The Oxford Road Bowstring Arch Truss is a bridge engineer's equivalent to putting on last year's winter coat and finding a crumpled ten dollar bill in the pocket. Discovering this historic structure provided the opportunity to glimpse into the past, and enjoy the craftsmanship that is difficult to find on modern bridges. The bridge went from an ignored, run down old structure buried in the woods to a practical, useful structure serving as a reminder that we don't build them today like they used to.

Old School Craftmanship

By Brian Rhodes, P.E.

Figure 1: Oxford Road Bowstring Arch Truss spanning Howard Creek.

Structure Background

This unique structure was found off the shoulder of Oxford Road in Hamilton County, Ohio. The bridge spanned Howard Creek in Crosby Township (*Figure 1*). The arch truss, built in the 1860s, is listed on the Ohio Historic Inventory as built by the Massillon Bridge Company. The Inventory also implies this structure is an example of a King Bridge design. This is likely incorrect given the structure's arch make-up.

Bridges made of iron were the order of the day in the late 1800s, and the bowstring arch was a common type. Wrought iron has excellent resistance to fatigue failure, an ability to hold protective coatings, excellent workability, as well as excellent resistance to corrosion. The latter property likely provided the structure its longevity, and current bridge engineers with the pleasure of restoring the structure.

The bridge is a 53-foot-8½-inch bow-string arch made of wrought iron. The design features external arch bracing at each floorbeam. This type of bracing was common in the era, and is required to prevent the arch from simply toppling over. Many other design features, such as the beveled blocks at each floorbeam hanger, eye at the end of the lower lateral bracing, and the configuration of the arch to tie connection at the bearing are astonishing on every level. The fabrication of such details, at the time of construction and today, is amazing. The real art in this structure is found in the construction of the arch itself. The arch is comprised of two plates latticed together. The diagonals between the plates are hollow tube sections held in place by the compressive force of the vertical bolts located at each angle block (*Figure 2*). The original deck on the structure was likely timber, although no evidence of a deck remained upon discovery of the bridge. The bridge was constructed on dry-stacked stone abutments. The abutments remained in relatively decent condition.

Figure 2: Arch detail at mid-span splice prior to rehabilitation.

Project History

The bridge was discovered by Hamilton County personnel during a construction project near Oxford Road. The decision to rehabilitate this structure was made by Hamilton County, citing its unique makeup. County Engineer Tom Brayshaw recounts, "This structure is an unusual example of an historic bowstring lattice

Figure 3: Structure as discovered adjacent to Oxford Road.

arch structure, which was eligible to receive enhancement funds through the Ohio Kentucky and Indiana Regional Council of Governments Urban Area Enhancement Funds Program." When selecting proposed structure relocation, the county decided the nearby Crosby Township Senior Center would be an excellent location. The township agreed to build a walking trail that the bridge would eventually become a part of.

Design Requirements/Research

The first phase of the structural evaluation and design involved a detailed inspection of the existing bridge. No maintenance had been performed on the bridge, no deck was in place, heavy vegetation and full size trees were growing between the floorbeams, and some members were missing (*Figure 3*). Of particular interest, the external bracing was missing at one of the floorbeams, and the railings, once located at the four bridge corners, were mostly gone. Parts of one of the railings remained, offering a glimpse as to what the original railing may have looked like. Many of the members had failed. The diagonal bracing connection at each floorbeam had failed in two locations. The hollow compression tubes that make up the arch section were mostly in tact. It was obvious, however, that during the sandblasting required for rehabilitation, additional deterioration would be revealed that was not readily visible in the field.

Figure 4: Bridge under rehabilitation at Ohio Bridge Corp.

The design process involved research of the bridge type, typical material properties, and applicable design codes. A majority of the research focused on obtaining typical material properties of the era. No testing of the existing metal was in the scope, and given the wealth of information found, this would not have been warranted. Research revealed many documents, the most helpful of which were those published by James L. Cooper, Professor Emeritus of History at DePauw University in Greencastle, Indiana. The publication, *Restoring Historic Metal-Truss Bridges*, provides coupon results for wrought iron bridges built in the era, as well as published material strengths of several steel mills. Another interesting reference was, *An Elementary and Practical Treatise on Bridge Building*, written by Squire Whipple in 1873. The publication states, "Good wrought iron bars, will not undergo permanent change of form under a tensile strain of less than from 20,000 to 30,000 pounds to the square inch; and though they will not actually be torn asunder with a stress below 50 or 60 thousand, and often more, to the inch, any elongation would certainly be deleterious to the work containing them, even if not dangerous from liability to fracture." This background information was essential to confirm the data given in AASHTO's *Manual for Condition Evaluation of Bridges*, a yield stress of approximately 26,700 pounds per square inch.

Figure 5: Relocated bridge receiving deck.

These member properties, along with field measurements, were used to construct a computer model of the structure utilizing STAAD design software. The structure was analyzed using the loading provided in AASHTO's *Guide Specification for Design of Pedestrian Bridges*. Members were checked for strength capacity. Splice connections in the bottom chord were checked for capacity using fastener properties typical of the era. The results of these analyses were that the structure was not capable of resisting the applied load. The decision was made to reduce the width of the structure. This modification would not change the original makeup of the structure, and would be relatively simple and non-intrusive to perform. It would essentially limit the loading of the bridge, allowing it to conform to AASHTO loading.

Fabrication/Construction

The contractor awarded the job of arch rehabilitation and construction was the Ohio Bridge Corporation of Cambridge, Ohio. This company has a background in historic bridge restoration, making them a perfect fit for this project. Tom Brayshaw noted, "Ohio Bridge seemed to take real pride in restoring historic bridges." As with any restoration, the preferred option is to save the original bridge components. For bridge componnts where this was not possible, Ohio Bridge fabricated new steel pieces. Ohio Bridge also fabricated the railing to be placed on the bridge. The original structure had only remnants of bridge railing at each corner. To meet code, a new railing would need to be fabricated for the entire structure length. The new railing was designed and detailed to resemble the makeup of the original railing, while still meeting code requirements for clear openings (*Figure 4*).

Figure 6: Relocated bridge prior to trail construction and railing installation.

Paint preparation for a historic structure can be a double-edged sword. Obviously, the least harsh preparation is preferred. Unfortunately, a delicate paint preparation often results in poor paint quality. This bridge was sandblasted to provide a clean surface. This approach also revealed deteriorated areas not readily visible. The paint system used on this structure is an OZEU system applied in 3 coats. Hamilton County hired a paint inspector to provide additional assurance of a high quality paint job. This proved to pay off in the end, as the paint preparation of the structure and the paint application are excellent.

During the rehabilitation of the structure, new abutments were being constructed concurrently at the new site. The abutment and wingwalls were constructed using a formliner to emulate the substructure found at the original location. Capstones were cut and placed over the exposed faces of the wing walls and abutment back wall to provide a finished look.

The bridge was trucked to the new site, and dropped into place. Timber stringers, decking, and blocking were placed on top of the floorbeams (*Figure 5*). A timber curb on each side provided a place to mount the new railing (*Figure 6*). The bridge was dedicated on September 16, 2006. The structure received a County Engineers Association of Ohio Historic Preservation Award, and is being considered for others.▪

*Brian E. Rhodes, P.E. is a project engineer in the Cincinnati, Ohio office of URS Corporation. URS Corporation is a global engineering design firm with 28,900 employees. He can be reached via e-mail at **Brian_Rhodes@URSCorp.com**.*