

THE ALTERNATE TECHNICAL CONCEPT PROCESS FOR FOUNDATIONS AT THE NEW MISSISSIPPI RIVER BRIDGE, ST. LOUIS

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The New Mississippi River Bridge (MRB) employed conventional design-bid-build procurement, but the bidding process included the opportunity for pre-qualified bidders to develop and propose confidential Alternative Technical Concepts (ATC's) for evaluation and approval in advance of bidding. The ATC process provides a mechanism for value-engineering prior to bid, with incentives and opportunities for both the owner and the bidding contractor.

The contract described in this paper is for the river bridge composed of a cable-stayed crossing with two pylons and the anchor piers on each side of the river. The Massman-Traylor-Alberici (MTA) team developed a re-designed foundation system for the main pylon and anchor foundations which utilizes their equipment and experience along with field load test measurements to optimize the foundations. The paper describes the experience with the use of the pre-bid ATC process on the project from the perspective of the bidder, and outlines some of the benefits and limitations of this concept with respect to foundation design and construction. Some keys for success are identified and impediments to the effective implementation of the process are described.

INTRODUCTION

A dual-tower cable-stayed bridge over the Mississippi River, shown in Figure 1, is being constructed by a joint venture comprised of Massman, Traylor Brothers, and Alberici (MTA). The project is referred to as the New Mississippi River Bridge (MRB) and is located in Missouri and Illinois, just north of downtown St. Louis. This bridge, along with several other approach construction contracts, will carry traffic along I-70 over the river and is intended to significantly reduce traffic congestion in the area. The main span of the bridge is 1,500ft and each back span is 635.75ft for a total bridge length of 2,771.5ft.

The MRB uses a conventional design-bid-build project delivery method, but the bidding process included the opportunity for pre-qualified bidders to develop and propose confidential Alternative Technical Concepts (ATC's) for evaluation and approval in advance of bidding. The foundations for the river bridge, which have recently been completed, were the result of one such ATC. The project illustrates the successful use of this innovative approach to the construction contracting, which offers the opportunity to

combine some aspects of design-build into a conventional procurement system.

This paper describes the experience with the use of the pre-bid ATC process on the project from the perspective of the bidder, and also outlines some of the benefits and limitations of this concept with respect to foundation design and construction. Some keys for success are identified and impediments to the effective implementation of the process are described.

OVERVIEW OF ATC PROCESS

The idea of an Alternative Technical Concept (ATC) is to provide a mechanism through which a construction team can propose a technical concept that is not a part of the base bid design or not normally used or allowed in the owner's existing standards or specifications or design guidelines. The effective use of the concept can align incentives for both the contractor and the owner to develop ideas which remove inefficiencies or constructability problems in the design, and improve the project by reducing costs, time, and risks of adverse outcomes for all concerned.



Figure 1 The New Mississippi River Bridge (rendering from Missouri Dept. of Transportation)

Owner's Incentive for ATC's.

The incentive for an owner to include the provision for ATC proposals is to encourage a contractor to develop innovations to help reduce costs or improve value. The owner derives obvious benefit from reduced costs. Examples of improved value might include reduced schedule time, reduced impact on traveling public or nearby infrastructure, improved service life of the structure, added features that have been identified as desirable, etc. The value of improved project delivery date to the owner may be quantified by an early delivery incentive bonus. The value of other aspects can be more challenging to quantify unless a value-based selection process is used. ATC's are often included in design-build procurement with a value-based selection process, and the case for the added value of an ATC is documented in the submittal of the proposal to the owner. The owner's evaluation of the value is incorporated into the scoring criteria used with the best-value selection process.

Constructor's Incentive for ATC's.

Incentives for the constructor to identify and submit ATC proposals include cost or schedule savings which might be realized by the constructor, improved constructability which might reduce risks of cost overruns or schedule impacts, and competitive advantages during the

bidding process. In a conventional bid-build environment, an owner's designer must develop construction plans for the broad market of potential bidders, particularly on public works projects. Individual contractors might seek to develop ATC's which allow them to utilize equipment advantages or special expertise that might not be readily available to competitors.

Use of ATC's in Public Works Construction.

While ATC proposals are common with design-build project delivery, a pre-bid ATC is very unusual for a conventional bid-build project, at least in the public works sector. Post-award proposals by contractors on conventional projects are sometimes considered as part of an agency's process for value-engineering (VE) or cost reduction incentive proposals (CRIP). Post-award proposals of this sort are often limited by schedule requirements and time constraints, and the incentives related to possible competitive advantage during the bidding process are no longer present.

ATC PROCESS ON THE NEW MRB

For this project, the Missouri Department of Transportation (MoDOT) and their designers, HNTB, initiated the pre-bid ATC process on this conventional bid-build project primarily as a means to encourage bidders to develop innovative ideas to reduce costs. The project

had been through numerous previous preliminary designs, all of which had been judged to exceed funding constraints. After lengthy negotiations and political wrangling, the states of Missouri and Illinois and the federal government developed a budget of \$667 million for the entire project, which included the river bridge plus approach structures and interchanges on both sides of the river.

The river bridge represents "Contract B" and includes the two towers supporting the cable stayed bridge along with the anchor piers on either side, as illustrated in Figure 2.

The process began with an open industry informational meeting in St. Louis early in the bidding process, at which time the procedure for "Innovative Alternate Technical Concept - Design Bid Build Procurement Approach" was introduced along with an overview of the project. This early disclosure allowed prospective bidders to begin planning and to initiate teaming arrangements with engineers, suppliers, and subcontractors. Only general contractors who were prequalified were eligible to submit pre-bid ATC proposals for consideration.

Upon approval and acceptance of an ATC from a prequalified bidder, that bidder would receive alternative construction drawings which could be used as the basis of their bid. A bid including an approved ATC would be considered equally valid to a bid on the base design. Qualified contractors could decide to bid only the base bid design, and need not go through the prequalification process in order to submit a bid on the base design.

Owner-Contractor Interaction.

Because of the competitive bidding, the ATC procedures had to be clearly defined and strictly followed by all parties. Confidentiality of bidders' ideas was critical to maintain the integrity of the process and so only a small group of owners' engineers and representatives participated in the discussion and review of ATC proposals.

The lack of a finalized design and the ongoing design activities during the pre-bid period presented a challenge to the development of ATC proposals. As the design progressed, base bid plans along with design criteria were made available at various stages of development of

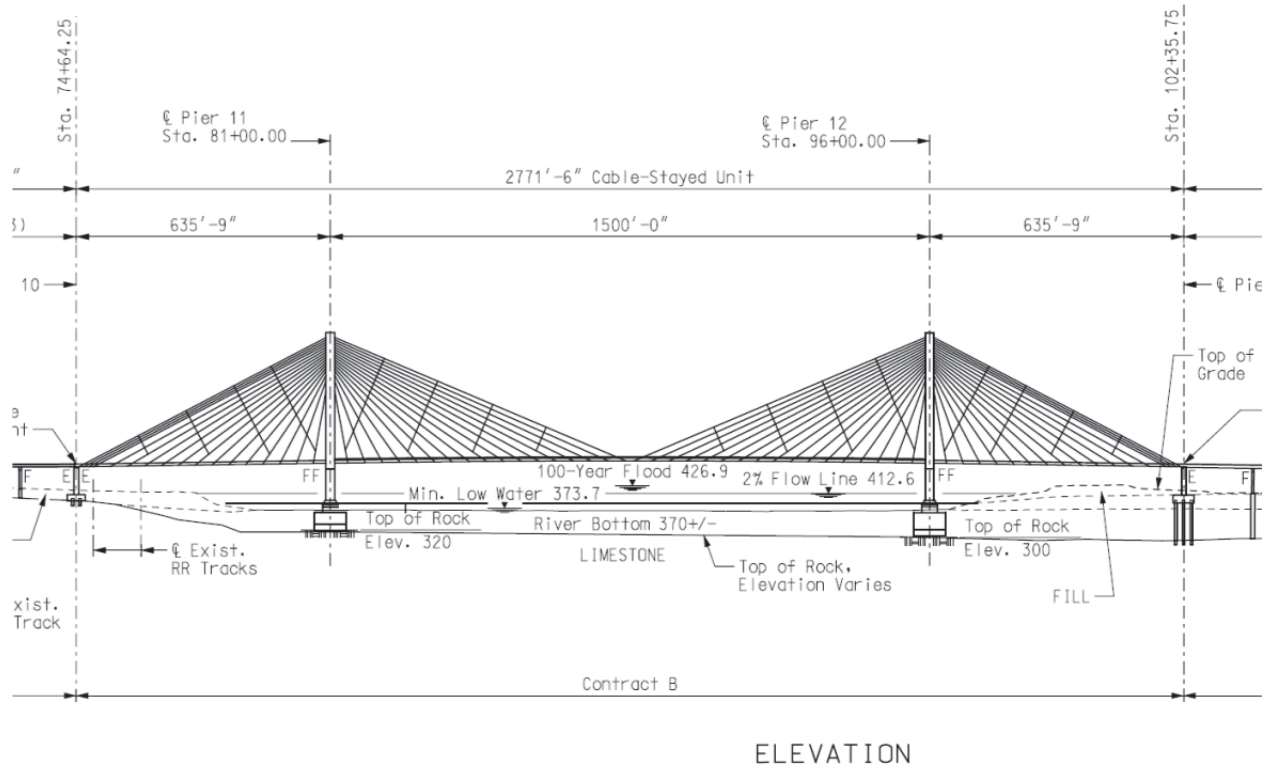


Figure 2 New Mississippi River Bridge, Contract B

the design, and the ATC meetings with prequalified contractors provided an opportunity to ask questions. The joint venture (MTA) construction team met with their design professionals and conducted confidential brainstorming sessions during this period in order to identify opportunities and develop ATC proposals. The ATC meetings with the MoDOT and their design team provided opportunities to introduce ideas and receive feedback from the owners regarding feasibility and receptiveness to various alternatives.

Design Responsibility, Risks, and Foundations.

A significant issue to the construction team was the characterization of an ATC change as “minor” in which the owner simply incorporated the alternative into the design, or “major” in which the design responsibility for the modification was borne by the bidder. The way in which this item is treated is particularly important with respect to foundation construction, in which there are risks associated with uncertainties in the subsurface conditions.

With the base bid, the owner keeps the risks associated with uncertainties in the subsurface conditions. The constructor’s risks are associated with the successful implementation of their means and methods for the conditions that are indicated on the contract documents. If conditions are encountered which necessitate a change in the design, the constructor would normally be entitled to additional compensation through a change order.

An ATC can increase the constructor’s exposure to risks related to performance of foundations or subsurface uncertainties. The constructor must assess the risks and potential savings may be offset by increased contingency allowance in the bid to cover this risk.

The owner must carefully consider accepting an alternative design which increases the owner’s risks related to performance of foundations or subsurface uncertainties, particularly during the pre-bid ATC process when potential cost savings are less transparent to the owner.

On the MRB, the most significant ATC that was offered by MTA and accepted by MoDOT was the re-design of the drilled shaft foundations. The following section describes the ATC foundation design. A critical component of the

ATC was the inclusion of a full-scale load test on a non-production drilled shaft to provide verification of the ATC design parameters.

FOUNDATION ATC

The historic Eads Bridge, located nearby the MRB, was completed in 1874 as the first major crossing of the Mississippi River this far south. Eads’ bridge still functions, in large part due to his successful installation of pneumatic caissons through the sandy soils to bear on the limestone bedrock below. From his work as a salvage diver, James Eads recognized the exceptional force of the currents and scour potential of the great river, and the difficulty this condition posed to conventional bridge foundations. The Eads Bridge represents the first use of such deep caissons in North America. The more famous Brooklyn Bridge was completed 9 years afterward using similar pneumatic caissons.

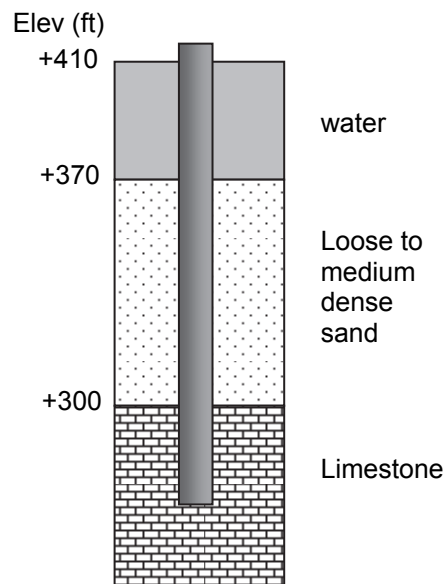


Figure 3 Subsurface Conditions

Conditions Affecting Foundation Design.

The ground conditions at the new MRB were similar to that at the Eads bridge, with about 40ft of water at the pylon locations underlain by 70ft of alluvial sand over limestone bedrock. The schematic diagram shown in Figure 3 represents conditions at the East Tower; conditions at the West Tower were similar. Because of concerns related to potential solution cavities, the pre-bid site exploration was quite thorough. The rock

was found to be sound and hard with recovery and RQD near 100%. Seams and fractures in the bedrock were logged using downhole acoustic televiewer and borehole video.

Lateral and overturning forces play a major role in the foundation design. The design scour conditions remove all of the overburden above the bedrock at the tower locations. Lateral and overturning loads result from vessel collision forces, overturning from wind on the tall towers and 1500 ft main span, and seismic loadings associated with the nearby New Madrid fault.

The baseline design contained options for both a caisson foundation bearing on rock as well as a group of 9.5ft diameter drilled shafts with a mud-line footing. At both pylons, the baseline design used groups of fourteen drilled shafts, each with 44ft long rock sockets and connected by a 120ft by 70ft pile cap. The baseline foundation for each anchor pier included four drilled shafts with 28ft long rock sockets.

Foundation Type Selection.

The caissons at the Eads Bridge have proven the success of this foundation type, although hand excavated pneumatic caissons have been replaced by open well dredged caissons. Open well caissons have been used successfully on several Mississippi River bridge projects recently, including the Emerson Bridge at Cape Girardeau, Missouri and the US 82 Greenville Bridge between Mississippi and Arkansas. The members of the MTA team have experience and skill with the construction of open well caisson foundations, and are familiar with the potential advantages and limitations. However, the team quickly concluded that modern construction techniques allow drilled shafts to be constructed much more quickly and economically. A significant limitation to the use of caissons is the schedule impact of the time required to complete the construction sequence.

Features of the ATC Foundation Design.

The ATC foundation design included two primary features that improved the cost effectiveness over the base bid design. The first was the use of larger diameter drilled shafts that took advantage of the team's experience and equipment in constructing these foundations. Larger diameter drilled shafts in this strong rock are able to provide much greater flexural

strength and axial resistance. The use of fewer, larger diameter individual drilled shafts allowed the size of the footing to be reduced, which saves material, reduces the cofferdam needed for the footing construction, and reduces seismic demand related to the footing mass. Fewer individual drilled shafts to construct also reduced the time required for construction, so long as the productivity was not substantially reduced because of the size.

The second feature was the inclusion of a load testing program (which was not part of the base bid) which allowed the team to take advantage of higher resistance factors and the base and side resistance that were to be verified by the load test. From the owner's perspective, the proposed load test was a key feature which provided verification that the ATC foundation design would meet the performance requirements.

At each pylon, the resulting ATC foundation design reduced the number of drilled shafts from fourteen to six, with the diameter of the shafts in rock increased to 11ft from 9.5ft. The ATC also allowed the pylon pile caps to be reduced in plan size to 88ft x 55ft from 120ft by 70ft; the pylon cofferdam seals were also reduced accordingly. At Pier 11 (Missouri Pylon), the ATC design rock socket length was reduced to 22ft from 44ft; at Pier 12 (Illinois Pylon), the ATC design rock socket length was reduced to 16.5ft from 44ft. The anchor piers drilled shafts were unchanged from the base design except for the length of socket, which were reduced to reflect the higher resistance factor from load testing and the inclusion of base resistance.

Distribution of Risks with the ATC Foundation.

The specifications required a pilot boring to be performed at the location of each drilled shaft to confirm that the rock conditions were consistent with the design prior to construction. Therefore, any unanticipated differences in the rock bearing stratum could be identified prior to construction of the drilled shafts. The ATC foundation proposal was not intended to relieve the owner's risks related to differing site conditions.

Beyond the potential for differences in the subsurface conditions, the responsibility for risks of unfavorable foundation performance was an important issue for the ATC proposal. The load test would provide a direct measure of the axial

resistance, so the confidence in the performance of the ATC foundation design for support of the bridge is enhanced. However, load test measurements which indicate lower unit values of side and base resistance than used in the design could result in necessary adjustments to the embedded length.

The ATC foundation design relied on unit side resistance values of about 23ksf which were consistent with the base bid design, and so the owner's risk associated with unit side resistance was unchanged by the ATC proposal. The responsibility associated with design base resistance of 265ksf in sound rock that is consistent with the contract documents was undeniably borne by the construction team, who acknowledged and accepted the responsibility to meet bottom of hole cleanliness requirements. The base of the shaft excavations were to be cleaned using an airlift pump and inspected with a downhole camera prior to concrete placement.

Although the foundation redesign might logically be recognized as a substantial change to the design of the bridge, this ATC was ultimately determined to be a "minor" change per the definitions discussed previously; i.e., the owner retained the design responsibility. The footing design was completed by the owner's engineer, HNTB, and the constructor's risks were limited to the embedded length requirements for the rock sockets as described above, to be verified by the load tests. The successful completion of the test shaft and verification of performance with the load test was therefore very important.

LOAD TEST SHAFT

After successfully winning the job (followed soon thereafter by record flooding of the Mississippi River), construction of the load test shaft took place during May and June, 2010. Permanent casing was installed to rock, and the rock socket was advanced using a large diameter coring tool. Cores were successfully extracted using a hydraulic tool, which provided an interesting opportunity to log the shaft (Figures 4 and 5).

The acoustic televiwer logs of the rock at each drilled shaft location also proved to be a valuable aid in planning for core extraction, as the near-horizontal seams in the rock were ideal locations to break off a core for removal. The cores were so large and heavy that the crane could only remove lengths up to about 4 to 5 ft.



Figure 4 Coring at the Load Test Shaft



Figure 5 Core From the Load Test Shaft

The test shaft and other drilled shaft excavations were cleaned very effectively using an air lift pump, as shown in Figure 6. Because the construction included a permanent casing to rock, the rock socket could be drilled using water alone and the cleaning could be readily accomplished using river water. A full exchange of the fluid in the hole was efficiently accomplished by pumping from and discharging into the river, a practice which might be precluded elsewhere but which is allowed in the "muddy Mississippi". Inspection using a downhole camera confirmed the effectiveness of the base cleaning operations. Concrete placement was completed without incident.



Figure 6 Air Lifting the Shaft Excavation

The load test performed using the Osterberg cell (O-cell) technique. Four individual O-cells were installed to within 11 inches of the base of the shaft, with a tremie pre-assembled through a center hole for concrete placement as shown in the photo of Figure 7. The bottom plate had a diameter of 9 feet so that the base load could be concentrated onto an area smaller than the full 11 ft shaft diameter, thereby allow higher unit base resistance to be mobilized during the test.



Figure 7 O-cell Assembly

The load test was successfully completed, and the O-cells were loaded to the limit of the

pumping system to apply a total load to the foundations of 72,000 kips. This magnitude of load represents a world record for the largest load test ever performed on a drilled shaft foundation. Neither the side nor base resistance was fully mobilized at the maximum load. The upward movement of the shaft was around 0.05 inches at an average unit side resistance of over 40 ksf and the downward movement of the shaft was just under ¼ inch at a base resistance of around 450 ksf.

PRODUCTION FOUNDATIONS

Construction of the remainder of the production shafts was completed without significant incident during 2010. The construction of the tower foundation footing was completed within a sheetpile cofferdam; the photograph in Figure 8 shows construction of the East Tower (Pier 12) foundation after completion of the seal slab and prior to placement of the footing reinforcement.



Figure 8 Cofferdam at East Pier

SUMMARY

The ATC process was successfully employed on the conventional bid-build contract at the new MRB. The process effectively achieved the objective of encouraging bidders to participate in the design process to improve economy and efficiency. The MTA team used the process to competitive advantage to win the job, reduce time in the schedule, and aid constructability by optimizing the foundation design to their equipment and experience.

MoDOT and their designers have estimated that the savings to the owner as a result of the foundation ATC was approximately \$5 million.

