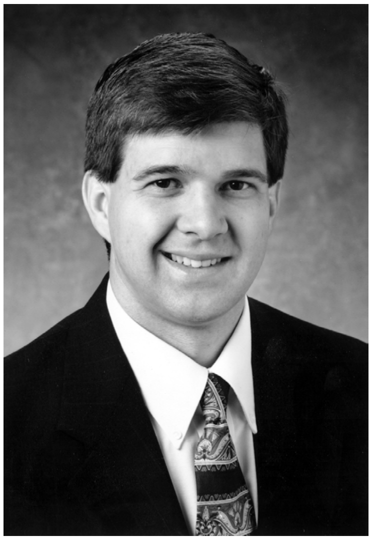
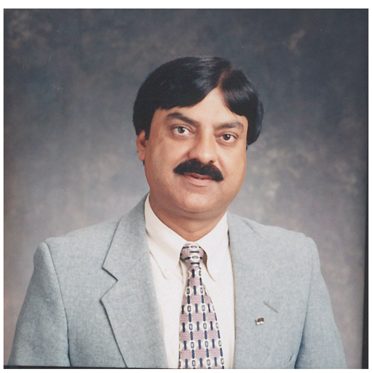
KANSAS CITY "TRIANGLE" URBAN INTERCHANGE REPLACEMENT



FRANK BLAKEMORE, P.E.



BAKUL DESAI, P.E.

BIOGRAPHY

Frank Blakemore is a Senior Project Engineer with HNTB and has worked on a variety of projects including the Kansas City Triangle, the Gateway Boulevard arch bridge in Nashville, and the Great River Bridge (cable stay bridge over the Mississippi). Some of his other experience includes both segmental and cast-in-place post-tensioned box girders. Frank is a registered Professional Engineer in Missouri and Colorado and was the Project Engineer for this project.

Bakul Desai has been with HNTB for over 25 years and currently is an Associate Vice President with the firm. Bakul served as a Bridge Project Manager on this Triangle project. He has designed and managed several interchange bridge projects and major water crossings that includes suspension bridges, cable-stay bridges, arch bridges, cast-in place and precast post tensioned segmental bridges and other types of bridges. Bakul is a registered professional engineer in several states.

SUMMARY

A major trend in bridge engineering has been the replacement of aging urban interchanges due to a combination of physical deterioration of the structures and the need to expand the capacity of the interchange. The Kansas City "Triangle" in Kansas City, Missouri is one such high-profile interchange that is currently being replaced at an estimated cost of $230 million and scheduled over an eight-year construction period. Because of the deteriorating physical condition of the structures and the large increase in traffic through this urban interchange, there were numerous traffic accidents and severe congestion that prompted the Missouri Department of Transportation to select HNTB to entirely redesign this complex interchange. The "Triangle" interchange contains over 900,000 square feet of bridges and provides for the intersection of I-435, I-470, and U.S. 71 highways while crossing two creeks and two local streets. This paper will focus on the three items that define the standard for all future urban interchange replacements:

- Construction phasing
- Creative and innovative engineering solutions
- Aesthetic considerations

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By
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PROJECT DESCRIPTION

This project encompasses the daunting task of increasing capacity for an interchange handling two interstate highways, a four-lane U.S. highway, and several main thoroughfares; without reducing the capacity of the interchange during construction. This paper focuses on the design aspects involving the interstate highway bridges crossing the four-lane U.S. highway, several local streets, and two creeks.

Due to the mandate of not impeding current traffic flow, the project required very intricate construction phasing so that new bridges could be built alongside the existing traffic. In some locations this required temporary bridges that would carry traffic until the appropriate roadway or bridge could be opened. Also, as part of this construction phasing, thought had to be given to the actual erection sequence for these large bridges over active roadways.

The phasing of construction is broken into six contracts, one scheduled to be let each year, with the construction duration of each contract lasting anywhere from 12 months to three years. The first two contracts were roadway work to provide additional capacity. Contracts C thru E were the main bridge contracts and were let in successive years, starting in 2001. Due to budgetary constraints, a portion of one bridge was pushed into a later contract.

Figure 1. Aerial view of Kansas City "Triangle" Contracts C and D

In order to accomplish the goal of not reducing traffic capacity of the interchange during construction, a sequence of construction was developed that allowed several bridges to be built in each contract. In the first contract, the bridges that carried NB I-435 (Br. A6245, Br. A6248), SB I-435 (Br. A6246), and the ramp from SB I-435 to EB I-470 (Br. A6236) were built. These bridges consisted of composite prestressed beam units in the tangent portions of the bridges and composite plate girder units in the curved and flared portions of the bridges. Bridge A6245 consisted of two four-span units (440 feet, 390 feet) and a three-span unit (369 feet). The three-span unit flared from a roadway width of 86.67 feet to 110.91 feet. Bridge A6246 consisted of two four-span units (440 feet, 390 feet), three four-span units (410 feet, 430 feet, and 433 feet), and a three-span unit (349.5 feet). All units have a constant deck width of 44.67 feet. Bridge A6236 consists of three three-span units (247 feet, 316 feet, and 357 feet) and two four- units (408 feet, 453 feet). The deck width for this bridge is 58.67 feet for the first three units and flares to 79 feet in the last two units. All of these bridges carry traffic over Hickman Mills Creek, Hickman Mills Drive, and Marion Park Drive. Bridge A6248 carries NB I-435 over U.S. 71 highway and consists of two three-span units (431 feet, 350 feet) with a deck width of

62.67 feet. The substructures of these bridges were hammerhead type piers with form liner and rustication treatments applied for aesthetics. At the end of this construction phase, Bridges A6246 and A6236 were opened to traffic.

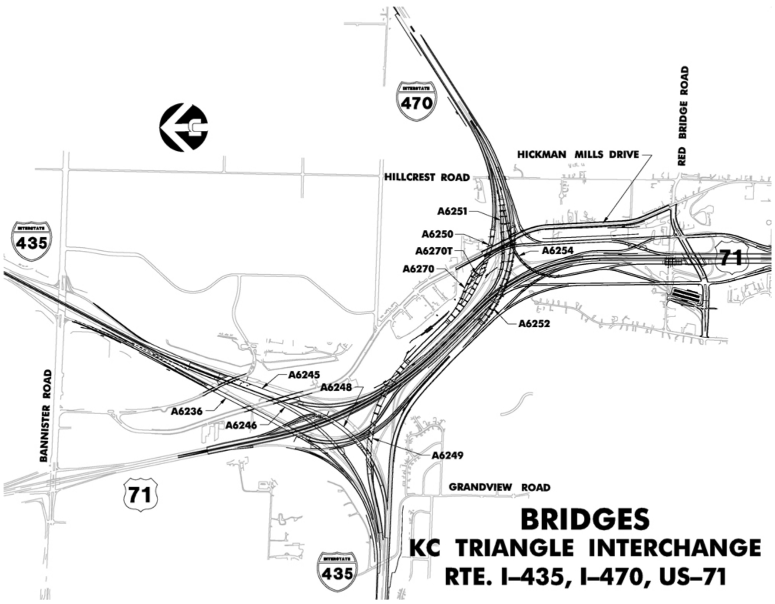

Figure 2. Plan View of Kansas City Triangle

In Contract D, the bridges that carry WB I-470 (Br. A6249, Br. A6250) and a ramp from NB U.S. 71 to WB I-435 (Br. A6270) were built. All of the bridges in this contract have continuous composite plate girder superstructures. As part of the construction phasing, a temporary bridge (Br. A6270T) was built to connect the ramp to Bridge A6270. The temporary bridge utilized a composite rolled beam superstructure (four simple spans) and steel pile bents. Bridge A6249 has two four-span units (595 feet, 635.5 feet) and two two-span units (400 feet, 209 feet). The deck width is 74.67 feet. Bridge A6250 consists of two three-span units (330 feet, 333 feet) and two four-span units (452 feet, 585 feet). The deck width varies from 62.67 feet to 112 feet at the flared end of Unit 1. Bridge A6270 is a five-span unit (603 feet) with a deck width of 42.67 feet. To maintain the same aesthetic appearance, the hammerhead pier substructure units were given the same form liner and rustication treatments as those in Contract C.

The construction in Contract E includes the bridges carrying EB I-435 to EB I-470 (Br. A6252), WB I-470 to SB U.S. 71 (Br. A6254), and WB I-470 to NB U.S. 71 (Br. A6251). These bridges also have continuous composite plate girder superstructures. Bridge A6252 has a four-span unit (556 feet), two three-span units (440 feet, 429 feet), and a two-span unit (244 feet). The deck width is 74.67 feet. Bridge A6254 consists of two four-span units (428 feet, 524 feet) and a five-span unit (591 feet), all with a constant deck width of 32.67 feet. On this bridge two steel capbeams were utilized in the substructure to span across a ramp and Bridge A6252, individually. Bridge A6251 contains a two-span unit (184 feet) which is a gore area for Unit 2 of this bridge and Unit 1 of Bridge A6254. (Units 2 and 3 of Bridge A6251 are scheduled for a later contract and consist of a five-span unit (607 feet) and a four-span unit (458 feet). The out-to-out deck widths vary from 89 feet to 42.67 feet. The hammerhead pier substructure units were also given the same form liner and rustication treatments as the previous contracts. See Figure 2 for bridge locations.

CONSTRUCTION PHASING

The most critical aspect for the successful replacement of an urban interchange is the effectiveness of the construction phasing. Proper phasing of an interchange replacement will show progress to the traveling public, ease congestion incrementally (instead of increasing it), and provide cost savings to the owner. Several examples of how the phasing required modifications to typical construction methods include the opening of Bridges A6245 and A6248, column construction on Bridge A6236, the need for a temporary bridge (Bridge A6270T), and the erection sequence for the steel capbeams over U.S. 71 highway.

When first studying the different traffic movements and planning the sequence of bridge construction, it became apparent the NB I-435 bridges (A6245, A6248) could not be opened until the ramp from NB I-435 to NB U.S. 71 was completed. Unfortunately, this ramp cuts through the future embankment for NB I-435. Since construction would be underway for the adjacent SB I-435 bridges (A6246, A6236), it was cost effective to build A6245 at the same time. Bridges A6245 and A6248 were not opened for several years after completion, until ramp construction was finished in the Contract D. The commuting public didn't voice any concern over why these bridges were delayed in their opening. This is probably due to the fact that of the four bridges constructed in Contract C, the two longest bridges opened on schedule and provided immediate traffic congestion relief.

Another interesting aspect of the construction phasing related to Contract C is that certain piers on Bridge A6236 required modification to allow construction under this Contract. Because of the proximity of the existing SB I-435 embankment, the typical hammerhead pier shape could not be constructed. Instead the piers were constructed as two drilled shafts with a typical capbeam. See Figure 3. After the existing SB I-435 bridge and embankment are removed in a later contract, the piers will be modified by constructing a "shell" around the drilled shafts that will replicate the other piers.

Figure 3. Modified pier shapes on Bridge A6236

In Contract D, the connection of a ramp to Bridge A6270 could not be completed for several years and traffic had to be rerouted to allow for the ramp construction. The solution to this phasing problem was the use of a temporary bridge (A6270T). This bridge connected the temporary ramp S-W to the third span of Bridge A6270. Because of the short spans (50' max.), a rolled beam superstructure was used. A cost analysis was performed to determine if the typical concrete multi-column bent or a steel pile bent would be more efficient. The steel pile bent proved to be the cost effective choice, partially because it had some salvage value. A cast-in-place deck was used because of the irregular geometry of the bridge.

Because of the high capacity of traffic that U.S. Highway 71 carries, a criteria of the design was to ensure that traffic would not be shut down completely on this highway (temporary closures of 15 minutes to erect girders were acceptable). The portion of the bridge construction that this criterion affected most was the erection of the steel capbeams that span U.S. 71 (on Bridges A6249, A6252). As a result of careful placement of field splice locations and coordination with traffic control plans, this criterion was met. The four-lane highway did require dropping of a lane in each direction for specified weekend closures, but all lanes remained open during the work week. To achieve this, a construction sequence was specified on the bridge plans that showed the specific order of erection of the girder segments and steel capbeams. Typically, the erection sequence specified that the capbeam would be placed atop the columns and then the girders framing into the capbeam from the nearest completed span would be erected to stabilize the capbeam. In some cases the traffic would be diverted from two lanes in each direction to one lane in each direction on either the NB or SB lanes. This provided the contractor a large working space to assemble and erect the capbeams and girders.

CREATIVE ENGINEERING SOLUTIONS

Throughout the project, creative and innovative engineering solutions were required to solve the complicated problems arising from building such large structures next to active traffic lanes in a coordinated manner. One of the creative engineering solutions was the use of steel capbeams because of limitations on placing substructure elements. In some cases these capbeams spanned up to 180 feet while carrying six lanes of traffic, and in other cases the capbeam would be supported by 110 foot tall columns in order to span across a new bridge. Another creative solution, staging the construction of columns in different contracts, was previously discussed.

Figure 4. Steel capbeams over U.S. 71 (Bridge A6249)

Because of the locations of ramps (and a bridge) and to allow for the possibility of widening U.S. 71 Highway (a four-lane highway that passes underneath most of the bridges) in the future, framed-in steel capbeams were utilized at key locations. Bridge A6249 has five steel capbeams, Bridge A6252 has three steel capbeams, and Bridge A6254 has two steel capbeams. Bridges A6249 and A6252 each had locations where steel capbeams were required at three successive bents. All of the capbeams in this project were supported on each end by pot bearings atop columns. See Figure 4 for an aerial view of the steel capbeams on Bridge A6249.

Bolted connections were used to frame the girders into the steel capbeams. An end plate was welded to the girder before erection, and then the end plate was bolted to the side of the steel capbeam. Since the girders were designed as continuous over the steel capbeam, the girder-capbeam connection was designed and detailed to provide continuity for the top and bottom flanges of the girders. To achieve this, the top flange of the girders was extended to the centerline of the steel capbeam and a splice designed to carry the full moment capacity of the section. An end plate was welded to the web and bottom flange and then bolted to the web of the steel capbeam. Inside the box, a diaphragm was located at the centerline of each girder and plates corresponding to the bottom flange were aligned with the bottom flange of the girder.

For a typical framed-in steel capbeam, the girder depth would be 6 feet and the steel capbeams depth 10 feet. As a result of this type of connection, the steel capbeam box section was designed for the torsion induced by the longitudinal moments of the girders. To determine the torsion at each location of the capbeam, HNTB's proprietary girder design software, BDGS, was modified to incorporate steel capbeam supports. By inputting the appropriate section properties of the steel capbeam and utilizing a grid analysis, the moments, shears, and torsions for the various sections were determined.

Planning for the prospect of future widening was also incorporated into the design of the steel capbeams. On certain bridges (A6252, A6249), it was identified that a future widening may be necessary, so the design allowed for the placement of two exterior girders. At these locations, the steel capbeams were detailed and fabricated with diaphragms at the future girder locations.

AESTHETICS

An increasingly important aspect of urban interchange replacements is the use of aesthetic treatments. In order to provide a view that would be visually pleasing to the thousands of motorists utilizing the interchange everyday and to the local residents, form liner treatments were extensively used. For the Kansas City Triangle Interchange, funding was available for aesthetic enhancements. At the beginning of the project several areas were identified where these funds could be used: pier shapes, form liner treatments on the substructure, rustications on the substructure, and form liner treatments for MSE walls and sound walls. After several public meetings to gather input and consultation with HNTB's bridge architect, MoDOT decided on using form liner treatments where applicable and modifying the pier to be more aesthetically pleasing.

A standard form liner pattern was chosen using input received from public involvement meetings, and then applied to the piers, abutments, retaining walls, and sound walls. For the form liner treatment, an Ashlar Stone pattern was chosen. Although the plan documents didn't require a specific manufacturer, the choice of

Figure 5. Aesthetic treatments of pier

patterns was limited to four form liner manufacturers so that there would not be a wide variation in the appearances of the different contracts. To achieve continuity of the pattern within each contract, the plans specified that the same form liner pattern was to be used at all locations (piers, abutments, MSE walls, and sound walls).

Additionally, MoDOT elected to use a modified hammerhead type pier shape instead of their typical multi-column bents. The pier shape was modified by placing an 8” by 12” chamfer on the corners of the column and by placing rustications to the columns spaced at approximately 12’. Another aesthetic feature that was added to the column was a recessed portion of the wide face of the column that also contained a form liner pattern. See Figure 5. Typical overall dimensions of these columns are 4’ wide by 12’ long. A similar shape was used for the larger columns that supported the steel capbeams.

SUMMARY

To date, the Kansas City “Triangle” interchange is a successful example of how to replace an outdated interchange. This success is due to the use of construction phasing, creative engineering solutions, and aesthetic considerations. With the proper use of these elements, the “Triangle” has been transformed from a daily traffic congestion nightmare to an icon of engineering that the surrounding community is proud of.