RAPID CONSTRUCTION OF IN-WATER PRECAST CONCRETE PIERS ON THE ROUTE 70 OVER MANASQUAN RIVER BRIDGE REPLACEMENT PROJECT

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ABSTRACT

In recent years, the use of precast concrete bridge components has increased dramatically. Precast components offer significant advantages over cast-in-place concrete including rapid construction, improved durability, reduced environmental impacts, reduced on-site labor and improved work zone safety. While precast superstructure components, such as concrete girders, parapets and deck slabs have seen widespread use, precast substructure components have had only limited application. Using precast concrete substructures can have tremendous impacts on a bridge construction schedule through time saved in establishing a work zone, forming, placing reinforcement, placing concrete, stripping formwork and curing; all of which can be accomplished off site and in parallel with other construction operations[1]. On the Route 70 over Manasquan River Bridge Replacement Project the in-water pier construction was subject to environmental permit restrictions and schedule constraints, which influenced the pier design and method of construction. To meet the project needs a precast pier solution was developed. Using precast cofferdams, columns and pier caps connected by post-tensioning, the contractor achieved an efficiency of 19 working days per pier and accelerated the completion of the first half of the bridge. The project is approximately 700 calendar days ahead of schedule and is anticipated to be complete in December 2008.

Keywords: Accelerated Bridge Construction, Precast Concrete, Piers, Cofferdams, Columns, Cap Beams, Rapid Construction, In-Water, Piers, Aesthetics, Post-Tensioning, Substructures

INTRODUCTION

It has long been a goal of the Federal Highway Administration (FHWA) and the New Jersey Department of Transportation (NJDOT) to implement a “Get in, get out, stay out” approach to bridge and highway construction projects[2]. One of the primary methods of implementing this strategy is to employ prefabricated bridge elements and systems. Since the existing Route 70 over Manasquan River bridge was structurally deficient and functionally obsolete, the NJDOT recommended it for replacement. In January 2001, NJDOT challenged its design consultant, Arora and Associates, P.C., to provide a design that would allow for the accelerated construction of the project by using precast concrete substructure components that could be fabricated off-site, shipped to the project site and then quickly assembled. To satisfy environmental in-water work restrictions, it was critical to develop a structural system for the bridge piers that would allow the contractor to complete the pier construction as quickly as possible and with a minimum of environmental disturbances.

BACKGROUND

The Route 70 over Manasquan River Bridge (Structure No. 1511-150) crosses a navigable waterway and is considered a gateway to both Monmouth and Ocean Counties in the coastal region of the State of New Jersey. The bridge serves vehicular, pedestrian and marine traffic at this crossing. The original bridge was constructed in 1936 and was 625-ft long with a single leaf bascule span over the navigation channel. The 17 approach spans were supported on reinforced concrete pile bents (see Fig. 1).

Fig. 1. Existing bridge elevation.

The bridge was in poor condition due to a number of substandard elements. The pile bents had been repaired but continued to deteriorate at the waterline, the abutments had experienced movement and the deck exhibited cracks, spalling and efflorescence. The movable span had been retrofitted with a sprinkler system to cool the movable span and prevent it from becoming stuck in the open position during the summer months. The bridge had been given an overall sufficiency rating of 20.6 out of 100. The bridge also did not meet current geometric standards. It only provided 11-ft travel lanes, a 50-ft navigation channel and a 15-ft vertical underclearance. Due to its low underclearance, the bridge had to be opened on demand to allow for the passage of marine traffic, which caused disruptions and impeded the flow of vehicular traffic along the Route 70 corridor.

THE PROJECT

The proposed replacement bridge is the centerpiece of a $52 million project that will carry the dualized section of Route 70 across the Manasquan River and provide a missing link along the Route 70 corridor (see Fig. 2). The project will also provide for the long-term regional vehicular and marine transportation needs along the Route 70 corridor and the Manasquan River. In addition to these considerations, the NJDOT and FHWA have a goal of eliminating movable bridges, where possible, to eliminate traffic delays, facilitate the passage of emergency response vehicles, reduce annual operating and maintenance costs and to provide for a more reliable, passive transportation infrastructure.

Fig. 2. Architectural rendering of the proposed replacement bridge.

The bridge section will have a 2'-8" median, one 4'-8" inside shoulder, two 12-ft lanes and one 10-ft outside shoulder in each direction. 6'-0" sidewalks and 1'-4" parapets will be included on each side of the bridge. The project will widen the bridge from 56'-10" to 94'-8" and shift the centerline of Route 70 by 28'-10" (see Fig. 3).

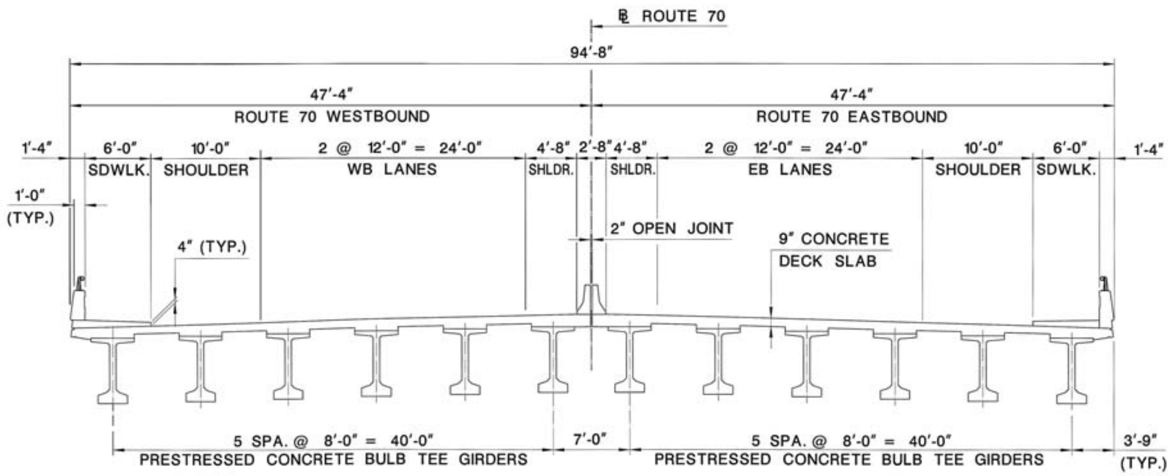

Fig. 3. Superstructure cross section.

The 724-ft long, fixed bridge will consist of twin structures, each having two three-span continuous superstructure units (119'-120.25'-120.25') comprised of bulb tee girders spaced at 8'-0" on center. The superstructure will be supported on two abutments and five architecturally treated in-water piers with pile foundations. With this span arrangement, the proposed bridge foundations can be constructed adjacent to the existing bridge foundations. Marine traffic needs will also be accommodated by increasing the bridge underclearance to 25-ft, widening the navigation channel to 75-ft and shifting the centerline of channel 15-ft towards the centerline of the river.

In addition to the bridge replacement and roadway widening, the project included many additional elements. A new bridge fender system and a public fishing pier were both designed using Fiber Reinforced Polymer (FRP) composite piles and lumber. Retaining walls, bulkheads, ramps, traffic signals, water quality stormwater management retention basins and manufactured treatment devices (MTDs), highway lighting, ITS improvements and utility relocations were also included.

CONTEXT SENSITIVE DESIGN

Early in the project, NJDOT requested that bridge architectural recommendations be developed to enhance this gateway structure and provide a well-balanced, aesthetically pleasing structure that would fit into this unique river environment. The needs of the surrounding communities of Brick Township and the Borough of Brielle were taken into consideration through a series of public meetings. The community involvement process resulted in a revision to the bridge height, changes to the project footprint and the addition of 1,677 linear feet of precast concrete noise walls.

During the final design phase of the project, the bridge was designated as the "September 11 Memorial Bridge" by the State of New Jersey in remembrance of the 166 people from Monmouth and Ocean Counties who died in the September 11, 2001 terrorist attacks. The project scope was then enhanced to include additional architectural treatments, pylon monuments, plaques and signage with landscaping.

TRAFFIC CONTROL

Route 70 is a heavily traveled regional corridor with a Two-Way A.D.T. (2005) of 32,300 vehicles. Since Route 70 is also a coastal evacuation route, NJDOT required two lanes of traffic be maintained in each direction during construction. To address the maintenance and protection of traffic needs and minimize the amount of right of way purchased to construct the project, it was decided to construct the project in stages and on a parallel alignment shifted approximately 29-ft south of the existing crossing.

After performing a partial demolition of the existing bridge, the eastbound bridge structure would be constructed approximately 3-ft from the south fascia of the existing bridge. Traffic would then be transferred onto the newly constructed first half of the bridge (see Fig. 4).

Fig. 4. Traffic has been shifted onto the newly completed eastbound half of the bridge and the existing bridge is being demolished.

Traffic would be maintained in four 10'-11" wide temporary lanes, which would utilize the entire bridge deck surface including the sidewalk and shoulder areas. Pedestrian traffic would be maintained on a temporary structure cantilevered off the south fascia of the eastbound structure. Demolition of the existing structure could then be performed, followed by the construction of the second, westbound half of the bridge next to the north fascia of the eastbound structure. A final stage would then be required to shift traffic into its final lane configuration.

ENVIRONMENTAL

In-water work restrictions were stipulated in the environmental permits issued by the United States Army Corps of Engineers in their Nationwide Permit 23 and the New Jersey Department of Environmental Protection in their CAFRA and Waterfront Development Permits. To protect the winter flounder and anadromous (alewife) fish runs during migration and spawning, a timing restriction of January 1st to April 30th was imposed to prohibit in-water construction activities and to reduce the possibility of increased turbidity. Additional permit considerations were to minimize impacts to coastal wetlands, subtidal/intertidal shallows and State open waters.

The investigation of the project site also uncovered the presence of salt laden soils, arsenic and beryllium in the riverbed sediments. To address these conditions, the project footprint in the riverbed was reduced to minimize the amount of riverbed sediments that would need to be excavated to construct the pier foundations.

Using the proposed construction sequence, a total of ten pier halves would be constructed in the river. Demolition of the existing bridge and construction of bulkheads at the proposed abutments would also be subject to the same in-water work restrictions. If a rapid method of pier construction was not utilized, the project schedule could become susceptible to impacts from winter concrete construction restrictions. Any delay in the construction schedule would require that traffic be maintained in the temporary lane configuration for up to an additional construction season, which would result in increased user costs and inconvenience to the motoring public. Therefore, it was critical to design the piers so that they could be constructed quickly and the superstructure construction advanced before cold weather could delay the project.

PIER AESTHETICS AND PRECAST SOLUTION

Arora studied the project aesthetic issues with its architectural subconsultant H2L2 Architects/Planners, LLP and the NJDOT Bureau of Landscape and Urban Design. Traditional solid-shaft and multi-column pier types constructed on plinths were evaluated against more creative architectural concepts[3]. The preferred alternative, which resulted from the architectural study, was to use V-shaped piers, with eased edges and punctured by symmetrical, sloped geometric voids. The large simple shapes would visually reinforce the pier’s weight-carrying ability and provide a dramatic appearance from the water and the shoreline[4] (see Fig. 5).

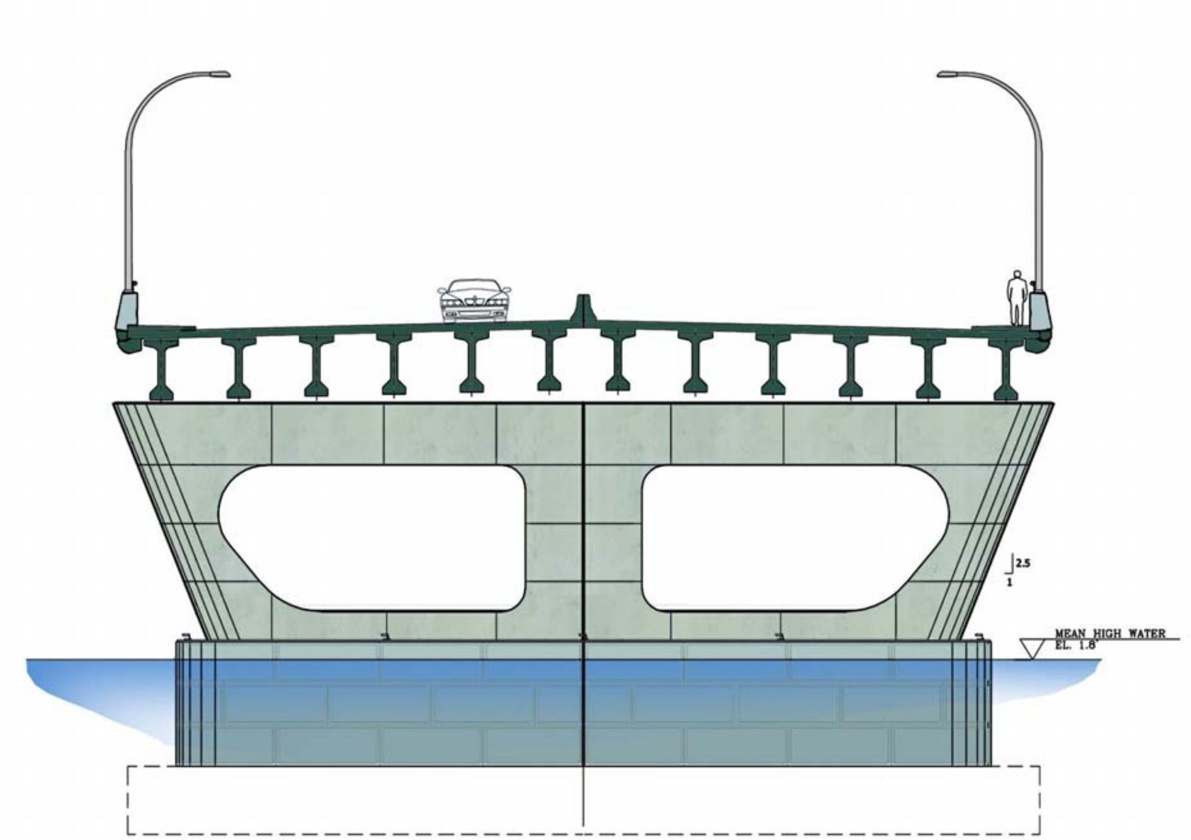

Fig. 5. Initial architectural recommendation for the proposed piers.

The NJDOT was pleased with this unique, striking architectural recommendation, and requested that it be studied for design development. At the same time, NJDOT challenged the design team to simplify the design and utilize precast concrete to the maximum extent possible to minimize the duration of the in-water construction activities. The process resulted in a pier architectural design with each pier being supported at the waterline on a simulated masonry faced plinth and having a pair of prismatic vertical columns at the centerline of the bridge and inclined tapered columns sloping outward towards the bridge fascias. A cap beam would then connect the tops of the columns. In the final condition the piers would appear uplifting with two symmetrical trapezoidal openings (see Fig. 6). In addition to the distinctive pier treatment, the parapets, sidewalks, retaining walls and noise walls associated with the project also received architectural treatments.

To meet the architectural and schedule requirements, a structural system was selected for the piers, which consisted of architecturally treated precast concrete cofferdam shells, columns and cap beams connected through post-tensioning. 8,000 psi HPC was used for all of the precast bridge elements for added strength and durability.

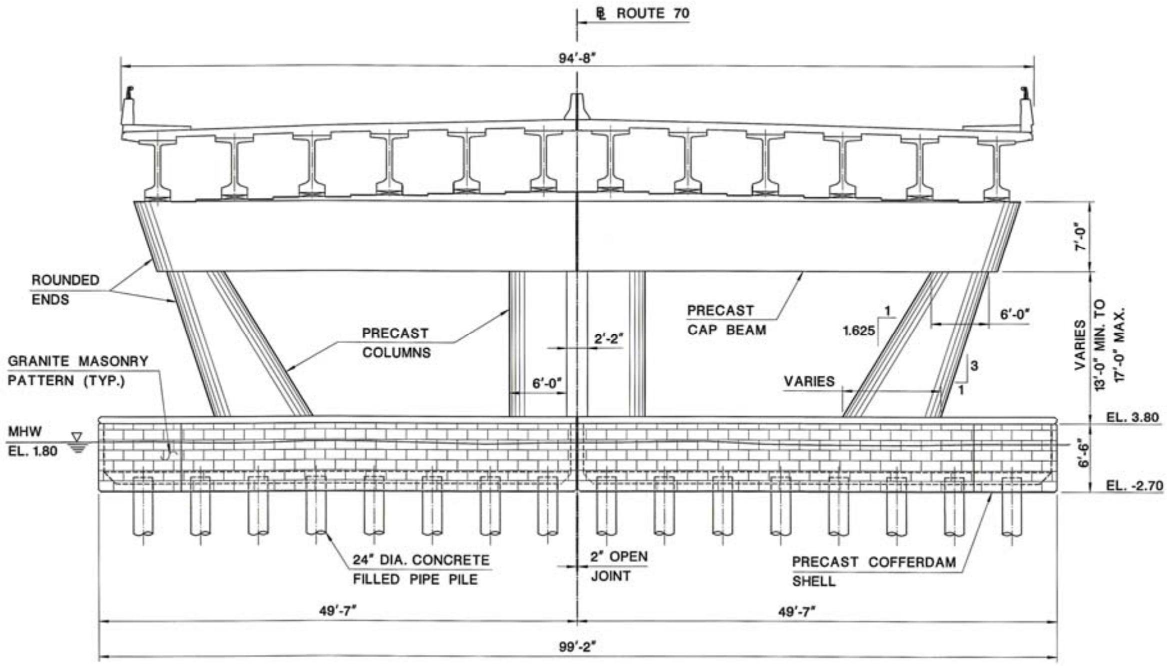

Fig. 6. Final precast pier configuration.

PILE FOUNDATIONS

The foundations utilized 24-inch diameter concrete-filled steel pipe piles driven to an estimated tip elevation of –110. For the eastbound and westbound structures, groups of 37 piles were used at the fixed piers, 26 piles were used at the continuity piers and 32 piles were used at the expansion piers. To construct the foundations, the contractor, George Harms Construction Co., Inc., chose to drive pilot piles with a template around the perimeter of each pile group (see Fig. 7). These piles were used to support a temporary frame from which the cofferdam sections could be hung.

The remaining piles for each footing were then driven through openings in the floor of the cofferdam shell. To facilitate the pile driving, a vibratory hammer was used to advance the piles 60-ft through the upper riverbed muck layer. An impact hammer was then used to drive the piles another 50-ft to the estimated pile tip elevation. After a 7-day setup, each test pile was restruck to verify they had achieved a capacity greater than the 800 kip ultimate pile driving resistance. By utilizing the setup characteristics of the sandy subsurface layers, the required pile capacities were developed without the necessity of driving to a lower stratum.

Fig. 7. Perimeter piles driven with a template.

FOOTINGS

The typical footing size for each half of each pier was 30-ft wide by 49.5-ft long. Rather than constructing the footings below the riverbed, which is 16-ft deep at some locations, and inside traditional braced steel sheeting cofferdams, the pier foundations were constructed at the waterline within precast concrete cofferdam shells. The cofferdam shells provided driving templates for the piles, served as architecturally treated formwork for the footings and minimized disturbances to the riverbed. The precast concrete cofferdams offered significant advantages in terms of cost and time of construction over traditional steel sheeting cofferdams.

The contract plans detailed the architectural and dimensional requirements for the cofferdams and provided nominal reinforcement for shipping and handling of the units. The cofferdams were faced with a #1104 random cut stone pattern and coated with a clear epoxy waterproofing seal coat. This gave the appearance of the pier footings being faced with wet granite masonry at the waterline. The contract documents allowed the contractor to introduce joints to fabricate smaller sections, which could facilitate casting, shipping and erection of the individual components, and gave him the responsibility of selecting his own method of temporary support for the cofferdam shells. The contractor fabricated the cofferdams in sections varying in length from 7.2-ft to 14.5-ft. They were then trucked to the site and loaded onto barge platforms (see Fig. 8).

Fig. 8. Cofferdam section has been trucked to the project site and fitted with lifting beams.

The individual sections were hoisted into place and bolted together using couplers consisting of 1¼" anchor bolts, 4" structural tubing and 1" threaded rods (see Figure 9).

Fig. 9. Precast cofferdam section being hoisted into place.

The remaining work for each footing was to:

- Seal the annular spaces around the pile heads,
- Place tremie concrete,
- Dewater the cofferdam,
- Cut the piles off at 6-inches above the floor slab,
- Transfer support of the cofferdam to the pile heads through a series of smaller support beams and hanger rods,
- Concrete the piles, and
- Make a mass pour of footing structural concrete (see Fig. 10).

Fig. 10. Work being performed inside a cofferdam. Structural support of the cofferdam has been transferred to the pile heads. Piles are being filled with concrete.

PIER COLUMNS AND CAPS

The pier columns were designed to be constructed from hollow segmental units connected by post-tensioning strands extending from anchorages cast in the footings to tie points in the cap beams. Precast manufacturers were consulted during the design phase to determine a preferred segment height for fabrication and shipping. 4-ft high segments with a 9-inch wall thickness were selected. However, the contract plans allowed the contractor to modify the segment heights for his convenience and method of construction. During the shop drawing development process, the contractor again exercised the provisions in the contract documents to modify the precast concrete columns. The columns were fabricated as complete units of approximately 16-ft in length rather than the 4-ft segments shown on the plans; however, the architectural appearance of the columns was not altered. Using complete column units cut the column erection sequence from four steps to a single step.

7-ft deep by 5-ft wide hollow prestressed concrete box beams were designed for the cap beams. Since the cap beams had rounded exterior ends, the contractor was given the option of precasting the beams as complete units or casting the rounded ends in place after the beams had been erected. The precast option was selected to minimize costs and avoid onsite work.

The post-tensioning design was based on using ½" diameter ASTM A416 seven wire, Grade 270, low relaxation strands. The contractor proposed substituting 1¾" diameter, ASTM A775, Grade 150, threadbar for the specified strands. The contractor preferred to use threadbar because it was easier to install in the sloping outer columns. Since the proposed post-tensioning system performed the desired function, it was determined to be an equivalent system, and the requested substitution was allowed.

The precast pier column and cap components were then fabricated offsite, delivered via trucks and loaded onto barges (see Fig. 11).

Fig. 11. Precast pier columns and a cap beam have been loaded on a barge and are being prepared for erection.

The pier construction was then advanced rapidly and the architectural form of the piers quickly took shape (see Fig. 12 and Fig. 13).

Fig. 12. The first precast pier columns have been erected.

Fig. 13. The precast columns and cap beam have been erected to complete the first pier. The cap beam will be prepared for cast-in-place concrete leveling pads.

The contractor had mobilized a number of large land-based and barge-mounted cranes, which provided flexibility in handling the larger concrete members. Working from the barge platforms, the individual pier components were hoisted into place and connected using the post-tensioning threadbar. The erection of pier column and cap beam components was accomplished in a matter of hours for each operation. Construction of the pier columns and cap beams, which would have normally taken weeks for an individual pier, was reduced to days.

GIRDERS

The bridge was designed so that either Prestressed Concrete Economic Fabrication (PCEF) Bulb Tee girders or New England Bulb Tee girders could be accommodated. The contract plans were detailed using the PCEF XB 71 47 section, which is the section that was ultimately supplied by the contractor. Galvanized steel intermediate diaphragms were used to secure the girders at the time of erection. Cast in place continuity diaphragms were used at the piers (see Fig. 14).

Fig. 14. Span 6 PCEF Bulb Tee girders have been erected.

CONSTRUCTION SCHEDULE

The construction contract was awarded in December 2005. After the kickoff meeting in January 2006, the contractor initiated the shop drawing submittal and review process. As discussed above, requests were made within the framework of the contract documents to modify the precast concrete cofferdam shells and columns. There were also a number of minor modifications made to the girders and cap beams, which were introduced by the precast fabricator based on experience with similar precast components. The modifications improved quality, reduced costs and facilitated construction operations.

During the pier construction the contractor operated on a six-day workweek to advance the pier construction as quickly as possible. Several crews were employed, which moved from one pier location to the next, performing the same tasks for each pier. Once an element of a pier was constructed the crew performed the same series of tasks for the construction of the same element on the next pier, and likewise for each step in the pier construction process. In this way the pile foundations, cofferdams, columns and cap beams were rapidly constructed for all of the piers (see Fig. 15).

Fig. 15. Crews work on multiple piers at the same time. Piers are shown in various stages of completion.

The in-water work, which initially consisted of pile driving, began on July 1, 2006. The contractor's crews worked steadily moving from one pier to the next until the last pier cap on the eastbound half of the bridge was completed on October 23, 2006. The schedule for the construction of the eastbound piers 1 through 5 is illustrated in Fig. 16. Also shown are schedules for typical precast and cast-in-place piers.

Activity ID	Activity Description	Orig Dur	Early Start	Early Finish
Rt. 70 / Manasquan - Precast Pier Construction				
Construct all Eastbound Precast Piers (P1 - P5)				
A1000	PILES	54	01JUL06A	21SEP06A
A2000	PRECAST COFFERDAMS	45	12JUL06A	19SEP06A
A3000	CAST-IN-PLACE PIER FOOTINGS	38	01AUG06A	25SEP06A
A4000	PRECAST PIER COLUMNS	31	23AUG06A	05OCT06A
A5000	PRECAST PIER CAPS	37	30AUG06A	23OCT06A
Construct Single Precast Pier (Typical)				
B1000	DRIVE TEST PILES	7	11JUL06A	19JUL06A
B1100	TEST PILE ORDER LENGTHS	5	18JUL06A	26JUL06A
B1200	FURNISH PILES	7	25JUL06A	04AUG06A
B1300	DRIVE PRODUCTION PILES	14	04AUG06A	23AUG06A
B2000	INSTALL PRECAST COFFERDAM	10	07AUG06A	18AUG06A
B3000	POUR FOOTING CONCRETE	3	24AUG06A	28AUG06A
B4000	ERECT PIER SEGMENTS/PT	8	19SEP06A	27SEP06A
B5000	ERECT PIER CAP	10	30SEP06A	13OCT06A
Conventional Pier Construction				
Construct Single Cast-In-Place Pier (Typical)				
D0500	CONSTRUCT COFFERDAM	15	11JUL06*	31JUL06
D0600	EXCAVATE AND DEWATER	3	01AUG06	03AUG06
D1000	DRIVE TEST PILES	7	04AUG06	14AUG06
D1100	TEST PILE ORDER LENGTHS	5	15AUG06	21AUG06
D1200	FURNISH PILES	7	22AUG06	30AUG06
D1300	DRIVE PRODUCTION PILES	14	31AUG06	20SEP06
D1350	SETUP - PLACE TREMIE CONC	2	21SEP06	22SEP06
D1360	TREMIE CURE	5	23SEP06	27SEP06
D1400	CONSTRUCT FOOTING	3	28SEP06	02OCT06
D1500	CONSTRUCT PIER COLUMNS	5	03OCT06	09OCT06
D1600	CONSTRUCT PIER CAP	11	10OCT06	02NOV06

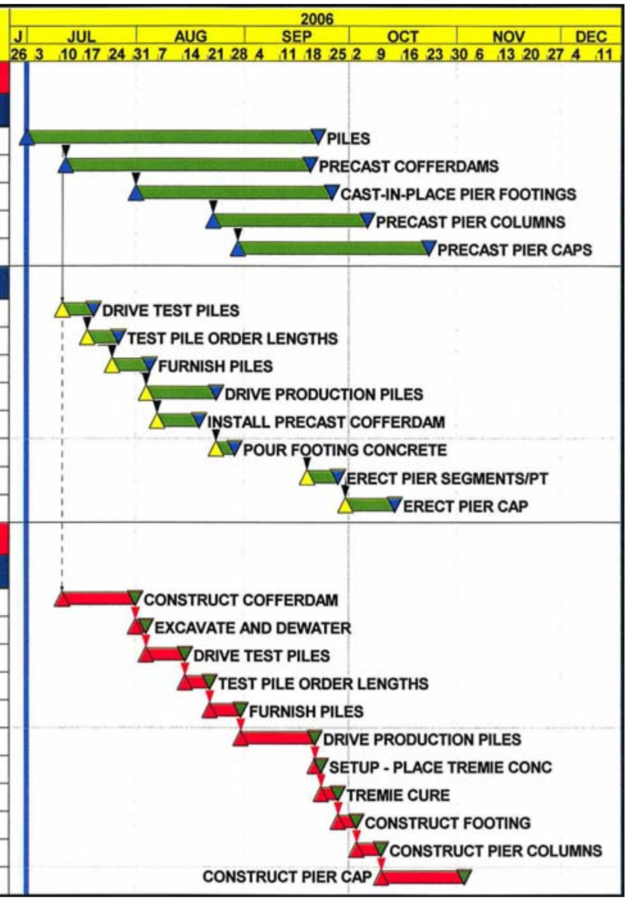

Fig. 16. Construction schedules are shown for all of the precast eastbound piers 1 through 5, a typical precast pier and a typical cast-in-place pier.

The construction of all the precast eastbound piers, including their pile foundations, was accomplished in 96 working days. A typical individual precast pier was constructed in 63 working days. The overall duration required to construct five precast piers was only 33 working days longer than the time it took to construct a single pier. This was due to the process involved in constructing all five piers at the same time with multiple crews. Since there was slack in each of the individual pier construction activities, the contractor could have achieved a far shorter construction duration for a single pier. However, the greater goal was to construct all of the piers in the shortest amount of time. When all five piers are considered together, the pier construction activities are on the project critical path. A truer representation of the duration of the precast pier construction can be obtained by simply dividing the overall duration of 96 working days by 5 piers, which results in a duration of approximately 19 working days per pier.

The effect of using precast components can also be quantified by comparing the construction duration of a conventional pier to that of a precast pier. If conventional cofferdam and cast-in-place construction were used, it is estimated that a pier could be constructed in 115 calendar days or 82 working days. Using a six-day workweek would improve the overall cast-in-place duration to 99 calendar days, but it would not decrease the total number of 82 working days required. During the actual construction of the eastbound half of the bridge, the contractor ordered the production piles ahead of time and started driving production piles before all the piles had been furnished to the site. This yielded a savings of 4 working days. Since the pile foundations would be similar for each type of pier, this savings should also be considered for a cast-in-place pier, and the duration should be reduced to 78 working days.

Based on this comparison, the cast-in place construction duration would have been 59 days longer or more than 4 times the precast construction duration. Doubtless efficiency for multiple pier construction would also be realized for cast-in-place piers, and a multiple cast-in-place pier duration should be used for the comparison. However, it is not expected that the duration would approach the 19 working day efficiency achieved for all the precast piers.

With the implementation of the precast pier system, the contractor was able to advance the superstructure construction and the first girders were erected on September 29, 2006 (see Fig. 17). This early start on the bridge superstructure coupled with a mild winter allowed the contractor to complete pouring the bridge decks in early January 2007.

Fig. 17. Eastbound bridge piers 1 through 5 have been completed, and the bulb tee girders have been erected.

If conventional pier construction had been employed, valuable time would have been lost for construction of temporary cofferdams, forming of the pier footings, columns and cap beams, curing and finishing the substructure concrete. The pier construction would have extended into December 2006, and there would have been no chance of constructing the eastbound bridge deck before Spring 2007.

Because of the accelerated bridge construction using precast components, the contractor was able to shift traffic over to the newly constructed first half of the bridge by April 13, 2007. The existing bridge was then demolished down to the waterline during the remaining in-water work restriction period. After July 1, 2007, the contractor expects to complete the in-water demolition work and begin driving piles for the construction of the pier foundations for the westbound half of the bridge. The project is approximately 700 calendar days ahead of schedule and is anticipated to be complete in December 2008.

CONCLUSION

The Route 70 over Manasquan River Bridge Replacement Project utilized a precast concrete substructure solution to meet the project needs and facilitate construction of the bridge. The precast concrete components, including the precast pier system, were detailed on the contract plans to allow the contractor and his fabricators to modify the design so that there would be maximum economy in materials used, reduced costs to the owner and the most efficient method of construction could be employed by the contractor. The 5 in-water piers were constructed in a total of 96 working days with an average duration of approximately 19 working days per pier. This type of efficiency can be expected on future projects with 5 or more in-water piers. As the industry continues to gain experience with this type of construction, it is expected that even greater efficiencies will be realized. Once construction of the project is completed, the use of precast substructures will have resulted in a high quality architecturally treated signature bridge constructed almost 24 months ahead of schedule.

ACKNOWLEDGEMENTS

The author would like to acknowledge the contributions of the following team members, without whom this project would not have been possible:

- Pankesh Patel, P.E. – Project Manager, New Jersey Department of Transportation
- David Wallis – Resident Engineer, New Jersey Department of Transportation
- Alan Haring, P.E. – Project Engineer, Arora and Associates, P.C.
- Andrew Baran – Constructibility, Arora and Associates, P.C.
- H2L2 Architects/Planners, LLP – Architect
- Robert Harms – Vice President, George Harms Construction Co., Inc.
- Jeff Brantly – Sr. Project Engineer, George Harms Construction Co., Inc.

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