Washington, D.C.

by Yvonne Thelwell, District Department of Transportation

Washington, D.C., is a city steeped in history, of which the transportation network is an integral part. City planner Pierre L'Enfant's 18th-century vision of carefully laid-out streets, avenues, and circles has evolved into the current network of roads, bridges, bikeways, and transit that ably serves hundreds of thousands of users daily. Within the city's 68-square-mile footprint, the District Department of Transportation's (DDOT's) bridge inventory includes 235 city-owned bridges, 39 National Park Service bridges, 38 railroad-owned bridges, and 15 tunnels. Averaging 3.5 city-owned bridges per square mile, this far exceeds the bridge density of any state in the nation. Challenges faced by DDOT when making the decision to replace or rehabilitate a bridge include maintenance and protection of vehicular, pedestrian, and bicycle traffic, the structure's historical significance, aging infrastructure, extensive utilities, and high construction costs. Rehabilitation of our historic bridges faces an additional challenge: extensive coordination with and approval by the State Historic Preservation Office (SHPO) for the District of Columbia.

Concrete Arch Bridges

The city has numerous concrete arch bridges that, through robust engineering and good materials selection, have withstood more than 100 years of service life. Cyclical maintenance on these bridges includes the removal of pigeon debris, cleaning and flushing drains, cleaning joints, sealing cracks, sealing concrete, and repairing damage from accidents and storm events. It is also important to perform maintenance-based activities to address deficiencies identified during the inspections; these activities may include repairing or replacing drains, replacing joints, patching or repairing concrete spalls, and performing scour countermeasures. With routine maintenance, the concrete arch bridges will be in service for many years to come. These bridges are a tribute to the long-term durability of concrete and demonstrate that with good detailing, longevity for our bridges can be achieved.

Pennsylvania Avenue Bridge

Pennsylvania Avenue Bridge spans Rock Creek, Rock Creek Parkway, and Rock Creek Park Trail. The original 1858 bridge—constructed of 48-in.-diameter cast iron water mains as the load-bearing arch members—carried both water and vehicular traffic, including a horse-drawn streetcar from 1863 to 1872.[1] With a length of 200 ft and a width of 40 ft, the bridge was one of the largest single-span iron pipe arch structures in the world. In 1913, the District of Columbia (DC) Board of Commissioners chose to erect a 276-ft-long, 73-ft-wide concrete arch bridge around the original bridge rather than build a new bridge, at a cost of $121,032.[2]

The bridge underwent reconstruction of the superstructure in 1979. In 2018, rehabilitation of the arch and superstructure to extend the service life was completed. This rehabilitation required a thorough knowledge of the bridge, its history, and the needs of the local community to achieve an efficient and durable design that met both the project's technical requirements and the aesthetic and historic preservation demands. The goal to extend the life of the bridge without compromising its aesthetic appeal or character was achieved.

To preserve the uniqueness of the bridge, composed of pre–Civil War cast iron water mains and concrete arches from the early 20th century, advanced modeling and structural engineering techniques were required to "reconstruct" the history of the bridge. This design analysis provided an understanding of the existing stresses in the arch system and the effects of the proposed rehabilitation on the bridge's load-carrying capacity. The analysts used a combination of hand calculations and finite element analysis that modeled all aspects of the structure in three dimensions, including time-dependent loadings such as creep and shrinkage, effects of load removal and replacement, and settlement of supports. Furthermore, maintaining and protecting vehicular and pedestrian traffic was a major

Pennsylvania Avenue Bridge over Rock Creek Parkway. Originally constructed in 1858 of 48-in.-diameter cast iron water mains as the load-bearing arch members, the bridge was one of the largest single-span iron pipe arch structures in the world. In 1913 a concrete arch bridge was constructed around the original bridge. The concrete superstructure was reconstructed in 1979, and the arch and superstructure were rehabilitated in 2018 to extend the bridge's service life. Photos: District Department of Transportation.

The Francis Scott Key Bridge crossing the Potomac River is a reinforced concrete open-spandrel, ribbed-arch bridge, which was completed in 1923. Designed in the Classical Revival style by Nathan C. Wyeth, the bridge was added to the National Register of Historic Places in 1996. Photo: District Department of Transportation.

concern of the public. By developing details to accommodate staged construction, the project team was able to reduce the detour time to be 30% less than originally scheduled. The rehabilitation received an American Council of Engineering Companies of Metropolitan Washington Honor Award.

Francis Scott Key Bridge

Francis Scott Key Bridge, often referred to as the Key Bridge, spans the George Washington Memorial Parkway, the Potomac River, the Whitehurst Freeway, and the Chesapeake and Ohio Canal. It is the oldest surviving Potomac River bridge and was added to the National Register of Historic Places in 1996.

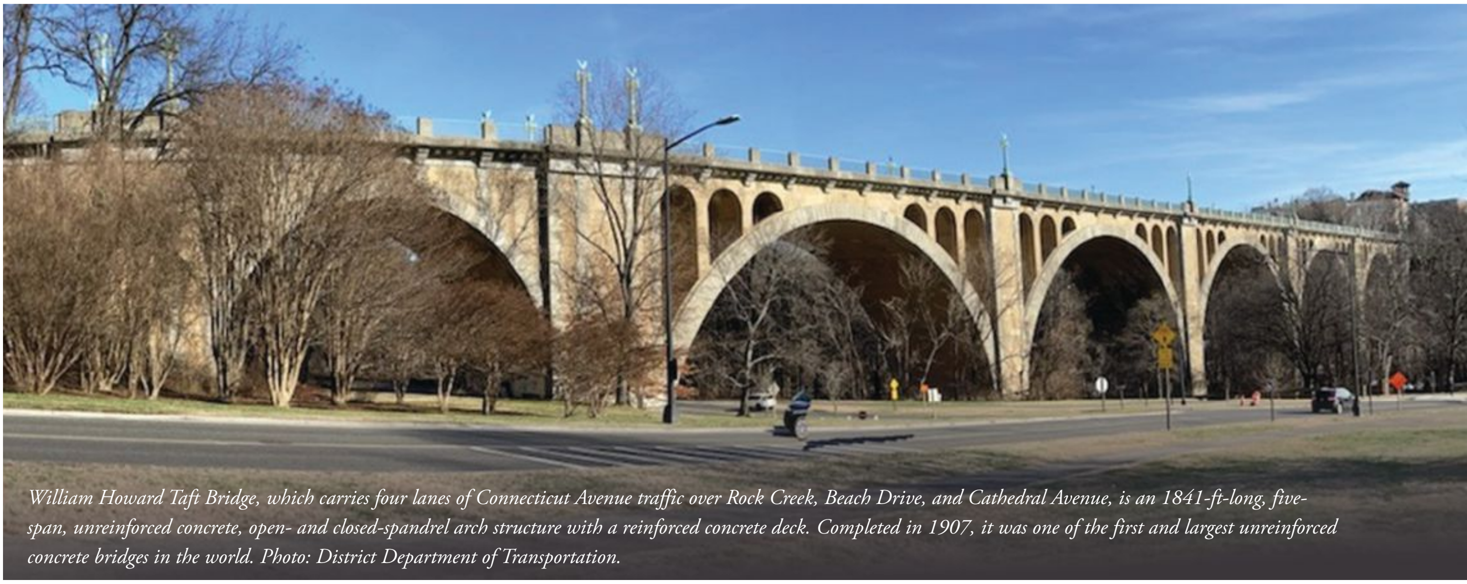
A congressional charter was obtained in 1830 to construct an aqueduct to extend the Chesapeake and Ohio Canal across the Potomac River. "The Aqueduct" was the first river crossing constructed at this site, consisting of a large wooden trough supported by stone piers. The bridge consisted of two large Howe trusses strengthened by timber arches. The wooden construction soon began to rot and leak, so it was abandoned as a link in the canal system. When the Civil War broke out, the government seized the bridge for military use until 1866, after which a company took custody under a 99-year lease.[1] A wagon bridge was erected on the stone piers, but high tolls were charged. Under pressure from enraged residents, Congress passed the Riddleberger Bill, which authorized $125,000 to purchase the bridge or erect a new bridge at Three Sisters Island.[2] In the late 19th century, construction of a new superstructure on the old piers began. The substructure began to deteriorate, requiring three of the eight piers to be reconstructed between 1897 and 1907. Increased deterioration required a 4-ton load limit and closure during periods of heavy ice flow, and eventual replacement.[2] The original structure was designed and constructed by the U.S. Army Corps of Engineers and constructed by day labor under the supervision of the Corps of Engineers at an approximate cost of $2.5 million.

Despite material and labor shortages caused by World War I, a new bridge with seven reinforced concrete open-spandrel, ribbed-arch spans was completed in 1923 and dedicated to the author of the Star Spangled Banner, Francis Scott Key. The bridge includes solid concrete piers resting on footings founded on a rock bed. An eighth span was later added on the Virginia side.

The Key Bridge was designed in the Classical Revival style by Nathan C. Wyeth, a prominent architect who designed several other landmark structures, including the White House's West Wing. The 1781-ft-long bridge has an out-to-out width of 90 ft and a curb width of 66 ft. In 1955, trolley tracks across the bridge were eliminated and the deck was widened from 70 to 80 ft. In 1987, the deck was replaced and widened further to 90 ft (although the width of the roadway remained unchanged), followed by a major repair in 2019. It currently carries 60,000 vehicles and 8000 pedestrians and bicyclists per day.

William Howard Taft Bridge

The William Howard Taft Bridge carries four lanes of Connecticut Avenue traffic over Rock Creek, Beach Drive, and Cathedral Avenue. This 1841-ft-long, five-span, unreinforced concrete, open- and closed-spandrel arch structure with



William Howard Taft Bridge, which carries four lanes of Connecticut Avenue traffic over Rock Creek, Beach Drive, and Cathedral Avenue, is an 1841-ft-long, five-span, unreinforced concrete, open- and closed-spandrel arch structure with a reinforced concrete deck. Completed in 1907, it was one of the first and largest unreinforced concrete bridges in the world. Photo: District Department of Transportation.

Q Street Bridge is on a 12-degree horizontal curve. The color of the bridge's stone evokes the warm tones of Spain and Italy. In 1973, the bridge was added to the National Register of Historic Places. Photo: District Department of Transportation.

a reinforced concrete deck was one of the first and largest unreinforced concrete bridges built in the world.

Although three steel arches were proposed in an 1890s competition, the progressive concrete arch was selected. The winning design used cast-in-place concrete with bush-hammered surfaces to emulate granite. Arch ring stones, brackets, moldings, railings, and other trim are all precast concrete. Concrete blocks were used as permanent forms as well as for the finished surface. All arches are hingeless and without reinforcement. Lions at each end of the bridge, sculpted by R. Hinton Perry, were not completed until six months after the bridge opened because it was feared that the project would run out of money, in which case the sculptures would have been eliminated. The lions were restored in 1965 and then fully replaced in 2000.[1]

The plans for the bridge were prepared by the DC Bridge Division in consultation with George S. Morrison, engineer, and Edward Pearce Casey, architect. The bridge was built in 1907 at a cost of $846,331.[2] In 1931, the bridge was renamed in honor of President William Howard Taft.

The Q Street Bridge

Also known as the Dumbarton Bridge or the Buffalo Bridge, the Q Street Bridge is a five-span, reinforced concrete closed-spandrel arch structure on a 12-degree horizontal curve. It spans Rock Creek Valley between the DuPont Circle and Georgetown neighborhoods. Acquiring a used bridge for the site was originally considered, but a structure of the same caliber as the Taft Bridge was chosen instead. The majestic bridge was completed in 1915 at a cost of $223,553 with input from architect Glenn Brown, engineer Daniel B. Luten, and public planning bodies that included the city's newly formed Commission of Fine Arts.[1] The bridge is 342 ft long, with a 33-ft-wide roadway and 7-ft-wide sidewalks on each side.

Flanking both ends of the bridge are four large bronze buffalo sculptures by sculptor Alexander Phimister Proctor.[2] The arches are decorated with sculptures of Native American heads designed by Glenn Brown based on a life mask of the Sioux chief Kicking Bear. The color of the bridge's stone was intended to evoke the warm tones of Spain and Italy. In 1973, the Dumbarton Bridge was added to the National Register of Historic Places.

16th Street over Piney Branch Parkway

The 16th Street over Piney Parkway Bridge is a 272-ft-long, single-span concrete arch, and was the first parabolic arch bridge erected in the United States. It consists of two large parallel arches and a platform supported by spandrel beams, encased by a concrete facing, giving it a very solid, simple appearance. The unreinforced concrete bridge was built one side at a time. Architectural features include appliques and an exposed pebble aggregate covering the surface with a triple arch ring and coping of smooth concrete. The abutments are smooth pilasters flanking the arch. Tigers, sculpted by Alexander Phimister Proctor, adorn the ends of the bridges. It was designed by the DC Division of Bridges and was constructed in 1906 at a cost of $135,000.[1] Its rehabilitation, which began in 2022, includes concrete repairs, slope improvements, light and signal upgrades, sculpture restoration, addition of stormwater management biofiltration planters, and replacement of the pedestrian fence.

State-of-the-Art Bridges

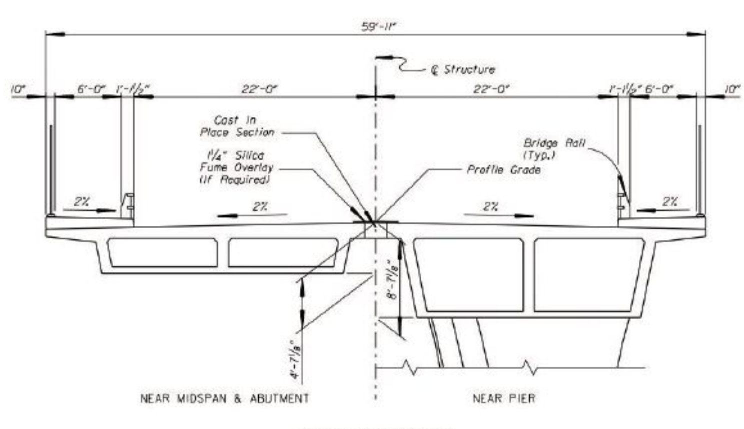
During the 21st century, DDOT has added state-of-the-art bridges to its inventory, including the Southern Avenue over Suitland Parkway Bridge and the Frederick Douglass Memorial Bridge, both under design-build contracts.

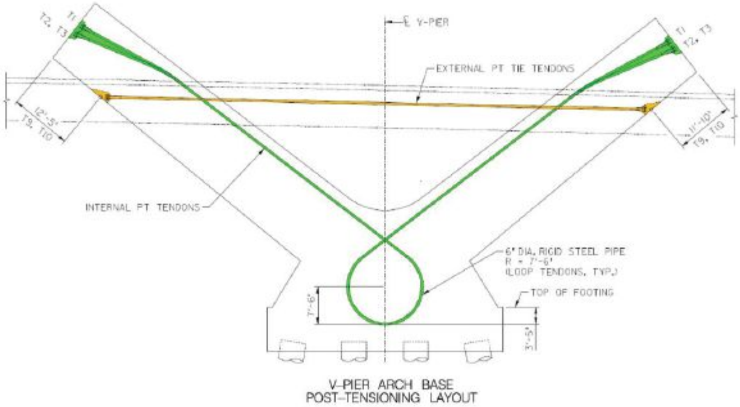
Southern Avenue over Suitland Parkway Bridge Replacement

The Southern Avenue over Suitland Parkway Bridge replaced a 390-ft-long steel structure

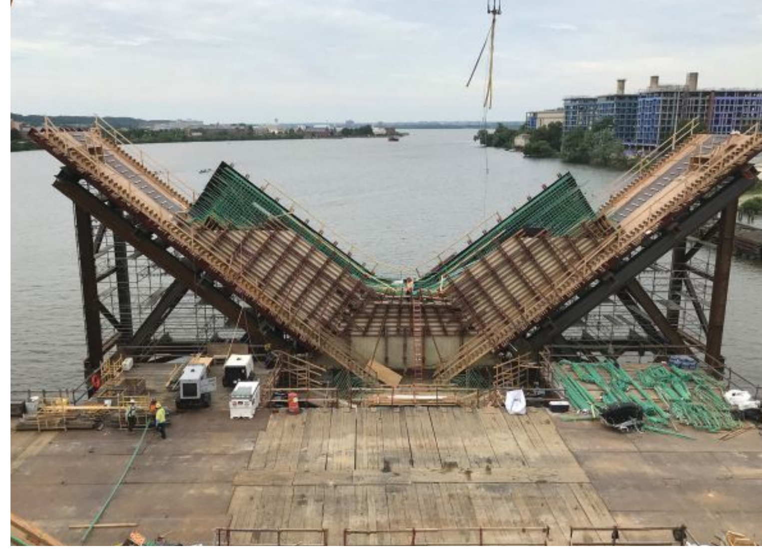
The Southern Avenue Bridge over Suitland Parkway is a three-span, 413-ft-long cast-in-place concrete, post-tensioned, haunched box-girder structure. Photo: CDM Smith.

Typical cross sections for the Southern Avenue Bridge. Figure: CDM Smith.





Cast-in-place concrete V-piers for the Frederick Douglass Memorial Bridge are both internally and externally post-tensioned. The V-piers use very-low-permeability concrete to meet strict corrosion-protection requirements. Figure: HNTB.



Each V-pier of the Frederick Douglass Memorial Bridge required 950 yd³ of concrete, completed in four mass placements with cooling tubes. Photo: District Department of Transportation and HNTB.

with a three-span, 413-ft-long, cast-in-place concrete, post-tensioned, haunched box-girder bridge structure, under a design-build contract with Federal Highway Administration, Eastern Federal Lands Highway Division.

Two lanes of traffic were maintained during construction and demolition of the previous bridge. Scaffolding and falsework structures were required to support the box-girder superstructure during construction of the cast-in-place bottom slabs, walls, and top slabs. The design included installation of a total of 342 longitudinal post-tensioning strands through ducts in the box-girder walls. The multistrand tendons were tensioned until they elongated more than 34 in., giving the structure the strength it needed to span the 164 ft across Suitland Parkway.

The project was completed in 2007. It was the recipient of the 2007 ABC Excellence in Construction Award in the Heavy/Industrial/Transportation Construction category for the Washington, D.C.. metro region.

Frederick Douglass Memorial Bridge over the Anacostia River

The Frederick Douglass Memorial Bridge replaced a 70-year-old swing structure spanning the Anacostia River. The old bridge had required frequent and costly maintenance and repairs, was functionally obsolete with substandard sidewalks, and was structurally deficient with truck traffic prohibited in the curb lanes due to load-rating restrictions. The new bridge is an iconic, 1445-ft-long, three-arch structure (452 ft 6 in., 540 ft, and 452 ft 6 in.), with all components designed and detailed for a 100-year service life.

The cast-in-place concrete V-piers use internal post-tensioning (eight tendons with twenty-seven 0.6-in.-diameter strands in corrugated plastic ducts, stressed at both ends then grouted) and external post-tensioning (27-strand, 0.6-in.-diameter, coextruded high-density polyethylene [HDPE] sheathed strand, with wax-filled HDPE external ducts) to resist the ultimate demand loads. The concrete mixture proportions were specifically developed with high slag content to obtain a very low permeability to meet the strict corrosion-protection requirements for the bridge (nonreplaceable components required a 100-year minimum service life, and replaceable components required a minimum 30- to 75-year service life). Concrete crossbeams built integrally with the V-piers extend out transversely beneath the bridge deck to support the superstructure's longitudinal edge girders on elastically restrained bearings.

The 10-in.-thick precast concrete deck panels (5000-psi 28-day design strength) required a 180-day cure, necessitating intense coordination with the suppliers. Durability features include a 1-in.-thick polyester polymer concrete overlay with a high-molecular-weight methacrylate sealer prime coat, 6500-psi portland cement concrete closure pours, stainless steel reinforcement across construction joints, and epoxy-coated longitudinal and transverse reinforcing steel.

Another major component of this design-build project is the reconstruction of the Interstate 295 (I-295)/Suitland Parkway Interchange, which had many deficiencies. The existing bridges were structurally deficient and functionally obsolete, the existing interstate did not meet current design standards, and the interchange ramps did not meet current design standards for speed, shoulder width, and sight distance. The new bridges include the I-295 bridges over Firth Sterling Avenue and CSX railroad tracks, Suitland Parkway and Howard Road, Ramp A over Suitland Parkway, and Ramp F over Howard Road. All bridges use precast, prestressed concrete bulb-tee girders that were selected for durability and cost advantages. The design using prestressed concrete girders was the most economical option even though the profile of I-295 over Suitland Parkway had to be raised to meet the vertical clearance requirements with the deeper girders.

The Frederick Douglass Memorial Bridge opened to traffic in 2021. The approaches are scheduled for completion in 2022.

Conclusion

DDOT continues to overcome many challenges while honoring the District of Columbia's history by keeping our historic bridges in a state of good repair and constructing new state-of-the-art structures for an extended service life. Performing routine, cyclical, and condition-based maintenance activities on our historic concrete arch bridges involves a relatively minor investment and can ensure longevity for future generations. Meanwhile, new bridges are designed and constructed for an extended service life by using durable materials and systems, details that provide easy access for performing maintenance activities, and details that allow easy replacement of components that have a service life shorter than the service life of the full bridge.

References

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2. Robertson, J. N. 1956. *Washington Bridges*. Washington, DC: Department of Highways, Office of Planning, Design and Engineering.

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