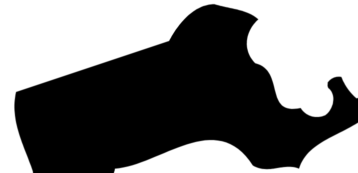

MassDOT—Concrete Bridge Pioneers

by Alexander K. Bardow, Massachusetts Department of Transportation

A typical early reinforced concrete T-beam bridge built by the Massachusetts Highway Commission. This bridge, erected in 1909, is over Palmer Brook on what became U.S. 20 in the town of Becket. Photo: Massachusetts Department of Transportation Bridge Section Archives.

The history of concrete bridges in Massachusetts is closely tied to the history of the Massachusetts Department of Transportation (MassDOT). The Massachusetts Highway Commission, the first predecessor of the MassDOT, was established by the state legislature "to improve the public roads" in 1893, during the early era of reinforced concrete bridge construction.

Early Days

In an article published in the December 1929 *Journal of the Boston Society of Civil Engineer*s, Arthur W. Dean, the chief engineer of Massachusetts Department of Public Works (successor to the Highway Commission), wrote that Massachusetts "was the pioneer in this country in the use of reinforced concrete for bridges," a distinction that Massachusetts maintains to this day.

In those early days, the highway commission experimented with reinforced concrete for a practical reason: it was difficult to obtain good rubble masonry at a reasonable cost for the construction of culverts and bridges. As stated in its January 1903 Annual Report, in order to save money, the highway commission started to use reinforced concrete because it could be built with less-skilled labor and, as an added bonus "the resulting structure is more pleasing to look at, as well as more enduring."

Many of these early bridges were either beam bridges with a reinforced concrete deck or closed spandrel arch bridges. At first, design services were performed by consultant engineers, but by 1904 the highway commission started to design bridges with its own in-house staff.

An early bridge designed and built by the highway commission, and the largest surviving example, is the Sisk Bridge. Built in 1910, it carries Old State Highway over the West Branch of the Westfield River in Chester, Mass., with a skew span of 110 ft and a skew angle of 30 degrees.

By the end the twentieth century, the Sisk Bridge was showing its age, with significant freezing and thawing damage of the concrete of the spandrel walls and the outside edges of the arch. However, the rest of the arch was in very good condition. Based on the results of material testing, a structural analysis revealed that it was structurally sound to carry modern truck loads. The bridge was successfully rehabilitated in 2010, which included a slight widening with arch extensions and new spandrel walls while retaining the existing 1910 reinforced concrete arch in the middle. (See *ASPIRE*™ Summer 2011.)

Precast, Prestressed Concrete

The introduction of prestressed concrete after World War II signaled a new era in the construction of concrete bridges in Massachusetts, and once again, Massachusetts was an early leader in the use of this material. While Massachusetts did not build the first prestressed concrete bridge in the United States, it did recognize the potential of this material for rapid bridge construction.

This realization played an important role in 1955 when—over a span of several days in August—two hurricanes, Connie and Diana, ripped across the state. The heavy rains associated with these hurricanes brought massive flooding to many waterways in central Massachusetts. Bridges were destroyed in domino fashion as debris, swept downstream by the flood waters, piled up against a bridge until it failed, and the resulting wreckage was carried down to repeat the cycle at the next bridge.

In the aftermath, 220 Massachusetts bridges in 80 cities and towns were destroyed. The devastation required a rapid construction method to replace the fallen bridges, reconnecting roads and restoring isolated communities. Massachusetts officials turned to precast, prestressed concrete beams to rapidly restore the transportation network.

Because many of these bridges spanned less than 40 ft, Massachusetts selected adjacent deck beams (voided slabs) with a membrane and asphalt wearing surface as the structure type. Two standard beam depths were selected: 17-in.-deep beams for spans of 20 to 30 ft and 21-in.-deep beams for spans of 30 to 40 ft. Bridges with spans over 40 ft were individually designed, but many used prestressed concrete deck beams or I-girders.

This decision proved to be an excellent one. Not only were the bridges replaced within two years, but many are still in service and carrying modern traffic loads today. A review of the

The Sisk Bridge in Chester, carrying Old State Highway over the West Branch of the Westfield River was originally built in 1910 by the Massachusetts Highway Commission and rehabilitated in 2010. The original reinforced concrete arch is sandwiched between new arch extensions and spandrel walls, and carrying modern highway loads. Photo: CME Associates Inc.

latest bridge inspection reports for these nearly 60-year-old bridges finds that many are still in satisfactory to good condition, and show few signs of deterioration of the prestressed concrete beams.

Modern Innovations

Massachusetts' current concrete bridge era can be traced to 1990 when the Precast/Prestressed Concrete Institute New England (PCI NE) Technical Committee began to expand by including state department of transportation engineers as committee members. Massachusetts joined in 1990, followed by Rhode Island and Connecticut. By 1994, all six New England states were represented on the committee.

At first, the committee worked to standardize precast concrete beam details, at least from the standpoint of the precaster. Individual states still retained their respective bridge details, but the precast concrete beams were designed to a standard size and cross section detailing, eliminating those individual state standards. The most important aspect of this committee was that all six states agreed to use the same basic beam details.

The energy the committee developed in working on the standard beam details carried forward into the development of a bulb-tee beam standard for New England—the New England bulb-tee (NEBT) beam series. Although the New England standard was the AASHTO I-girder, states were finding that it had limitations in its range of applicability and there were more efficient girder shapes in use elsewhere in the country, such as bulb-tees.

Starting in March 1994, the PCI NE Technical Committee began developing an efficient bulb-tee girder section, adaptable to post-tensioning for continuity and beam splicing to accommodate longer spans. This girder design accounted for the capabilities of the region's precasters including weight and length restrictions for transport.

By July 1994, the NEBT had been sufficiently developed to warrant independent reviews. Professor Maher Tadros of the University of Nebraska, the developer of the NU bulb-tee girder, provided feedback that the PCI NE Technical Committee used to improve the girder. Next, Reid Castrodale, who was then at the Portland Cement Association, ran head-to-head comparisons of the NEBT with the AASHTO girders and PCI bulb-tee girders. These comparisons confirmed the section's capabilities.

The NEBT became the new standard New England bulb-tee girder and, when New York joined the committee and also adopted the NEBT, it became the northeast girder standard. Further, the Canadian provinces of Quebec and New Brunswick adopted the NEBT, making it an international girder shape.

The PCI NE Technical Committee continued in its trail blazing by developing and issuing standards for rapid construction. These included: precast concrete footings, abutments, wingwalls, full-depth deck panels, and railings. These details were issued in 2006, with many being incorporated into the Federal Highway Administration's manual on Rapid Bridge Construction.

In addition, the committee continued to develop new, more efficient beam shapes to facilitate rapid construction. These efforts lead to the development of the northeast extreme tee (NEXT) beam. This modified double-tee beam is intended for medium span bridges and designed to address limitations of

An example of the adjacent deck beam bridges used to quickly replace many of the smaller bridges destroyed by the hurricanes of 1955. This bridge is on Fowler Street over Warren Brook in the town of Upton. Photo: Massachusetts Department of Transportation.

An example of a NEBT beam bridge developed by the PCI Northeast Technical Committee. The Massachusetts Department of Transportation has been a member since 1990. This bridge is on River Road over Mill River in Northampton, Mass. Photo: Massachusetts Department of Transportation.

adjacent box and deck beam bridges, which include complexity of fabrication, erection, and inadequate room for utilities.

The committee realized the significant advantages double-tee type beams have in span range, ease of fabrication, and their ability to accommodate utilities. Additionally, once in place, the top flange acts as a form for a conventional deck, thereby accelerating construction. The concept was brought to the committee in October 2006, the development started at the November 2006 meeting and the new beam shape standards were issued in February 2008. The committee developed beams for several overall widths while keeping the stem spacing in a NEXT beam unit constant allowing the beams to match a variety of roadway cross sections.

The beam has been further refined to include a decked NEXT beam series. In this series, labeled the NEXT-D, the top flange is now a full-depth deck cast integrally with the beam stems. Once these units are set, the deck elements are connected through closure pours creating a continuous deck element. The NEXT-D beam promises to be an important beam type for rapid bridge construction.

The Future

The Massachusetts Accelerated Bridge Program, an initiative of Governor Deval Patrick, which began in 2008 and is intended to be a laboratory of innovation, has allowed MassDOT to deploy many rapid bridge construction concepts and beam types developed by the PCI NE Technical Committee. Massachusetts remains an enthusiastic member of this committee and looks forward to continuing the advancement of concrete bridge technology and innovative solutions in the northeast and continuing our concrete bridge pioneering legacy.

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For more information about Massachusetts Accelerated Bridge Program, visit www.eot.state.ma.us/acceleratedbridges/.

The NEXT Beam, or Northeast Extreme Tee beam, developed by the PCI NE Technical Committee, is designed for rapid construction of bridges. This is the State Route 19 (Wales Road) Bridge in Brimfield, shown while still under construction in 2011. Photo: Massachusetts Department of Transportation.