CONCRETE BRIDGES IN MARYLAND

The Advent of Concrete Bridges in Maryland

The first mention of the use of concrete occurs in the Maryland Geological Survey's *Report on the Highways of Maryland*, published in 1899. In his chapter, "The Present Condition of Maryland Highways," Arthur Newhall Johnson noted that "iron bridges are. . .fast replacing the longer wooden spans." Observing that comparatively few I-beam bridges, "one of the cheapest and best forms for spans less than 25 or 30 feet," had been built in Maryland, Johnson recommended a transitional form of reinforced concrete construction, stating "no method of construction is more durable than the combination of masonry and I-beams, between which are transverse arches of brick, the whole covered with concrete, over which is laid the roadway" (Johnson 1899:206). Hired in 1898 as the first Highway Engineer of the Maryland Geological Survey Commission, Johnson had previously been a member of the Board of Highway Commissioners of Massachusetts (Maryland State Roads Commission 1964:42).

Although the design described by Johnson appears never to have been built in Maryland, another composite design was constructed in Baltimore soon thereafter, in 1902, at Lancaster Street over the Central Avenue Sewer. Built under the "system of replacing temporary wooden structures with permanent stone, or iron, started in 1900," the Lancaster Street bridge was originally constructed with "an iron I-beam construction, with a wooden floor." The wood floor was subsequently found to be "a source of perpetual expense, very unsatisfactory, and more or less dangerous." Dissatisfied with this bridge, City engineers converted the bridge into "the most important and novel" of structures by the use of "Ferro-Concrete, or Armored Concrete" construction techniques. As

described in the 1902 *Annual Report of the Chief Engineer*, the transformation of the bridge occurred in the following fashion:

> The iron beams were first well cleaned, then covered with coal tar and surrounded with concrete; the spaces between the beams were filled with a floor of concrete six inches thick, reinforced with six-inch mesh expanded metal: on top of the concrete was placed a coating of coal tar to exclude the moisture, the whole finished with a vitrified brick pavement [Baltimore City Chief Engineer 1903:10].

The use of a metal mesh to reinforce the concrete was the first step in Maryland toward the development of true reinforced concrete construction; the concrete was no longer simply encasing the metal members for protective purposes but also contributed to the bridge's load-bearing capacity. The experiment with this type of construction was a success: "the conclusion was reached that such a floor was strong enough to withstand four times the heaviest load that could ever come upon it" (Baltimore City Chief Engineer 1903:10).

The first Maryland concrete bridge to feature reinforcing bars was the bridge at Sherwood Station, built in 1903 by Baltimore County. The announcement of this bridge's completion in the *Third Report on the Highways of Maryland* reveals the pride that was felt at its construction:

> The bridge that was built this year, 1903, near Sherwood Station shows the progressive character of the work that the County Roads Engineer is inaugurating. What is known as the steel concrete form of construction was adopted, which uses reinforced concrete beams instead of simple steel or wooden beams as in other forms of construction; this is the first example of its kind in the State [Johnson 1903:169].

The announcement goes on to report that "steel rods are imbedded in the concrete beams to enable them to withstand heavy loads; but no steel surface is exposed to air, so that there is practically no cost for maintenance of a bridge of this character" (Johnson 1903:169).

It should be pointed out that perhaps one of the reasons for the optimism expressed is that concrete construction relied upon local materials and labor. A great number of Maryland's metal truss bridges had been fabricated by out-of-state bridge companies, a fact that surely did not go unnoticed by local officials and residents. Daniel Luten certainly did not ignore this point when advocating his concrete bridges: "Concrete bridges are built with home labor and materials. The money expended for a concrete bridge returns directly to the taxpayers" (Luten 1917).

Baltimore City quickly followed with a reinforced concrete bridge of its own, at Lexington Street over Gwynn's Run. Although termed a "culvert," its 66-foot span certainly qualifies it as a full-scale bridge. The structure was "the first reinforced concrete arch which has been built by the city" (*Annual Report of the City Engineer* 1905:92) and may be the first reinforced concrete arch in the state. According to the report, "Kahn" bars were used to reinforce the concrete. However, this was not the first time that Baltimore City had built a concrete arch; a concrete arch, in an unreinforced form, was used in 1900 to lead the Schroeder's Run sewer as an open drain underneath residences (*Annual Report of the City Engineer* 1901:7).

The success of reinforced bridges at Sherwood Station and in Baltimore City quickly led to the adoption by the Maryland Geological Survey of a plan for reinforced concrete bridge construction, as described by Walter Wilson Crosby, Chief Engineer: "The general plan has been to replace these [wood bridges] with pipe culverts or concrete bridges and thus forever do way with the further expense of the maintenance of expensive and dangerous wooden structures" (Crosby 1908:379). The first noteworthy step in this plan appears to have been the construction in 1906 of a 200-foot-long, multiple-span, reinforced concrete deck girder bridge over the Choptank River (Crosby 1908:73).

Washington County, the location of many early nineteenth century stone arch bridges, built a number of arches during this early period. Maryland Historical Trust survey forms indicate that in 1906 the Nelson Construction Company of Chambersburg and Pittsburgh, Pennsylvania, built a reinforced concrete single-arch bridge for the Washington County Commissioners (MHT WA-II-128). Apparently the County Commissioners were pleased with the results; the same company (occasionally appearing as Nelson Merydith Company) built bridges of the same design for the county in 1907 (MHT WA-V-063), 1908 (MHT WA-I-344), and 1909 (MHT WA-II-176).

After the success of its first reinforced concrete bridge in 1904, Baltimore City appears to have made a commitment to the arch design. In 1908 construction of three reinforced concrete arch bridges was begun, at Hollins Street over Gwynns Run, University Parkway over Stony Run, and Edmondson Avenue over Gwynns Falls (*Annual Report of the City Engineer* 1909:12-14). The plans for the Edmondson Avenue bridge were prepared by W.J. Douglas, a bridge engineer from the District of Columbia. The Baltimore Ferro-Concrete Company constructed the multiple-span, 540-foot-long bridge between 1908 and 1910.

In the *Third Report on State Highway Construction* (1908-1910), Chief Engineer Crosby noted the construction of two double-span arch bridges built by the Luten Bridge Company, both spanning Rock Creek in Montgomery County (Crosby 1910:48). These appear to have been the first arch bridges constructed by the noted bridge company in Maryland, although only a thorough survey can confirm or deny this assessment. Luten built a number of arch bridges throughout Maryland in the following decade, including a single-span arch over Gwynns Falls at Liberty Road in 1913 (Maryland State Roads Commission 1916:67) and a four-span bridge over the Anacostia River in 1914. Built for the State Roads Commission for $11,619, the Anacostia River bridge was 199 feet long and featured a 22-foot-wide roadway. In 1919 Luten built the still-extant Sandy Island Bridge over the Choptank River at Goldsboro for the Caroline County Commissioners (MHT CAR-257). This bridge, consisting of four closed spandrel arches with a classical balustrade, is a fine illustration of the refined architectural aesthetic that Luten's "Park Bridge of Attractive Design" made possible.

The Development of Standard Plans

There are indications that standard plans for Maryland bridges were drawn up in 1909, but the first clear issue of such plans occurred in 1912, concurrent with the reorganization of the State Roads Commission, which involved the consolidation of the construction and maintenance departments and the establishment of eight districts with their own Resident Engineers (Maryland State Roads Commission 1916:57). The decentralization of the Commission "saved the State thousands of dollars yearly in expenses" and resulted in increased effectiveness, a result experienced by other states which took the same approach.

Although decentralization had its advantages, there was the danger that "the right hand wouldn't know what the left hand was doing" as the Commission embarked upon the formidable task of improving the roads and bridges of Maryland. In addition to highway resurfacing, road improvement entailed the replacement of large numbers of bridges that were inadequate to the vehicular needs of the state. If Resident Engineers were to replace all of these bridges with individually designed spans, they would not be able to keep up with the amount of work that needed to be done. Reinforced concrete construction had been successfully used to build safe bridges with reduced labor costs and, it was hoped, reduced maintenance costs, but the labor involved in individually designing all bridges would have been prohibitive. A method of reducing design time was critically needed.

The introduction of standard plans allowed the Resident Engineer to find a quick and effective solution to the problem. Although standard plans were not applicable to all bridge sites, for reasons of engineering or aesthetics, they could be used in a great number of cases.

The creation of standard plans and a description of their use was first announced in the 1912-1915 *Reports* of the State Roads Commission:

> Standard plans have been made for all bridges of spans up to 36 feet in length and it is only necessary for the Resident Engineer to investigate the foundations, then refer to the standard plan and select the type of foundation that will fit the location and conditions and take off the length of spans. The water shed is carefully figured up by the Resident Engineer when he makes his preliminary inspection and it is afterwards checked by the Engineer of Surveys. On old roads all openings of the old bridges and culverts are carefully noted, the high-water mark established and the storm areas computed. On spans exceeding 36 feet separate designs are worked up for each individual case [Maryland State Roads Commission 1916:57].

Published on a single sheet, the 1912 Standard Plans included those structures that were amenable to such an approach: slab spans, (deck) girder spans, box culverts, box bridges, abutments, and piers (Maryland State Roads Commission 1912b). Slab spans, with lengths of 6 to 16 feet in two-foot increments, featured a solid parapet railing that was integrated into the slab. (Deck) girder spans, with lengths of 18 to 42 feet in irregular increments, also featured an integrated solid parapet railing. It is interesting to note that the Standard Plan features a 42-foot span, apparently contradicting the above statement that individual plans were drawn up for spans exceeding 36 feet. The roadway for all spans was a uniform 22 feet, which exceeded by 8 feet the then current 14-foot-wide standard section for concrete road construction (Maryland State Roads Commission 1930b:85).

In the *Report* for the years 1916-1919, a revision of the standard plans was noted:

> During the four years covered by this report, it has been found necessary to revise our standard plans for culverts and bridges, to take care of the increased tonnage which they have been forced to carry. Army cantonments. . .increased their operations several hundred per cent, and the brunt of the enormous truck traffic resulting therefrom, was borne by the State Roads of Maryland. In addition to these war activities, freight motor lines from Baltimore to Washington, Philadelphia, New York, and various points throughout Maryland, and the weight of many of these trucks when loaded, was in excess of the loads for which our early bridges were designed [Maryland State Roads Commission 1920b:56].

Published on separate sheets, the new standard plans (Maryland State Roads Commission 1919) for slab bridges reveal that the major changes were an increase in roadway width from 22 feet to 24 feet and a redesign of the reinforcements. The diameter of the reinforcing bars was reduced in the 1919 slab span design (on a 10-foot span from 3/4 inch to 5/8 inch) and the space between bars was reduced (5 inches to 4½ inches), thereby increasing the number of reinforcing bars but decreasing their individual size and weight. The slab spans continued to feature solid parapets integrated into the span. The range of span lengths remained 6 to 16 feet, but the next year (1920) witnessed the issue of a supplemental plan for a 20-foot-long slab span (Maryland State Roads Commission 1920b); presumably there was also a plan for an 18-foot-long span, but this has not been located.

It should also be noted that among the 1919 standard plans for reinforced concrete structures was a design for a movable bridge operator's house. It was during this period in Maryland that reinforced concrete was gaining ascendancy over timber and steel as the material of choice for constructing the stationary approach spans of movable bridges.

The *Report* for 1920-1923 states that "new standard plans have been prepared for slab and girder spans and the type of the latter has been changed from the beam to the T-beam design, with a resulting saving in material" (Maryland State Roads Commission 1924b:58). Thus, by 1923 the State Roads Commission had decided to adopt the T-beam design which had been described by Tyrrell in 1909 (Tyrrell 1909:186), advocated by the U.S. Bureau of Roads in the teens, and already adopted by several states by 1920.

The 1924 standard plan for the T-beam spans contained a note which characterizes the new mode of construction: "No construction joint allowed between girders and slab. Girders with slab to be poured as a monolithic mass." Among the changes included in the 1924 standards for T-beams were a reduced beam section; span designs in lengths of regular two-foot increments; and a reduced range of span lengths which incorporated designs from 22 feet to 40 feet.

The 1924 standard plans remained in effect until 1930, when the roadway width for all standard plan bridges was increased to 27 feet in order to accommodate the increasing demands of automobile and truck traffic (Maryland State Roads Commission 1930b). The range of span lengths remained the same, but there were some changes designed to increase load bearing capacities. The reinforcing bars were increased in thickness for both slab and T-beams and the cross section of the T-beam bottom flange became more robust (for the 22-foot-long span, thickness was increased by 3 inches and height by 4.5 inches). Visually, the 1930 design can be distinguished from its predecessors by the pierced concrete railing that was introduced at this time.

Three years later, in 1933, a new set of standard plans was introduced (Maryland State Roads Commission 1933). This time, their preparation was not announced in the *Report*; new standard plans were by this time unremarkable. Once again accommodating the ever-increasing demands of traffic, the roadway width was increased, this time to 30 feet. The slab span's reinforcing bars remained the same diameter but were placed closer together to achieve still more load bearing capacity. In order to accomplish the same goal for the T-beam span, the number of beams was increased from five to six, the first such change since the introduction of girder spans in 1912. The increase in the number of beams allowed a decrease in section size for girders which made them equivalent to the 1924 T-beam section.

A system of standard nomenclature for plans was introduced at this time: span type was indicated by a two-letter designator followed by span length and the year of the plan. Thus, CS-18-33 indicates an 18-foot concrete slab of the 1933 standard plan design; CG-36-33 was a 36-foot concrete girder (T-beam) of the same year. The inclusion of the year designator gave ready access to design details for each bridge and indicates that the State Roads Commission anticipated revisions to standard plans.

Concrete Arch, Beam, Slab, and Rigid Frame Bridges in Maryland

In Maryland, as in the rest of the nation, the standardized concrete types became the predominant bridge types built. An examination of data on the extant concrete bridges on Maryland state roads (State Highway Administration 1993) indicates the growth of the standardized beam and slab bridge at the expense of the arch; but further research and field survey will be needed to substantiate this conclusion. In the period 1911 to 1920 (the decade in which standardized plans were introduced), beams and slabs constituted 65 percent and arches 35 percent of the extant 29 bridges built. In the following decade, 1921-1930, the beam (now the T-beam) and slab increased to 73 percent and the arch had declined to 27 percent of the 129 extant bridges; in the next decade (1931-1940) the beam and slab achieved 82 percent and arches had further declined, constituting only 18 percent of the total of extant bridges built between 1931 and 1946 on state-owned roads.

Although beam and slab bridges became the utilitarian choice, it appears that the arch was selected when aesthetic as well as other site conditions were considered. The architectural treatment of extant arch bridges supports this assessment. Baltimore's Clifton Avenue Bridge, built in 1927, features an open spandrel arch and refined architectural detailing. The Route 195 bridge over Sligo Creek (MHT M:37-7) is another example of the architectural distinction achieved by arch bridges. Built in 1932, the bridge features three open spandrel arches. In Washington County, the Route 40 bridge over the Conococheague Creek (HAER No. MD-41-17) is notable for its grace; built in 1936, it features three open spandrel arches, the spandrel openings capped by arches that complement the profile of the arch ribs. A known four-span Luten arch of the "Park Bridge of Attractive Design" was built in 1919 to carry Maryland Route 287 over the Choptank River near Goldsboro (MHT CAR-257).

Maryland state bridge inventories indicate that there are nearly 70 extant arch bridges on state highways that were constructed in the 1900-1940 period, as well as an equivalent number from the same period that are located on county or municipal roads. For the vast majority of these bridges, neither the specific form of arch (i.e., barrel, closed spandrel, or open spandrel) nor the degree of architectural detailing is known from the information available. Likewise, although it can be safely assumed that the majority of the 90 beam and 122 slab bridges built between 1900 and 1940 rigorously conform to standard plans, there may be early examples that precede standardization as well as later, individually designed and more architectural versions of these types.

Maryland's early twentieth century bridges also include at least 11 structures representative of the rigid frame bridge type, as developed during the 1930s and early 1940s in the United States. Although historical research has uncovered little more than brief references to these bridges (references primarily drawn from the 1993 Maryland Department of Transportation Inventory of Bridges), they constitute examples of a category of modern concrete bridge that has been recognized as technologically significant by historians and industrial archaeologists.

The State Highway Administration's current list of county-owned and municipal bridges references a structure that may be the earliest known example of a rigid frame bridge in Maryland. This is the bridge in Worcester County carrying Big Mill Road over Big Mill Pond, and briefly listed as a "concrete rigid frame" built in 1919 but reconstructed or rebuilt in 1930 (Maryland Department of Transportation 1993b). This may be an early example, as Westchester Parkway engineer Arthur Hayden did not pioneer small-span rigid frame bridge design until 1922-1923. The Big Mill Road Bridge warrants further investigation to determine its exact nature.

The earliest extant rigid frame bridge listed on the 1993 statewide inventory of bridges is Bridge 6031, consisting of two 35-foot spans carrying State Route 97 over Big Pipe Creek in Carroll County. The longest Maryland rigid frame structure located through historical research is Bridge 11018, a 120-foot, two-span rigid frame bridge built in 1937 to carry State Route 135 over the Savage River in Garrett County. Five out of the total of 11 rigid frame bridges constructed between 1934 and 1941 were built in connection with a major project of the Maryland State Roads Commission, the upgrading and widening of U.S. Route 40 from the Maryland-Delaware line to western Maryland.

Of these five structures, three are located in Washington County (two built in 1936 and one in 1941), and one each in Harford and Howard counties (built in 1938 and 1939, respectively). One of the five Route 40 rigid frame bridges, Bridge 12027 crossing a branch of Winters Run in Harford County, consisted of five 10-foot-long spans.