Davis Narrows Bridge in Brooksville, Maine: Fast Track Solution to an Environmentally Sensitive and Tourist Location

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ABSTRACT

The unique features of the existing Bridge, the sensitive environmental habitat, and the tourist attraction at the Davis Narrows Bridge over the Bagaduce River in Brooksville, Maine created a set of issues that demanded a fast track approach to bridge design and construction. The Maine Department of Transportation after considering several options decided to custom design a single span bridge using all precast elements. The Precast abutments and wingwalls were designed as post-tensioned units over driven piles to reduce excavation, forming and curing time, and to eliminate the use of cofferdams. Extensive geotextiles were used to stabilize the causeways and reduce impacts to Eelgrass patches. The new abutments were installed behind the existing granite block abutments to avoid changes to hydraulics favored by locals and tourists. Precast Box-beams were erected efficiently using a launching girder. The entire project from demolition of the existing bridge to pavement and guardrail installation on the new 89 foot, $1 million Bridge was completed in only 30 days. The ease with which the bridge was constructed not only impressed the locals but also the Contractor and the Owner.

INTRODUCTION

The Davis Narrows Bridge spans the Bagaduce River and connects the towns of Penobscot and Brooksville along the rugged coastline of Downeast Maine. The bridge site posed a number of challenges due to its unique wildlife habitat, pristine waters, local oyster farm, tourism, poor sight distance, and long detour to mention a few. These issues motivated the Maine DOT to consider a fast-tract and low-impact design that would not only address the issues at hand but also one that would prove to be an effective solution to similar problems at other locations.

The existing Bridge was constructed back in 1941 using painted rolled steel beams on dry laid granite blocks. The granite blocks were constructed on rock fills that form the 100 foot long causeways on both approaches leading to the bridge. The paint on the beams had failed and corrosion was hastened by the salt water underneath. The FHWA Sufficiency Rating had dropped to only 31. It was thus programmed for replacement in the 2004-2005 Work Plan.

The causeways create a constriction on the daily tide cycle which in turn produces a hydraulic head of about three feet in each direction at the abutments between high and low tide. The rapids from this phenomenon have become one of entertainment value on which many tourists and locals ride their kayaks and inflatables during the summer months. The locals were thus not in favor of changing any of the hydraulic characteristics.

The Bagaduce River near the Bridge site is also one of few areas in Maine where the Horseshoe crab breeds. The Horseshoe crab is an ancient creature that is said to predate the Dinosaurs by 100 million years. Another concern was the presence of Eelgrass on two corners of the bridge. Eelgrass, which is a salt water seagrass, is protected by the Federal Clean Water Act. It provides natural habitat and food to marine organisms. The Bagaduce Watershed Conservation Association had requested the complete transplant of Eelgrass that would have been affected by the causeway riprap. The Maine DOT biologist was able to precisely mark the Eelgrass patches on survey plans using backpack GPS units. Prior to construction, these patches were hand transplanted by divers and volunteers.

The bridge site is also a natural fishing ground not only for the local people but also for cormorants, larks, and the Blue Heron besides other species of birds. Throughout the construction, these birds provided a natural sight for the construction crew. The oyster farmer just upstream of the bridge had requested that the silt and sediments from the construction be reduced to an absolute minimum. This was achieved by using precast abutments instead of cast-in-place which significantly reduced equipment movement, excavation, and flow of any concrete into the tidal area. Use of precast units for abutments also eliminated the need for cofferdams which would have disturbed the river sediments. The use of silt booms at both abutments was all that was needed with the precast system.

Given the sensitive nature of the project surroundings, the design team considered the options available and decided on an all-precast system to quickly install the bridge, address the issues at the site, and open the road to traffic in the shortest time possible.

BRIDGE DESIGN AND CONSTRUCTION

The bridge was designed by the Maine DOT Bridge Program design team during the winter of 2004-2005 according to AASHTO LRFD Bridge Design Specifications. Some of the precast features were conceived from the Andover Dam Bridge in Upton which is the only other bridge in the state with precast abutments. The new bridge is single span, 89 feet long and 32 feet wide with integral abutments. The design theory for the precast abutment was based on using conventional integral-abutment dimensions and then splitting the abutment into segments that can be easily transported and erected. Since the abutment units are supported on piles, the entire abutment needed to act as a single unit which was accomplished by post-tensioning the units with threaded bars. The project was advertised in May of 2005 and awarded to Reed and Reed Inc. contractors of Woolwich, Maine in July, 2005 for a total bid price of $1.06 million. All precast abutment units and box beams were manufactured by Strescon Ltd. of New Brunswick, Canada. The construction was expected to be quite challenging because the work schedule needed to be synchronized with the daily tide cycles. The Maine DOT principal designer also spent the entire 30 days of bridge closure at the construction site to help address issues as they came up. The project was completed 5 days ahead of the allotted 35 day closure. The details of the construction process are given below.

Abutments and Wingwalls

Since the hydraulics of the bridge could not be changed, the existing granite block abutments could not be removed entirely. As a result the new integral abutments were designed twelve feet behind the existing abutments (See Figure 1-3). It would have been nearly impossible to drive conventional steel sheet-pile cofferdams because of the rocky river-bottom and the long causeway that allowed significant flow of water through them. As a result, the excavation for the abutments was done within controlled embankments and at low tide. Silt booms were used on the outside to reduce seepage of silt and sediments. The dimensions of the precast and post-tensioned abutment units are similar to that of conventional cast in place integral abutments in Maine.

The integral abutments of the bridge are supported on four piles which are driven to bedrock (See Figures 2, 5). Light I-beams were placed transversely on each side of the piles to ensure that the abutments were seated level. The HP 14x89 piles were one size heavier than required to account for some section loss due to salt water conditions. The piles are expected to be wet at all times. The abutments consist of two 16 foot long precast center units and two 4 foot long precast extended wing wall units. All contact surfaces were specified to be match cast at the precasting plant and coated with epoxy concrete adhesive just prior to post-tensioning in the field. All four units are post-tensioned (PT) together with six threaded bars. The PT bars were designed to resist biaxial loads on the center units from traffic and earth pressure, and cantilever loads on the wingwalls due to earth pressure. The match cast joints also consisted of four shear keys to help align the precast units during erection. Voids were designed into the abutment units to receive the piles. These voided areas were enlarged to reduce the shipping weight of the precast units. Once the abutments were lifted into place and the post-tensioning was completed, the voids were filled with Self Consolidating Concrete (SCC) through six inch ducts on top of the abutment units. The six PT ducts were pumped with conventional grout. The final lock off tension in the PT bars was designed to prevent any cracks due to Service Loads. Although the PT bars provided bending resistance, the steel reinforcement in each unit was designed for deep beam bending action, and punching shear resistance over the voided areas. All steel reinforcement in the abutment units were epoxy coated.

Only the small tapering top portions of the wingwalls that abut the box beams were cast in place. This was necessary to obtain a tight fit of the beams against the abutments. The use of precast abutments significantly reduced impact to the river and tidal areas, and reduced the construction time by a third.

Superstructure and Approach Slabs

The superstructure is made of eight butted Precast Pre-stressed Box Beams (B-II 48) that were post-tensioned transversely to act as a single unit (See Figure 4). They were delivered three per day which was also the beam erection rate. A 110 ton and an 80 ton crane erected the beams in place. The contractors were very innovative in their approach to erecting the box beams. The heavy beams would have required widening the causeways with temporary fills to swing the beams into place and thereby causing significant impact to the natural habitats. This was eliminated by the use of custom made steel launching beam with a trolley supported on Hilman rollers. The contractors used the truck that brought the beams to back-up the beams across the channel thereby eliminating the need to lift an entire beam off the truck with one crane. The use of pea stone concrete mix in the shear keys instead of the conventional sand grout reduced the possibility of discharging material into the river. As an additional measure, the foam backer rods in the shear keys were bonded to the beams prior to erection and then compressed into place during erection of adjacent beams.

Transverse post-tensioning strands were located at five points along the length of the beam. Although the designers intended the curbs to be precast with the beams, it was determined that cracks would have developed during transportation through the rough local roads. Thus the curbs were cast in place, and this operation started as soon as only two beams were erected. The precast approach slabs were erected next and these were positively connected to the abutments using six #6 loops providing longitudinal restraint to the beams. The loops were placed through pockets in the approach slabs and into precast holes in the abutment units. The pockets were later filled with sand grout. All steel reinforcements except for the pre-stressing strands were epoxy coated.

The use of precast pre-stressed butted box beams significantly reduced erection time. Substantial time was also saved by not having to construct a leveling slab. High Performance Membrane was torch-applied on the beams by a subcontractor followed by a three inch Hot Mix Asphalt pavement.

PROJECT SCHEDULE AND COST

The contractors were given a total of thirty five days of road closure to complete the project with incentives of $1000 per day and equal disincentives. They decided to work on causeways leading to the bridge first and then close the bridge for completing the rest of the project. The causeways were built back in 1941 with massive rocks and boulders that allowed significant flow of water through them. To reduce impact to existing flow characteristics, the new approach roads on the causeways were built on choke stone layers stabilized with high-flow geotextiles. This took three weeks to complete followed by the bridge closure on September 6th, 2005.

The first week of closure was used to remove the tops of the existing abutments followed by excavation at the new abutment locations. The second week was used for driving the piles and erecting the abutments. Some time was lost when two of the pile locations were blocked by large boulders in the excavation. The contractors did not claim addition time because the presence of boulders was clearly indicated in the boring logs. The contractors brought in a larger excavator to removes the large boulders. The four precast units that make up an abutment took only two hours to erect and post-tension. The grouting operation was done the following day at low tide. During the third week, the beams were erected using a steel launching beam structure and a crane on either end. The curbs were constructed as soon as the first fascia beam and an adjacent beam were in place. The wingwall tops were cast early fourth week followed by installation of bridge rail and application of the high performance membrane. The heavy cranes were also disassembled during this week and removed from site. Pavement was applied during the last two days leading to bridge opening. The bridge was opened to traffic on October 5th, 2005. The approach guardrails were installed during the two days following the bridge opening and no lane closures were needed due to the low traffic volume at that time. The contractors also left the site four days after the bridge was opened to traffic.

The Davis Narrows Bridge was constructed on a very unique site which posed some significant construction challenges. The structure itself is one of a kind and as such the cost of this bridge cannot be easily compared to other bridges in Maine. The unit cost of the structure itself was $233 per square foot. The price of the Box beams were 56% higher than the estimated price and this was attributed to the high demand for Box beams during that particular time, besides the temporary shortage of cement. The increased cost of transportation was also a factor. The bid price of the precast abutments per cubic yard of concrete was 80% higher than conventional cast in place concrete.

CONCLUSION

Overall, the precast systems were fabricated as designed and erected efficiently as expected. The contractors were very pleased with the swiftness with which they could handle the precast units and also the ease of installation. At final inspection and finalizing submittals, the contractor and Maine DOT gave each other high marks for job satisfaction. This was truly a project which had many challenges but finally came together with the help of dedicated teams from both the Maine DOT and the contractors, and certainly with the technology of precast units. The success of this project and that of the Andover Dam Bridge has motivated other designers at Maine DOT to consider similar All-Precast solution on their projects.

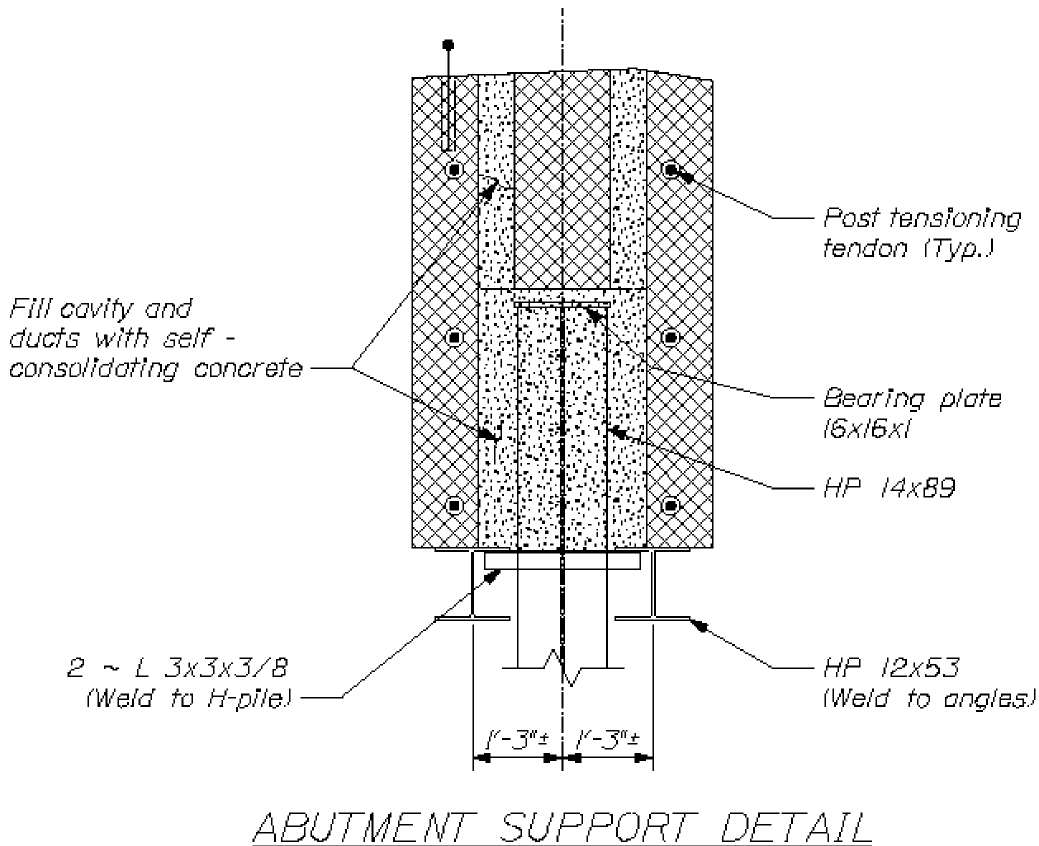

Figure 1: Precast Abutment Section showing void and PT bar locations.

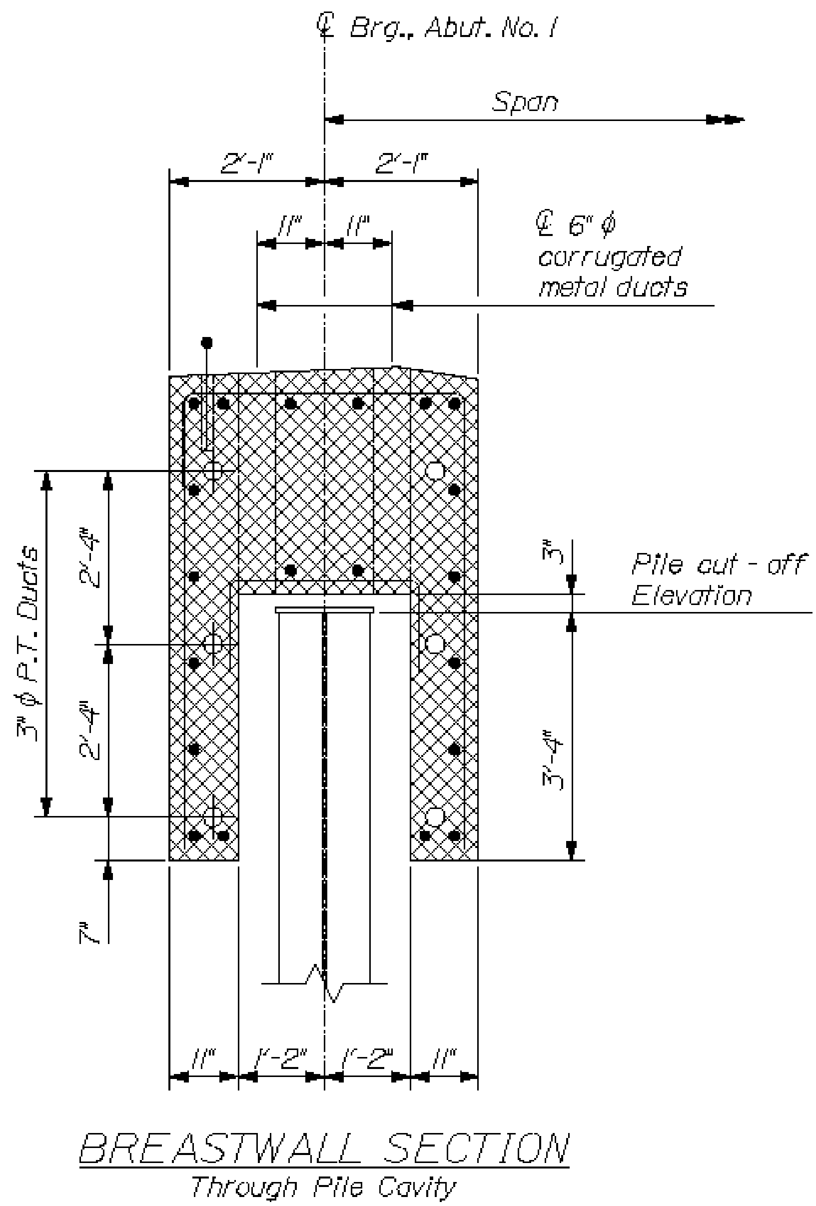

Figure 2: Precast Abutment dimensions.

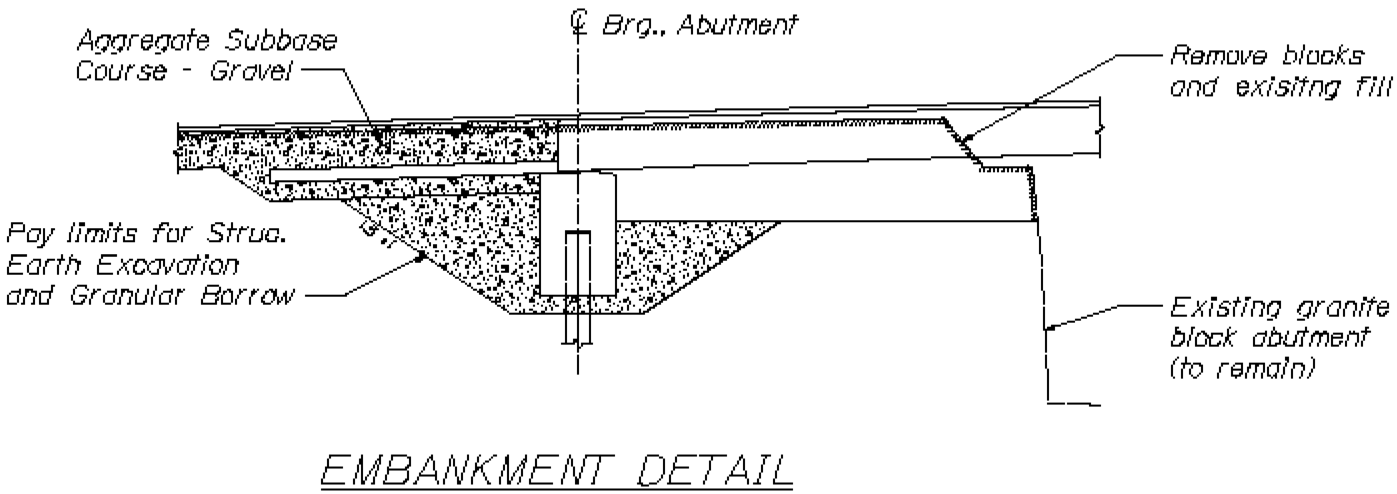

Figure 3: Embankment details showing new and existing abutment.

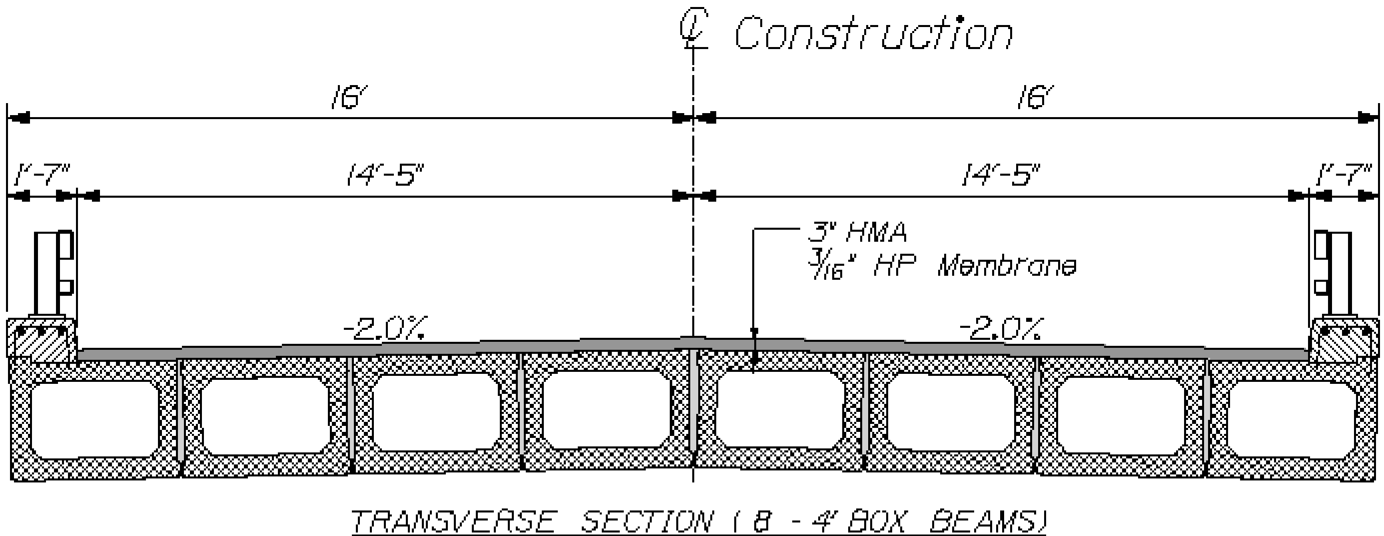

Figure 4: Typical Superstructure Cross-Section.

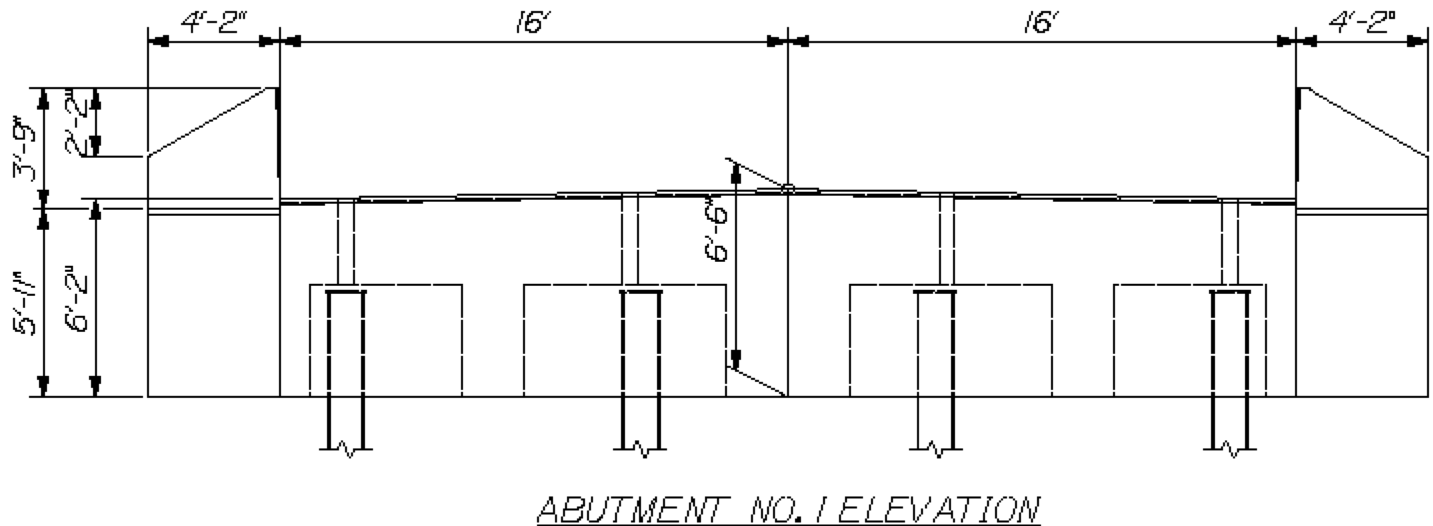

Figure 5: Typical Abutment Elevation.

Photo 1: Removal of Existing Steel Girder Bridge.

Photo 2: Extensive use of Geotextiles to stabilize Causeway.

Photo 3: Placement of Center Precast Abutment units.

Photo 4: Precast Abutment voids being aligned with Pile tips.

Photo 5: Self-Consolidating Concrete poured into the voids.

Photo 6: All four Precast Abutment units in place

Photo 7: Launching Beam and first Precast Box beam in place.

Photo 8: Completed Bridge showing causeways.

Photo 9: Completed Bridge photo taken 9 months after completion.