MISSISSIPPI MILESTONE

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Steel was selected for this highway interchange in Mississippi because it could accommodate the curved design and could be erected with minimal disruption to traffic.

Its curved girders are record-breaking and its geometry mind-boggling. But despite being a structural engineering feat, Madison, Mississippi's Single Point Urban Interchange (SPUI) blends gently into its suburban environment and unobtrusively handles what was once a choking burden of traffic. While drivers may not notice the unusual design of the structure linking Interstate 55 and Mississippi Route 463, its shape makes it a distinctive landmark from the air. Due to its configuration of lanes and ramps toward a central bank of traffic signals, the Single Point Urban Interchange, or SPUI (pronounced "spew-ee"), is shaped much like a bow tie: narrow at the middle and wider at the abutments. The challenge for the project team was to create that bow tie from steel.

The need to upgrade the interchange was clear: the left turns associated with the existing diamond interchange created crippling backups for commuters and local through traffic in the booming City of Madison, just five miles north of the Jackson city limits. By 2020, daily traffic volumes for the interchange are projected to exceed 60,000 vehicles. The decision to implement a SPUI, the first in Mississippi, was the result of carefully weighing costs, capacity, available space and constructability. A SPUI, with its tightly-curved ramps guiding traffic to one bank of three-phased traffic signals, would handle high volumes of traffic without consuming as much real estate as a cloverleaf interchange.

MDOT selected the Jackson office of Michael Baker Jr., Inc., a unit of Pittsburgh-based Michael Baker Corporation (Baker), in July 1995 as the project's prime engineering design consultant. Both design and constructability considerations led Baker and MDOT to select steel rather than concrete for the SPUI. Precast concrete girders would have to be straight, which would make the SPUI unnecessarily wide in the middle. Cast-in-place girders could be curved, but the formwork required would make maintenance of traffic on the Interstate below very difficult. Steel could accommodate the curved design and could be erected with minimal disruption to traffic.

While the choice of steel in such a situation is not particularly unusual, the design of the SPUI's superstructure is uncommon. A typical SPUI design uses a series of short, straight, diagonal girders to fan out the ends of the bridge. However, such girders are complicated to model, fabricate and frame and can look choppy from below. Baker instead designed two-span, continuous curved girders, which are somewhat simpler to model and fabricate and offer the added benefit of creating smooth lines on the underside of the bridge.

One of Baker's early design tasks was to create the girder layout for the two 30 m (98′) spans. The SPUI tapers from 80 m (262′) wide at the abutments to 50 m (164′) wide at the center pier. In laying out the girders, the limiting dimension was the spacing between webs at the abutments, which was kept to a maximum of 3.5 m (11.5′). Six pairs of girders were required. The pair of girders in the center of the bridge is straight. Five curved girders are on each side of the center girders, with progressively sharper curves toward the outside of the bridge.

To put these numbers in perspective, a typical curved girder might bend two or three degrees. The outside girders on this project curve 45 degrees. To the best knowledge of the project's engineers, fabricators and constructors, these are among the most sharply curved bridge girders in the United States.

To economically reduce torsion and best support the slab layout, trapezoidal box girders were used. Computer analysis on this project was very detailed. Each pair of girders has a unique design and therefore had to be modeled individually, then combined with all other girders to become one model for the 3-D finite element analysis. Baker leased software from Bridge Software Development International, Ltd. of Coopersburg, PA, for 3-D analysis and design of the structure and its members. The girders were designed to stand up against their own dead load and the weight of the slab, as well as live loads generated from influence surfaces, as if each girder were a separate bridge.

The girders are 1.53 m (5′) deep, 2.44 m (8′) wide at the top, and 1.75 m (6′) wide at the bottom. The five inside pairs of girders were shipped in three segments per span, and were field spliced using M22 galvanized high-strength bolts conforming to ASTM A325M Type 1. On those girders, web splice plates are 12 mm (.47″) thick, 480 mm (18.9″) wide, and 1,376 mm (54.2″) tall, with 84 bolts. Bottom splice plates are 14 mm (.55″) thick, 480 mm (18.9″) by 1,576 mm (62.0″), with 72 bolts. Top splice plates are 16 mm (.63″) thick, 305 mm (12.0″) by 784 mm (30.9″) and require 20 bolts.

The pair of outside girders is so sharply curved they had to be shipped in five pieces per span. Those web splice plates are 12 mm (.47″) thick and 1,376 mm (54.2″) by 632 mm (24.9″), with 112 bolts. The bottom splice plates are 14 mm (.55″) thick and 1,576 mm (62.0″) by 632 mm (24.9″) with 96 bolts. The top splice plates are 16 mm (.63″) thick, 1,240 mm (48.9″) by 305 mm (12.0″), with 32 bolts.

Summary of Bridge Girder Curvatures

Girder Pair	Radius of Curvature in Meters	Curvature in Degrees
1 (inside straight pair)	Infinity	0
2	228.8	7.6
3	106.0	16.5
4	68.1	25.6
5	49.4	35.4
6 (outside pair)	**38.7**	**45.0**

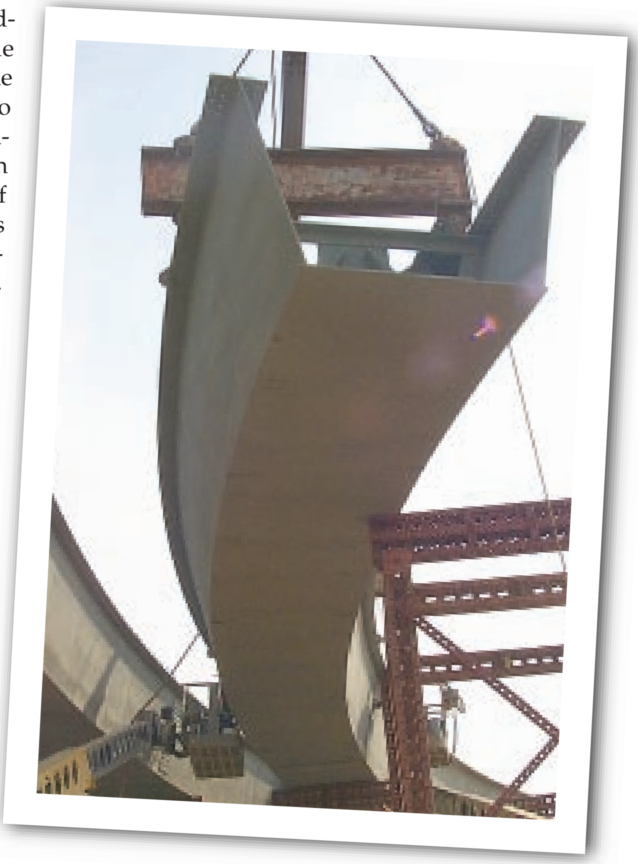
The end diaphragms at the abutments and on the middle pier are steel plates within the box girder. The two straight middle girders each have 10 bolted K cross-frames from abutment to abutment. The number of cross-frames per girder increases toward the outside of the bridge, with the outer, most sharply curved girders requiring 20 bolted K cross-frames due to their greater length and torsional forces. Lateral bracing is bolted from cross-frame to cross-frame to stiffen the bridge against torsion.

To handle the strong uplift reaction of the curved girders at the abutments and at the center pier, the uplift for each girder had to be modeled and its bearing unit designed individually. The three pairs of inside girders are designed with double bearing devices. The uplift on the outer three pairs of girders is so great that they each require a single bearing unit. Baker's design specifies three different types of disc bearings. On the three pairs of inside girders, fixed disc bearings were used at the center pier, preventing the girder from moving at the center point. On the three outside pairs of girders, guided expansion bearings were used at the center pier, fixing the girders lengthwise but allowing them to "breathe" sideways. At the abutments, floating, non-guided expansion bearings were used to allow the bridge to expand or contract with temperature changes.

Main structural elements, such as web and flange plates and splice plates, are ASTM A709M Grade 50 steel. The total weight of Grade 50M steel is 680,000 kg. (1,499,128 lbs.). For the cross-frames, diaphragms, lateral bracing, and stiffeners, 190,000 kg. (418,874 lbs.) of ASTM A709M Grade 36M steel was used. All steel members were painted, first with a shop coat of inorganic zinc, then with two field coats of acrylic latex paint.

Tensor Engineering of Indian Harbor Beach, FL, performed the detailing of shop drawings. Detailing was complicated by the curved girders, which created unusual shapes throughout the structure. For example, the 90-degree cross section of a curved girder at the abutment is skewed, which makes fitting the diaphragms very difficult.

The fabricator was Grand Junction Steel, based in Grand Junction, CO. Fabrication began in June 2000 and delivery of steel members for the south



Curved box-girder during erection.

Structural steel was pre-assembled at the fabricator's yard to ensure a proper fit before it was trucked to Mississippi.

half of the interchange was under way by mid-September. Because of the extreme curvature of the girders, the curves had to be cut to comply with AASHTO requirements. Structural steel was pre-assembled at the fabricator's yard to ensure a proper fit before it was trucked to Mississippi.

MDOT, Baker and Grand Junction Steel worked closely with the construction contractor, Key Constructors, Inc., of Madison, MS, to anticipate construction issues such as the effects of temperature on the curved girders. Rather than pre-drilling all the members and then struggling to connect them on site as they expanded lengthwise and sideways in the Mississippi heat, some of the final fitting was left to the construction phase. The contractor set the girders in place, and when the girders had reached the right temperature and expansion, crews drilled and tapped holes for high strength bolts in the bottom flanges to align with the pre-drilled holes in the bearings.

Construction of the $27.1 million project began in November 1999 and is expected to be completed by late summer 2002.

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OWNER
Mississippi Department of Transportation, Jackson, MS

PRIME DESIGN CONSULTANT AND STRUCTURAL ENGINEER
Michael Baker Jr., Inc., Jackson, MS

STEEL DETAILER
Tensor Engineering, Indian Harbor Beach, FL (AISC & NISD members)

CONSTRUCTION CONTRACTOR
Key Constructors, Inc., Madison, MS

SOFTWARE
Bridge Software Development International, Ltd. (BSDI), Coopersburg, PA