CONCRETE BRIDGES FOR VALUE ENGINEERING

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ABSTRACT

Traditionally, transportation projects are designed by engineers, bid by contractors, and built by the low-bid contractor according to the design plans and specifications. Several states now allow for Value Engineering Change Proposals (VECP) that expand the traditional design-bid-build sequence. Value Engineering allows the low-bid contractor to propose alternate construction methods and materials that reduce project cost without sacrificing functionality, durability, or aesthetics. If approved, the Value Engineering savings is typically split between the contractor and the state's department of transportation. Two case studies are discussed where bridges were completely redesigned after the projects were bid. These two VECP projects changed superstructure type from steel girder to prestressed I-girder as well as changing span arrangement and substructure type. Combined savings for the two projects was approximately $3 million.

Keywords: Bridge, Concrete, Prestressed, Value Engineering, Link Slab, Fast Track Design

INTRODUCTION

Recently, Palmer Engineering has been involved in several Value Engineering Change Proposals where prestressed concrete I-girders have been used in the redesign of bridges. Our experience has shown that where span arrangements allow, significant savings can be realized by replacing steel girder superstructures with prestressed girder superstructures. Following are two projects that highlight some of the design considerations that went into VECP redesigns resulting in approximately $3 million in savings. In contrast to traditional design projects, VECP projects are typically fast paced with most design decisions made up front instead of being made throughout the design process. Since both projects were already let to contract before the VECP's were proposed and accepted, fast-track design was essential for the contractors to meet the original finish dates.

Design for the VECP projects was performed in a fast-track style, submitted and approved in phases corresponding to the normal sequence of construction. First, the overall concept for the design was reviewed and approved. Then with preliminary design of the superstructure, the substructure was fully designed, reviewed, approved, and construction began. During substructure construction, the prestressed beam design was finished and beams were fabricated to be ready when the substructure was completed. Lastly, the concrete deck was designed, completing the plan set.

Although both projects were in Ohio, the Ohio Department of Transportation's (ODOT) VECP guidelines are typical of many states. They require that the proposed changes have no adverse affect on service life, reliability, economy of operation, ease of maintenance, safety, necessary standardized features, and any engineering commitment such as environmental mitigation measures. Savings for the projects were calculated by the contractors, reflecting their reduced cost to construct the VECP bridge. ODOT, like many other states, does not consider life-cycle cost in VECP proposals.

ASHTABULA COUNTY, OHIO

US Route 20 over the Ashtabula River is a 1224-foot long bridge that crosses approximately 85 feet above the Ashtabula River and its floodplain. Originally designed as an eight-span bridge with seven steel plate girders, it was re-designed as a nine-span, prestressed concrete girder bridge through a Value Engineering Change Proposals (VECP). Palmer Engineering teamed up with Prestress Services (Decatur, Indiana) and the low bidder on the job, The Ruhlin Company (Sharon Center, Ohio), to propose a nine-span, prestressed concrete girder bridge (Fig. 1 & 2). Low bid for the original design from the 7 bidders was $10.7 million with the bridge representing $8.6 million of the bid. The VECP for the bridge redesign resulted in a savings of a little over $1 million, about 12% of the bid for the original bridge.

Fig. 1: Ashtabula Bridge Looking East

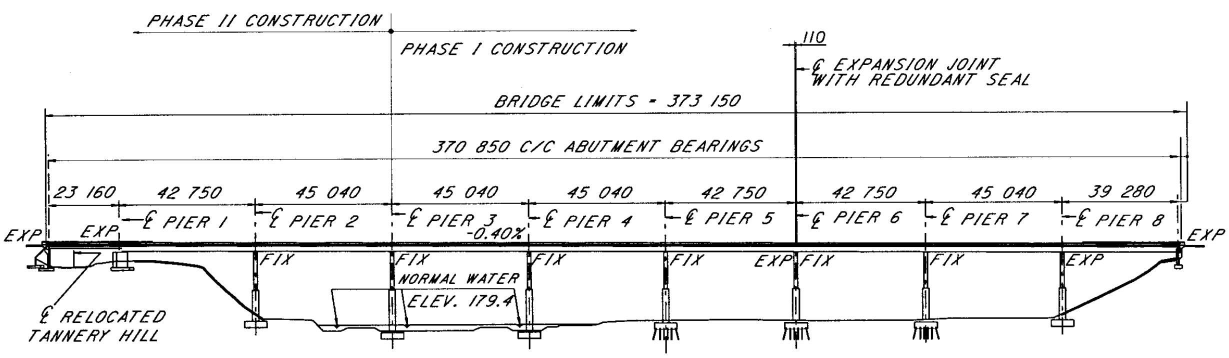

Fig. 2: Bridge Elevation (metric)

DESIGN FEATURES

The bridge is 75.9 ft. wide overall consisting of four driving lanes and a 9.8 ft. sidewalk on each side of the roadway. Pedestrians are separated from traffic by traffic barriers with bicycle-safe barriers and rails on the bridge fascias. Eight prestressed concrete I-beams spaced at 9.5 ft. with an 8.5-inch concrete deck comprise the cross section (Fig. 3). Type III PCI beams are used for clearance-restricted span 1 while 78-inch type IV modified PCI beams are used for the remaining eight spans of the bridge.

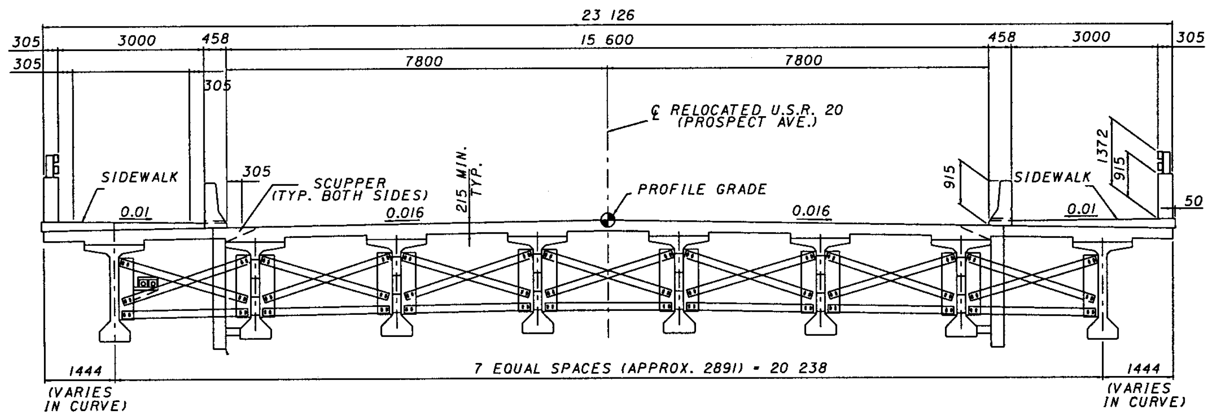

Fig. 3: Typical Deck Section (metric)

Piers for the nine-span redesign were positioned to avoid the main river channel, wetlands, and a local city street under span 1. Maximum spans are 147 ft. with the first four spans passing through a 2887 ft. (880 m) radius horizontal curve with the remaining five spans in a tangent. The moderate curve was accommodated with the prestressed beams by chording the spans from pier to pier and varying the overhangs (Fig. 4).

Fig. 4: Looking West (spans 1-4 curved)

The original bridge had a depth change in the steel girders toward the end of the first span, which allowed for shallower beams and more clearance over the city street under span 1. The VECP bridge accommodates type III PCI beams in the first span linked to type IV modified PCI beams in the remaining eight spans through a “link slab” (Fig. 5 & 6).

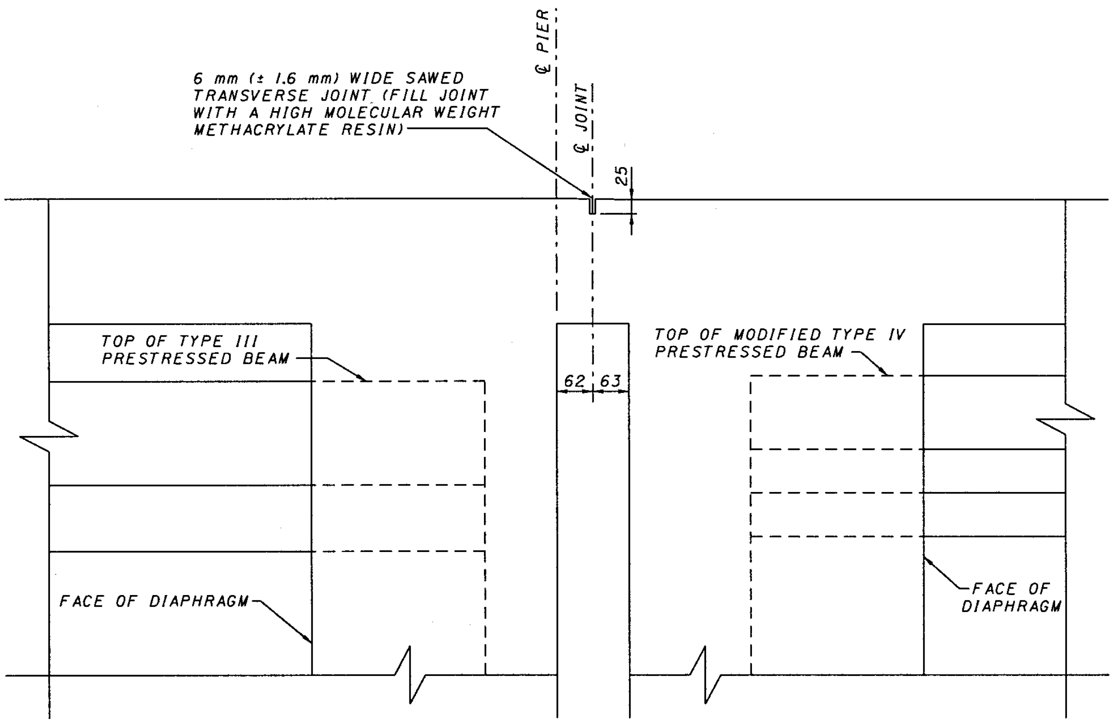

Fig. 5: Pier 1 section showing Link Slab

A ‘link slab’ eliminates the need for an expansion joint between span 1’s 45-inch deep type III PCI beams and the 78-inch deep PCI beams in the remaining eight spans. At the link slab pier, beam ends are designed as non-continuous simply supported ends. Girder stirrups are excluded from the slab for a length equal to 5% of the span in order to create a ‘debonded’ slab spanning a gap that is left between the diaphragms of the different size beams. A joint is sawcut in the slab over the gap and is then sealed with High Molecular Weight Methacrylate sealer for one foot on each side of the sawcut.

Tall piers were redesigned as two-column piers with a midheight strut. Pier 1 was a short wall type pier where the link slab joins the two different size prestressed girders. The contractor preferred to found the piers on spread footings instead of the original drilled shafts, where possible. After further evaluating his cost of constructing spread footings in a deep braced excavation versus the cost to drive piles, the contractor decided to change from spread footings to footings on steel H piles at piers 5, 6, and 7. This change was made “on the fly” in the fast-track design since redesign of all piers to spread footings on rock had already finished.

Because design thermal movements are smaller for concrete bridges than for steel bridges, the VECP bridge uses three strip seals instead of the original bridge’s two modular expansion dams. By judiciously locating fixed piers and positioning the third joint near the two-thirds point of the bridge, at pier 6, the thermal movements at the three joints were nearly equalized.

Fig. 6: Pier 1 - Link Slab at change in Girder Depth

TRADEOFFS

One tradeoff using a prestressed concrete superstructure versus the original steel plate girders is the span length that is economical for span-by-span construction. For this reason, one pier was added to the bridge with others repositioned for a more efficient span arrangement for prestressed girders.

Another tradeoff is the extra weight of the superstructure. The extra weight requires more substructure capacity than the lighter steel bridge would need. Heavier concrete beams also require larger cranes for erection and higher capacity bearings. However, the concrete beams have the advantage of being inherently more stable during erection. Sequencing and bracing during erection are not as complex or critical as for steel girders.

The VECP bridge uses three strip seals, at the bridge ends and at pier 6, instead of the original bridge's two modular expansion dams. The extra joint is a potential sight for leakage so the joint at pier 6 incorporates a redundant compression joint seal (Fig. 7). The compression seal is below the strip seal and is included strictly as a corrosion preventative measure. ODOT viewed the three strip seals of the VECP bridge as comparable the two modular expansion dams of the original design. As added corrosion protection, every prestressed beam framing into an expansion joint was sealed with epoxy urethane for ten feet from its end.

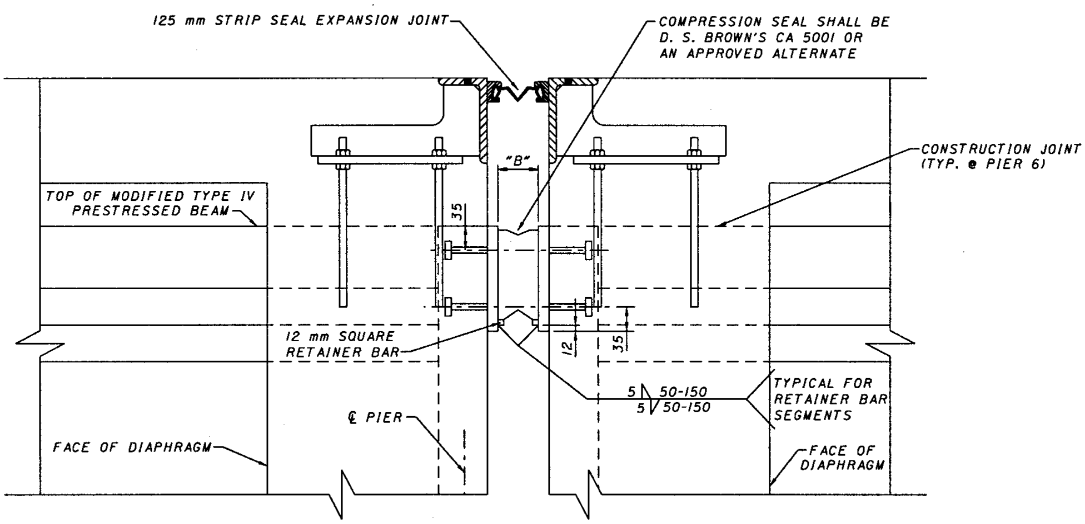

Fig. 7: Pier 6 Expansion Joint (redundant compression seal)

Other tradeoffs are more subjective such as bridge aesthetics. The original design called for weathering steel girders on hammerhead type piers. The VECP bridge uses prestressed concrete girders on more open H-type piers. The exterior of the beams and the above ground portion of the piers were completely sealed with epoxy urethane sealer in order to provide a uniform appearance.

Fig. 8: Looking East from Ashtabula River

LORAIN COUNTY, OHIO

State Route 254 over the Black River is a 1420 foot-long bridge that crosses approximately 85 feet above the Black River and its floodplain. The original design plans called for a six-span bridge with six steel plate girder bridge supported on two-column, hollow, tapered piers. Palmer Engineering teamed up with Prestress Services (Decatur, Indiana) and the low bidder on the job, Kokosing Construction (Fredericktown, Ohio), to propose a twelve-span, prestressed concrete girder bridge supported on single column hammerhead piers (Fig. 9 & 10). Low bid for the original design from the 11 bidders was $12.95 million with the bridge representing $10.4 million of the bid. The VECP for the bridge redesign resulted in a savings of a little over $2 million, about 19% of the bid for the original bridge.

Fig. 9: Lorain Bridge Looking West

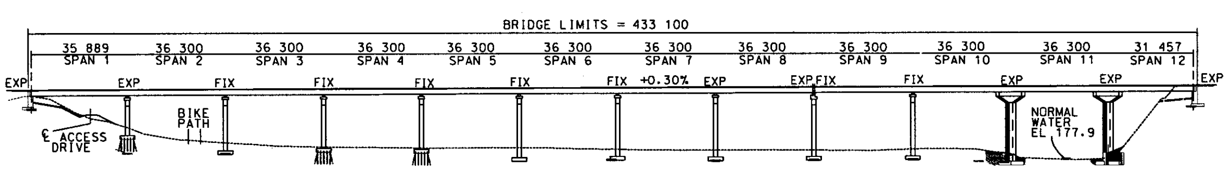

Fig. 10: Elevation View

DESIGN FEATURES

The bridge is 63 ft. wide overall consisting of four driving lanes and a 4.9 ft. sidewalk on each side of the roadway. Seven prestressed concrete I-beams spaced at 9.4 ft. with a 9.4-inch concrete deck comprise the cross section (Fig. 11). Type IV modified PCI beams, 66 inches deep, are used for all spans of the bridge.

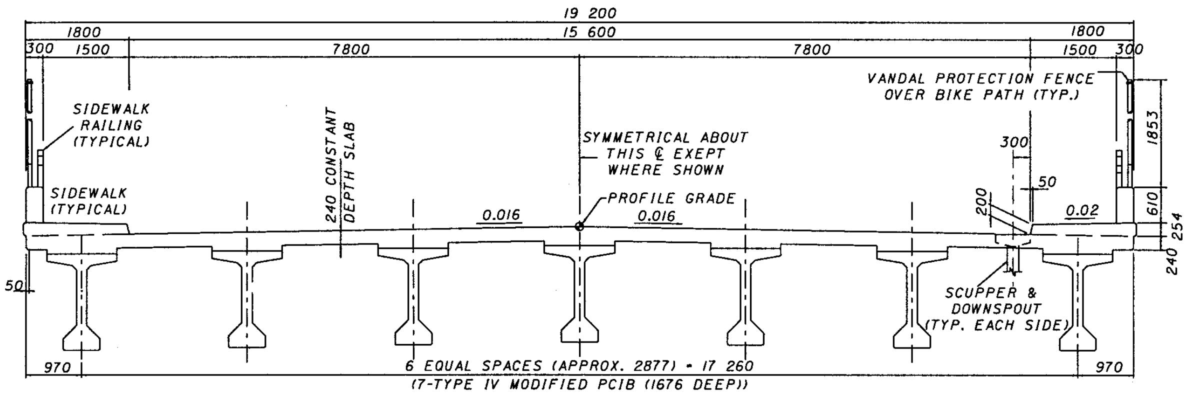

Fig. 11: Typical Deck Section

Piers for the twelve-span redesigned bridge were positioned to avoid a Lorain County Metro Parks Department (LCMPD) access road under span 1, the LCMPD walking/bike path, wetlands, and the main channel of the Black River. Maximum spans are 119 ft. with the roadway being in a constant 0.3% uphill grade and tangent.

Piers were redesigned as single-column hammerhead piers with piers 10 and 11 being skewed to better align with the flow of the Black River. Similar to the Ashtabula project, the contractor decided to change from spread footings to footings on steel H piles at piers 1, 3, and 4. This change was made “on the fly” in the fast-track design since redesign of all piers to spread footings on rock had already been completed. The contractor also had features “designed in” to the piers such as greater lift heights on concrete pours, resulting in fewer pours and fewer lapped rebars to tie. Also, specific rebar configurations were requested and designed in which lead to efficient construction of the piers.

The area of the Black River and its floodplain where the bridge crosses is owned by the LCMPD. A bike path through the parkland crosses under the bridge and is heavily used during good weather. Because of the bridge’s exposure to the public’s view, aesthetics of the proposed bridge was a concern of ODOT and the Lorain County Metro Parks Department. To help assess the visual impact of the proposed bridge, Palmer Engineering prepared 3-D computer renderings of the proposed bridge (Fig. 12). These renderings were presented to ODOT and LCMPD and any concerns about the aesthetics of the proposed bridge were eliminated.

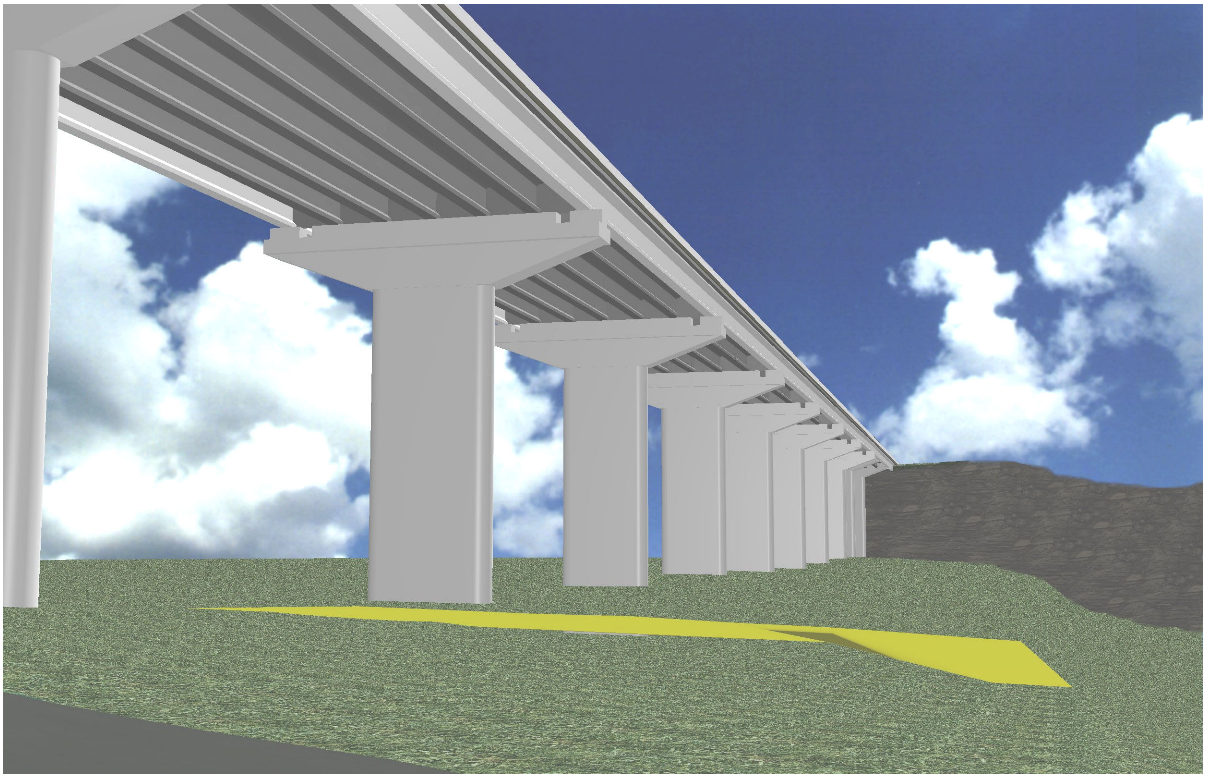

Fig. 12: 3-D Rendering of Proposed Bridge

The original bridge was designed so that future inspections could be conducted without the use of a snooper truck. Similarly, the VECP bridge incorporated this inspection facilitating feature. Access hatches in the sidewalks allow an inspector to descend a ladder from roadway level down to the pier caps (Fig. 13). From there, the inspector can traverse the pier caps on built-in walkways in order to inspect the bearings. Pass-through openings in the pier caps allow for inspection of both sides and built-in inspection tie-offs keep the inspector safe.

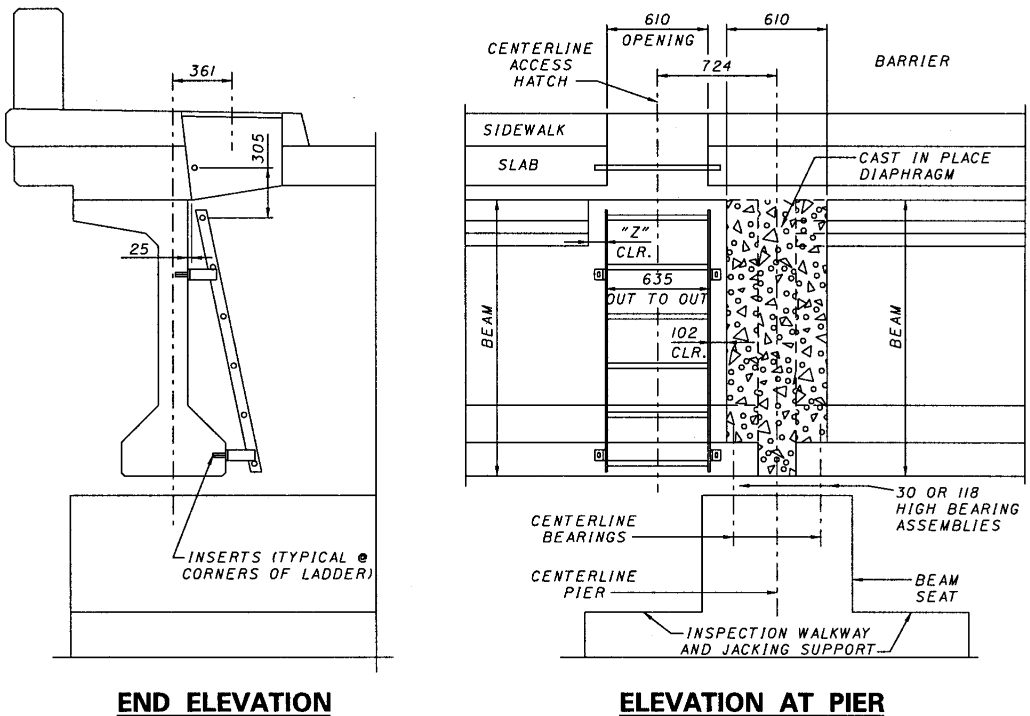

Fig. 13: Inspection Access Hatch and Ladder

An ever-present concern is leakage of corrosive salt water through expansion joints in bridges. The Lorain County bridge was originally designed with a leakage collection system at the expansion joints. Palmer Engineering was able to incorporate extensive corrosion protection in the re-designed bridge. For example, the original steel finger joints were replaced with a leak-resistant strip seals. Also, a neoprene leakage collection system captures any leakage through the strip seal and pipes it to the ground. Additionally, the ends of the prestressed concrete beams were completely sealed for 15 feet on each side of the expansion joint with epoxy urethane sealer. Further, the beams were elevated slightly above the pier caps by the use of steel stub columns to ensure that the bottom of the beams remain dry. Altogether, these redundant design features should prevent corrosion in the event the strip seal fails to prevent leakage.

Because design thermal movements are smaller for concrete bridges than for steel bridges, the VECP bridge uses three strip seals instead of the original bridge's three steel finger expansion joints. By judiciously locating fixed piers and positioning the third joint near the two-thirds point of the bridge, at pier 8, all strip seals have approximately the same movement demand. Also, the original steel rockers and bolsters were replaced with steel reinforced elastomeric bearings.

Fig. 14: Lorain Bridge Looking East

TRADEOFFS

One tradeoff using a prestressed concrete superstructure versus the original steel plate girders is the span length that is economical for span-by-span construction. For this reason, six piers were added to the bridge with others repositioned for an efficient prestressed girder span arrangement. This increase in substructure does create more piers and bearings to inspect. However, by using proven types of piers and elastomeric bearings, future maintenance should not be increased.

Another tradeoff is that the extra weight of the concrete beams requires more substructure capacity, larger cranes for erection, and higher capacity bearings. These effects were somewhat offset because spans lengths were significantly reduced by doubling the number of spans. On the other hand, concrete beams have the advantage of being inherently more stable during erection. Sequencing and bracing during erection are not as complex or critical as for steel girders.

The VECP bridge uses three strip seals, instead of the original bridge's three steel finger expansion joints. Also, the original steel bearings were replaced with elastomeric bearings. While still debatable, we feel that the strip seals and elastomeric bearings are improvements for long-term maintenance. Additionally, the original bridge was to be painted and might have warranted future painting which is eliminated by using prestressed concrete.

Fig. 15: Spans 1 & 2 as seen from Bike Path

Other tradeoffs are more subjective such as bridge aesthetics. The original design called for weathering steel girders on five, two-column piers. The VECP bridge uses prestressed concrete girders on eleven single-column hammerhead piers. The exterior of the beams and the above ground portion of the piers were completely sealed with epoxy urethane sealer in order to provide a uniform appearance. Because this subjective tradeoff was a major concern early on, 3-D computer renderings were used to evaluate the proposed bridge's appearance. After viewing the computer renderings, the governing agencies decided this was an acceptable tradeoff.

Fig. 16: Looking West from Black River

CONCLUSIONS

Fast-track design allowed the contractors to begin building the substructure before the final superstructure was designed on these two Value Engineering projects. Fast-track design can seem unnatural for designers accustomed to the traditional design process. Parts of the bridge were being constructed as soon as the designs were approved, with other portions of the bridge yet to be designed. However, although the time frame is greatly compressed with a fast-track approach, the engineer's path is still a logical progression through the design.

The two case studies serve to illustrate the economy of prestressed concrete bridges when bridge sites allow for span-by-span construction with spans of less than 150 feet. Value Engineering is effective for states because it allows them to 1) approve only those changes they deem acceptable and 2) know the cost savings before approval is granted. A VECP is a way for contractors to explore alternate methods, technologies, or materials, tailored to their own equipment and experience that will earn them profit for their resourcefulness. For designers, Value Engineering is a relatively new way to do business, working directly with a contractor, where alternate designs can be proposed.