"Gateway" Scores Touchdown

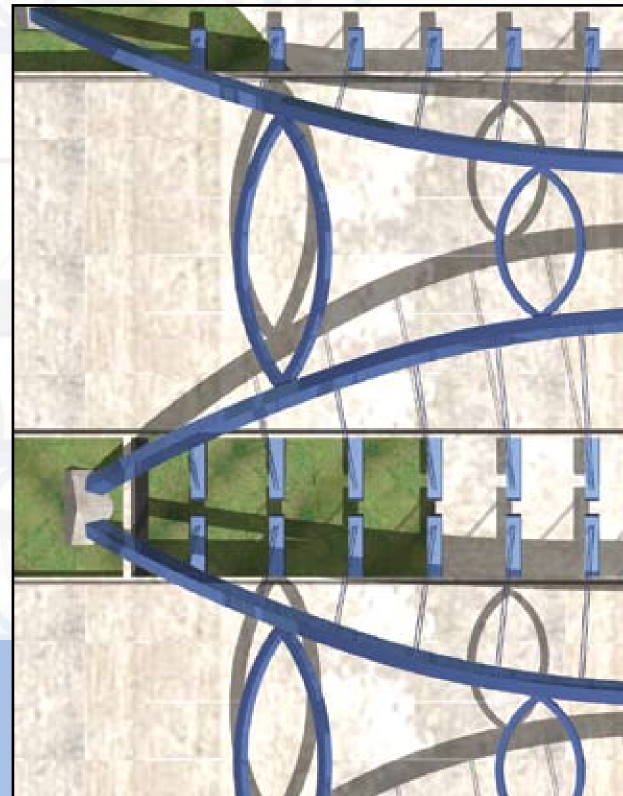


Figure 1: Median space resembling a football with laces

Modified Tied Arch Bridge is Detroit's Newest Icon

By Muthiah Kasi, P.E., S.E., CVS and Ihab Darwish, Ph.D., P.E., S.E.

Unique Features

Redundancy and beauty of a true-arch and the economy of a tied-arch

Unequal rib lengths are first in the U.S.

Pressurized ribs to reduce inspection and maintenance cost

Redundant foundation and hangers to improve safety

Unique football shaped bracing

Rare concept — foundation ties under the roadway

Successful cost management (within 4% of estimated cost)

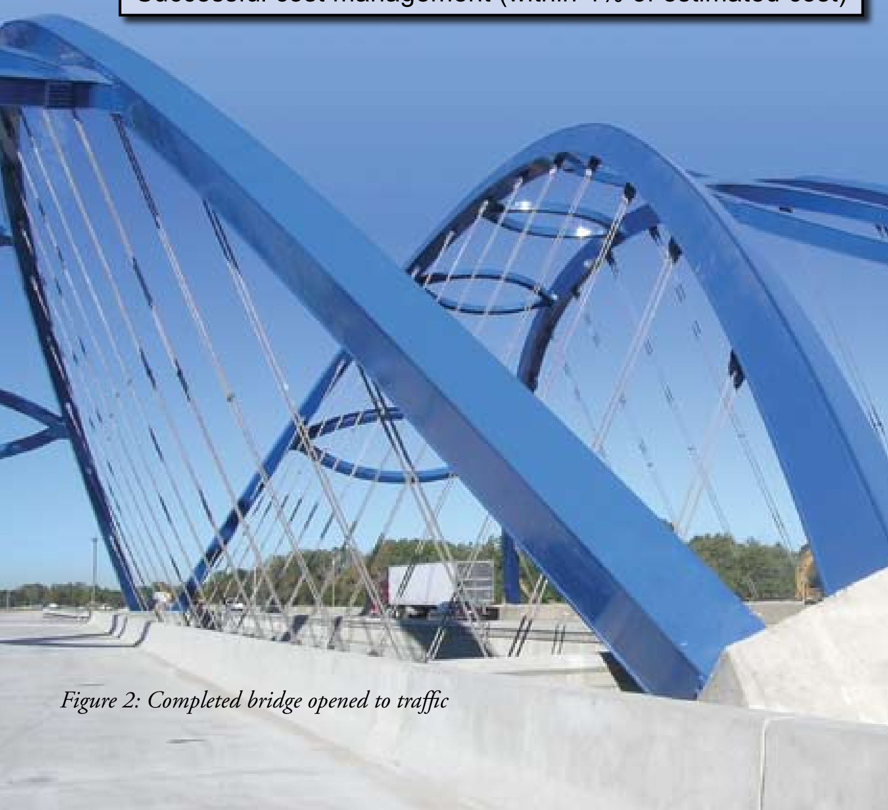


Figure 2: Completed bridge opened to traffic

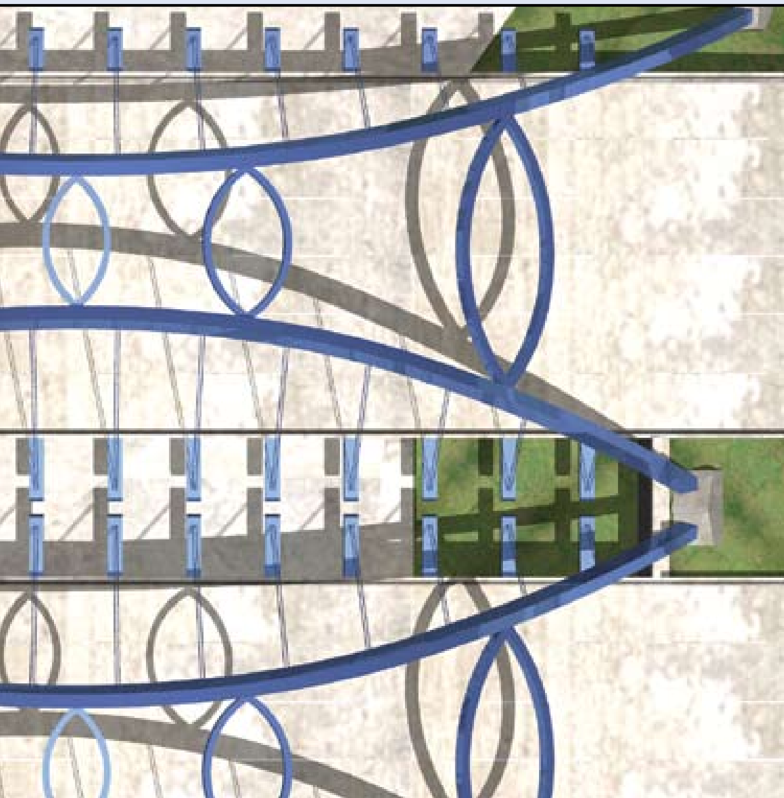
A new Detroit icon has appeared along I–94 over Telegraph Road (U.S. 24) in Taylor, Michigan. The "Gateway Bridge" welcomes visitors as they drive into the city from the Metro Airport.

The inspiration for this icon came from a 1987 article by Frank Peters, Arts Editor of the St. Louis Post Dispatch, about Benesch's I–255 tied arch bridge across the Mississippi River. Peters wrote, "Once in a while engineering and architecture, function and form, utility and beauty, meet as equals in a triumph of design." Muthiah Kasi (Benesch) long had a vision about designing an arch bridge to rival I–255. He also loves football. The chance to design a structure that would lead to Super Bowl XL was a golden opportunity. He visualized oval shaped braces resembling footballs. He also saw that the median space between the bridges, when seen from above, would resemble a football with laces (Figure 1).

The proposal for a single point urban interchange (SPUI) at I-94 and Telegraph Road opened the door for the football metaphor bridge. The design team explored many possibilities for this structure. Designing a conventional single-span girder bridge would require raising the I-94 profile in order to achieve the required vertical clearance over Telegraph Road. To avoid this raise, maintain clear sight distance and improve aesthetics at the interchange, Benesch proposed an arch bridge. 3D modeling and design enhancement helped meld engineering functions and aesthetic quality. Michigan Department of Transportation (MDOT) engineers worked closely with the design team to make this structure a reality and cost effective.

Following the selection of the bridge type, a series of value engineering studies were conducted on all structural elements of the arch.

For information on the "Gateway" Project Team see the on-line version of this article at www.STRUCTUREmag.org



The interior and exterior arch ribs are inclined 25 degrees towards each other, while maintaining the desirable vertical clearance. Five football shaped braces hold the ribs together. The bases of the exterior arch ribs (296 feet) are located at Telegraph Road, while interior rib (257 feet) bases are located at the I-94 level, resulting in unequal lengths (Figure 3). The ribs are 3-foot x 4-foot box-sections. Due to the size of the ribs, they are pressurized with dry air to absorb moisture, making corrosion inspections and maintenance easier.

The unequal lengths of the arches posed a challenge to the design team. "Stiffness of each arch had to be varied to achieve equal deflection." says Dr. Hiba Abdalla (Benesch), who developed the computer models (*Figure 4*) to determine the geometry and size of the ribs.

A perfect arch carries only compression under applied dead load. In order to find an economical shape of the arch that would result in minimum bending stresses under dead loads, the shape of the ribs was adjusted to closely approximate the equilibrium thrust line, which corresponds to the applied dead loads. Starting from a basic circular shape with a constant radius, the bridge was analyzed under dead loads. After determining the equilibrium thrust line, a compound circular curve was fitted through the thrust lines. The structural model was then re-analyzed with the new shape of the ribs. The final shape of the arch ribs was reached when the bending stresses were negligible, resulting in lighter arch ribs and smaller deflections under dead load.

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Figure 3 (below): Unequal rib lengths

Figure 4: Performance of arch under live load

Figure 5: Transverse I-beams with box shaped end

The superstructure is comprised of a nine-inch-thick, cast-in-place reinforced concrete deck, four stringers and two 41-inch deep stiffening girders, all supported by 14 equally spaced transverse steel beams. Beams, girders and stringers act compositely with the deck. The depth of the transverse I-beams varies. Ends of the beam extend beyond the deck (*Figure 5*). These ends are boxed shapes using two additional outer webs, which improves the aesthetics and increases the torsional resistance of the beams should a strand within the hanger assembly be lost or replaced. The stiffening girders distribute the live loads among the adjacent hangers.

Hangers from the arch ribs support the superstructure. Each hanger assembly consists of two 2⅛-inch-diameter structural strands, each structural strand capable of carrying the total load. Each strand is anchored to the end of the transverse beams and attached to the ribs using a 1¾-inch-thick hanger support plate. The hanger support plate, welded to the arch webs, transfers the forces into the rib. To reduce the possibility of "wake galloping" of the hangers, one separator is used to connect the two strands together (*Figure 6*).

In true arches, the longitudinal arch thrust is taken by the foundation supports, such as the piles. In a tied arch, the thrust is taken internally by the tie. In both cases, there is no redundancy in case of a failure of the thrust resistance. For this modified tied arch, the longitudinal arch thrust is resisted by multiple foundation elements; the longitudinal reinforced concrete foundation ties, the transverse foundation ties and the battered piles.

The longitudinal foundation tie is designed as the main carrying member of the longitudinal arch thrust. In this case, the tie is sized such that the concrete in the tie can carry the total longitudinal arch thrust without cracking. Also, the reinforcing bars in the ties are sized to carry the total arch longitudinal thrust without yielding. The transverse foundation tie, which is tied to the abutment/wing wall foundation and battered piles, will also resists a portion of the longitudinal thrust (*Figures 7a and 7b*).

Figure 6: Spacer to minimize hanger vibrations

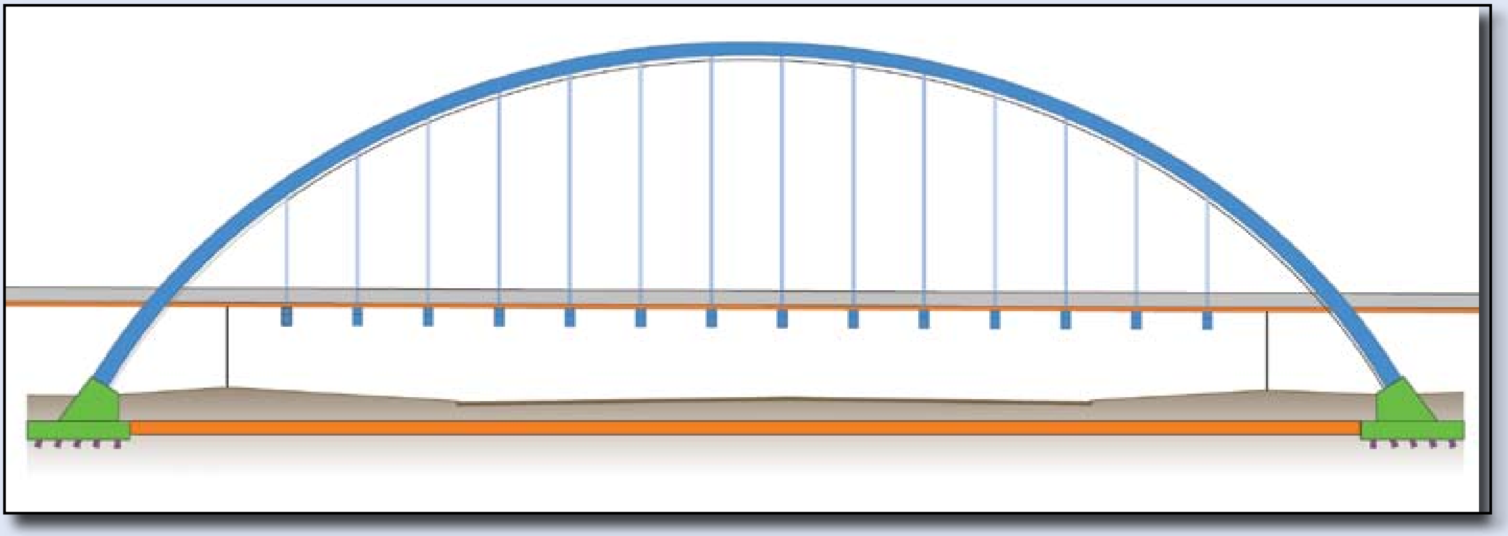

Figure 7a: Longitudinal tie connecting thrust blocks

PDM Bridge in Eau Claire, Wisconsin, fabricated the 1.6 million pounds of steel for each bridge. MDOT and Benesch guided the fabrication process, structural details and erection of the bridge (*Figure 8*).

The original design required shoring during casting of the deck. This cautious method is expensive but not risky. During construction, C.A. Hull, the contractor, chose to cast the concrete deck with the hanger cables carrying the load. With careful management and construction procedures, the deck was completed successfully.

The I-94 Modified Tied Arch Bridges are a response to the efforts of the Detroit Regional Gateway Advisory Council (DRGAC) to revitalize Detroit's economy. The local business community and other parts of the private sector have given their support to enhance the I-94 corridor. With visitors from all over the world coming to Detroit, this structure at the gateway to the Detroit Metro Airport will function as a landmark to the city. ▪

Figure 7b: Longitudinal and transverse tie at thrust block

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Figure 8: Arch mid-section being lifted into place

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