How to Build a 700 Ft. $20M Concrete Bridge in One Year

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ABSTRACT

The 1930 Perry Street Bridge was a sand filled concrete arch bridge with seven spans of 103 ft. in length for a total length of 721 ft. The badly deteriorated old bridge was the only transportation avenue from North Napoleon to South Napoleon across the Maumee River. All emergency services and the schools in Napoleon are located on the North side of the Maumee River and half the people live on the South side.

The Ohio Department of Transportation (ODOT) asked if the bridge could be replaced during one year of construction. The Department knew they would have to provide temporary emergency services for South Napoleon.

Two other design parameters were imposed upon the new design. The new bridge had to look exactly like the old sand filled arch structure. And work disturbing the river bottom for a period from April 15 to July 15 was disallowed.

The basic assumption for the new bridge was a variable depth, spliced, deck bulb-T precast prestressed girder bridge which is proportioned to look exactly like the old bridge.

Also to meet the time requirements, it was decided to construct the new drilled shaft piers through the middle of the old piers so the construction would not touch the river bottom.

The roadway was closed for construction on Feb. 1 2005 and the ribbon was cut on the completed new bridge on Oct. 29, 2005.

KEYWORDS; Critical Bridge, Environmentally Sensitive Site, One Year Of Construction, Totally Precast Design, Spliced PPC Girders, Variable Depth Girders, Spliced Tendons

INTRODUCTION

Designed in 1928 and built in 1930, the Perry Street sand filled concrete barrel arch bridge had served the citizens of Napoleon, Ohio well. Being the only crossing of the Maumee River, the bridge carried school children, workers, police and fire emergency personnel and medical emergencies from South Napoleon to North Napoleon and back home again. But over 70 years of dutiful service had taken its toll on this formidable and important structure. It was getting old and deteriorated.

Fig. 1 The 1930 Perry Street Bridge in Napoleon, Ohio before replacement

In 2000, a study[1] was performed relative to replacing the old bridge with a new one at the same or nearby location. During this study period, the citizens of Napoleon made their wishes known regarding the location and appearance of the new construction. The environmental documents were also prepared during this study period.

The Ohio Department of Transportation (ODOT) decided the best course of action was to rehabilitate the old bridge to such an extent that it would remain serviceable until a second new bridge could be constructed at some other location in Napoleon so that two crossings would be available to the folks living in Napoleon. ODOT ear marked $15M to Henry County for the purpose of designing and building the second bridge. ODOT also advertised a design/build contract to rehabilitate the Perry St. Bridge.

However as the rehabilitation project began with removing old concrete, the workers began chipping away the old concrete spandrel beam and could not find sound concrete for a stopping place. The District (ODOT District Two, Bowling Green, Ohio) asked the designer to visit the site and help make an assessment of the situation.

During a conference telephone call, the Ohio Department of Transportation asked if a design and construction methodology could be developed which could build a replacement bridge in one year. A commitment was made that if the construction could be timed correctly, the old bridge could be demolished and a replacement bridge be built in one year.

Thus the Perry Street Replacement Bridge Project was born.

CONCEPT DEVELOPMENT

Four parameters defining the design and construction of the replacement structure weighed heavily on the development of the concepts to be incorporated in the project. These parameters were defined by the public meetings with the citizens of Napoleon, the environmental documents and the time commitment to the Department. The four parameters were:

1. The new bridge had to look exactly like the old bridge. It had to be the same shape and have the same number of spans.
2. Construction could not disturb the bottom of the river from a period beginning on April 15 to June 15 because of fish spawning.
3. The new bridge had to be constructed in the same location the existing bridge occupied.
4. The old bridge had to be demolished and replaced with the new bridge in a single year.

The initial concept was to incorporate as much precast concrete as possible. This would allow casting the pieces to begin in the winter prior to the year of construction. Thus the onsite construction would be limited to building foundations and erecting the pieces of concrete. Since the new design had to replicate the arches which determined the size of the concrete beam sections, it was decided to attempt to design the new bridge for zero tension in the concrete similar to the design criteria used for segmental box girders. The replication of the arches provided plenty of concrete to carry the stresses which enabled the achievement of the zero tension state in both the longitudinal and transverse directions except for a few longitudinal sections under live load applications.

The bridge had to consist of seven spans measuring 103 ft. in length exactly like the old bridge. In the evaluation, a five span bridge would probably have been less expensive. The variable depth sections to replicate an arch meant the spans would be substantially too heavy to haul an entire span length of beam to the erection site. Thus the decision was made to incorporate cast-in-place splices in the spans to get the length and weight of the modules to a magnitude which could fit on a truck trailer.

A quick construction schedule was completed to determine how much time was required to build the seven spans. A decision had to be made regarding the casting of the bridge deck. Should the deck be cast in place conventionally or should the engineers design and detail something in precast concrete? The preliminary construction schedule quickly showed that insufficient time was available to cast the 700 ft. by 73 ft. bridge deck in place. The Department wanted the new bridge to carry four lanes of traffic with full shoulders and sidewalks resulting in a new bridge which is wider than the old bridge.

During the conceptual phase, an initial construction cost was developed to assist the Department in budgeting and encumbering funds for the project. The final concept incorporates a combination of precast prestressed construction schemes all of which have been used individually but, to the designer's knowledge, had never been used in this exact combination.

Thus there was a concern of possible extra costs related to contractor perceived risks. To help allay these concerns, the design team met with representatives of the precast concrete industry in Ohio and held two contractor seminars where the concepts were explained and both precaster and contractor input was requested. Both groups provided very valuable information and seemed to appreciate the opportunity to participate. The discussions were much livelier than expected in the beginning. The bid results indicated some success of alleviating risk concerns.

During concept development, a scheme was devised enabling construction of drilled shafts in the river all spring while being in compliance with the April 15 to June 15 river work restrictions. The solution was to drill shafts through the existing piers which were founded with spread footings on shale. This concept is addressed more completely in the DESIGN SECTION.

The final cross-sections developed during the conceptual phase included a precast deck bulb-T which has proved efficient in carrying longitudinal loads and a variable depth slab with minimum thickness of 81/2 in. cast monolithically with the bulb-T section. To simulate the arch of the old bridge, the deck bulb-T sections were set to a 12 ft.-0 in. depth over the piers and 4 ft.-0 in. depth at midspan. The beams were to be spliced at the quarter points of the spans resulting in all modules being approximately 50 ft. in length and of similar weights. The exception is the end-span modules which are 75 ft. in length and are heavier.

Precasters indicated they could build the modules to a straightness tolerance of ½ inch for the 50 ft. lengths because they are extremely stiff. Thus the joints were detailed to separate the adjacent slabs to be plus or minus ½ inch and required the joints to be filled with a stiff grout which had to be troweled into the joint.

Fig. 2. The longitudinal slab joints and transverse post-tensioning tendon block outs are shown after filling with epoxy grout and concrete.

The edge of the slab was cast with a small ledge to hold the grout in place. The contractor was advised that the designer did not want any of the adjacent slabs to be touching because there was not enough capacity in the ledges to carry the transverse post-tensioning loads. The Department also wanted the bottoms of the joints to be sealed to prevent any grout from leaking through the joints.

DESIGN

Substructure

The critical element in meeting the desired one-year construction schedule was the construction of the substructure. As previously mentioned, the schedule was made more difficult by the restrictions on construction in the river during spawning season. During the preliminary meetings with contractors, they identified a key to rapid construction of the piers as re-use of the existing pier bases. However, the erection of precast modules resulted in construction loads exceeding the capacity of the existing spread footings. Also, the condition of the existing pier concrete was in doubt even though cores indicated 8000 psi concrete strengths. Compliance with the restrictions and contractor input was accomplished by designing the piers to be supported on drilled shafts which would be drilled through the existing pier bases. The existing pier bases were to be left in place from the waterline down. Substructure work after the installation of the drilled shafts would take place above the waterline and therefore would not be subject to the restrictions.

Fig. 3 Pilot holes, 42 in. in diameter, were drilled full depth through the leveling course and existing pier.

To further expedite the substructure construction, the piers were designed as cap and column type piers with precast pier caps. In order to reduce their weight, the precast caps were divided into three sections which would be post-tensioned together. (The abutment beam seats were also designed as precast sections.) Since the aesthetic requirements dictated that the piers should be wall type piers, the plans included a cast-in-place fascia wall surrounding the pier columns. If necessary to meet the schedule, this fascia wall could be constructed after the superstructure was in place. The piers would be constructed from a combination of causeways and barges. An alternate for precasting panels and attaching them to the caps to serve as curtain walls was allowed in the contract documents.

Superstructure

The superstructure consists of three precast elements: pier modules, mid-span modules, and end-span modules (see Figure 9). The superstructure was analyzed using a rigid frame time dependant concrete analysis computer program. The program allows the bridge to be constructed piece by piece within the model and tracks the forces generated during erection as well as the time dependent effects. The design concrete strength for the precast modules was 5,500 psi at release and 7,000 psi at 28 days, which is typical for Ohio Department of Transportation projects. The modules were designed using a combination of pretensioned and post-tensioned tendons. The pretensioned strands were used to control the stresses during shipping and erection. The number of pretensioned strands varied for each type of module. The continuity post-tensioning consists of two 3 in. diameter ducts with 12-0.6 in. strands in each duct. Tendon couplers were used on the post-tensioned tendons to shorten the length of duct that the strands would have to be fed through. This would also allow the contractor to re-use some of the strongbacks and to begin the transverse post-tensioning earlier. The transverse post-tensioning ducts were designed to be installed parallel to the top of the flange and the depth of the flange was varied to achieve the required eccentricity by varying the center of gravity of the concrete with respect to the center of gravity of the pretensioning strand.

The design construction sequence was as follows. First, the pier modules are installed and temporarily fixed in place at piers 1 and 2. Next, the span 2 mid-span module is set in place on strongbacks. Then the span 1 end-span module is placed. The closure joints are then poured and these four segments are post-tensioned together. Next, the pier 3 modules and span 3 midspan modules are placed, the closure joints are poured, and the tendons are coupled and stressed. The span 3 process is then repeated at spans 4 and 5. Finally, the pier 6 modules, span 6 mid-span modules, and the span 7 end-span modules are placed, the closure joints are poured, and the tendons are coupled and stressed. The transverse post-tensioning could begin in a span when erection had preceded at least three spans beyond the last span to be transversely stressed.

Fig. 4 Post-tensioning tendon couplers were utilized to provide continuous prestress in the longitudinal direction of the bridge and to prestress the cast-in-place splice joints. The plastic duct had to be modified to allow movement of the anchor casting during subsequent tendon stressing after the closure joint was placed. The duct modification was fabricated from plastic five gallon buckets.

CONSTRUCTION

Bidding

Bids were taken by ODOT on July 14, 2004 as scheduled. The low bid for the A+B contract totaled $19,855,220 with 250 days at $10,000 per day. That computes to be a construction cost of $17,355,220 or a square foot cost of $330 per square foot.

The square foot cost is high for three reasons. As previously mentioned, we determined that a five span structure would be more economical than a seven span structure, but the citizens wanted seven spans. The extra concrete required to simulate an arch structure added to the cost. The third factor is the requirement to build the bridge in one year requiring us to develop and use some details which led to speed of construction at an increase in the cost e.g. precasting slabs on the beams versus casting the slab in place in a conventional manner.

The roadway was shut down on Feb.1, 2005 and the construction commenced with the demolition of the existing bridge. The contractor chose to remove and dispose of the top slab and the fill in the arches with a back hoe per the requirements of the environmental documents. Then the arches were charged with explosives and dropped into the river where the pieces of concrete were removed with the back hoe. As mentioned in the design section, the existing piers were cut off near the water line.

Module Fabrication

Since the winning bid was submitted by a prime contractor who was already building a large precast segmental concrete cable-stayed bridge in Toledo, some 30 miles East of Napoleon, they chose to precast the modules in the Toledo casting yard and haul them to Napoleon. The contractor constructed three casting beds for the pier modules, mid-span modules and the end-span Modules. They purchased two sets of forms each for the pier modules and the mid-span modules. The total project includes 54 pier modules, 45 mid-span modules and 18 end-span modules. The casting was started in early March of 2005 and completed in July of 2005 so that all the modules were essentially ready and waiting by the time on-site erection started.

Fig. 5 Pier module segments were stored in the casting yard. The module in the fore ground with 03-04-05 casting date was the first module to be cast for the project. The top post-tensioning tendon is stressed in the form to carry the dead load handling stresses in the pier module.

Fig. 6 The mid-span modules had to be supported from tipping over due to the center of gravity being right underneath the top slab.

The Contractor only made one major revisions to the design details for the casting. Because the Pier Modules were 12 ft. in depth, they chose to change the pretensioning tendons near the top to post-tensioning tendons. This change eliminated the requirement to construct substantial bulkheads to support the pretensioning force 10 to 12 ft. up in the air.

The Contractor also chose to cast the piers in place rather than utilize the precast alternative. They were concerned about attaching the precast panels to the precast caps.

The Mid-Span Module beds were set up for pretensioning to carry dead load stresses during handling and hauling. The two sets of forms were set in series so that a single stressing operation stressed both beds prior to placing concrete in the individual forms.

Hauling

The prime contractor contracted with a specialized transportation firm to haul the modules from Toledo to Napoleon. The modules were of three distinctive shapes and weights resulting in the hauler providing three different trailer configurations. The loads were all permit loads which had to stay on State highways and two of the module types required police escorts because of their weight and size. The hauler also had to deal with curfews from the City of Toledo to get the heavy loads out of town before or after rush hours.

However, the transporting of the modules to Napoleon went flawlessly. They achieved an average delivery rate approaching three modules per day.

Fig. 7 The first module arrived at the site for erection on June 29, 2005. Special trailers were required to haul each of the different types of modules from the casting yard in Toledo to the construction site in Napoleon.

Erection

When performing the design computations, the designers assumed the bridge would be erected from barges with barge mounted cranes. However, possible alternatives were discussed during the contractor work shops.

The Contractor chose to erect the modules with the assistance of a rock causeway placed in the river allowing sufficient flow to maintain the river levels. They were only flooded out once which cost them two weeks but they were two weeks ahead of schedule on the bridge at the time.

The temporary causeways proved to be a wise choice with the dry summer experienced in Northwest Ohio. Much of the time, the barges used were dragging bottom because of the low water levels of the Maumee River.

All of the modules were placed with large cranes located on the rock causeways. Man lifts and smaller equipment was placed on barges for worker access in the river opening.

Fig. 8 The contractor chose to erect pier modules on piers 1, 2 & 3 in the first unit making the first post-tensioning tendons one span longer than was assumed in the design requiring no design changes but a shop drawing modification.

Longitudinal and Transverse Stressing

The longitudinal and transverse post-tensioning tendons were installed and stressed without significant problems. They hung one of the tendons up when installing the tendon prior to the closure joint concrete setting up. They also had some problems pushing the transverse strands through the junctions of the slab joints. It seemed to depend on whether the laborers cut the ducts at the high or low points. A larger strand pusher helped that problem.

Fig. 9 Completed Bridge Photo by Grand Lubell Photography

CONCLUSIONS

All of the goals of the project were achieved. The Perry St. Bridge replacement was completely constructed in one year. The biggest reason the schedule was successful was a high degree of cooperation among the Contractor, the owner construction personnel and the design engineer. Most of the problems were solved before they really became problems and affected the schedule.

From all reports, the fine citizens of Napoleon and Henry County, Ohio are pleased with the final results. There were a substantial number of them standing at the ends of the construction as sidewalk superintendents reviewing every move the contractor made during construction. We believe they feel they were a part of the success of the project and indeed they were.

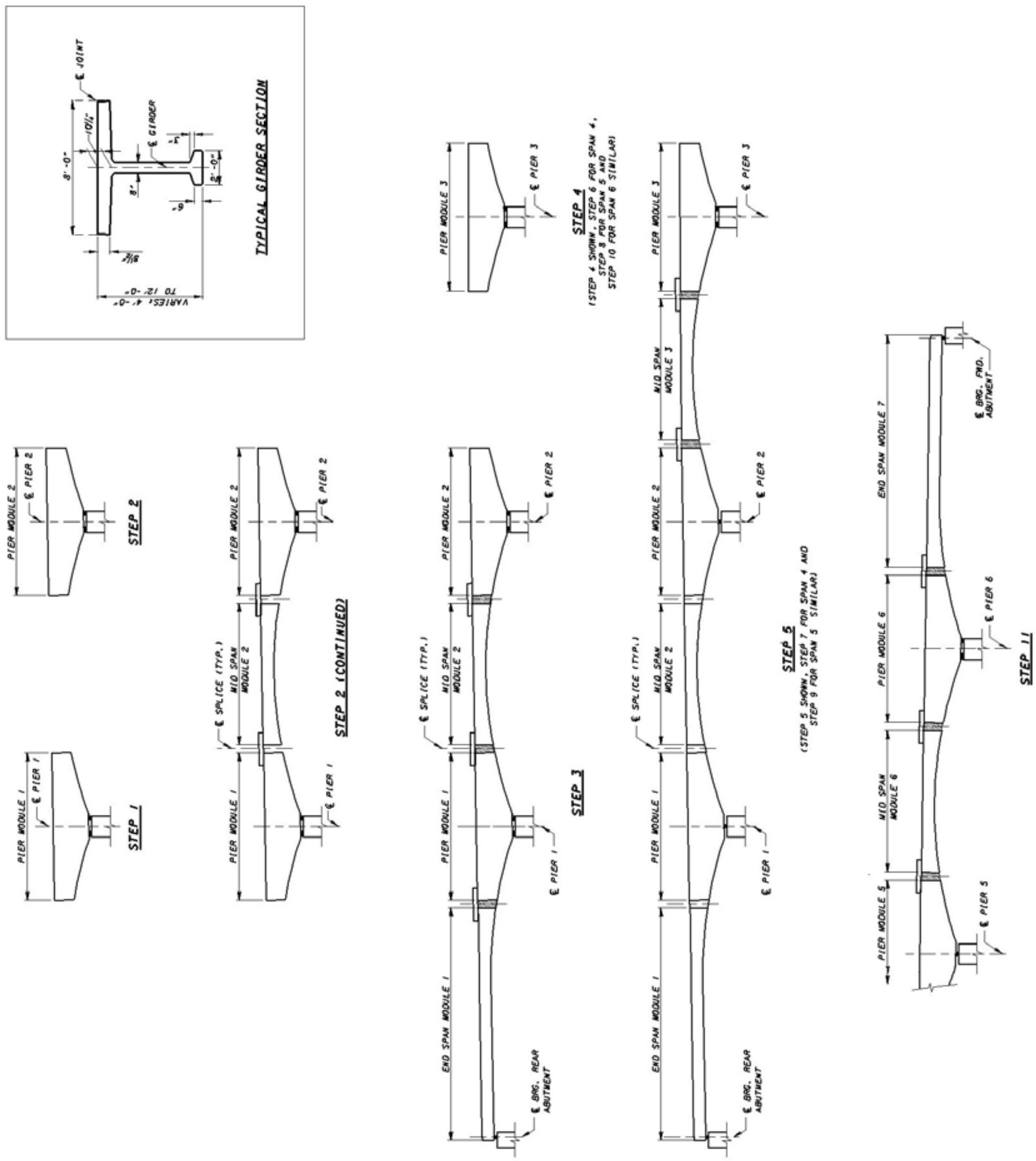

Figure 9 . Cross Section of Deck Bulb T Section and the Construction Sequence.

Reference 1: Sverdrup Associates Inc.,*HEN-108-15.55,Structure Preliminary Design Report,* Ohio Department of Transportation, September 20, 2000