A DESIGN-BUILD BRIDGE VENTURE IN HIGH-PERFORMANCE CONCRETE

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ABSTRACT

In 2004, the Memphis-Shelby County Airport Authority solicited design-build proposals for the construction of a service road parallel to the Taxiway Yankee runway located at the Memphis International Airport in Memphis, Tennessee. This project would require a two lane bridge to cross the eight lane Winchester Road that would support a special purpose firefighting vehicle with a gross weight of 185,000 pounds. The design-build team of Barge Waggoner Sumner & Cannon and Ray Bell Construction Company embarked on the venture to design and build the bridge and its approaches. This would provide access between the north and south sides of the airfield.

The design-build team determined that by using closely spaced 72 inch prestressed HPC bulb-tee girders, it would enable them to develop a preferred 129 foot single span configuration, utilizing integral stub abutments with mechanically stabilized earth (MSE) retaining walls. This eliminated piers in the Winchester Road right-of-way, simplified seismic design requirements, shortened construction time, and minimized the impact to on-going operations. The HPC-based, single span solution provided a simple, expeditious, and more economic alternative for the client. This Paper will describe how the design-build proposal strategy and high performance concrete (HPC) were used to successfully accomplish the project.

Keywords: High-Performance Concrete, Design-Build, Mechanically Stabilized Earth Retaining Walls, Single Span, Bulb-Tee Girders, Economic Solution, Rapid Construction

INTRODUCTION

In the spring of 2004, the Memphis-Shelby County Airport Authority (MSCAA) solicited design-build proposals for the construction of a service road parallel to the Taxiway Yankee runway located at the Memphis International Airport in Memphis, Tennessee. This project would require a two lane bridge to cross the eight lane wide Winchester Road that would support a special purpose firefighting vehicle.

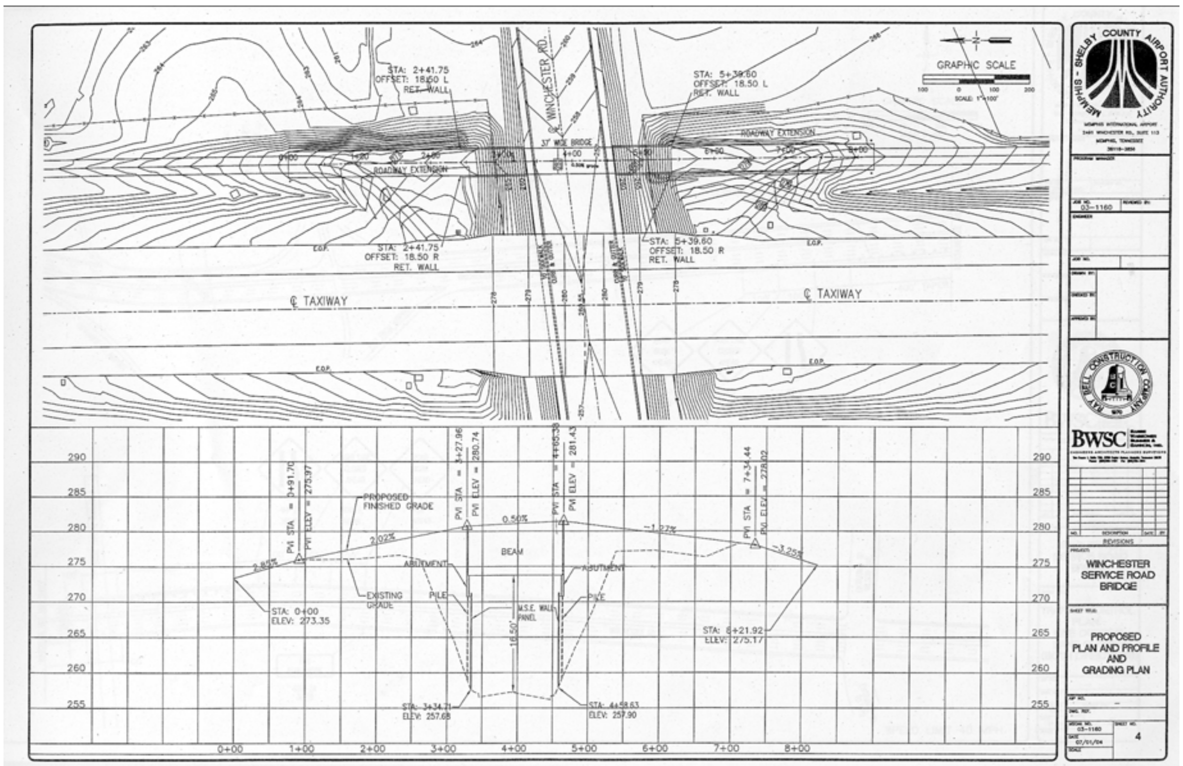

Fig. 1: Plan and profile of project site.

The main purpose of this structure was to provide airport emergency services an unrestricted link between airfield properties located on the north and south sides of the Memphis International Airport campus, which was separated by Winchester Road. At that time, the airport emergency services had to use the existing aircraft taxiway to access the south side of the airfield. Sharing this taxiway could potentially delay emergency service response time by having to coordinate usage of the existing taxiway bridge with aircraft operations. In addition, this arrangement increased the safety hazards to passengers and airport personnel by operating vehicular and aircraft traffic on the same route.

Later in the summer of that same year, the design-build team of Barge, Waggoner, Sumner and Cannon, Inc. (BWSC) and Ray Bell Construction Company (RBCC) was awarded this project. The team embarked on a joint venture to design and build the service road bridge and its approaches which would alleviate the existing problems associated with using a shared route and provide the airport emergency service operations with improved access between the north and south sides of the airfield.

DESIGN/BUILD STRATEGY

While a design-build contracting mechanism is relatively new and seldom used in the bridge design industry, it has been gaining popularity in recent years. For the client, the primary benefit of a design-build project is that the engineer/contractor team has a good pulse on current market prices for materials and current construction methods. This enabled the design-build team to balance and optimize initial and long term cost, construction duration, and minimize the effects of ongoing operations at the airport and on the state's transportation systems. Although this type of contracting mechanism has inherent risks for the design-build team, these risks can be mitigated by focused project management and a good working relationship between a reputable engineer and contractor. This in turn produces a win-win situation for the client and the design-build team.

The MSCAA determined that a design-build venture would be in their best interest for this project. At that point, they developed and specified that their top priority for the team would be to design and construct this vital link optimizing initial and long-term cost, short construction duration, and minimized impact on the airport and Winchester Road operations. This would ultimately provide their emergency services unfettered access to the south side of the airfield, thereby increasing response time at a reduced safety hazard to passengers and personnel.

The design-build team's strategy hinged on two key design elements implemented to meet MSCAA's objectives. These key design elements consisted of a slab-girder superstructure made of simple span, high strength, precast/prestressed concrete beams. Both of these design elements optimized the costs, construction time, and impact with on-going operations. It also provided the added benefit of an aesthetically pleasing structure that would bolster the airport's image with the community. The use of high performance concrete (HPC) for the girders was the critical parameter that allowed the design-build team to achieve the two key design elements and ultimately accomplish MSCAA objectives for the project.

Photo 1: Elevation rendering of proposed project.

Photo 2: Aerial rendering of proposed project.

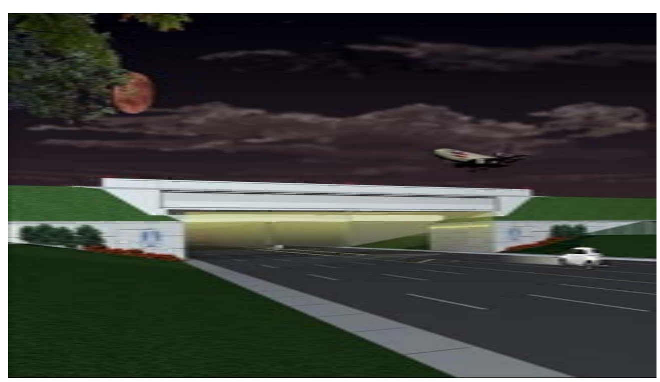

Photo 3: Elevation rendering of proposed project.

TECHNICAL ASPECTS FOR THE IMPLIMENTATION OF THE DESIGN/BUILD STRATEGY

In order to comply with the key design elements, the engineering design process had three challenging and atypical technical aspects to consider. The unique technical aspects consisted of stringent seismic design criteria, distinctive design live loading, and high performance concrete that would extend the upper bounds of traditional precast/prestressed concrete girder design.

Stringent Seismic Design Criteria. Since the structure is located in Memphis, Tennessee, it falls within the limits of the New Madrid Fault System, a major seismic zone that has the potential to exert extremely large forces into the bridge structure. It was determined that the structure would be located within an area that could be subjected to a seismic acceleration coefficient of 13.14% g, placing the structure in Seismic Performance Category B. However, since the structure could be configured as a single span, the code permitted a simplified seismic design approach eliminating the need for rigorous seismic analysis and design. This resulted in a reduction of the engineering design fees and material cost that would have been required to provide seismic details.

Design Live Loads. At the core of the engineering design process for any structural system are the design loads to which the structure will theoretically be subjected. This structure is unique in that the design vehicle live loading criteria is based on a much heavier design vehicle than the typical design live loading for most vehicular bridges. Most vehicular bridge structures are designed to support an AASHTO-prescribed theoretical design truck. For this structure, AASHTO's standard specifications load factor design (LFD) was the governing design methodology. Therefore, the code-prescribed truck that is typically used for design would be the HS 20-44 truck with a theoretical gross weight of 72,000 pounds.

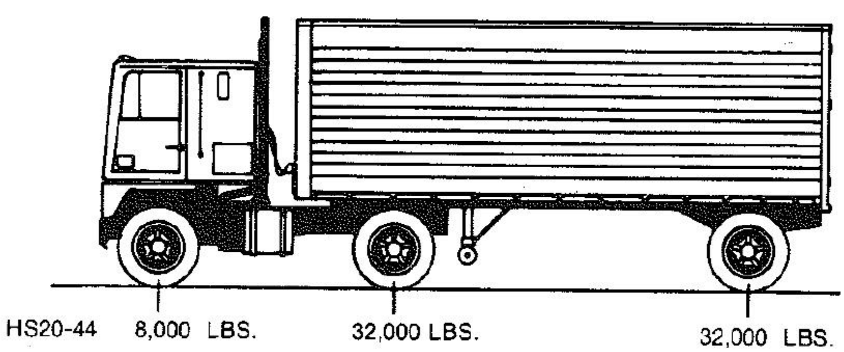

Fig. 2: Standard AASHTO HS20-44 design truck.

The sole purpose of this structure, however, was to transport the airport's emergency response and maintenance squadron, including the Aircraft Rescue Fire Fighting (ARFF) vehicles. At the time of design, the heaviest of these vehicles was the Oshkosh M-23 Series with a gross loaded weight of 148,000 pounds. Looking ahead, MSCAA instructed the team to design the structure to support a theoretical future ARFF vehicle with a gross loaded weight of 185,000-pounds which is roughly 2.5 times heavier than the load for which a typical highway bridge structure is designed.

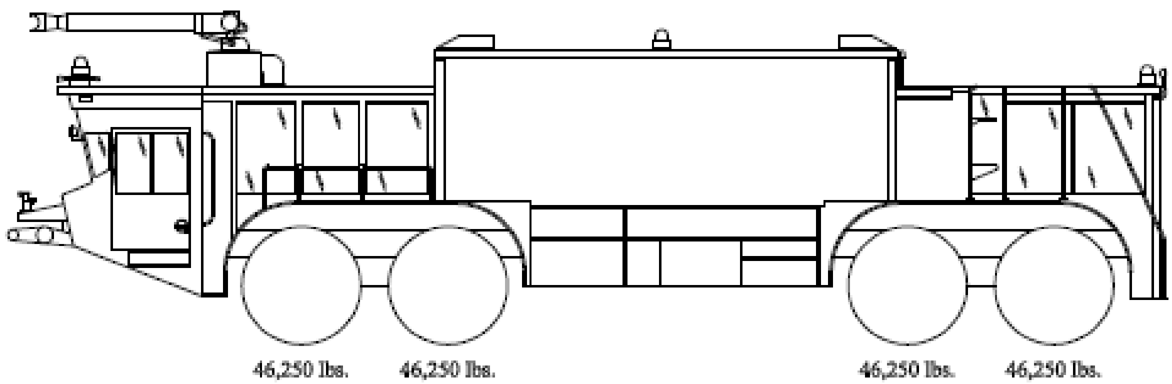

Fig. 3: Future theoretical ARFF design vehicle.

High Performance Concrete That Extends the Upper Bounds of Traditional Precast/Prestressed Concrete Girder Design. The single span arrangement required a span length of 129 ft. 2 ¾ in. and a beam length of 126 ft. 2 ¼ in.

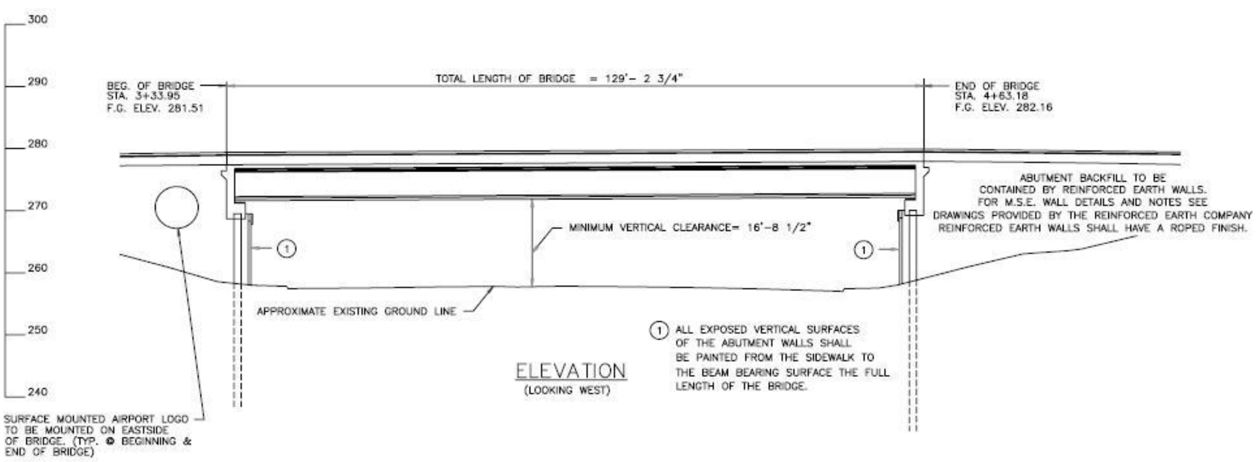

Fig. 4: Elevation view from design plans, showing single span configuration.

While this is a respectable span length for prestressed girder construction, it is well within feasible and practical design limits of a 72 inch bulb-tee girder. However, what makes this design unique is that this beam would be required to support loads up to 2.5 times that of typical loading, which in turn strains the upper bounds of the design for traditional precast/prestressed concrete girder design. The remaining variables in the design to achieve this span arrangement consisted of cross-section girder spacing, concrete strength, strand size, and strand arrangement. At the time of design, a 72 inch bulb-tee girder was the largest beam the local precaster could produce. In addition, 0.6 inch diameter strands were all that was available and practical. The designers were limited to a combination of three variables to make the span arrangement feasible. First, the designers closely spaced the girders in the cross-section at 6 ft. 3 ½ in. on centers.

Photo 4: View of the new bridge's single span configuration.

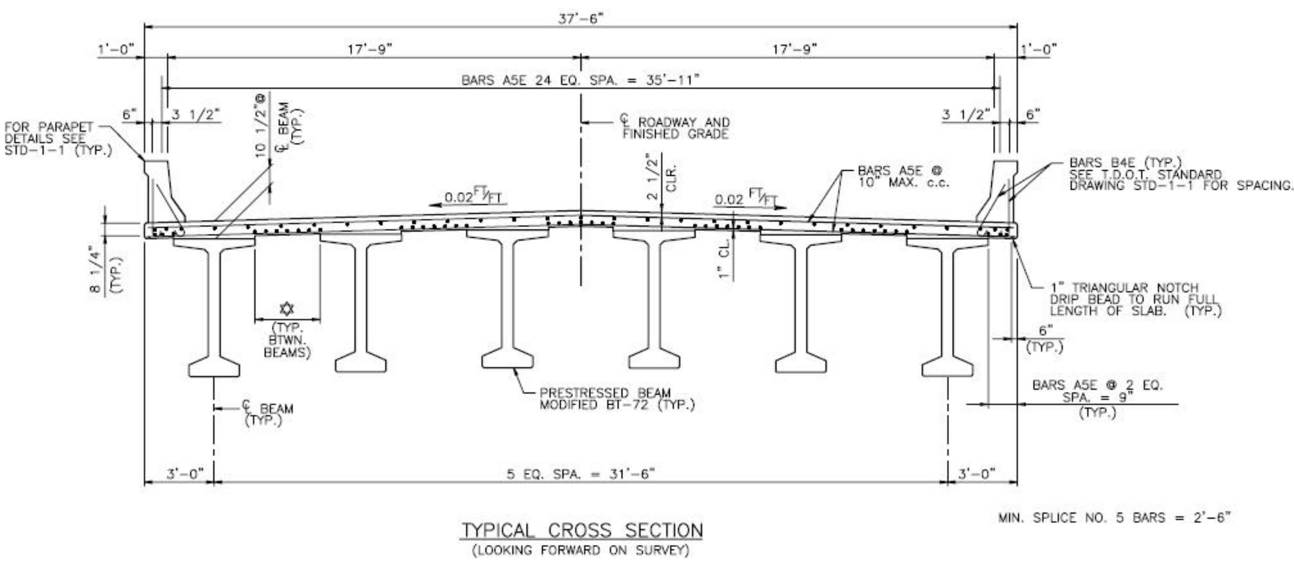

Fig. 5: Typical cross-section from design plans, showing girder spacing.

Photo 5: Cross-section of the new bridge.

Secondly, and most importantly, the designers and the precasting plant worked together to develop a high performance concrete mix that would permit the use of 28 day concrete design strength of f'c = 10,000 psi. At the time, this was the upper limit of practical concrete design. With all the variables maximized to their practical limits, the engineers were able to configure a 56 strand partially draped arrangement that provided the girders with the strength and serviceability requirements to sufficiently support the design vehicle. The use of high performance concrete in the girder was the primary element that enabled the team to accomplish the two key design parameters.

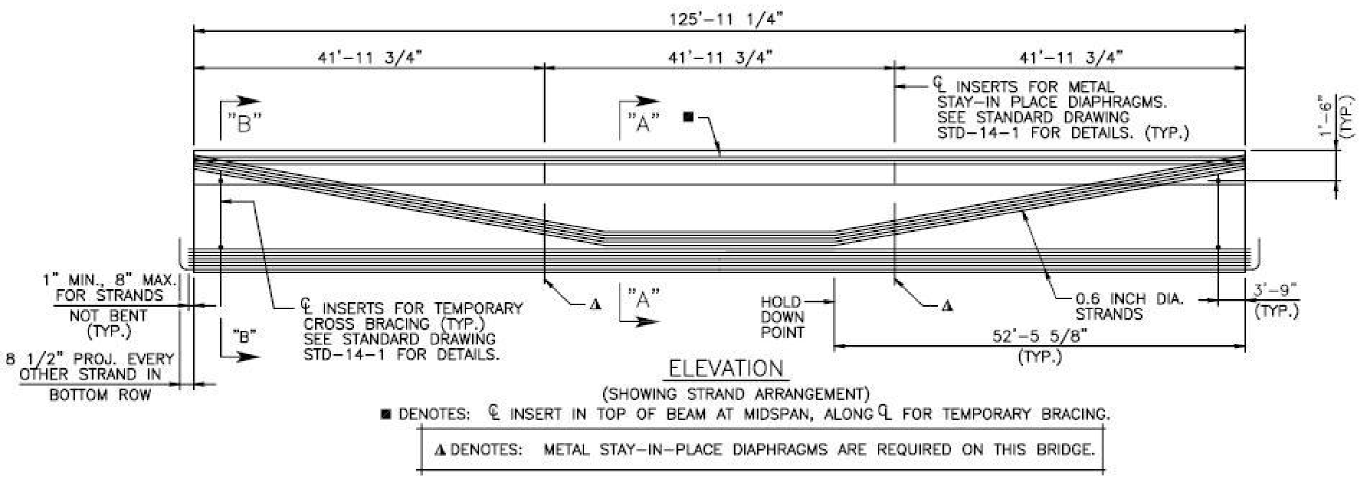

Fig. 6: Girder details from design plans.

RESULTS OF DESIGN/BUILD STRATEGY

The critical technical aspects of the project were feasible solely based on the use of high performance concrete. Therefore, the design/build strategy was successfully implemented, accomplishing MSCAA's top priorities. This in turn resulted in the successful completion of the project which provided the airport with an efficiently functioning transportation system for their emergency response services.

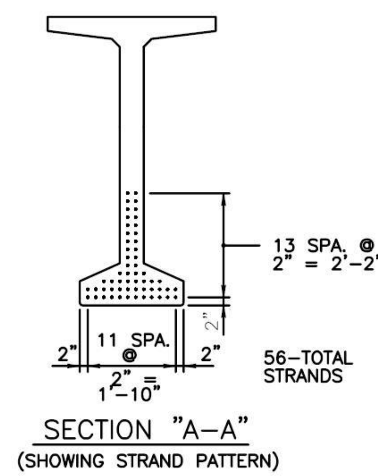

Fig. 7: Girder details from design plans.

Initial Cost

High Performance Concrete. The use of high performance concrete in the girder design was the key design element that permitted the use of a single span structure and a slab-girder superstructure consisting of precast/prestressed concrete girders. This provided the lowest initial cost option for the structure.

Single Span Structure. The elimination of intermediate bents produced a single span structure which significantly reduced the initial cost associated with the engineering design. The single span configuration simplified the analysis, design, and detailing of the structure. From a construction aspect, the single span configuration significantly reduced initial cost associated with materials, construction labor, traffic control implementation, general construction site safety, reduced interruption to ongoing airport operations, and commercial traffic on Winchester Road. The design/build team estimated that the single span configuration resulted in approximately a ten percent savings in the overall initial cost of the structure. The single span bridge layout provided a much greater cost effective design-build alternative.

Slab/Girder Superstructure Configuration Using HPC Precast/Prestressed Concrete Girders. The design-build team proposed the use of closely spaced 72 inch precast/prestressed HPC bulb-tee girders for the single span bridge design. In terms of material cost, the choice to use precast/prestressed concrete girders was less expensive than a steel girder alternative. In addition, three prestressed concrete plants with the ability to produce the beams were located within one hundred miles of the construction site. This provided a competitive bidding environment for pricing and scheduled delivery. From a construction standpoint, choosing HPC over steel, Ray Bell Construction Company was able to erect the superstructure without relying on an additional steel erection subcontractor. Choosing a local precaster enabled the prime contractor to set all the beams in one day further lowering MSCAA's initial cost.

Photo 6: Girders of the new bridge.

Construction Duration and Impact with Ongoing Operations

Project Duration. Once the design-build team was awarded the project, the engineering design and construction was completed within seven months. By using a design-build contracting mechanism for this project, the airport was able to begin using the bridge for its daily operations in approximately half the time than the traditional design/bid/build project delivery would have permitted.

Photo 7: Bridge abutments under construction.

Photo 8: Construction after beams were set.

Photo 9: Construction during deck slab placement.

Single Span Structure. For this project, a single span bridge configuration was proposed, minimizing engineering time associated with analysis, design, and detailing. Elimination of the center bent minimized construction time associated with setting up a work zone and constructing the center bent. In addition, this reduced the impact of crane towers in the clear/safety zone of the runway and on flight operations of the airport. It also lessened the impact on traffic flow of Winchester Road, a major vehicular thoroughfare in Memphis.

Slab/Girder Superstructure Configuration Using HPC Precast/Prestressed Concrete Girders. The use of precast/prestressed HPC bulb-tee girders for the single span bridge design and choosing a local precaster to supply these girders enabled the prime contractor to set all the beams in one day. This further expedited the construction duration and the impact to airport and Winchester Road operations.

Traffic Control. During the course of this project, lane closures were kept to a minimum, and traffic control implementation associated with reduced construction time further alleviated inconvenience to commercial transportation and the traveling public on Winchester Road. For the majority of the construction phase, vehicular traffic on Winchester Road experienced the closing of only the exterior right lane for approximately seven hundred feet in each direction. Six lanes remained open and unimpeded for most of the project. The only exception occurred on the day the precast/prestressed HPC bulb-tee girders were erected. On this day only two lanes, one in each direction, were open for traffic, and all traffic was stopped in fifteen minute increments to allow the contractor to lift and set the girders.

Long-Term Cost

The design-build team was selected for the project primarily for providing the client with the most cost-effective proposal. After the design-build team had been selected, further discussion revealed that the client was equally interested in the initial cost of the structure and the long-term maintenance cost as well. The client was cognizant of the fact that proper drainage of water from the structure was necessary to greatly reduce the long term maintenance cost of the structure. Visual staining of the concrete, as well as the physical deterioration of the bridge components due to water and other elements of nature, were of particular concern. There are several bridge construction practices that have sufficiently addressed proper drainage as well as greatly reduced the long-term maintenance cost of a structure. Three of these details were implemented in order to provide the client with a high quality structure.

1. High-Performance Concrete. While the primary use of high performance concrete in this project was for strength, a secondary benefit was that high performance concrete exhibits increased durability over traditional concrete mixes. This produces lower maintenance cost over the life of the structure.

2. Integral Construction at the Abutments. The thermal expansion of the structure was small enough to warrant the elimination of all joints in the bridge by making the superstructure integral with the substructure. In other words, the girders have a positive connection to the abutment back walls, and the abutment back walls and concrete deck were poured monolithically. The removal of the expansion joints in the structure eliminated one of the highest maintenance costs associated with a bridge structure. The long-term maintenance of the joints themselves is extensive. In addition, structural deterioration of the beam ends, bearings, and substructure units that are incurred due to improper water drainage through an expansion joint system is completely removed for all practical purposes. Also, the integral construction provides a secondary benefit for the structure. It creates a stronger and more efficient structural behavior of the bridge, particularly during a seismic event.

Photo 10: Close-up of integral construction technique.

3. Bridge Drainage. In addition to the elimination of deck joints by means of integral construction, the bridge cross slope in combination with the grade of the bridge, permitted the design team not to use any deck drains. Deck drains must be maintained on a regular basis, or they create a potential for visual staining and structural deterioration to the superstructure and substructure. Water stops were also placed in the cold construction joint between the bridge deck and the parapets. This is another level of precaution against water seepage that can contribute to the visual staining of the concrete.

CONCLUSION

The Memphis-Shelby County Airport Authority project proved the value of high performance precast/prestressed concrete beams. The use of this product in the highly competitive bidding environment of a design-build approach to project delivery allowed the team to achieve the desirable benefits of least cost, low maintenance, shortest construction time, and minimal disruption to airport and traffic operations. The superior qualities of precast/prestressed concrete in bridge construction were established in head to head competition with other bridge building materials.

Photo 11: Winchester Service Road Bridge.

Photo 12: Winchester Service Road Bridge, aerial view.