SECTION IX: CONCRETE BRIDGES

HISTORICAL DEVELOPMENT

Concrete bridges constitute the greatest number of Maryland's known historic bridges. Technologically, the development of concrete bridges is an important chapter in the history of bridge building, being the application of a rediscovered material to both traditional and new forms and largely supplanting the metal truss bridge in the spanning of short and medium distances. Aesthetically, concrete bridge design introduced a greater level of decorative treatment, as the plastic nature of concrete allowed variety and ease of construction for these decorative details. Although the greatest number of concrete bridges are the results of standardized designs, there are many concrete bridges that feature stylistic embellishment.

Although used for building by the ancient Romans, the modern rediscovery of concrete as a common building material was a nineteenth century phenomenon, with reinforced concrete developing in the late nineteenth and early twentieth centuries (Plowden 1974:297). In bridges, concrete was first used as a construction material in plain or unreinforced concrete structures. The first applications of the material were to the arch bridge, a design developed (like concrete itself) by the Romans and used, in its masonry form, in great numbers in early years of this nation. An early example of the application of concrete to the arch bridge in the United States was the 1871 Prospect Park Bridge in Brooklyn, New York (Armstrong 1976:115; Plowden 1974:297). Within two decades, the understanding of material behavior quickly had progressed to the composite use of concrete and steel, often termed "ferro-concrete."

The addition of iron reinforcement to masonry structures had been used in isolated cases for centuries, since the nature of masonry as a compressive material with inherent weaknesses in tension was appreciated by ancient engineers. The interaction of the two materials remained to be studied by late nineteenth and early twentieth century engineers (Plowden 1974:297). The incipient theoretical understanding of metal utilized to reinforce concrete in the new plastic masonry was realized by an American experimenter, Thaddeus Hyatt (1816-1901), who began to study reinforced concrete's possibilities in the 1850s and received a patent for reinforced concrete in 1878 (American Society of Civil Engineers 1976:65). However, it was French and German engineers who first studied and tested the principles of steel reinforcement for tensile stresses in concrete arches in the 1880s. A serious obstacle to the use of concrete arches was the unknown character of their behavior under live loads. From 1890 to 1895 the Austrian Society of Engineers and Architects conducted extensive experiments on full-size concrete arches and the results were published in engineering journals throughout Europe and America (Plowden 1974:298).

In 1889, prior to the publication of the Austrian reinforced concrete arch tests, the first reinforced concrete arch in the United States was built in Golden Gate Park, San Francisco. Designed by Ernest L. Ransome, it was reinforced with rods or bars, possibly of the twisted type patented by Ransome in 1884 (Armstrong 1976:115; Plowden 1974:298). Early concrete bridge development included experimentation with different forms of steel reinforcing. Bar reinforcement became the predominant type used in the early twentieth century, and is the reinforcement type encountered today; however, the predominant type through the end of the nineteenth century employed beams rather than bars. The I-beam type was introduced by Austrian engineer Joseph Melan, who patented a scheme for arched I-beam reinforcement in the United States in 1894. Melan's design was modified and patented by another Austrian engineer, Fritz von Emperger, who built a number of beam-reinforced arch bridges in the United States beginning in 1897 (Plowden 1974:298).

Beam reinforcement was soon recognized as requiring an inordinate amount of steel, and bar reinforcement began to be explored as a more efficient use of material. Bars could be bent and placed in regions of high tensile stresses, thus saving enormous quantities of materials while producing stronger bridges with lower dead loads. Many variations in shapes, patterns of surface deformation (provided to maintain the adhesion between the bars and the concrete), and bending schemes were developed and patented (Plowden 1974:298).

Among the American engineers who contributed to the development of reinforced concrete bridge technology during this formative period was Edwin Thacher (1840-1920). An 1863 civil engineering graduate of Rensselaer Polytechnic Institute, Thacher became interested in steel-reinforced concrete construction in the late 1880s, and by 1895 had made this a specialty. He designed and constructed viaducts and bridges for leading southern railroads during the period 1889-1904. Also during that period, he became the western representative of Fritz von Emperger's company, and was instrumental in disseminating the Austrian engineer's technological innovations in the United States. In partnership with W.H. Keepers, he designed the first major reinforced concrete bridge in the United States, a three-span Melan-type concrete arch with imbedded steel truss bars over the Kansas River at Topeka. Erected between 1894 and 1899, this structure was the largest of its kind at the time (Plowden 1974:299).

Thacher developed an improved reinforcing bar. Throughout the development of reinforced concrete technology, engineers sought methods of improving the adhesion between the reinforcing steel and the concrete surrounding it. Their efforts generally involved various deformations to the surface of the bar, such as the "projections" called for in Thacher's 1899 patented design. Ernest L. Ransome patented the first deformed reinforcing bar in 1884, which aimed to increase the mechanical connection between the steel and the concrete by twisting the bar. The "Thacher Bar" (U.S. Patent No. 714,971) was designed as an elongated bar with longitudinally oriented cross-shaped deformations integrally formed on the upper and lower surfaces. This configuration enabled the reinforcing steel to remain uniform in net section throughout the bar, ensuring that the strength of the bar would be the same at every point and that no unnecessary metal would be used in its manufacture. In addition, sharp corners were minimized during manufacture, so that the bond between the bar and the concrete would be further improved. William Mueser, Thacher's associate in the Concrete-Steel Engineering Company, credited the bar as the first product of its type to achieve its final shape by a direct rolling process. The Thacher bar, like those used in current concrete design, was available in a range of sizes, starting at 1/4 inch and increasing in 1/8-inch increments to 2 inches.

With growing confidence, bridge engineers made increasing use of reinforced concrete. In an 1899 *Engineering News* article, "Concrete Steel Bridge Construction," Thacher, who held patents for iron as well as concrete bridges, exemplified early enthusiasm for concrete. He wrote of concrete-steel bridges:

> They are more beautiful and graceful in design, architectural ornamentation can be applied as sparingly or as lavishly as desired; they have vastly greater durability, and generally greater ultimate economy; they are comparatively free from vibration and noise; they are proof against tornadoes, high water or fire; the cost of maintenance is confined to the pavements, and is no greater than for any other part of the street; home labor is employed in building it, and the greater part of the money that it costs is left among the people who pay for it, and its cost as a rule does not much, if any, exceed that of a steel bridge carrying a pavement. . . .Public confidence in concrete and concrete-steel construction, is gaining rapidly in this country and in Europe, where there is plenty of precedent, and where the people have been more thoroughly educated up to it, there has been no lack of confidence in it for some years. . . .We hear nothing now from intelligent men about mud bridges [Thacher 1899].

Although scientifically understood with some degree of sophistication in the 1890s, concrete began to be used more widely and in a more structurally efficient manner in the United States after the first decade of the twentieth century. In 1903-1904 the American Society of Civil Engineers formed its Joint

Committee on Concrete and Reinforced Concrete in an attempt to standardize concrete design. Their first report was published in 1909. In 1916, the Committee on Reinforced Concrete Highway Bridges and Culverts of the American Concrete Institute (ACI) issued its first report which classified highway bridges and recommended appropriate design loads. According to bridge engineer-historian Tyrrell, between 1894 and 1904 about 100 concrete bridges had been built in the United States in spans up to 125 feet (Tyrrell 1911), and in 1916 Waddell claimed that "for city bridges of short span its use is becoming almost universal" (Waddell 1916), with other wide applications noted.

The development of prestressed concrete has increased the usefulness of concrete in modern bridge design. Prestressing entails the application of a permanent load to the concrete through tensioned cables to increase its load-bearing capacity. The principle was developed in Europe during the 1930s and first applied in America to the 160-foot-long Walnut Lane Bridge erected in Philadelphia in 1949 (Plowden 1974:321). Guided by the Bureau of Public Roads' 1955 *Criteria for Prestressed Concrete Bridges*, the use of prestressed concrete in bridge design was rapidly taken up throughout the nation. The technique has found wide application in the construction of precast concrete members used on overpasses of the interstate highway system (Armstrong 1976:117).