. In addition to carrying the deck, these cross walls also perform the function of carrying the spandrel walls and distributing the weight of the same uniformly over the entire width of the arch barrels. The clear distance between the cross walls is made constant for all arches so as to permit the standardization of formwork to the greatest degree possible. The thickness of the

cross wall varies from 1' - 6" for the lowest (those near the crown of the arches) to 2' for the highest degree possible. The thickness of the cross wall is more by practical considerations of construction requirements than by theory. A passageway on the longitudinal center line of the bridge is left through all cross walls to permit access to all parts of the back of the arches. Because of the camber line of longitudinal grade line, the cross walls on the side of the arch nearer the draw span are somewhat higher than the corresponding walls on the side toward the shore; and, to compensate for the extra weight of the former due to the extra height, openings are placed in the higher walls, the weight of the omitted material being equal to the excess weight due to the extra height. The net effect of this procedure is to make the dead load on all arches ponderably symmetrical about the crown, with the consequent simplification of design work.

The bases of these cross walls are poured integrally with the arch barrels, and vertical dowel bars are left projecting from these bases so as to insure monolithic action between the walls and the arches. A horizontal construction joint between the cross walls and the deck is placed at the under side of the latter.

The spandrel walls will not be placed until after the deck slab is finished. This procedure is followed for two reasons, namely, that as much dead load as possible be carried by the arches before the spandrel walls are placed, to avoid dead-load stresses in the latter, and also to insure the necessary transverse stiffness in the arches to distribute the weight of the spandrel walls.

<u>Deck Slabs:</u> The roadway slab is 11" thick, and acts structurally with the cross walls so as to constitute, with the latter and with the arch barrel, a beam having approximately an **H**-section which is intended to provide the requisite transverse stiffness for the purpose mentioned above. The wearing surface of the roadway is of asphalt and is 3½" thick.

The main reinforcing steel of the deck runs longitudinally. In addition, a considerable amount of transverse steel is placed both in the top and bottom of the deck slab as reinforcement for the **H**-beam just described. The structural part of the sidewalk is a 6" slab which will carry a wearing surface 4" thick. The actual placing of the wearing surface, which is ornamental in quality, will be done after the construction of the superstructure. This surface will most likely be pre-cast to insure the desired ornamental effects, and set on the structural slab like large tiles.

The deck is designed to carry a continuous line of 20-ton buses on all six lanes of the roadway, or such portion of that aggregate load as gives rise to critical conditions in the various members of the structure. In addition, provision is made to carry a 40-ton tank in the two lanes adjacent to the curbs, the other lanes of the bridge being vacant. As a matter of fact, the latter condition is hardly more severe than the load due to the buses. The sidewalks are designed for a uniform load of 100 psf. An impact allowance of 30 per cent was made for the design of both slabs but, because of the mass of the bridge, no impact allowance was provided for the design of the arches.[80]

---

[80] John Nagle, "The Arlington Memorial Bridge," *The Military Engineer* 20, no. 110, (March-April 1928): 154-160.

To confirm the design, Princeton University Professor George E. Beggs carried out a series of studies using scale models. These studies indicated that the deck had a beneficial stiffening effect upon the arch, thereby reducing live load stresses. But since the dead loads on the structure were so high in comparison to the live loads, this beneficial effect was not taken into account, although it could have resulted in the use of somewhat less material and a lower cost. While the contribution of such an integral deck to the overall structure would ultimately become a standard element of arch bridge design, this did not happen overnight. Bridge engineers, being conservative by nature and experience, generally stayed with proven design paradigms and ignored the usefulness and design possibilities of the deck stiffening for many years thereafter. Beggs also conducted a separate set of model tests to account for the distribution of the granite and concrete spandrel dead load by the transverse walls. The moment coefficients developed from these tests were used throughout the Arlington Memorial Bridge's design process.[81]

In December 1927, with the substructure work nearly complete, the AMBC awarded the main contract for erection of the masonry arches to the Hunkin-Conkey Construction Company of Cleveland, Ohio.[82] Like H.P. Converse, Hunkin-Conkey was a nationally recognized firm with considerable bridge experience, and the company's responsibilities included all of the concrete, steel, and granite construction work for the fixed spans above the 10' elevation.

The anticipated construction sequence is described above in the excerpt from Nagle's "The Arlington Memorial Bridge" article in *The Military Engineer*, but a few additional details and deviations deserve mention. As construction continued, the engineers made some design revisions based on test results that enhanced the bridge's structural strength. They thickened the granite *voussoirs* so that the outside of each span would function as a true arch and support the granite facing. They also added a concrete wall to the end of each span, which supported not only the roadway superstructure but also the ends of each spandrel.[75] This made each spandrel wall 94' wide and significantly increased the span's dead load. Since an arch is loaded in compression, this actually strengthened the bridge. Where the design live load of the bridge was equivalent to that imposed by a continuous row of city busses in all lanes, these changes also

[81] Nolin, *Historic Structure Report*, 201-202.
[82] *Office of Public Buildings and Public Parks of the National Capital, Annual Report*, 1928, 51.

meant that each of the outer lanes of the bridge could now carry up to 40 tons, enough to allow the passage of Army tanks.[83]

Construction of the Arlington Memorial Bridge superstructure continued into spring 1929, when an unexpected problem resulted in a serious delay. The H.P. Severin Company, which had been contracted to build the Boundary Channel Bridge and other work on Columbia Island, discovered an unstable rock shelf 13' thick under the island that extended under Abutment 4 of the Arlington Memorial Bridge. This so-called "rotten rock" had not been revealed by borings two years earlier. Additional borings on both shores revealed a thin layer of sand and gravel under Abutment 1 as well. Both strata had to be removed and the abutments stabilized before construction could proceed further at the ends of the bridge. Work on the bridge's abutments and approach spans resumed once these stability issues were addressed, and except for exterior masonry facing, H.P. Converse had essentially completed the two structures by mid-1929.[84]

Like so many elements of the Arlington Memorial Bridge, the seemingly mundane issue of pavement was a subject of debate. Kendall's original specification called for a "3½" wearing layer" on the masonry spans and approaches, but he did not specify a material.[85] The Strauss drawings show a similar allowance for the wearing layer, but they make no mention of its composition, either. The Corps of Engineers argued for a surface of concrete or asphalt that would be economical to install and maintain, as well as provide a smooth surface. The AMBC members preferred a more classical surface, such as Belgian blocks. These roughly rectangular granite paving stones could be laid in an attractive pattern that would be more consistent with the bridge's other monumental elements. After debates about the performance versus appearance qualities of several surfaces, the AMBC ultimately chose appearance. The roadway would be Belgian blocks of 4" granite stones laid in a repeating fan design often called a tulip pattern. This formal treatment was no doubt attractive and appropriate for a memorial structure, but the rough surface was not popular with motorists who traversed the bridge regularly.[86]

---

[83] *Office of Public Buildings and Public Parks of the National Capital*, *Annual Report*, 1928, 49; "Bids to Be Invited For Constructing New Bridge Spans," *Washington Post*, October 9, 1927.
[84] *Office of Public Buildings and Public Parks of the National Capital, Annual Report*, 1929, 66.
[85] "Intermediate Piers Deck and Supports," AMBC Drawing No. 2E3-21, is typical.
[86] The Belgian block paving of the Arlington Memorial Bridge is no longer extant, but the same paving was applied to the similarly styled, but shorter Boundary Channel Bridge (HAER DC-7-B) on Memorial Avenue between

Granite

Most Arlington Memorial Bridge contractors supplied all of the raw materials, such as concrete aggregates and steel to build their portion of the bridge, but the granite needed to face the concrete arches, piers, and abutments posed a unique problem. The sub- and superstructure contractors could install the stones, but they had no good sources for them, and architect William Kendall of McKim, Mead & White had very definite ideas about the color and texture needed to fulfill his design. This, plus the fact that the granite would be a major expense, meant that the AMBC had to be involved with its procurement. Finding sources that could quarry uniformly acceptable granite and finish the massive quantity of stones to the required precision became the AMBC's first big challenge. As engineer John Nagle later noted, "the architectural requirements were the most severe that the granite industry had ever been called upon to meet."[87]

On Nagle's recommendation, the AMBC undertook a study of all granite quarries on the Atlantic coast to determine not only the quality and quantity of their stone, but the ability of each company to handle such a large project in the time required. The AMBC members knew little about the granite industry, so they engaged J.D. Sargent, President of North Carolina Granite Corporation, to render expert assistance with the plans and specifications. The Commission members might have preferred to let one contract for all the granite in the overall project (which also included the Boundary Channel Bridge, Watergate steps, and Arlington Cemetery entrance drive and gate), but they doubted that any one quarry would be able to furnish all of it and decided to divide the work. Ultimately, six granite companies furnished stone for all parts of the project under fourteen contracts, with two of them furnishing granite for the Arlington Memorial Bridge.

In 1926, the AMBC advertised for proposals to supply all of the Arlington Memorial Bridge granite. The Stone Mountain Granite Corporation of Stone Mountain, Georgia, returned the lowest price, but the architects felt that this stone's bluish-grey color was unsuitable, at least for the bridge's superstructure. The North Carolina Granite Corporation of Mount Airy, North Carolina, was the next lowest bidder, and its stone, being whiter than that from Stone Mountain Granite, was deemed to be ideal in color and grain for the superstructure. Consequently, the

---

Columbia Island and the Virginia shore that was constructed as part of the overall project. That paving remains in service and clearly visible. See Nolin, *Historic Structure Report*, 232-233.

[87] John L. Nagle, Speech to Mt. Airy, North Carolina Kiwan1s Club, August 22, 1930, NARA, RG 42.

AMBC awarded North Carolina Granite a $1.615 million contract to provide the granite for the superstructure of the bridge above the spring lines of the piers and abutments, the pedestals for the equestrian statues, and the western end pylons. The company also carved the bison heads on the keystones, the *fasces* on the piers and abutments, and the medallions enclosing the bas-relief eagles under a separate contract. These carvings were delivered rough-cut and finished only after installation. Stone Mountain Granite was awarded a $207,000 contract to furnish the granite for the piers and abutments up to the spring line of the arches. The faces of the stones from both vendors were bush hammered for an appearance like natural weathering, and they were delivered with all holes for lifting, anchors and cramps cut so that they were ready for installation. A third granite firm, Grenci & Ellis, Incorporated, of Peekskill, New York, furnished the two free-standing eagles for the western-end pylons and the sixteen bas-relief eagles applied to the piers and abutments.[88]

Detailed design of every stone and setting was done by the Corps of Engineers under Nagle's direction. The engineers calculated the precise dimensions of each stone to yield the correct proportions. One critical element of this was defining the rabbets along each stone's edges so that they would form consistent perimeter channels to define each stone when laid up. The full width of a channel was cut into one stone, so most stones had rabbets cut into two edges that would mate with non-rabbeted edges of the adjacent stones. This simplified the carving and produced uniform channels when assembled, but it required careful, tedious work on the part of the drafters to avoid errors. They assigned a unique setting number to each stone to indicate its exact position on the bridge. This helped avoid drafting errors, and it provided a clear guide for the masons who set the stones.[89]

Granite Management

As described above, the selection and procurement process was daunting in itself, but receiving, storing, and keeping track of some 150,000 individually cut and numbered stones required meticulous planning and great attention to details. To accommodate this immense

[88] *Annual Report of the Director of Public Buildings and Public Parks of the National Capital*, 1927, 19-20.
[89] "Mount Airy Granite, Center Arch No. 6 to End Abutment No. 3," AMBC Drawing No. 2A3-41, is typical of the set of drawings that detailed stone dimensions and locations. These drawings note the stones with anchors, the carved channels along their edges, and areas that were to be "in rough for carving." The 2A1 series consists of the similar set of drawings from Stone Mountain Granite.

quantity of stone, the AMBC contracted with the G.B. Mullin Company of Ijamesville, Maryland, to build a stone yard on the Virginia shoreline between the Boundary Channel and the Rosslyn Connecting Railroad (operated as the Rosslyn Branch of the Pennsylvania Railroad). A short spur connected the Rosslyn Branch to the yard, and an additional 3,500 feet of track allowed the arriving flat cars to be spotted next to the location selected to store those particular stones. This trackage also allowed contractors to move stones around the yard on two Army-furnished flat cars, particularly between their storage locations and a dock for barges on the Boundary Channel. The Army loaned a 40-ton crane for loading and unloading stones for the duration of the project, and Army Corps of Engineers personnel maintained the inventory records.[90]

The carloads of granite began arriving in late June 1926, with shipments from Stone Mountain Granite for the top portions of the pier foundations. Shipments from North Carolina Granite started to arrive shortly thereafter, and they continued for a year, with the last of 125 carloads arriving in June 1928. Stones to face the substructure were the first to be moved to the bridge and installed, with the first of these going on Abutment 1 and Pier 1, which had concrete in place. As construction progressed, this yard became the destination for other bridge components as well, and its long-term storage capability proved quite useful throughout the project. Most of the steel sub-assemblies from bascule span contractor Phoenix Bridge arrived well before they could be erected, and many of them were stored in the yard for several months.

Bascule Span

The design of a movable span for navigation within the aesthetic constraints established by the AMBC was a challenge probably unparalleled in any other movable bridge. Professor Burr, the first place winner of the 1900 design competition, suggested, but did not detail, what turned out to be the successful concept. Although bascule bridges of significant size were just beginning to gain acceptance in American engineering circles in 1900, Burr "held that the swing plan does not offer a sufficiently graceful appearance ... nor does it permit desirable architectural treatment of the adjacent features of the structure. On account of the uncertainties of operation

[90] *Annual Report of the Director of Public Buildings and Public Parks of the National Capital*, 1927, 19-20.

of lift bridges and their unsightly appearance, it was considered that the bascule type should be selected." [91]

The Corps of Engineers Board of Award agreed and further suggested that, "the substitution of a curve, instead of a right line, for the lowest part of the draw is regarded as desirable." [92] All but one of the draw-span designs submitted in 1900 was parallel-chord trusses, the simplest design for bascule and vertical lift spans. With exposed trusses, these early designs looked totally different from the graceful arch spans flanking them and usually abutted against massive towers and piers for both stability and, in the case of lift spans, support for the wire ropes and upper sheaves. Their designers tried to ornament them as major features of their monumental compositions, but they were unacceptably massive structures that seriously conflicted with the overall desired aesthetic for the entire bridge. The Senate Park Commission of 1901 likewise agreed and recommended that the draw span be designed to blend in with the remainder of the bridge and not include central towers. The War Department concurred as well. The Chief of Engineers at the War Department, Lansing H. Beach, wrote to express his view that Congress, over the years, had intended that the Potomac remain open as a commercial waterway for large vessels by "numerous appropriations" to develop the river into a deep and wide channel leading to the wharves at Georgetown, and by removing the historic Long Bridge and constructing the existing Railway Bridge and the Highway Bridge in its place, both of which were required to have draws.[93]

On October 17, 1923, Sherrill solicited tentative plans and bids for the bascule span design from six engineering firms prominent in movable bridges. In his letter, Sherrill stressed his desire to make the bascule as inconspicuous as possible, by:

> 1. Making the draw piers as nearly identical to the other piers as possible, to allow for the future removal from the design of the bascule and its replacement by a fixed span;
> 2. Elimination of the control houses and tender's booths from the deck, where they were usually placed, and making the observation windows as inconspicuous as possible; and

---

[91] "The Memorial Bridge Across the Potomac," 363.
[92] "The Memorial Bridge Across the Potomac," 369.
[93] Lansing H. Beach, Chief of Engineers, War Department, to Secretary of War, Jan. 18, 1923, NARA RG 42.

3. Lowering of the springing lines of the draw arch to match the masonry arches stressed the necessity to make the bascule and its piers as nearly identical as possible.

These considerations basically mandated an underneath counterweight type of double-leaf bascule with an external arch-shaped façade to hide its internal structure. This proved to be more difficult to achieve than the bridge commission members thought when it requested proposals. Meeting both the operational and aesthetic constraints ultimately required a unique design, with which only one of the proposers had experience. At the time, the solicitation seemed little more than an exercise to Sherrill. While he obediently requested draw span design proposals, Sherrill, along with the rest of the AMBC, continued to believe the bascule would be deleted from the design and replaced by a fixed masonry span before the bridge was actually built.

Evaluation of the proposals took far longer than the time normally allotted, but this was an unusually complex design problem. Walter J. Douglas, consulting engineer for the entire project, judged the competition, and he selected the Strauss Engineering Corporation (formerly Strauss Bascule Bridge Company) of Chicago to design the span. Douglas noted that Strauss, "had wide experience in the design and detailing of bascule bridges," and he was particularly impressed with the excellence of their structural and mechanical details.[94] In fact, Strauss was the only submitting firm that had first-hand experience with a unique type of bascule bridge known as the Chicago type that Strauss had invented. He had completed several of them across the Chicago River in that city, many to replace unsightly swing spans. A Chicago-type bascule span had the mechanism and much of the structure below the deck, making the design a good basis for the Arlington Memorial Bridge's bascule. Strauss held several patents for movable bridges that he aggressively protected; winning a suit and appeal against the City of Chicago for infringement after city engineers designed and built a Chicago-type bridge without engaging him.[95]

Bascule Design

Strauss conceived the design as a Chicago-type double-leaf bascule with an open-truss structural frame and underneath counterweights. He modified the common Chicago-type truss to

[94] Walter J. Douglas to U.S. Grant 3d, Dec. 1, 1926, NARA, RG 42.
[95] Baker, Alschuler and Evans, "City of Chicago v. Strauss Bascule Bridge Co.," 7th Circuit, 261 F. 358, 1919.

place *all* structural members below the deck where they could easily be concealed. Each leaf is composed of two main bascule trusses with curved lower chords placed under the curbs at the edges of the roadway. Since the main trunnions about which the span would rotate also had to be below the deck level, Strauss could not use completely straight upper chords. They had to include a vertical offset of 2' - $7^{5}/_{8}$" to provide clearance for the trunnions and bearings. These main trusses are connected and elaborately braced between the upper and lower chords, as well as at each panel point to maintain the span's alignment, especially when raised during significant winds. As noted earlier, the outer two panels at the tips are plate girders, while the five heavier and deeper panels toward the heel are arranged in a modified Warren plan. Strauss specified a high-strength steel, relatively uncommon at the time, for the main truss members and gussets in the panels near the trunnions to reduce weight while maintaining adequate strength. Cantilevered trusses attached to the outside of the main trusses supported the sidewalks.

The articulated counterweight required its own pair of trunnions located 18' from the main trunnions on the heel end of the main trusses and, like the main trunnions, intersected the upper chords. With the size and weight of each span and counterweight, these trunnions had to be quite large. Each counterweight weighs about 2,400 tons, and the rest of the leaf weighs about 1,400 tons. The total weight "is four times what might be considered typical of a large highway bascule leaf and may be considered a notable feature of AMB."[96] Each counterweight "hangs as a pendant from counterweight trunnions at the rear end of each bascule truss, the arrangement being such that the counterweight moves parallel to itself as the leaf rotates upon the main trunnions."[97] The large mass of the counterweights necessitated two pivoting arms connecting each counterweight to the fixed structure to insure that the counterweight remained in a specific orientation as it moved.

The main truss design dictated that the trunnions had to be located 30' above the floor of each abutment. This was accomplished by supporting them on steel trunnion posts secured to steel grillage foundations built into the abutment floor. Strauss elected to place a pair of connected trunnion posts on each side of the span. The main truss would fit between them. The trunnions would rotate with the span in bearings near the tops of the trunnion posts. Thus, two

[96] Maguire, *Report on Bascule Span of Arlington Memorial Bridge*,
[97] R. S. Foulds, "Erecting 3,800-Ton Bascules in the Arlington Bridge," *Engineering News Record* (Mar. 3, 1932), 319.

trunnion post assemblies supported the entire 3,800-ton weight of the span and counterweight, plus any wind loads when the span was open. Conveniently, the trunnion posts could also support one end of the stationary deck that spanned the abutment.

Many of Strauss' earlier Chicago-type bridges had counterweights that were fixed to the heel end of the deck, and this design caused the heel end of the deck to descend when the span was opened, leaving a large opening in the deck that required a substantial barrier to prevent vehicles from driving into it. This would not be aesthetically suitable for the Arlington Memorial Bridge, so Strauss chose to locate the heel break in the deck (the divide between the fixed and movable portions) on the toe side of the main trunnions and extend the fixed deck over the length of each abutment. In this arrangement, the heel of the bascule span's deck would rotate up and over the trunnions and stop just above the abutment's deck when the span was fully open.

Douglas approved of this concept and explained his reasoning to Grant thusly: "Each leaf of a bascule bridge is a lever with unequal arms, so counterweighted as to be balanced when closed and not under live load and also when open and not under wind pressure. The deck or floor over each leaf may be cut in front or back of the point of support or fulcrum."[98] He went on to explain that, if the deck is cut in back of the trunnion, the bridge will tend to open if the live load, i.e., vehicles, is between the trunnion and the heel break in the deck. To avoid the necessity of the complicated rear brake and heel lock mechanisms required to hold such a bridge closed, Strauss chose the forward floor break. In addition to the advantage of remaining closed under live load, with this arrangement no gap was created when the leaf was raised, providing a traffic barrier and preventing debris from falling into the machinery below.

The final design, dictated by the 184' distance required between the abutments to maintain the bridge's overall proportions, placed the centerlines of the east and west trunnions 216' apart. When open, the clear width for navigation is only 140', "due to the unusual manner in which the lower chord of the arch span projects forward of the pier when the leaf is raised."[99]

As discussed in the Description section of this report, Strauss employed articulated counterweights to be able to conceal them within the abutments. Compared to a Chicago-type bridge having counterweights mounted solidly on the truss's heel, each leaf of one with

[98] Walter J. Douglas to U.S. Grant 3d, Dec. 1, 1926, NARA RG 42.
[99] Maguire, *Report on Bascule Span for Arlington Memorial Bridge*.

articulated counterweights required at least eight additional bearings, some of which could be difficult to access. Accordingly, articulated counterweights increased the initial expense as well as maintenance time and cost, and they could present serious problems, especially in bridges that were not operated frequently. Without the proper lubrication and periodic operation, counterweight trunnions were known to seize, which could cause structural failures in the counterweight hangers, stabilizing links, or trunnions, most of which rendered the bridge inoperable and often unsafe. Even though the Arlington Memorial Bridge opened only a few times per day at most, there is no record of any such failure, indicating that the bascule span was well maintained throughout its service life. Never very common, all but a few Chicago-type bridges with articulated counterweights have been replaced with simpler bridges.[100]

The limited space available for the counterweights within the abutments presented another problem. The restricted volume of the counterweights meant that very heavy concrete would be required. While Strauss and Phoenix Bridge had previously used concrete loaded with steel punchings to add weight, calculations quickly revealed that the standard mix would not work in this case. Strauss' original specifications called for steel punchings as coarse aggregate to obtain the required unit weight, but "this bridge would have required about 3,000 tons of punchings—an amount too large to be accumulated from all the available sources in the time allowed."[101] Additionally, the counterweight would be too large to fit in the available space. A denser mix was needed.

To determine the ideal concrete mix for the counterweights, Phoenix Bridge Company employed Professor Willis A Slater of Lehigh University. Slater found that using primarily steel punchings was unsatisfactory, not only because they were the most expensive ingredient, even if a sufficient quantity could be found, but also because a high proportion of them caused segregation of the concrete. They were too smooth to bond well with the Portland cement, which made concrete that was difficult to work and weak after it cured. Slater tested five other coarse aggregates and found the best formula to be a mix of cement, sand, and a limited amount of steel punchings supplemented with finely crushed iron ore. The iron ore was effective in increasing the concrete's density, it was easily distributed evenly during mixing, and it bonded well with the

[100] Terry L. Koglin, *Movable Bridge Engineering* (Hoboken, NJ: John Wiley and Sons, 2003), 46.
[101] Maguire, *Report on Bascule Span for Arlington Memorial Bridge*.

cement. At the time, the only iron ore available in the required quantity was located in Sweden, so the required amount was shipped to the site.

Once the span's weights and the basic arrangement of the drive mechanism were reasonably well known, Strauss's electrical engineers set to work on power and control circuit design and specifications for the various electrical components. The basic circuits were similar to previous bridges in many respects, but the Arlington Memorial Bridge's relatively large motors required heavier-gauge wiring, contactors, and power supply equipment than those needed for smaller bridges, and the three control panels with partially overlapping functions added complexity to the control circuitry. Alternating current electrical power was to come across the east half of the masonry spans to Abutment 2, where a motor-generator set would supply the DC electricity needed for the variable-speed drive operation. To mitigate a commercial power failure with the bridge open, they included an emergency generator to furnish sufficient DC power to close the bridge.

To transfer shear and equalize deflections at the toes of the leaves when closed, bascule bridges typically have a mechanism to connect them to each other called a span lock. Most use sliding, rectangular bars on one leaf that mate with matching holes on the other leaf. To eliminate shear loads in the bars, especially in large bascule spans, Strauss had invented a different type of span locking device that he specified for the Arlington Memorial Bridge. Strauss placed a pair of span locks in the toe of the east leaf, with matching sockets in the west leaf. Each lock featured an internally expanding jaw arrangement that extended and opened in a vertical direction to engage the west leaf's sockets. They were motor-driven via a crankshaft and controlled from the operator panel. For emergencies and maintenance, each was supplied with a removable handle that allowed manual actuation. Though more complicated than the conventional bar-type center locks, Strauss had developed it to "eliminate vertical play between the ends of the leaves under heavy traffic," and this bridge seemed to be an ideal application.[102]

To reduce the physical size of the truss members, Strauss specified that the main stress-bearing sections of the bascule truss and all stress-carrying connecting details were to be made of

---

[102] "Bridges by Strauss," Pamphlet, Strauss Engineering Corporation (Chicago, 1929). For a general discussion on span locks, see James M. Phillips III, "Bascule Bridge Locking Devices," The First Biennial Symposium and Exhibition on Movable Bridge Design and Technology (Tallahassee, FL, Nov. 4, 1985).

high-strength silicon steel meeting ASTM A94-27.[103] The minimum specified yield strength of silicon steel is 45,000 psi. Other structural steel members carrying lesser loads, including the roadway stringers and floor beams, the tie-plates, lacing bars, and cross-diaphragms for the bascule truss members are of standard carbon steel. This carbon steel had a minimum specified yield point of 30,000 psi.[104]

Strauss specified that most of the special fittings, such as the trunnion bearings and counterweight trunnions, were to be machined steel castings, but for the highly stressed main trunnions he required that they be forged rather than cast, then machined and polished to final dimensions. Both types of trunnions would rotate in phosphor bronze bearing sleeves with diameters machined to match. Those for the critical main trunnions have a diametric clearance of 0.034" ± 0.003". The clearance for the counterweight trunnions was 0.038" ± 0.003".[105]

Bridges across navigation channels are normally fitted with fenders to protect the piers or abutments from damage that would likely occur should a vessel veer off-course and strike one. Such collisions have caused a few bridges—not all of them draw spans—to collapse, so this is not a trivial concern.[106] For the Arlington Memorial Bridge, fenders constructed of heavy timbers were fitted on the channel sides approximately 25' from the foundations of Abutments 2 and 3. These extended to the river bottom and wrapped half way around each end of the abutments. Unlike the bridge itself, fenders could be repaired when necessary at a reasonable cost, and repairs of deteriorated members are known to have occurred as late as 1976.[107] The fenders are no longer extant, having been removed prior to 1988.

The engineers calculated that the ornamental pressed-steel façades to conceal the bascule trusses would add significant weight and cost to the span. "The bascule draw span is estimated

---

[103] "Specification for High Strength Structural Steel A94," ASTM, 1927. Also see note 16, page 28.
[104] "Yield strength" is the maximum amount of tensile force that can be exerted on a material without it permanently deforming. English units are pounds per square inch of cross section area.
[105] "Main Trunnion and Bearing," AMBC Drawing No. 2E6-37; and "Counterweight Trunnion and Bearing," AMBC Drawing No. 2E6-38.
[106] Possibly the best-known modern event of this kind occurred on May 9, 1980, when the bulk freighter *Summit Venture* collided with the Sunshine Skyway Bridge across Tampa Bay, Florida, in bad weather. The bridge piers had no fenders, and one pier failed on impact, causing 1,200' of the bridge to collapse, killing thirty-five people. See Deborah Blum, "Freighter rams Skyway, span falls into sea, at least 30 die," *St. Petersburg [FL] Times*, May 10, 1980. Many other collisions have caused damages short of collapse.
[107] For fender details, see Project 15A3, Repair of Bridge and Approaches, Arlington Memorial Bridge," U.S. NPS, 1976, sheets 14-16, NARA, RG 79.

to cost about $750,000, of which at least 50 percent is for ornamentation," said Nagle, who continued, "the bascule draw span will be treated on both sides with an ornamental fascia of pressed metal work which will be painted to agree as closely as possible, in both color and tone, with the granite facing of the masonry arches, the motive being to obliterate the otherwise jarring effect of a steel span, and to preserve the architectural continuity of the bridge."[108] The fascia trusses were fabricated and erected in the same manner as the main trusses, and the fascia were assembled from pressed panels of $^{3}/_{16}$" "rust-proof steel" and cast aluminum star, button, and key details. The original design, apparently by Strauss, dated May 26, 1928, was revised by McKim, Mead & White within a year to make the cast aluminum details more ornate. The architects did not make changes to the fundamental design of the fascia's panels, but the fascia was constructed with these detail changes. To avoid marring the fascia with rivets, they were spot welded to girts on the fascia trusses.[109] With the additional weight of the fascia panels, Strauss looked for ways to reduce the total weight of the span. He decided not to conceal the underside of the truss, which alone saved almost as much weight as the fasciae. For all practical purposes, only boat and ship navigators would see the span from below. Even when open, motorists would see the solid deck, not the opposite truss. The aluminum balustrades were considerably lighter than those made with granite, and they were much easier to attach so they would not break loose when the span was opened. Strauss also balked at the idea of using Belgian blocks to pave the leaves, and ultimately approved asphalt. This saved weight, but it also eliminated the possibility of any blocks dislodging and falling, possibly onto stopped cars.

Bascule Construction

The bascule span construction contract was advertised in June 1928, with bids due in July. The Phoenix Bridge Company, a subsidiary of the Phoenix Iron Company of Phoenixville, Pennsylvania, won the contract, even though the AMBC was *still* attempting to delete the bascule span. The final, deciding vote was likely cast when U.S. Grant III, Sherrill's successor, received a letter in September from Secretary of War Dwight A. Davis firmly restating the War

---

[108] Nagle, *Arlington Memorial Bridge*, 155.
[109] "Fascia and Balustrades," AMBC Drawing No. 2E6-26, shows the original design, and "Metal Detail," Rev. Mar. 22, 1929, no AMBC number, details McKim, Mead & White's revisions.

Department's desire for a bascule on the grounds that too much traffic would be obstructed by a solid span.[110]

The Phoenix Bridge contract included fabrication of all bascule components, except for the masonry abutments, and erection of the bascule spans on site. Phoenix Bridge subcontracted the electrical and mechanical equipment to W.V. Pangborne of Philadelphia and Faucus Machine of Cleveland, respectively.

One of the company's first tasks was to calculate and order the rolled steel sections needed, since these materials had relatively long lead times. Its pattern shop also began making wooden patterns for the steel castings that the foundry would produce. Component-fabrication work in Phoenixville started in September 1928, but the job soon proved to be more challenging than expected. The company encountered a number of problems manufacturing the bascule's components and insuring that all subassemblies fit up with one another properly to enable assembly at the site to proceed smoothly. The design was unusual, and the components had to be precisely made. As a consequence, the production of these elements went forward much slower than anticipated. By the end of June 1929, just 60 percent of the bascule subassemblies had been fabricated, and only the trunnion posts and the counterweight truss for the east leaf had actually been assembled.[111]

In common with standard steel fabrication practices of the time, the span's members were assembled almost exclusively from plate, angle, and bar stock using hot rivets. For quality and economy reasons, Phoenix Bridge assembled posts, braces, chord members, and other components at its Phoenixville, Pennsylvania, yard, and shipped the largest possible subassemblies to the job site. The larger members typically had a rectangular cross section with angles at the corners, plates making up two parallel sides, and flat-bar lattices on the remaining two sides. The repetitive work of riveting these together accurately was better done in the controlled conditions at the yard than over the river, and it made the erection of these subassemblies at the site much easier, quicker, and safer. It also made materials tracking easier once the components left the yard, having to keep track of one large member at a time instead of hundreds of small parts. One photograph shows one of the four racks being assembled at the

---

[110] Dwight A. Davis, Secretary of War, to U.S. Grant 3d, Sept. 17, 1928, NARA, RG 42.
[111] *Office of Public Buildings and Public Parks of the National Capital, Annual Report of the Director of Public Buildings and Public Parks of the National Capital* (Washington: Government Printing Office, 1929), 66.

Phoenixville Yard, but close inspection reveals that it was being assembled with only alignment pins at major connections and bolts in what would ultimately be riveted connections.[112] While not absolutely certain, this implies that the photograph shows a trial assembly at the yard to insure that all parts, joints, and rivet holes of this complex assembly were correctly aligned to insure easy erection on the bridge. With the correct fabrication of the rack's subassemblies assured, it would be disassembled so that the reasonably sized subassemblies could easily be shipped by rail to the Virginia storage yard. Such a procedure is still a common practice for large, critical assemblies, though the subassemblies are now generally welded fabrications that are bolted together at the job site.

Erection of the bascule span on-site presented its own set of problems. Since sufficient vertical clearance for river traffic had necessitated inclusion of the draw span in the first place, Phoenix Bridge had to assure unimpeded navigation during the construction period as well. To accomplish this, they erected the leaves one at a time. This allowed each leaf to be constructed in its horizontal (closed) position, which aided steel erection and was essential for pouring the concrete counterweight and deck. The company completed the east leaf before starting to erect the west one. Thus, the west side of the channel was open while the east leaf was under construction. When completed, the east leaf was opened to provide clearance through the east side of the channel, and the west leaf could be erected horizontally without being an obstruction to navigation.

During the bascule erection period, the fenders around the abutments were supplemented by a fender in the center of the channel to prevent vessels from going outside the open half of the channel and into the work zone. When both leaves were finished, they could be raised and lowered as necessary to permit navigation and allow final adjustments to the center locks, limit switches, and dampers. The central fender was then removed to make the full width of the channel available.[113]

Like the Hunkin-Conkey Construction Company that had erected the fixed spans, Phoenix Bridge had to use barges to deliver materials, as well as to support an erection derrick. Since the abutments were in place, the company located a 30-ton derrick on each one as that leaf was being erected. Together, the fixed and floating derricks could lift and position the

---

[112] Nolan, *Historic Structure Report*, Illustration 36, 213.
[113] The central fender is visible in Nolan, *Historic Structure Report*, Illustration 34, 208.

subassemblies where they were needed. Their lifting capacities were one factor in determining the maximum size and weight of the subassemblies fabricated at Phoenixville.

The first parts of each leaf to be erected were the trunnion posts. The steel grillages on which the trunnion posts rest were set and carefully leveled. The trunnion posts, weighing 22 tons each, were then bolted to them and aligned to one another. This was a critical step, since the two trunnions had to be on precisely the same axis for the leaf to rotate smoothly and without excessive bearing wear, if not failure. Phoenix Bridge made a set of dummy trunnions with hollow cores for this purpose. They were placed in the trunnion posts' main bearings, and a wire then stretched taut through their axes. The bearing housings were then adjusted with shims as necessary to obtain an accurate alignment. The distance and alignment between the east and west side trunnion axes was also measured with exactness to ensure that the two leaves would meet properly when closed.

Once the trunnion bearings were set, the rear parts of the main trusses, counterweight trunnion pins and counterweight trusses were assembled. Dummy trunnions were again used to insure correct alignment of the counterweight trunnions. Steel false work was erected on the abutment floor to support the counterweight. A wooden form was then assembled atop the false work, using 3" bottom planks and sidewall panels that had been prefabricated on shore. The ingredients for the special counterweight concrete were delivered on barges and mixed in batch mixers on the top of the abutment. As was (and is) commonly done, workers tried to use pneumatic compactors to deaerate and homogenize the concrete, but the compactors kept striking the counterweight's reinforcement steel and the method had to be abandoned.

Workers then erected the rest of the truss, including the fascia truss and fascia. When the weight of the structure was sufficient to balance the counterweight, the false work was removed. Adjustment blocks were added to the counterweight as needed to maintain this balance as workers added components. While the truss was being completed, other workers installed the electrical system and the drive machinery.

After the counterweight and steel truss structure were completed, the reinforced-concrete deck and sidewalks were installed. As noted above, the sidewalk wear surface was intended to be an exposed aggregate that matched the walk around the Lincoln Memorial, but the exact nature of that material is not now known, as none of it is extant. The granite curbs were set in

mortar, the curb catch basins and drainage pipes were added, and asphalt paving was laid. Bronze, castings with interlocking, comb-like teeth, protected each edge of the toe and heel joints and provided smooth running surfaces across the 2" (maximum) gaps.[114]

The final elements to be installed, other than paving, were the aluminum balustrades, ornamentation, and light fixtures. The balustrades on the bascule span replicated those on the fixed spans, but the granite specified for the fixed spans was unsuitable for the bascule leaves. In addition to being quite heavy (for an already heavy span), the assemblage of base, posts, and top rail would not be able to withstand being rotated to almost vertical when the span was opened. The solution was to fabricate them from aluminum segments cast to match their granite counterparts. Much lighter than granite, the hollow aluminum balustrades were fastened to the fascia truss using 4"-diameter wrought-iron pipes through every fourth balustrade that securely clamped the assembly together.[115] The lampposts also required a substantial addition to keep them in place during bridge operation. They were hollow, so 4"-diameter wrought-iron pipes bolted to the trusses extended the length of the lampposts' interiors to hold them securely in place during open-and-close cycles.[116]

Solving all of the materials, logistics, and erection problems took almost another year. The greatest challenge to the schedule had been the bascule span's counterweights. Most of the east leaf's erection was delayed until the correct concrete mix could be determined and the Swedish iron ore delivered. The east leaf was structurally complete and functional by the end of May 1930, and it operated somoothly. It was immediately raised so that work on the west leaf could begin. Once underway, erection of the west leaf proceeded at a rapid pace, since the major problems had been solved on the east leaf, and except for pavement, Phoenix Bridge completed it during July 1930. With its paving complete, the bascule span was finally ready for service in late October 1930. It had cost a total of $1 million, one-third more than had been estimated.[117]

---

[114] "Break-In-Roadway Castings – Center Break," AMBC Drawing No. 2E6-28; "Break-In-Roadway Castings – Trunnion Break," AMBC Drawing No. 2E6-29; and "Break-In-Sidewalk Castings," AMBC Drawing No. 2E6-30.
[115] "Fascia and Balustrades," AMBC Drawing No. 2E6-26.
[116] "Bascule – Lamp Post Anchor Metal Details," AMBC Drawing No. 2A6-5. This drawing shows the bronze lampposts proposed by McKim, Mead & White, but the anchor is correct for the iron lampposts actually installed.
[117] *Office of Public Buildings and Public Parks of the National Capital, Annual Report*, 1930, 79.

Controversies and Debates

Any large, visible public project seems destined to be a source of controversy, and the Arlington Memorial Bridge was certainly no exception. From the earliest concepts of a bridge from Washington to Arlington, debate ensued over the location and type—fixed or draw—of bridge needed, mostly between engineers who wanted a straight-forward, practical structure without any movable spans, and city planners and designers who felt strongly that any new bridge should contribute to the city's beauty and the ideals expressed in Pierre L'Enfant's initial concept for the seat of the federal government. Following the Civil War, the idea of making the bridge a monumental structure emerged, first to honor Union General (later President) Ulysses S. Grant, and later a symbolic representation of the reunification of North and South. This only complicated questions about the bridge's proper location and type, and questions about whether the structure, if built at all, would be primarily a practical river crossing or a monument that would seriously compromise the bridge's utility.

If these conceptual questions were not tough enough to resolve in their own right, the number of different governmental entities responsible for different, sometimes overlapping, aspects of the project, including the Army Corps of Engineers, three different civilian commissions, and local governments, plus the enigmatic United States Congress and presidents from Jackson to Hoover, virtually guaranteed conflicts between at least some of them over details large and small. Now introduce the Great Depression in the middle of construction. Most of the century-plus debate that led up to the design, location, and, finally, funding and construction of the Arlington Memorial Bridge have been addressed above, but a number of major and minor design features aroused such passions that they deserve additional consideration.

From the time that William Mitchell Kendall first envisioned his concept for the Arlington Memorial Bridge, granite that would complement the Lincoln Memorial was part of his design. Thinking in a classical mode, he saw the bridge as a stone arch bridge constructed entirely of granite. Others, particularly Clarence O. Sherrill, knew immediately that the cost of such a structure would be prohibitive, even if the quantity of granite needed could be located. Early in the design process, Sherrill told Kendall that economic conditions—even before the onset of the Great Depression—dictated that the structural core of the fixed spans would be

reinforced concrete, but that the core could be faced with granite. Kendall, who did not take kindly to anyone challenging his designs, was reluctant to accept this decision and continued to argue for an all-granite bridge, but the economic advantage of concrete plus its structural efficiency gave Sherrill the confidence to insist that his decision be followed, and the testing and evaluation done by George Beggs at Princeton validated his choice. In truth, this concept had already been established as desirable; the idea for a concrete-and-steel structure faced with stone hearkened back to the Burr-Casey scheme of 1899-1900.[118]

Kendall's design for the Arlington Memorial Bridge included an abundance of ornamental and symbolic details to emphasize its monumental role. The eagle and *fasces* details on the piers are discussed above, as are the bison keystones and the Virginia entrance eagles, but Kendall also proposed that the bridge have bronze railings interrupted by masonry pedestals over the piers. These pedestals were to support forty sculptured allegorical figures to symbolize achievements in the arts and sciences. Kendall initially went so far as to have the allegorical figures bear torches that were to light the bridge. Reacting in an uncharacteristically calm manner to criticism of his June 1923 presentation from members of the CFA, Kendall agreed to abandon the idea of lighting incorporated in the sculptural figures, but he was unwilling to give up the figures.[119] His modified figures are prominent in the rendering of the bridge he submitted later that year, though they stand atop a solid granite, not bronze, railing.

Kendall's stubborn insistence on retaining these figures, along with six tall pylons on Columbia Island, strained relations between him and Sherrill's successor, Ulysses S. Grant III. The CFA had never expressed firm support for the sculptures along the bridge parapets, or the six pylons, feeling that they could overwhelm the adjacent Lincoln Memorial rather than complement it. Nevertheless, in late 1927 it had approved Kendall's recommendation for the pylon sculptors. Seeing this as encouragement, Kendall continued to press Grant into hiring sculptors for the statues and pylons. Unsuccessful by late 1928, the consulting architect sought a firm commitment to do so from the AMBC itself, but it shared Grant's reservations. Their reluctance was two-fold. The project was proving to be considerably more expensive than estimated, and cost control had become a significant, but short-term, consideration. Grant, however, also harbored a long-term worry that time and history would harshly judge the subjects

[118] Zangrando, "Monumental Bridge Design," 375-377. Also Nolin, *Historic Structure Report*, 93, 97.
[119] Nolin, *Historic Structure Report*, 93-94.

of the sculptures unworthy of the bridge. The stock market crash of October 1929 could only have helped to confirm his judgment, and the allegorical figures were omitted. [120]

Except for the need for a draw span, no topic produced a more prolonged debate among members of the AMBC, the CFA, and Grant than the design of lampposts for the bridge. After Kendall's original proposal of allegorical figures holding torches was quickly rejected in 1923, no serious consideration of appropriate lighting standards for the roadway of the Arlington Memorial Bridge occurred until early 1929, when the superstructure assumed a recognizable form. In January of that year the Phoenix Bridge Company and Strauss Engineering Corporation asked the AMBC for information about the lampposts that would be placed nearest the bascule, since they were responsible for coordinating the manufacture and installation of the draw-span warning signals that were to be attached to those posts. Although McKim, Mead & White furnished details for both a post mounting block and Kendall's 1923 design of bronze standards bearing double lamp globes to the AMBC later that year, the commission had no input from the CFA, who was charged with approving any design. Delaying his reply until June 25, 1930, Design Engineer John L. Nagle was finally forced to write Joseph Strauss and regretfully inform him, "that the design of the lamp post has not yet been finally approved," and consequently he was unable to send a drawing.[121]

By mid-1930 a determination of the actual lighting system to be employed had to be made. At the June 30 meeting of the CFA, Colonel Grant's assistant, Maj. G. H. Gillette, presented a drawing of McKim, Mead & White's lamppost design and conveyed the architects' request that the CFA approve making 140 of the 15'-high lamp-posts. There were to be forty standards on the main bridge—two on each arch, placed approximately 110' on center. The remaining standards would be installed on other portions of the larger project. With the impacts of the Great Depression being fully felt by then, Grant had added his suggestion that the CFA consider using the classical, double-light standard designed by former CFA member Henry Bacon in 1923 and already approved for use on principal streets in the District of Columbia. The potential savings did not influence the CFA, which rejected the suggestion.[122]

[120] Nolin, *Historic Structure Report*, 113-114.
[121] McKim, Mead & White to Major J. C. Mehaffey, March 8, 1929; and John L. Nagle to the Strauss Engineering Corporation, June 25, 1930, both NARA, RG 42.
[122] Commission of Fine Arts, Minutes of June 30, 1930, meeting, NARA, RG 66. The Bacon light standard was approximately 21' tall, and the commission members felt this to be much too tall for the bridge.

On July 23, the CFA met in Kendall's New York office, where he presented and discussed his design. The commission members approved the drawings, pending their review of a full-size plaster model set up on the bridge.[123] Before a final decision could be made, Grant asked the CFA to inspect actual examples of the 21'-high Bacon double-light standard and an older, 15'-high, single-light Washington lamppost designed by Francis D. Millet, both of which had been set up on the bridge. At the inspection on October, 6,000-candlepower lights were used in these municipal standards. Additionally, Grant invited a representative of the Claude Neon Lighting Company to study the potential use of his company's product. The CFA members rejected any neon lighting installation that would "mar the architecture of the bridge," but they reported their opinion that a 15'-high lamp-post would be adequate. They did not, however, endorse the Millet design.[124]

Increasingly pressed to identify and order lighting for the bridge, Grant's requested the CFA to re-visit the matter at the bridge on November 7, where experiments with 1,000-watt, 500-watt, and 300-watt incandescent bulbs were conducted. At the meeting, H. E. Barnes of the Claude Neon Lighting Company proposed that handrails incorporating a neon light tubes be built along the curbs of the bridge's sidewalks. Grant and commission member Adolph Weinman felt that if a neon-lighting scheme could be worked out, it would eliminate viewing obstructions and the unfortunate verticality caused by numerous lampposts. It might also satisfy Kendall, who had already made it clear that he opposed anything taller than 15' and any lamp brighter than 300 watts.[125]

No decisions were made with respect to bridge lighting for the rest of the year, and on March 19, 1931, Gillette reported to the CFA that Kendall rejected any suggestion of neon lighting without even visiting the bridge to see it in place. On this occasion, Gillette showed a drawing of a lamp-post produced by the General Electric Company. This model had inverted lamps, and Gillette asked the CFA consider it since it had the advantage of throwing light in a way that would prevent a shadow being cast by the fixture.[126]

Gillette, rapidly becoming impatient with the CFA's indecision, introduced still another lighting proposal to the commission on February 26, 1932, where he showed photographs of a

---

[123] Commission of Fine Arts. Minutes of July 23, 1930, meeting, NARA, RG 66.
[124] Commission of Fine Arts. Minutes of October 16, 1930, meeting, NARA, RG 66.
[125] Commission of Fine Arts, Minutes of November 7, 1930, meeting, NARA, RG 66.
[126] Commission of Fine Arts, Minutes of March 19. 1931, meeting, NARA, RG 66.

lighting system manufactured by the Crouse-Hinds Company of Syracuse, New York. This system consisted of small granite posts with reflectors on the side of the posts that faced the roadway. Interested, the CFA requested that several of the posts be set up on the bridge for inspection. The following month, 4'-high models were placed at 60' intervals along the curb of the sidewalks. The CFA reported general satisfaction with the scheme, but delayed a definite conclusion until a model of a specific design for the Arlington Memorial Bridge could be seen. Frustrated by this time, Gillette said that Crouse-Hinds did not wish to invest a lot of money in custom models with no assurance of an order. In the meantime, Grant, realizing the CFA was nowhere close to making a decision, had ordered the standard 15'-high Washington, i.e., Millet, street lights installed. He really had no other choice, because the bridge was ready for traffic, and some kind of lighting had to be provided.[127]

This would seem to have settled the debate, especially after the bridge opened on January 18, 1932, but such was not the case. Kendall and the CFA still wanted a unique design, and neither felt constrained by any schedule or the economic situation. In May 1932, just prior to the Memorial Day celebration, Gillette, the CFA members, and Kendall again visited the bridge at night, this time to evaluate the Crouse-Hinds models at 55' intervals along the curbs. Everyone realized that the lighting, "struck the pedestrian in the eye and also the occupants of automobiles." Relocation to the balustrades proved no better, but during their visit, the members took the opportunity to observe the lighting provided by the standard street lights installed by Grant, which all felt were superior to any scheme for low-level illumination. The CFA notified Grant in a June 1, 1932, letter that the Crouse-Hinds system was unacceptable, and that it felt a standard "should be especially designed by McKim, Mead & White, architects of the Arlington Memorial Bridge, and that it should be a lower lamp post."[128]

In June 1932, in consultation with the CFA, Kendall submitted a design for yet another bronze light standard, but neither Grant nor the AMBC members were the least bit interested. The disastrous economic situation in the United States prevented the manufacture of any custom lampposts when functional standard ones were already in service, and as far as Grant was concerned, the matter was closed. Kendall, however, found it difficult to accept this as the final

---

[127] Commission of Fine Arts, Minutes of February 26, and March 25, 1932, meetings, NARA, RG 66.
[128] Commission of Fine Arts. Minutes of May 27, 1932, meeting, and Charles Moore to Lieutenant. Colonel U. S. Grant 3d, June 1, 1932, both in NARA, RG 66.

verdict. Over a year later, Kendall wrote to Charles Moore to say that the existing number of the 15'-high Millet lighting standards should be reduced by half—perhaps by staggering them on the north and south curbs—so that the resultant number, "would interfere less with the statues on the parapet, which I still hope will be put there at some time or other." But in a slight nod to reality, Kendall added that, "… just at present the Arlington Memorial Bridge scheme seems to be dead." [129]

As Kendall had feared, the Millet-style lampposts remained in place, and no further consideration was ever given to installing custom lighting or his allegorical statuary. Of all the Arlington Memorial Bridge debates and controversies, lighting was the only major issue that was never resolved in the prescribed manner. Fortunately, Ulysses Grant III combined artistic sensitivity with an engineer's practicality to choose a reasonable compromise that has withstood the test of time.

One minor controversy was perhaps more amusing than significant, but it illustrates the extent to which a wide variety of parties weighed in on the bridge's design and how seriously even trivial matters were taken. The design for the bas-relief eagles on the piers upset one Lt. Col. Thomas J. Dickson, a retired Army chaplain. The draft design for the bridge's sculptures showed half of these eagles facing right, and half facing left so that pairs of eagles faced one another. Dickson publicly criticized this design, arguing that left-looking eagles were "Mexican eagles," since the eagle on Mexico's flag faces left, while the eagle on America's Great Seal always faces right. He did not approve of honoring anyone but Americans on the bridge and said that *all* of the eagles should face right. His public attack on the design earned a public rebuttal from the Army Corps of Engineers, who countered that the eagles were ornamental and not heraldic.[130] The facing-pairs design was retained.

Except for paving and lighting, the Arlington Memorial Bridge was essentially complete by October 1931 (paving was completed by the end of the year), but a debate continued throughout the project about what the newly created Columbia Island should contain and how it should look. While there was general agreement that Columbia Island would be developed as a park area, the size, shape, and location of any monumental structures there and the streets needed were other issues entirely, and some large egos championed their ideas vigorously. The

---

[129] William Mitchell Kendall to Charles Moore, October 10, 1933, NARA, RG 66.
[130] "Army Officers Deny Bridge Eagles Are Mexican Birds," *Washington Post*, May 11, 1928.

extensive details are beyond the scope of this report, but the basic plan called for an Avenue of Heroes (now Memorial Drive) that would extend southwest from the Arlington Memorial Bridge across Columbia Island and the Boundary Channel Bridge, and continue to Arlington National Cemetery's new main gate, to be known as the Hemicycle. A plaza on the island would serve as an intersection with the Mount Vernon Memorial Parkway. Grant balked at the practicality and expense of such a plaza, and the parkway initially met Memorial Drive at a simple intersection. An earlier proposal for a monument to Robert E. Lee had already been dropped.[131]

William Kendall's grand plan, supported by the CFA, included two 166'-high columns at the crossing of the bridge axis and the axis of the island as symbols of the North and the South, but aviation advocates were concerned that the columns would be a safety issue for Hoover Field, a small airfield serving Washington located about a mile north of today's Reagan National Airport. Outraged, Kendall declared that the airport ought to be moved before allowing his design to be compromised. Nevertheless, Grant and the AMBC finally decided to delete the columns in December 1931 in the interests of aviation safety and economy.[132]

Paint for the Arlington Memorial Bridge's non-masonry components—mainly the bascule span—was not controversial, *per se*, but the bridge's monumental character meant that its paint would receive close attention, since it had not only to protect the metal components, but to also satisfy unusually strict aesthetic requirements. The AMBC wanted its color to match that of the granite facing, which initially was very light—similar to the granite used on the Lincoln Memorial, but neither the commission nor Kendall nor Strauss ever specified the color of the final coat. Specifications for coatings other than the final coat were not a problem. All structural steel work, including the ornamental fascia, received one coat of shop-applied primer composed of 25 lbs. of red lead to one gallon of linseed oil. The cast aluminum ornamental work got a coat of aluminum primer inside and out. A first field coat of "Detroit Graphite Company's No. 426 gray or equal" was then required for all structural work not embedded in concrete including the ornamental fascia and balustrades. The AMBC elected to assign the responsibility of color selection to one person, Grant, instead of trying to achieve a multi-party consensus. Thus, the visible exterior metal work, including the ornamental balustrade, the outside surfaces of the

[131] For additional details of the various proposals and events, see Nolin, *Historic Structure Report*, 98, 133-137.
[132] William Kendall to Herbert Hoover, Oct. 29, 1931, NARA, RG 42. Also Nolin, *Historic Structure Report*, 136; "Arlington Memorial Bridge," *Washington Post*, January 20, 1931.

ornamental fascia, and the edge courses of the underside structure of the leaves were then to receive a second field coat of "Detroit Graphite Company's Degraco or equivalent, having a color which, in the opinion of the contracting officer, satisfactorily matches the color of the granite work." The other structural metal surfaces, not visible from outside, received a second field coat of Detroit Graphite Company's No. 38 light, or equal.[133] This seems to have been a wise choice, since what could have been a contentious issue passed with little comment and the color Grant selected received wide approval.

With all of the disagreements, debates, and difficulties experienced during the construction of the Arlington Memorial Bridge, it is somewhat surprising, at least by today's norms, that only a single lawsuit was filed over the project. The Phoenix Bridge Company's contract with the AMBC to install the bascule span imposed a penalty for delays. As discussed above, numerous delays were incurred during the installation of the span and, per the contract, the federal government assessed a penalty of $12,300 on the firm. In response, Phoenix Bridge filed suit in the United States Court of Federal Claims, arguing that the delays were not the fault of the company, but were instead due to government-imposed changes in the bridge's construction. The company asked not only for relief from the penalty, but also for the federal government to pay the additional costs these changes incurred. During the trial, Phoenix Bridge claimed it could have rented its equipment and labor for $27,433 during the delay time and, thus, the federal government owed the company this rental income. The Court of Claims upheld the claim, and it ordered the government to rescind the penalty as well.[134]

Opening the Arlington Memorial Bridge

In early September, paving and some finishing touches were all that remained to be done, but alluding to the Columbia Island delays, U.S. Grant III said that the bridge would not open until early 1932, "because there is nothing to open it to."[135] By the end of 1931, the bridge itself was ready for traffic, but no date for an opening ceremony had been set. Throughout most of the project, the AMBC and the George Washington Bicentennial Commission (GWBC) both felt that the 200th anniversary of Washington's birth on February 22, 1932, would be the ideal time to

[133] Nolin, *Historic Structure Report*, 220-221.
[134] "Phoenix Bridge Company v. United States," 85 Ct. Cl., 603, 1937.
[135] "Unpaved Approach All That Bars Use of Memorial Span," *Washington Post,* September 8, 1931.

inaugurate the bridge and the parkway to Mount Vernon, but the economic malaise of the Great Depression had dampened the public's enthusiasm for any celebration. Consequently, no grand opening and dedication ceremony ever took place.

The Arlington Memorial Bridge was, at best, informally "dedicated" on January 16, 1932, when President Herbert Hoover, First Lady Lou Hoover, and members of the AMBC, CFA, NCPPC, GWBC, and the DC office of the Army Corps of Engineers made what Grant described as "an inspection trip." There were no formal ceremonies or remarks. As Grant described the day's events,

> The party, after being received by the President and Mrs. Hoover, left the Executive Office by automobile at 3:00 P.M., and proceeded by way of the Ellipse, Constitution Avenue, and the newly completed Bridge Plaza to the Bascule Draw Span at the middle of the Arlington Memorial Bridge where all members alighted to witness operation of the draw span. The entire party, headed by the President and Mrs. Hoover, then walked to the west end of the bridge where the automobiles were reentered and the party proceeded over the Mount Vernon Boulevard through Alexandria, Virginia to Mount Vernon. Here the party again alighted ... after which it returned over the same route to the White House where it disbanded. The weather was fine, and no untoward incidents occurred. [136]

The Arlington Memorial Bridge opened to traffic on January 17, 1932, when nearly 31,000 vehicles traversed the bridge.[137] The first funeral procession to Arlington National Cemetery to cross the bridge did so on January 18, the second day the bridge was open.[138] After this informal opening, public access was limited to only one lane in each direction on Saturdays and Sundays from 8:00 A.M. to 5:00 P.M. This limitation lasted into April as workers finished the approaches and minor details on the bridge.[139]

---

[136] Quoted in Zangrando, "Monumental Bridge Design," 455. Also "Memorial Bridge Opened Informally," *Washington Post*, January 17, 1932. British Pathé News captured this event on a newsreel film entitled "Hoovers Inspect New Potomac Span: President and First Lady accompany Vice President Curtis on opening of the Arlington Memorial Bridge," 1932. A preview is available at http://www.britishpathe.com/video/hoovers-inspect-new-potomac-span-aka-hoover-inspec/query/newsreels. This newsreel contains the only known images of the traffic-warning-light posts in operation. The Belgian block pavement on the fixed spans and the contrasting asphaltic surface on the bascule leaves are also visible.

[137] "Public, In 30,175 Cars, Tries Out New Memorial Bridge," *Washington Post*, January 18, 1932.

[138] "New Bridge Bears Its First Cortege," *Washington Post*, January 19, 1932.

[139] "Another Link in Arlington Bridge to Open Tomorrow," *Washington Post*, April 8, 1932.

The First Two Decades of Service

By the time of the Arlington Memorial Bridge's opening, the Great Depression economy was entering its worst year. On April 7, 1932, the House of Representatives deleted an $840,000 appropriation for completing the project from the budget. The funding cut meant that no further work could be done on the Columbia Island plaza nor any decorative statuary added to it.[140] The Memorial Drive work, however, received funding from other sources, which allowed paving of it to continue. Arlington County officials said that a pavement surface had been chosen, and the 30'-wide gravel road would be widened to 60' and paved with asphalt by July 1.[141]

By 1933, most of the remaining work on the project concerned streets and approaches. Virginia still had not settled on a route for any roads to the bridge, but Memorial Drive was nearing completion. The Hemicycle remained incomplete, as did bridges leading from Columbia Island to the Virginia shoreline. In the District of Columbia, work remained to be done on Constitution Avenue, NW, and on 23rd Street, NW.

The administrative and financial pictures changed significantly after Franklin D. Roosevelt took office as President of the United States in March 1933. Among his early actions was an impoundment of all funds already appropriated for the AMBC. After March 21, 1933, the Bureau of the Budget would only release funds as required to meet contract obligations. Then, on June 10, the President issued Executive Order 6166, which consolidated all federally-administered parks, monuments, and reservations under the jurisdiction of the NPS—effective July 28, 1933—and at the same time abolished the Office of Public Buildings and Parks of the National Capital, the Rock Creek and Potomac Parkway Commission, and the Arlington Memorial Bridge Commission.[142]

While this might sound like a death knell for the projects these commissions managed, such was not the case. Roosevelt remained convinced that massive federal spending on public works was essential not only to "prime the pump" of the economy but also to cut unemployment, and he proposed passage of the National Industrial Recovery Act (NIRA). The act contained $6 billion in public works spending, which included $400 million for road, bridge, and highway construction. With passage of the NIRA moving forward swiftly, District officials asked

---

[140] "Memorial Bridge Fund Stricken Out," *Washington Post*, April 8, 1932.
[141] "Memorial Bridge Approach Opened," *Washington Post*, April 10, 1932.
[142] Nolin, *Historic Structure Report*, 144-145.

Congress on June 12 for the funds to finish widening Constitution Avenue, NW. The act passed the following day and Roosevelt signed it into law on June 16, 1933. The Public Works Administration (PWA) was immediately established to disburse the funds appropriated by the act. The District of Columbia received a $1.9 million grant for road and bridge construction, and the city said on July 8 it would use a portion of these funds to finish Constitution Avenue. The Hemicycle and the watergate steps were also completed with NIRA funding.[143]

The Arlington Memorial Bridge was finally connected to the Arlington County road network in 1938. By that year, more than 18,000 vehicles a day used the bridge to access the George Washington Memorial Parkway.[144] On October 18, Virginia finally opened its first connection to the bridge, via Lee Boulevard (now Arlington Boulevard) at the north end of Columbia Island.[145]

Although these elements of the grand project came to fruition during the 1930s, the Arlington Memorial Bridge was still missing one key design element: statuary at its Washington entrance. Kendall and the CFA had disagreed over the proper embellishment for the Washington entrance throughout the project. Kendall continued to argue for his original concept of 35'-high pylons astride the entrance similar to those he designed for the Columbia Island entrance, but the CFA felt that these pylons would likely mar the view of the Lincoln Memorial from the bridge. Kendall saw the bridge as a monument unto itself, while the CFA had always intended it to compliment the Lincoln Memorial rather than compete with it. By summer 1928, Kendall had come to believe that Grant and the CFA had lost sight of the importance and meaning of the entire undertaking, and he was reluctant to accept the recommendation of Milton Medary, a member of the National Capital Park and Planning Commission, that low "sculptural massings" at the entrances to the bridge be substituted for the pylons in order to prevent "a most destructive effect upon the Lincoln Memorial." [146]

Kendall finally relented and in August 1928 presented a modified rectangular pylon design that the CFA still found unsatisfactory. However, the commission voted to construct the

---

[143] "Gotwals Planning to Finish Several Big Highway Jobs," *Washington Post*, June 13, 1933; "Commissioners Approve Plans On Road Work," *Washington Post*, July 8, 1933; and "Street Work Will Advance On Tax Funds," *Washington Post*, September 20, 1933.
[144] "Work Begun On Arlington Traffic Outlets," *Washington Post*, September 21, 1938.
[145] "Legal Matters Delay Opening of Bridge Link," *Washington Post*, October 19, 1938.
[146] Zangrando, "Monumental Bridge Design," 433.

Columbia Island pylons as originally planned.[147] The four pylons on Columbia Island—each 36'-7" feet tall and surmounted by 7'-high eagles designed by C. Paul Jennewein—were indeed built; two at the Arlington Memorial Bridge and two at the Boundary Channel Bridge. The stones on which the eagles rest were put in place in October 1929, just as the stock market crashed, and Jennewein's granite eagles were installed by June 1931.

Still baffled by what he saw as a misunderstanding of the object of the bridge, Kendall explained that his proposal for seated male figures at the Washington end of the bridge—representing art, science, justice, and religion, and standing for the reconciliation of North and South—reflected the primary purposes in building the bridge as a monument. Nevertheless, he agreed to consider equestrian statues at the bridge and parkway entrances. After some investigation, he sent Charles Moore a photograph of an example by sculptor Leo Friedlander, describing it as "magnificent."[148]

The November 8 and 15 meetings of the CFA took up the subject of using equestrian groupings to represent valor, peace, justice, and the arts. Kendall's excitement was contagious; and his interest in the Washington-end pylons began to fade. The commission members had difficulty imagining just what the visual impact of either concept would be. To help resolve the issue, Moore and the AMBC had the Army Signal Corps produce full-size composite photographs of the pylons and erect them on the site to give the members a better sense of what their final appearance would be. Upon seeing the photographs at the site, the CFA quickly rejected the tall pylons, as well as a shorter version the Signal Corps also made. The Signal Corps then produced full-size photographs of all four sides of an equestrian statue on a pedestal and erected them at the bridge. To make them, the Signal Corps photographed a model statue in Friedlander's New York studio, and sent the 8" x 10" images to Washington for enlargement and assembly into 16' x 16' - 8" panels. They were, at the time, the largest photographic prints ever made by the Signal Corps.[149] Following a December 6, 1928, visit to the site, the CFA recommended granite sculptural groups in place of the pylons for the bridge and parkway entrances—to be given "an architectural treatment in mass," and placed on pedestals whose tops would be raised to the height of the base of the Lincoln Memorial. Kendall suggested that the

[147] Commission of Fine Arts. Minutes of the Meeting of August 6, 1928, NARA, RG 66.
[148] William Kendall to Charles Moore, October 11, 1928, NARA, RG 66.
[149] "16-Foot Photos Aid in Selection," *Prescott* [AZ] *Evening Courier*, December 17, 1928.

sculptures at the bridge entrance represent war and those at the parkway entrance signify peace.[150]

Now content with the concept, the CFA sent Grant the names of seven sculptors it felt were qualified to do the work in February 1929, and he prepared guidelines for a competition. Grant invited thirteen artists to submit preliminary sketches and descriptions, which were to be judged by the CFA with the help of former sculptor members not participating in the competition. Ten sculptors responded and the CFA informed the AMBC on December 20, 1929, that American sculptors Leo Friedlander and James Earle Fraser had been selected to design the bridge and parkway sculptures. Each sculptor was to receive a fee of $135,000 from AMBC funds. The AMBC contracted with Friedlander and Fraser to create allegorical equestrian statues depicting the *Arts of War* and the *Arts of Peace*, respectively.[151]

The CFA approved Fraser's preliminary models for *Music and Harvest* and *Aspiration and Literature* (the groups comprising the *Arts of Peace* for the entrance to Rock Creek and Potomac Parkway) on October 24, 1932. (Alluding to the muses of inspiration, Fraser designed them around the mythical winged horse Pegasus.) After the AMBC was dissolved in Roosevelt's July 28, 1933, reorganization, the CFA assumed the burden of following the sculptures to completion, and it approved Friedlander's preliminary models for *Valor* and *Sacrifice* (the *Arts of War* for the entrance to the Arlington Memorial Bridge) on October 14, 1933.[152]

Grant had led the project admirably during his tenure as the AMBC's executive officer but, unfortunately, he had not been able to secure sufficient funds to complete the Washington entrance statues, so their funding and completion were left to the CFA and Moore. Since funds for the pedestals were available, he contracted with the North Carolina Granite Corporation to furnish granite for them. Erection went smoothly, and the four pedestals, decorated with carved classical wreaths, and thirty-six stars representing the states of the Union at the close of the Civil War, were completed in June 1931.

---

[150] "Statues to Adorn End of New Bridge," *Washington Post*, December 7, 1928; Zangrando, "Monumental Bridge Design," 437-438.
[151] *Office of Public Buildings and Public Parks of the National Capital, Annual Report*, 1929, 67; "Bids Are Sought For Bridge Work," *Washington Post*, June 2, 1929;
[152] Commission of Fine Arts, *Twelfth Report, July 1, 1929 to December 31, 1934* (Washington: Government Printing Office, 1936), 25.

Moore, who replaced Grant as the disbursing officer, was unable to get Roosevelt to commit funds for finishing the bridge plaza. Since the President had impounded the remaining project funds, only minimal funds were released intermittently by the Bureau of the Budget to allow Fraser and Friedlander to continue their work, but delays in funding and escalating prices led to the sculptors' increasing frustration. In 1936, the Director of the NPS suggested cancellation of the existing contracts with Fraser and Friedlander and negotiation of new ones. Both sculptors agreed.[153] Ensuing discussions about the possible execution of the equestrian groupings in bronze rather than granite concluded in 1939 when the CFA approved the bronze sculptures. New contracts allowing each sculptor $85,000 to produce plaster models were negotiated with Fraser and Friedlander in the spring of 1941.[154]

While the Great Depression decade of the 1930s wreaked economic havoc on the nation (and beyond), the massive growth in the federal government needed to administer President Roosevelt's "alphabet soup" of agencies intended to resurrect the economy brought a period of tremendous population growth in Washington, D.C., and its surrounding region. Between 1930 and 1940, the population of the District of Columbia grew by 36 percent, and the region within a twenty-mile radius of the White House grew by 43 percent—to a total of about 1,000,000 permanent residents. By the beginning of 1942 there would be another 200,000 inhabitants of the metropolitan area, and the wartime daily federal work force in downtown Washington would exceed 600,000. The population of some suburbs like Arlington almost doubled between 1942 and 1945.

As the population grew, so did the volume of traffic in the region, and the Arlington Memorial Bridge received its share of this traffic. By 1942, the bridge was carrying far more vehicles than any quantity feared by those who wished it to be more of a monument than transportation artery only ten to fifteen years earlier. While many crossed it commuting to jobs in downtown Washington, the 1943 completion of the Pentagon in Arlington, Virginia, added much more traffic across the bridge to and from what was then the world's largest office building. The bridge absorbed this increase in traffic without alteration or any significant maintenance or deterioration issues, but its Belgian block pavement generated increasing

[153] Zangrando, "Monumental Bridge Design," 464.
[154] Commission of Fine Arts, Minutes of the Meeting of September 15, 1939, NARA, RG 66; also Zangrando, "Monumental Bridge Design," 465.

criticism from urgent, wartime motorists who had little time to appreciate the monumental aspects of the bridge.

World War II made bronze a strategic metal, and its use was limited to essential war materiel, not decorative art work like statues. Continued post-war restrictions on the use of tin led Friedlander and Fraser to conclude that the composition of the bronze obtainable would lead to unsatisfactory castings, and they recommended that the statues should wait until satisfactory bronze was again available. With the completion and approval of their full-sized plaster models in 1947, the sculptors' contracts with the government were terminated. Still lacking funds to complete the statues, the NPS placed the models in storage.

Though serious problems were rare, the Arlington Memorial Bridge was not without them during its first decade of service. In March 1936, a major flood resulted in water entering portions of the control and equipment rooms and causing several short circuits in the bridge's electrical system. Temporary measures and careful operation kept the bascule span in service until permanent repairs could be made during 1938-1939. Under a contract for $9,245, the Electrical Underground Construction Co. of New York replaced the damaged electrical equipment, conduits, and wiring, in addition to installing two sump pumps to minimize the possibility of similar damage in the future.[155] In October 1936, a gear and a crankshaft in one of the center lock mechanisms broke so that the draw span could not be fully closed and locked. The bridge was closed to traffic for nine hours while crews repaired it.[156]

The first planned maintenance and repair work on the bridge occurred in 1939. The draw span was repainted and repaved in kind, the west engine room heated, and the granite on the Virginia abutments cleaned and repointed. This work required complete six-hour closures on August 30, August 31, and September 1.[157]

In 1945, the bridge had to be closed for two hours while workers freed one of the bascule leaves that had jammed before fully closing. The bridge closed again on the evening of August 2, 1947, and remained closed for most of the next day while workers replaced a gear and shaft in one of the center locks.[158] While draw spans of any design always require considerably more

[155] "Arlington Bridge Repair Work to Start Soon," *Washington Post*, November 28, 1938.
[156] "Memorial Bridge Shut 9 Hours As Crew Rushes Workmen [*Sic*] Gears," *Washington Post*, October 21, 1936.
[157] "3 Contracts Let For Arlington Bridge Repairs," *Washington Post*,, June 16, 1939. Also "Memorial Bridge Closings Listed," *Washington Post*, August 27, 1939.
[158]""Memorial Bridge Is Closed For Day During Repair Work," *Washington Post*, August 3, 1947.

maintenance than fixed spans, this occurrence, the second serious problem with the jaw-type center locks in just over a decade, demonstrates why many bridge owners replaced these mechanisms with the simpler sliding-bar type of lock. Such a replacement would have been a major project on the Arlington Memorial Bridge, both expensive and requiring a number of closure days to accomplish, so the jaw-type center locks remained in service. Fortunately, this particular kind of failure did not happen again, possibly due to better attention given to periodic lubrication and adjustment. They have, however, had a tendency to open since the bascule span was fixed in place, and the relative motion between the spans' two toes is a few inches, not the $^{1}/_{32}$" Strauss specified.

Although the Belgian block paving was attractive and fitting for the monumental character of the Arlington Memorial Bridge, the great increase in traffic and growing number of complaints from motorists pushed the NPS to replace it with a smoother surface. In a $207,000 project, the granite blocks on the roadway surface were removed, and the bridge resurfaced with asphalt similar to that used on the bascule span. The Corson and Gruman Company, a local asphalt paving contractor, performed the work, which began on July 16, 1951. Several of the bridge's six lanes were closed during the work week, with the bridge closed completely on weekends for four consecutive weeks. In a nod to the bridge's heritage, one row of granite blocks was retained to mark the roadway's median.[159]

Completion at Last

With the end of World War II in September 1945, a revived American economy, a new sense of optimism, and a European mood of appreciation for the United States' role in liberating much of the continent from Nazi domination allowed the Arlington Memorial Bridge to finally receive its finishing touches. In August 1949 the government of Italy offered to cast the four equestrian sculptures as a gesture of friendship to the United States.

The following year, the *Arts of War* and the *Arts of Peace* statues were cast using the *cire-perdue* method and then flame-gilded. They were then shipped to the United States for placement atop the existing, but previously bare, pedestals. The four 19'-high statues were

[159] The project and bridge closures were discussed in several *Washington Post* articles, including "New Face for Memorial Bridge," January 5, 1951; "Resurfacing of Bridge to Begin Monday," July 12, 1951; "Resurfacing of Memorial Bridge Starts," July 17, 1951; "Memorial Bridge Will Be Closed For 4 Weekends," July 22, 1951; "Memorial Bridge Closes Saturday," August 7, 1953; and "Bridge to Be Closed Again," August 18, 1951.

dedicated in a formal ceremony on September 26, 1951, when Italy's Prime Minister Alcide De Gaspari, presented the sculptures to President Truman and the American people. Sculptors Friedlander and Fraser were present and had the honor of unveiling their own works, which earned them an unprecedented double medal of honor from the National Sculpture Society.[160]

With the dedication of these statues, the last element of William Mitchell Kendall's bridge and approaches—albeit modified from his initial 1923 design—was in place. The Arlington Memorial Bridge had been in planning or under construction over a period of almost sixty-six years. Ironically, Kendall could not be present at the ceremony. He had died in 1941, never having seen his grand plan in its final form.

Into the Modern Era

As the second half of the twentieth century progressed, the Arlington Memorial Bridge continued to provide a convenient and reliable crossing over the Potomac River. While traffic across it steadily increased, the structure demanded little more than routine maintenance for over a decade. As noted above, ice and the road salts used to prevent freezing can both be damaging to steel and reinforced concrete, but they can cause pavement deterioration as well. Any paving material is flexed constantly by passing vehicles, but when young, asphalt is quite resilient, and it tolerates the flexing with little deterioration. Over time, however, asphalt loses some of its initial flexibility, which encourages cracks to form. Thermal expansions and contractions aggravate this, especially in climates with large seasonal temperature swings, and passing wheels can chip off small amounts of the newly exposed edges. The worst damage occurs during cold, wet weather, when precipitation will fill these cracks—which are at their widest due to thermal contraction of the asphalt—and freeze. Since water expands as it freezes, the ice puts pressure on the sides of the cracks, which often chips off chunks of asphalt to leave holes in the surface. While road de-icing salts reduce the risk of freezing, these same cracks give the salty water an avenue to penetrate the bridge's deck and structure, even when the storm drains are working properly.

Accordingly, road surfaces, including those on bridges, are patched to fill the holes and seal the cracks to the extent practical using small batches of asphalt and tar. On occasion, larger

[160] James M. Goode, *The Outdoor Sculpture of Washington, DC* (Washington: Smithsonian Institution Press, 1974), 403-404. Also Zangrando, "Monumental Bridge Design," 471.

areas of pavement must be cut out and replaced. Minor repairs of this nature were made to the Arlington Memorial Bridge each season, including fairly extensive patching in 1957 that required partial lane closures.[161] Patching continues as needed today.

The single greatest change for the Arlington Memorial Bridge began on February 28, 1961. Though it was not known for sure at the time, that date marked the last time the bascule span was opened for a vessel to pass. As had been projected during the bridge's design phase, commercial river traffic to Georgetown had steadily diminished to almost nothing, and any that remained travelled on barges that did not require the bridge to be opened. Pleasure craft suitable for navigation in this part of the river could also pass under the closed draw span. During the late-1950s, plans were drawn for two new bridges across the Potomac, one upstream and one downstream of the Arlington Memorial Bridge. The George Mason Memorial Bridge, an addition to the so-called "14th Street Bridge" complex, opened in 1962, and the upstream Theodore Roosevelt Memorial Bridge opened in 1964. Their significance to the Arlington Memorial Bridge is that, from their inception, they were designed without draw spans. When the Mason Bridge opened, it became the limiting vertical clearance on the river, so the Arlington Memorial Bridge would not need to open again.[162] The NPS permanently closed and de-energized the bascule span in 1965.

When permanently closing the draw span, the NPS took the opportunity to perform some needed maintenance work on the Arlington Memorial Bridge. It had done some significant repair work on the bascule's deck the previous year. Interestingly, the public's greatest concern was over lane closures during the work that would disrupt their commutes. By this time, most area residents had come to see this bridge far more as a vital transportation artery than as a memorial, a mindset reflected in the titles of most bridge-related articles in the *Washington Post*.[163]

The most visible result of the 1965 work was a new sidewalk wear surface. The original surface was an exposed-pebble-finish concrete intended to match in texture and color the paving surrounding the Lincoln Memorial. The sidewalk wearing surface was replaced with an exposed-aggregate compound poured in approximately 4'-square sections, a style that saw

---

[161] "Traffic to Move During Span Job," *Washington Post*, July 19, 1957.
[162] Dorothy Gilliam, "After 14 Years, Roosevelt Bridge Is Opened," *Washington Post*, June 24, 1964. Also "George Mason Memorial Bridge," http://www.riverexplorer.com/details.php4?id=1187 (Accessed January 9, 2014)
[163] "Drawspan Repairs Shuts Bridge Lanes," *Washington Post*, March 3, 1964.

widespread use during the period. Since the Lincoln Memorial paving had been changed over the years, and no remnant of it or the bridge's early sidewalks remains, the fidelity of this material to the original surface is not known. Also unknown is whether the wear surface was replaced any time before 1965.

Also in 1965, workers installed a pile footing on the south side of the Washington entrance to the bridge, just west of the *Valor* statue, to arrest subsidence at that point and repair damage to the granite face of Abutment 1 caused by that settling. Fortunately, the deeper foundation of the underlying structure had not experienced the same problem.[164]

The next significant repairs to the Arlington Memorial Bridge, done in late-1976, were accomplished under a different protocol than previous repair projects. Since 1915, the Bureau of Public Roads had furnished engineering services to federal agencies such as the NPS, but the creation of the Department of Transportation in 1967 also included the new Federal Highway Administration (FHWA). The FHWA's Federal Lands Highway Program assumed the Bureau of Public Roads responsibility to the NPS, and it introduced a more-formal, project-oriented protocol. Following a trend in the federal government, the FHWA's contract specifications and drawings started to include more-specific details about the work to be done with the goal of improving both the bid process and management of the ensuing projects.

The 1976 "Repair of Bridge and Approaches" project had several components.[165] Rusted areas of the bascule truss and trunnion posts were sand blasted and painted, and a chain-link pigeon barrier was installed to eliminate, or at least reduce, bird roosting on the truss members. Substantial amounts of guano had accumulated in some areas over the previous decade, and reducing the corrosive effects of it was essential. Numerous cracks in the concrete structure were repaired, and several areas of damaged sidewalk surface were repaired or replaced. Interestingly, the fenders protecting abutments 2 and 3 were not only left in place, but repaired, even though no more large vessels that could cause serious damage would pass under the central span. With the bascule permanently fixed in place, compressible seals were inserted into most of the gaps formed by the joints, but roadway portions of the heel joints were welded to seal them

---

[164] Nolin, *Historic Structure Report*, 232.
[165] This project is described in detail in a multi-sheet drawing package entitled "Repair of Bridge and Approaches: Arlington Memorial Bridge, Project 15A3." Copies are available at NARA-College Park, Maryland, in RG 79.

against water intrusion. This seems somewhat curious, since the project also called for the existing gutters under these joints to be repaired. The sidewalk portions were not seal-welded.[166]

This project involved more work than previous repairs, and it lasted for several weeks. It was necessary to partially close the bridge to do the work, but care was taken to minimize delays and inconvenience to motorists. During that time, three lanes in the direction of heaviest traffic flow—the normal number—were kept open during the morning and afternoon commutes, with only one lane in the opposite direction. At all other times, only one lane in each direction was open to traffic.[167]

By the early 1980s, it was evident that the bridge, which had never received a thorough rehabilitation, needed some major repairs to remain a viable component of the area's street network, so the NPS began to seek the necessary funding from Congress. Among the repairs needed were a complete resurfacing of the roadway and sidewalks, new lighting, and the removal of the fenders at abutments 2 and 3.

One of the contractor's first tasks was to remove the existing asphalt pavement applied in 1951 so that the weight of the bridge would not change when the new material was applied. After the old paving had been removed, a waterproof membrane was installed on the exposed concrete deck, followed by new asphalt. The expansion joints were replaced as well. To minimize the impact on motorists, the project plan closed two lanes at a time, and they were completed and opened before the next two lanes were closed. Proceeding in this manner, the repaving was completed the job in September.[168] With the old asphalt removed, the concrete deck was inspected and cracks repaired as needed, and the steel stringers that support the roadway across the hollow abutments 2 and 3 were also repaired to correct rust damage. The sidewalk wear surface was renewed using an exposed pebble aggregate similar to that it replaced. In addition to the work on the bridge, the projects included several revisions and repairs to the approaches to stabilize and widen approach sidewalks, install ramps for handicapped access, and repaint the bascule span's fascia. As before, an NPS official selected the color. Many of the existing cast-iron light standards had damage or deterioration, so new

[166] "Bascule Span Details," 15A3-7 and "Drainage Details," 15A3-8, both NARA, RG 79.
[167] Douglas B. Feaver, "Road Work to Impede Commuters," *Washington Post*, November 6, 1976.
[168] Stephen J. Lynton, "Memorial Bridge Work Set," *Washington Post*, April 19, 1985. Also "Traffic Alert" column, *Washington Post*, March 31 and August 4, 1985.

duplicates were cast and installed in the original locations. This project began in November 1985 and extended into the first quarter of1986.

The procedures employed were standard practices in the industry, but the unique appearance of the Arlington Memorial Bridge was compromised somewhat. The first alteration was the removal of the Belgian block median strip. The engineers felt that it was not worth the added expense needed to retain what they considered to be an anachronism. For the same reason, the twelve warning light posts that had been retracted flush with the pavement surface and their mechanisms were also removed. With these details gone, they decided to lay the asphalt continuously across the warning post holes and the seal-welded heel joints between the bascule and fixed portions of the structure, apparently believing that this would form a second barrier against storm water entering the hollow abutments and aggravating the rusting problems with the steel. The toe joint between the bascule leaves was retained as an expansion joint, but water there would continue to fall directly into the river. Interestingly, the heel joints across the sidewalks were not covered, since the sidewalks were not renewed with a continuously laid material like asphalt. Unfortunately, these four locations would experience some of the bridge's most serious deterioration over the next twenty-five years, due primarily from salty water finding paths through the joints rather than draining properly through the storm drains along the curbs. The elimination of the median strip, heel joints, and circular tops of the warning lights had changed the appearance of the bridge in small ways, but few of the motorists driving across the span noticed anything except a smoother ride.

The Arlington Memorial Bridge suffered no damage from the attack on the Pentagon on September 11, 2001, but the events dramatically raised the level of security concerns. In Washington, officials became seriously concerned that the abundance of government offices and monuments that symbolize the nation were too vulnerable to a wide variety of possible attacks. Only fourteen months after the attacks, Congress established the Department of Homeland Security (DHS) in 2002, which became the home for most existing security-related agencies. The DHS also sponsored vulnerability studies and prompted Congress to allocate sizeable funds for reducing those vulnerabilities. Congress soon enacted legislation requiring all federal monuments and memorial to have a security plan. As both a vital transportation link and a significant monument, the Arlington Memorial Bridge was one such structure, along with the

adjacent Lincoln Memorial and Arlington National Cemetery. Other than increased attention from the Park Police forces, there was little that could be done to reduce the threat. The nature of the bridge's function required essentially unlimited access to its sidewalks and roadway, making any kind of protective barrier moot.

A routine inspection by the FHWA in August 2003 described the condition of the Arlington Memorial Bridge as follows:

> This bridge is in fair structural condition due to extensive cracking, spalling, and general deterioration of concrete throughout the structure; and rusting of all steel in the bascule span. Additional problems include damaged expansion joints, displaced railing blocks, deterioration of the seawall at the east channel bank, and extensive deterioration of the access ladders. Repairs should be made as outlined in this report to prevent the possible development of more serious or costly problems in the future.
>
> During the summer of 2003 a deck study was also conducted. A total of eight, 4" diameter cores were taken from the deck at various locations along the north curbline and along the centerline. These cores indicate moderate deterioration throughout the deck with fracturing and water intrusion at various heights within the original concrete, as indicated by several cores. Although it is not critical at this time, a partial deck replacement should be scheduled within the next 5-10 years. The interior concrete repairs should be scheduled at the same time.
>
> With corrective action, periodic repainting, and regular maintenance, a useful life of approximately 30-35 years can be expected for this structure under current loading conditions. If corrective action is not taken, the deterioration will continue to progress and may eventually lead to loss of carrying capacity.[169]

With many security projects competing for funds following the September 11, 2001, attacks, no funds were available for extensive work on the bridge, so repairs continued to be made only as needed.

Although it did not involve work on the Arlington Memorial Bridge itself, the District of Columbia undertook a project in 2004 to realign traffic lanes of the Washington plaza and approach to the bridge. This resulted from a study conducted by the District of Columbia Department of Transportation and NPS that showed more vehicles using the bridge to travel inbound to the District from Virginia than using it to travel outbound. The $12.2 million project to modify the Washington plaza, also known as the Lincoln Memorial Circle began in April. (A

---

[169] *Bridge Inspection Report, Arlington Memorial Bridge, Structure No. 3300-16P* (Washington: U.S. Department of Transportation, Federal Highway Administration, Federal Lands Highway Bridge Inspection and Management Program, August 23, 2003), 2.

walking path encircles the memorial, but vehicle traffic is restricted to its west side.) As originally constructed, the circle had three outbound lanes toward the bridge and two going from it to the north side of the memorial, where other streets connected it to Constitution Avenue. This lane allocation was reversed. The Rock Creek and Potomac Parkway terminated at the circle from the northwest, and it received a direct connection to the bridge that became the bridge's third outbound lane. Alterations to the inbound streets allowed motorists to proceed to the north or south on Lincoln Memorial Circle. Those going south could directly access Ohio Drive along the river or Independence Avenue. Pedestrian safety was also enhanced with new, well-marked crosswalks and traffic lights to slow traffic. The fully modified approach plaza opened in early 2006.[170]

While the Arlington Memorial Bridge had been inspected regularly and reasonably well-maintained, the effects of more than eighty years of continuous service were becoming serious and evident. It had never undergone a complete rehabilitation, and as late as 2010, neither the NPA nor the FHWA had formulated serious plans, options, or funding sources for one. Repairs continued to be done as problems arose, even though those repairs became more frequent and costly.

The bridge's curbs and sidewalks required particular attention because of major rust deterioration on their steel support members, particularly near the bascule heel joints at all four locations. Many of these members had significant loss of section, with some of them completely rusted away. To ensure pedestrian and bicyclist safety, the NPS constructed four temporary bridges to span the heel joint areas. Built from aluminum with wood decks, these 40'-long x 8'-wide bridges are self-contained structures with integral railings and ramps at each end. Resting slightly above the affected areas, they transfer live loads to portions of the sidewalk known to have adequate support. These were installed during 2010 or 2011, but the exact date has not been ascertained.

In May 2011, the FHWA engaged Clark-Nexsen, an architect and engineering firm in Norfolk, Virginia, to make a detailed inspection of the bascule span, paying particular attention to member deterioration and differences from the construction drawing dimensions due to corrosion. Clark-Nexsen concluded that:

---

[170] Monte Reel, "Lincoln Circle Project Planned to Ease Traffic," *Washington Post*, April 7, 2004.

> Overall, the superstructure of the bascule span of Arlington Memorial Bridge is in fair condition with isolated areas of severe deterioration. The deterioration of the structure continues to progress at a rapid pace. The framing for the fixed portions of the sidewalks over the bascule piers is severely deteriorated. However, the temporary pedestrian bridges constructed to span across these areas are effective for ensuring the safety of pedestrians.
>
> The bearing seat for the fixed stringers along the back of both bascule abutments have significant delamination and spalling which should be addressed in the near future. Due to the loss of bearing area, the bearing seat should be repaired or supplemental supports installed.
>
> The areas of deterioration throughout the remainder of the structure should be considered in a load rating analysis and repaired accordingly. Particular attention should be given to the analysis of the curb stringers and the trunnion posts. The curb stringers on the south side of the west leaf between panel points 0 and 6 have significant deterioration in the flanges and webs and may control the rating.
>
> With the bridge in the closed position, the trunnion posts are not subjected to forces of the same magnitude as during opening and closing. However, the live load effects should be evaluated considering the significant deterioration of these members.
>
> It is our understanding that options for rehabilitation or replacement of this structure are currently being studied.[171]

Clark-Nexsen also furnished some short-term recommendations to stabilize the worst areas of deterioration until the bridge could be rehabilitated or replaced. This inspection was supplemented by ultrasonic thickness of the most-heavily rusted portions of the trunnion posts that showed 50-70 percent loss of section in base areas of the inner trunnion posts.[172] Fortunately, fixing the bascule span closed had significantly reduced the maximum loads the trunnion posts had to carry, and the bridge's capacity rating did not have to be reduced. If nothing else, these inspections validated the FHWA's predictions from the 2003 inspection.

Certainly the most unusual and unlikely event in the Arlington Memorial Bridge's life occurred on August 23, 2011, when the Washington region felt significant shaking from an intraplate earthquake with a magnitude of 5.8. The epicenter of the early-afternoon earthquake was near Mineral, Virginia, approximately 60 miles southwest of Washington. While other masonry structures in the Washington area, notably the Washington Monument and National

[171] *In-depth Inspection of Structure 3300-16P, Arlington Memorial Bridge* (Norfolk, VA: Clark-Nexsen Architecture & Engineering, May 6, 2011), 6-7.
[172] *Arlington Memorial Bridge, Trunnion Post Inspection* (Leesburg, VA: Fuchs Consulting, Inc., February 7, 2011), 5.

Cathedral, suffered significant damage, the Arlington Memorial Bridge did not. It seems likely that some of the interior concrete spalling observed during the post-event inspection may have been aggravated by the earthquake motion, but none was specifically identified as caused by it. The bridge was quickly inspected and re-opened to traffic.

Beginning in June 2012, the Cianbro Corporation of Pittsfield, Maine, oversaw an eight-week, $788,000 project to repair the bridge's deck, restore granite curbs, and replace sidewalks at both approaches. Closure of at least one lane—sometimes two—in each direction was necessary during September, October, and November.[173]

Despite these various projects, as of 2012 the bridge had never had a major overhaul.[174] That year, a report by the FHWA called for a complete overhaul of Arlington Memorial Bridge.[175]

A major inspection of the bridge's deck began in February 2013.[176] As anticipated, it identified large areas in the roadway where the concrete deck of the masonry spans and piers had deteriorated. It was clear that the piecemeal approach to repairing the bridge had run its course, and that a complete rehabilitation or replacement of it in the near future would be required. Without that, load restrictions, and perhaps closure, looked possible within a decade. The NPS and FHWA initiated the process to explore the options, develop cost estimates, perform an environmental assessment, and obtain the necessary funds. Early estimates for various options have ranged from $125 million to $250 million. A rehabilitation project could begin as early as 2016, and closure options being considered range from a complete closure of 40-100 days to partial closures that could lengthen the project duration to as much as four years.[177]

As this is written, the process continues, but no plan has been finalized. A general consensus among the interested parties is that the existing Arlington Memorial Bridge, which was listed on the National Register of Historic Places in 1980, should be rehabilitated rather than replaced for historic, economic, and traffic reasons. Debate continues, however, over the fate of

---

[173] "George Washington Memorial Parkway Arlington Memorial Bridge Repair," *TendersInfo*, June 14, 2012; "Repairs beginning on Arlington Memorial Bridge," *Associated Press*, September 10, 2012; and Meredith Somers, "Memorial Bridge Repairs to Take Two Months," *Washington Times*, September 11, 2012.
[174] "Public Scoping Newsletter: Rehabilitation of the Arlington Memorial Bridge, George Washington Memorial Parkway, Washington, D.C., and Virginia," National Park Service, U.S. Department of the Interior, March 2013, 2.
[175] Michael E. Ruane, "After 81 Years, Landmark Memorial Bridge Is In Dire Need of Renovation." *Washington Post*, April 13, 2013.
[176] Maggie Fazeli, "Memorial Bridge Inspection Set to Begin Today," *Washington Post*, February 19, 2013.
[177] For preliminary information, see "Public Scoping Newsletter: Rehabilitation of the Arlington Memorial Bridge."

the now-inert bascule span. Several options to replace or rebuild it are under consideration. With all options, this span will remain fixed in place.

APPENDIX – ILLUSTRATIONS

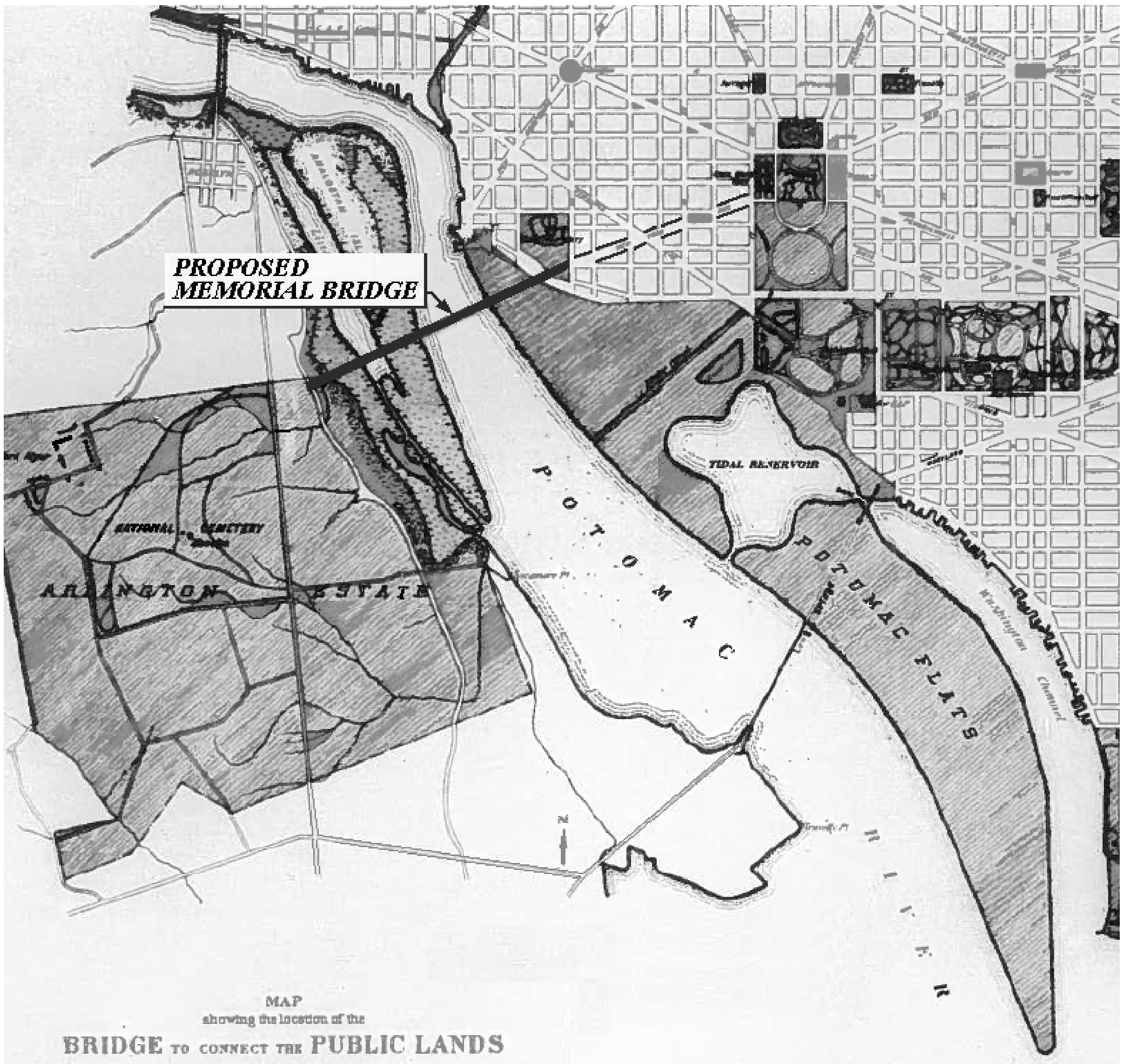

Figure 1. The initial location proposed for the Memorial Bridge was in line with New York Avenue. This was the best location before the Potomac Flats was reclaimed (shaded area), but it would not have entered Arlington National Cemetery in a desirable location. Some engineers claimed that this location would allow the bridge to be high enough that it would not need a draw span. This map is from 1890. (NARA RG 77, Cons. 722, No. 1)

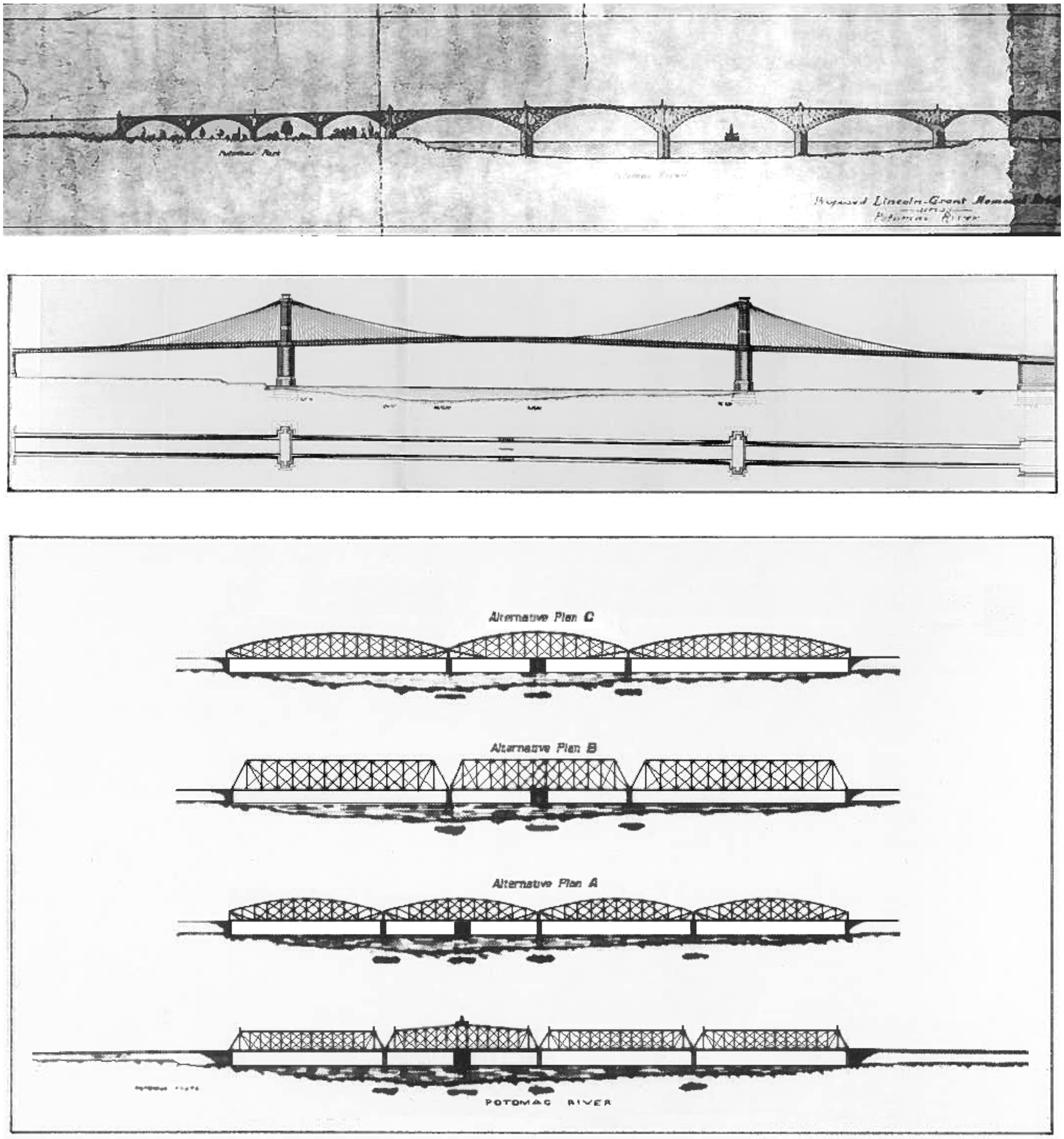

Figure 2. The first designs for a memorial bridge at the foot of New York Avenue exhibited a wide range of ideas. Army Capt. Thomas W. Symons proposed a fixed-arch "Lincoln-Grant Memorial Bridge" with an attractive profile (top), while Col. Peter C. Hains submitted a suspension bridge (center) high enough to clear river traffic and purely functional through-truss iron bridges with a swing span near the center (bottom). Hains included three- and four-span alternates, with one of each (A and C) employing lenticular trusses, a type rarely used in the United States. These designs were submitted between 1886 and 1890 in response to a Senate resolution. (NARA RG 77, Cons. 426, No. 2, and NARA RG 77 Cons. 722, No. 2. Also *U.S. War Department Annual Report, 1890* vol. 2 Appendix.)

Figure 3. This aerial view in mid-1928 shows the pier foundations in place. The large storage area needed for the granite facing stones is in the foreground. (NARA RG 42)

Figure 4. Each leaf of the bascule span was assembled with rivets from components fabricated at Phoenix Bridge's shop. The east leaf was erected first, and then raised to provide clearance for ships while the west leaf was being built. (NARA RG 42-AMB-1-30)

BIBLIOGRAPHY

Books, Articles, and Reports

Arlington Memorial Bridge, Trunnion Post Inspection. Leesburg, VA: Fuchs Consulting, Inc. February 7, 2011.

Bridge Inspection Report, Arlington Memorial Bridge, Structure No. 3300-16P. Washington: U.S. Department of Transportation, Federal Highway Administration, Federal Lands Highway Bridge Inspection and Management Program, August 23, 2003.

"Bridges by Strauss." Pamphlet. Chicago, IL: Strauss Engineering Corporation, 1929.

Commission of Fine Arts. *Twelfth Report, July 1, 1929 to December 31, 1934.* Washington: Government Printing Office. 1936.

Douglas, Walter J. "Foundations and Earthwork." In *American Civil Engineers Handbook*, *5th Ed*., ed. Thaddeus Merriman. New York: John Wiley and Sons, 1930.

Foley, Connie. *River Port and Capital: The Architectural and Natural Landmarks of Washington*. Washington: U.S. Department of the Interior, 1965.

Follett, George A. "The Construction of a Cofferdam." *The Military Engineer* 20, no. 109 (Jan.-Feb. 1928).

Foulds, R. S. "Erecting 3,800-Ton Bascules in the Arlington Bridge." *Engineering News Record* (March 3, 1932).

"George Washington Memorial Parkway Arlington Memorial Bridge Repair." *Tenders Info* (June 14, 2012).

Goode, James M. *The Outdoor Sculpture of Washington, DC.* Washington: Smithsonian Institution Press, 1974.

Green, Constance McLaughlin. *Washington: Capital City, 1879-1950*. Princeton, NJ: Princeton University Press, 1962.

Gutheim, Frederick. *Worthy of the Nation: The History of Planning for the National Capital.* Washington: Smithsonian Institution Press, 1977.

Hains, Peter C. "Reclamation of the Potomac Flats at Washington, D.C." *Transactions of the American Society of Civil Engineers* 31 (1894).

Heine, Cornelius W. "The Washington City Canal." *Records of the Columbia Historical Society of Washington, D.C*. vol. 53/56 (1958).

In-depth Inspection of Structure 3300-16P, Arlington Memorial Bridge. Norfolk, VA: Clark-Nexsen Architecture & Engineering, May 6, 2011.

Keyser, C. C. "Designing Concrete for Weight of 271 Pounds Per Cubic Foot." *Journal of the American Concrete Institute* 3 (April 1932).

Koglin, Terry L. *Movable Bridge Engineering.* Hoboken, NJ: John Wiley and Sons, 2003.

Maguire, Frank. *Report on Bascule Span for Arlington Memorial Bridge.* Washington: David Volkert and Associates, December 19, 1985.

"Memoirs of Peter Conover Hains," *Transactions of the American Society of Civil Engineers* 85 (1922).

"The Memorial Bridge Across the Potomac," *The Engineering Record* 41, no. 16 (April 21, 1900).

Morris, Clyde T., et al. "Concrete and Reinforced Concrete Arches: Final Report of the Special Committee." *Transactions of the American Society of Civil Engineers* 100 (1935).

Myer, Donald Beekman. *Bridges and the City of Washington.* Washington: Commission of Fine Arts, 1974.

Nagle, John. "The Arlington Memorial Bridge." *The Military Engineer* 20, no. 110, (March-April 1928).

Newton, Norman T. *Design on the Land.* Cambridge, MA: Belnap/Harvard Press, 1971.

Nolin. Elizabeth M. *Historic Structure Report: Arlington Memorial Bridge, Washington, D.C.* Washington: KressCox Associates, P.C., May 2, 1986.

Office of Public Buildings and Public Parks of the National Capital, Annual Report of the Director of Public Buildings and Public Parks of the National Capital. Washington: U.S. Government Printing Office, 1927, 1928, 1929, and 1930.

Ogburn, Fielding, Elio Passaglia, Harry C. Burnett, Jerome Kruger, and Marion L. Pickelsimer, "Restoration of Large Gilded Statues Using Various Electrochemical and Metallurgical Techniques." *Corrosion and Metal Artifacts: A Dialogue Between Conservators and Archaeologists and Corrosion Scientists.* National Bureau of Standards Special Publication 479, eds., Benjamin Floyd Brown, et al. Washington: U.S. Government Printing Office, 1977.

Phillips, James M. III. "Bascule Bridge Locking Devices." The First Biennial Symposium and Exhibition on Movable Bridge Design and Technology. Tallahassee, FL, November 4, 1985.

"Public Scoping Newsletter: Rehabilitation of the Arlington Memorial Bridge, George Washington Memorial Parkway, Washington, D.C., and Virginia." Washington: National Park Service, U.S. Department of the Interior, March 2013.

Report of the Arlington Memorial Bridge Commission. Senate Doc. No. 95, 68th Congress, 1st session. Washington: U.S. Government Printing Office, 1924.

Remini, Robert V. *Andrew Jackson and the Course of American Democracy, 1833-1845*. New York: Harper and Row, 1934.

Scott, Pamela. *Capital Engineers: The U.S. Army Corps of Engineers in the Development of Washington, D.C., 1790-2004*. Alexandria, VA: U.S. Army Corps of Engineers History Office, 2007.

"Specification for High Strength Structural Steel A94." *Annual Book of ASTM Standards.* American Society for Testing and Materials (1927).

Whitney, Charles S. "Design of Symmetrical Concrete Arches." *Transactions of the American Society of Civil Engineers* 86 (1925).

Zangrando, Joanna S. "Monumental Bridge Design in Washington, D.C. as a Reflection of American Culture, 1886 to 1932." Ph.D. dissertation, George Washington University, 1974.

Newspapers

"Amendment Aids Arlington Bridge." *Washington Post*, March 9, 1926.

"Arlington Bridge Delay Threatened By Ruling in House." *Washington Post*, January 12, 1927.

"Arlington Bridge Repair Work to Start Soon," *Washington Post*, November 28, 1938.

"Another Link in Arlington Bridge to Open Tomorrow." *Washington Post*, April 8, 1932.

"Arlington Memorial Bridge." *Washington Post*, January 20, 1931.

"Army Officers Deny Bridge Eagles Are Mexican Birds." *Washington Post,* May 11, 1928.

"Bids Are Sought For Bridge Work." *Washington Post*, June 2, 1929.

"Bids to Be Invited For Constructing New Bridge Spans" *Washington Post,* October 9, 1927.

Blum, Deborah. "Freighter rams Skyway, span falls into sea, at least 30 die." *St. Petersburg [FL] Times*, May 10, 1980.

"Bridge Commission Accepts Boston Bid." *Washington Post,* February 5, 1926.

"Bridge to Be Closed Again." *Washington Post*, August 18, 1951.

"Commissioners Approve Plans On Road Work." *Washington Post*, July 8, 1933.

"Drawspan Repairs Shuts Bridge Lanes." *Washington Post*, March 3, 1964.

"8-Hour Labor Day Enforced On Bridge." *Washington Post*, August 9, 1927.

Fazeli, Maggie. "Memorial Bridge Inspection Set to Begin Today." *Washington Post,* February 19, 2013.

Feaver, Douglas B. "Road Work to Impede Commuters." *Washington Post*, November 6, 1976.

"First Work is Done on Memorial Bridge." *Washington Post*, March 12, 1925

Gilliam, Dorothy. "After 14 Years, Roosevelt Bridge Is Opened." *Washington Post*, June 24, 1964.

"Gotwals Planning to Finish Several Big Highway Jobs," *Washington Post*, June 13, 1933.

"House Action Fails to Halt Bridge Work," January 14, 1927.

"House backs M'Carl's Memorial Bridge Ruling." *Washington Post*, April 16, 1926.

"Independent Offices Bill Passes House," January 15, 1927.

"Legal Matters Delay Opening of Bridge Link." *Washington Post*, October 19, 1938.

Lynton, Stephen J. "Memorial Bridge Work Set." *Washington Post*, April 19, 1985.

"Memorial Bridge Approach Opened." *Washington Post*, April 10, 1932.

"Memorial Bridge Bids will be Let, Ignoring M'Carl." *Washington Post*, January 7, 1926.

"Memorial Bridge Closes Saturday." *Washington Post*, August 7, 1953.

"Memorial Bridge Closings Listed." *Washington Post*, August 27, 1939.

"Memorial Bridge Fund Stricken Out." *Washington Post*, April 8, 1932.

"Memorial Bridge Is Closed For Day During Repair Work." *Washington Post*, August 3, 1947.

"Memorial Bridge Opened Informally." *Washington Post*, January 17, 1932.

"Memorial Bridge Shut 9 Hours As Crew Rushes Workmen Gears." *Washington Post*, October 21, 1936.

"Memorial Bridge Will Be Closed For 4 Weekends." *Washington Post*, July 22, 1951.

"New Bridge Bears Its First Cortege." *Washington Post*, January 19, 1932.

"New Face for Memorial Bridge." January 5, 1951.

"Officials Miss Ceremonies: Traffic Jam Blocks Roads to Arlington." *Washington Post*, November 12, 1921.

"Public, In 30,175 Cars, Tries Out New Memorial Bridge." *Washington Post*, January 18, 1932.

Reel, Monte. "Lincoln Circle Project Planned to Ease Traffic." *Washington Post*, April 7, 2004.

"Resurfacing of Bridge to Begin Monday." *Washington Post*, July 12, 1951.

"Resurfacing of Memorial Bridge Starts." *Washington Post*, July 17, 1951

"Repairs beginning on Arlington Memorial Bridge." *Associated Press*, September 10, 2012.

Ruane, Michael E. "After 81 Years, Landmark Memorial Bridge is in Dire Need of Renovation." *Washington Post*, April 13, 2013.

"16-Foot Photos Aid in Selection." *Prescott* [AZ] *Evening Courier*, December 17, 1928.

Somers, Meredith. "Memorial Bridge Repairs to Take Two Months." *Washington Times*, September 11, 2012.

"Statues to Adorn End of New Bridge." *Washington Post*, December 7, 1928.

"Street Work Will Advance On Tax Funds." *Washington Post*, September 20, 1933.

"3 Contracts Let For Arlington Bridge Repairs." *Washington Post,* June 16, 1939.

"Traffic to Move During Span Job." *Washington Post*, July 19, 1957.

"$2,500,000 Provided to Continue Work on Memorial Span." *Washington Post*, February 16, 1926.

"Unpaved Approach All That Bars Use of Memorial Span." *Washington Post,* September 8, 1931.

Weil, Martin. "Memorial Bridge reopened after crash that left vehicle in Potomac River." *Washington Post*, Feb. 25, 2013.

"Work Begun On Arlington Traffic Outlets." *Washington Post*, September 21, 1938.

Archival Sources

Bridges - Arlington Memorial, 1895-1938. Martin Luther King Jr. Public Library, Washingtoniana Room, Washington, DC.

Charles Moore Papers, General Correspondence, n.d.. Manuscript Division, Library of Congress, Washington, DC.

Engineering Plans. National Park Service. National Archives and Records Administration, College Park, MD. Record Group 79. Filed by the Arlington Memorial Bridge Commission drawing numbers. A box of index cards listing them is filed in RG 79.6.7.

Textual Records. Commission of Fine Arts. National Archives and Records Administration, College Park, MD. Record Group 66.

Textual Records. National Park Service. National Archives and Records Administration, College Park, MD. Record Group 79.

Textual Records. Office of Public Buildings and Public Parks. National Archives and Records Administration, College Park, MD. Record Group 42.

Engineering Plans and Inspection Reports. Arlington Memorial Bridge. Federal Highway Administration, Eastern Federal Lands Highway Division. Sterling, Virginia.

Electronic Sources

Brepohl, Erhard. "Fire-Gilding." *Theory and Practice of Goldsmithing*. Brunswick, ME: Brynmorgen Press, 2003. An excerpt is available at The Ganoskin Project, http://www.ganoksin.com/borisat/nenam/fire_gilding-9-3.htm (Retrieved September 24, 2013).

"George Mason Memorial Bridge." River Explorer. http://www.riverexplorer.com/details.php4?id=1167 (Retrieved August 17, 2013).

"Hoovers Inspect New Potomac Span: President and First Lady accompany Vice President Curtis on opening of the Arlington Memorial Bridge." Pathé News, 1932. http://www.britishpathe.com/video/hoovers-inspect-new-potomac-span-aka-hoover-inspec/query/newsreels. (Retrieved August 10, 2013).