Coordinated Construction

By Bakul Desai, P.E. and
Frank Blakemore, P.E.

Teamwork kept traffic flowing during steel erection for the reconstruction of this ailing 1960s interchange.

The Triangle interchange carried 250,000 vehicles daily as it interconnects two interstate highways, a four-lane U.S. highway, two creeks, and several main thoroughfares in Kansas City, MO.

Serving the southeast region of Kansas City, MO since the 1960s, the Grandview Triangle interchange carried 250,000 vehicles daily—far beyond its original design capacity. Future projections of 400,000 vehicles daily, combined with structural deterioration due to age, prompted the Missouri Department of Transportation (MoDOT) to resolve the ailing interchange's immediate and future needs. MoDOT, in concert with local design consultant HNTB Corporation, undertook a $230 million massive rehabilitation of "the Triangle" in 2000.

The renovation encompassed 20 new permanent bridges, three temporary bridges, 39 retaining walls, four major box culverts and extensions, and three sound walls. At different stages, 26 existing bridges were planned for demolition to acquire the final configuration of the interchange.

The project also encompassed the daunting task of increasing capacity for the interchange—already handling two interstate highways, a four-lane U.S. highway, two creeks, and several main thoroughfares—without reducing capacity during construction. MoDOT mandated that rush hour traffic could not be affected over the course of the expected eight years of construction. The mandate also required that the normal number of driving lanes be available to commuters during peak hours. Any temporary detours also would have to meet these stringent requirements.

To comply with this mandate, the project required very intricate construction phasing so the new bridges could be built alongside existing traffic. Thought had to be given to the actual erection sequence for the large bridges over active roadways, as well. In some locations, this required temporary bridges that would carry traffic until the appropriate roadway or bridge could be opened.

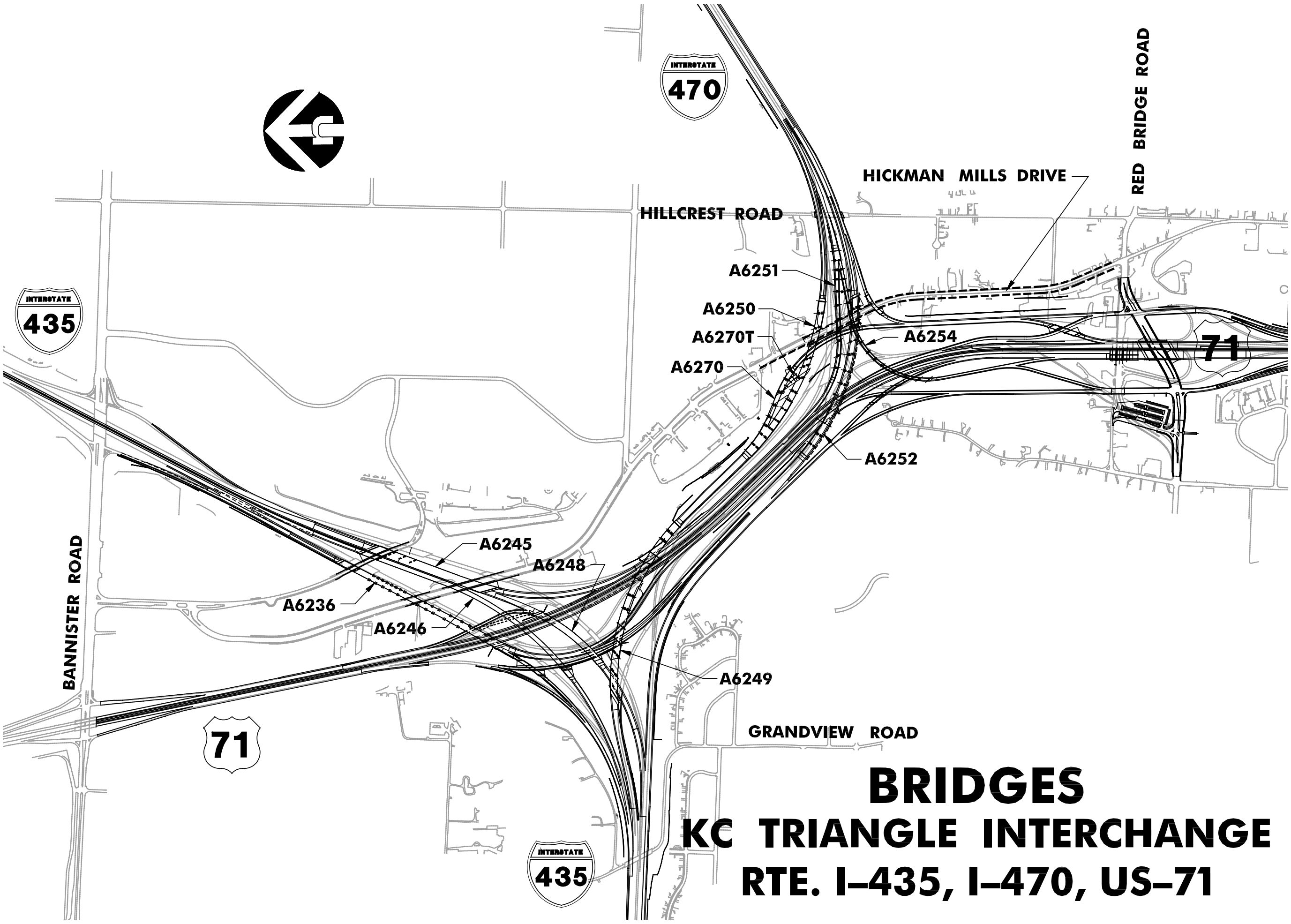
The phasing of construction was broken into six contracts. One contract was scheduled to be let each year, starting in 2001 through 2008, with the construction duration of each contract lasting anywhere from 12 months to three years. The first two contracts, A and B, were roadway work to provide additional capacity. Contracts C through E were the main bridge contracts and were let in successive years.

A sequence was developed that allowed several bridges to be built in each contract. At the end of each construction phase, new bridges were opened to traffic.

Construction Phasing

When first studying the different traffic movements and planning the sequence of bridge construction, it became apparent that the northbound (NB) Interstate 435 bridges (A6245 and A6248) could not be opened until the ramp from I-435 to NB U.S. Highway 71 was completed. Unfortunately, this ramp cuts through the future embankment for NB I-435. Since construction would already be underway for the adjacent southbound I-435 bridges (A6246 and A6236), it was cost effective to build A6245 at the same time.

The connection of a ramp to Bridge A6270, in Contract D, could not be completed for several years, so traffic had to be rerouted to allow for the ramp



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construction. The solution to this phasing problem was the use of a temporary bridge (A6270T). This bridge connected the temporary ramp southwest to the third span of Bridge A6270.

Because of the short spans (50′ maximum), a rolled beam superstructure was used. A cost analysis was performed to determine whether the typical concrete multi-column bent or a steel pile bent would be more efficient. The steel pile bent proved to be the economical choice, partially because it is recyclable and has salvage value.

Most of the bridges had relatively sharp curvature inherent in their horizontal profiles. Composite steel plate girder units facilitated these curved and flared bridges due to their framing flexibility. The substructures of the bridges were hammerhead-type piers with form liner and rustication treatments applied for aesthetics. A cast-in-place deck was used because of the irregular geometries of the bridges.

Because of the high capacity of traffic that U.S. Highway 71 carries, a criterion 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). Erection of the steel cap beams that span U.S. 71 (on bridges A6249 and A6252) was effected most by this condition, but careful placement of field splice locations and coordination with traffic control plans helped to ensure it was met.

This four-lane highway, which passes underneath most of the bridges, required dropping of a lane in each direction for specified weekend closures. All lanes remained open during the work week. A construction sequence was specified on the bridge plans that showed the specific order of erection of the girder segments and steel cap beams. Typically, the erection sequence specified that the cap beam would be placed atop the columns and

Steel cap beams facilitated erection. In some cases, these cap beams spanned up to 180′ while carrying six lanes of traffic.

then the girders framing into the cap beam from the nearest completed span would be erected to stabilize it. In some cases the traffic would be diverted from two lanes in each direction to one lane in each direction on either the northbound or southbound lanes. This would provide the contractor a large working space to assemble and erect the steel cap beams and girders.

Steel Framed-in Cap Beams

Throughout the project, creative engineering solutions were required to solve complicated problems arising from construction of such large structures next to active traffic lanes. One solution was the use of steel cap beams to accommodate limitations on placing substructure elements. In some cases, these cap beams spanned up to 180′ while carrying six lanes of traffic. In other cases, cap beams were supported by 110′-tall columns to span across a new bridge.

Due to the location of the ramps and bridges, and to allow for the possibility of future widening of U.S. Highway 71, framed-in steel cap beams were used at key locations. Bridges A6249 and A6252 each had locations where steel cap beams were required at three successive bents. All cap beams in the project were supported on each end by pot bearings atop columns.

Bolted connections were used to frame the girders into the steel cap beams. An end plate was welded to each girder before erection, and then the end plate was bolted to the side of the cap beam. Because the girders were designed as continuous over the cap beams, the girder-cap beam connection was designed and detailed to provide continuity for the top and bottom flanges of the girders. To achieve this, the top flange of each girder was extended to the centerline of the cap beam, and a splice was designed to carry the full moment capacity of the section. Inside the box, a diaphragm was positioned 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 cap beam, the girder depth was 6′ and the cap beam depth was 10′. As a result of this type of connection, the cap beam box section was designed for the torsion induced by the longitudinal moments of the girders. To determine the torsion at each location of the cap beam, HNTB's proprietary girder design software, BDGS, was modified to incorporate cap beam members. By inputting the appropriate section properties of the cap beam and using a grid analysis, the moments, shears, and torsions for the various sections were determined.

Planning for possible widening in the future was also incorporated into the design of the steel cap beams. On certain bridges (A6252 and 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 cap beams were detailed and fabricated with diaphragms at the new girder locations.

The framed-in cap beams are inherently non-redundant structures, thus mandating stricter fracture critical requirements with special shop inspection during steel fabrication. The analysis procedure for these cap beams was equally challenging due to the differential yielding of girder supports, depending on their relative locations of framing. Extremely tight horizontal and vertical controls were essential during fabrication and erection to account for the complex geometry consisting of up to 8% superelevations, which had to coexist with horizontal curves greater than 3°, profiles with vertical curves, and skewed supports.

Collaboration and Team Work

The Triangle's success to date can be attributed to collaboration, communication, and coordination. The team players consist of MoDOT, HNTB and its subconsultants, FHWA, the contractors, and the community. HNTB's public involvement professionals worked side-by-side with technical engineers while keeping MoDOT involved in the process. HNTB's technology group performed in concert with the technical staff during the development and maintenance of a web site, kiosk program, and public involvement video. Several public information meetings and public hearings were conducted to seek the community's buy-in for the project.

Given the anticipated size, complexity, and duration of the project, a core team consisting of MoDOT, HNTB, subconsultants FHWA, and city professionals was formed to coordinate and monitor the design and the construction process. Team meetings were held monthly throughout the project's duration to achieve greatly enhanced communication between the team members. Weekly meetings were held with contractors and sub-contractors to discuss the progress and anticipated issues related to construction.

Today, the Triangle interchange is no longer a daily nightmare of traffic congestion—thanks to the proper use of construction phasing, creative engineering solutions, and teamwork. ★

Bakul Desai is an associate vice president of HNTB Corporation. Frank Blakemore is a project engineer for HNTB Corporation.

Owner
Missouri Department of Transportation
District 4, Kansas City, MO

Design Consultant
HNTB Corporation, Kansas City, MO

Engineering Software
BDGS (HNTB proprietary software)
MicroStation
GEOPAK
MDX

Sub-Consultants
Bucher, Willis & Ratliff Corporation, Kansas City, MO (bridge engineering)
TapanAm Associates, Inc., Kansas City, MO (bridge engineering)
Taliaferro & Browne, Inc., Kansas City, KS (roadway engineering)
Schmitz, King & Associates, Olathe, KS (surveyors)

Detailer
Tensor Engineering Co., Indian Harbor Beach, FL, AISC member

Detailing Software
Tensor Engineering Bridge Geometry Program
MicroStation Version 7

Fabricator
DeLong's, Inc., Jefferson City, MO, AISC member (plate girders)

General Contractors and Erectors
Clarkson Construction Company, Kansas City, MO
APAC-Kansas, Inc., NEA member
APAC-Missouri, Inc.