EMPLOYING SPECIALIZED DESIGN AND MATERIALS ON THE LESNER BRIDGE REPLACEMENT PROJECT

Robert Bennett, PE RS&H, Virginia Beach, Va

ABSTRACT

Construction began for the City of Virginia Beach's Lesner Bridge Replacement Project in 2014. Crossing the Lynnhaven Inlet and adjacent to the Chesapeake Bay on Route 60, the bridges are an historical part of the main thoroughfare along the scenic north shore of Virginia Beach.

Funded by the Federal Highway Administration (FHWA) and The Virginia Department of Transportation (VDOT), this Locally Administered Project (LAP) consists of twin 1,575' long pre-cast segmental bridges. Because these bridges have been uniquely designed to use both the span-by-span and cantilever erection methods, the Prime Contractor (McLean Contracting) is utilizing a custom retro-fitted overhead lifting truss to perform the segment erection for this project. The 53' wide segments, being cast off site, will accommodate two lanes of traffic, with sidewalks and shoulders on each side.

The bridges, which are located in a harsh marine environment, require innovation to advance quality standards. Innovative materials such as self-consolidating concrete, low-permeability concrete, and corrosion resistant reinforcing steel are being used to meet this challenge. These specialized materials will contribute to the bridges sustainable 100-year design life.

KEYWORDS: Precast, Concrete, Segmental, Bridge, Lesner, Grouting

INTRODUCTION

Construction began in 2014 for the Lesner Bridge replacement project in Virginia Beach, Virginia. The total project cost of $116 M includes the engineering, property acquisition, utility relocation, permitting, landscaping, lighting, and includes $78 M for construction. The project was funded by the Federal Highway Administration (FHWA), Virginia Department of Transportation (VDOT), and the City of Virginia Beach. This Locally Administered Project (LAP) consists of twin 1,575’ (480m) long pre-cast concrete segmental bridges. In only 3 years, the new bridges will boast aesthetic lighting, multi-use pedestrian access, open space, and landscaping. The City’s team includes Designers Clark Nexsen and FIGG Engineering, Contractor McLean Contracting, and CEI Consultants RS&H, WR&A, and Quinn, all of whom are working together to replace the old bridges while protecting the environment surrounding the inlet.

These bridges span the Lynnhaven Inlet at the base of the Chesapeake Bay. The bridge segments being pre-cast in Portsmouth, Virginia are being delivered to the project site using a custom built 13-axial hauler. These bridges have been uniquely designed by utilizing nine typical 150’ (45.7m) spans with one 225’ (68.6m) main span. The longer span extending over the navigable channel, resulted in the contractor being required to use both the span-by-span and balanced cantilever erection methods. The prime contractor, McLean Contracting, is using a custom retro-fitted overhead lifting truss, as shown in figure 1, to perform the segment erection for this project. The 53’ (16.2m) wide segments will accommodate two 12’ (3.6m) lanes of traffic, with shoulders on each side, as well as a 10’ (3.0m) wide multi-use path for pedestrians. The Lesner Bridge Replacement Project is making use of specialized design elements, innovative materials, as well as advance construction processes to deliver a pair of bridges with a 100-year design life.

Figure 1- Lesner Bridge construction with overhead truss

DESIGN

The design for twin concrete structure began in 2007 and took more than 3 years to complete. Clark Nexsen, a local engineering firm who has an established work history with the City of Virginia Beach, teamed with FIGG Engineering group, based out of Tallahassee, Florida to design the structural elements of the bridges. Together these firms were awarded the design for the Lesner Bridge Replacement Project. FIGG utilized state of the art 3-D modeling as well as a set of detailed segmental construction drawings in the structural design. The bridge plans for the superstructure segments demonstrate a fully integrated 3D model and are prepared in multi-color with structural elements being color coordinated, utilizing bar bend detailing as well as post tensioning hardware that is consistent with supplier industry standards. The bridges will also display several forms of aesthetic accent lighting in the pier columns and along the deck exterior edge.

FOUNDATION

The structural components of the Lesner bridge project include the foundation which is supported by 4’ (1.2m) diameter drilled shafts approximately 110’ (33.5m) deep. These shafts are designed for their load capacity to be achieved by skin friction. The soil borings show mostly sandy material with some silty clays for the first 100’ (30.5m). Bearing capacity can be achieved through skin friction due to the principle of soil freeze. Soil freeze occurs in sandy soils when the soil adheres to the side of the shafts providing resistance to downward pressure.

Figure 2- Drilled Shaft Drilling Bucket

There was an extensive geotechnical report produced by the Engineer of Record’s Geotechnical Engineer. A total of 52 cone penetrometer tests, (CPT) were performed throughout the project limits. A CPT is a in-situ test that determines the engineering properties of the soil at a given location. The City also performed an analysis of a sacrificial test shaft which was installed and tested approximately a year before the construction contract was awarded. There are 59 drilled shafts in each bridge. The drilled shafts in the water utilized a permanent steel casing ranging from 30-54’ (9.1-16.5m) in length. The shaft installation process involves drilling using a single flight auger bit as well as a drilling bucket as shown in Figure 2. Polymer slurry is used during the drilling operation in order to maintain an open shaft. The shaft installation process on land only uses a temporary steel casing. Once the pre-tied reinforcing steel cage and concrete are placed, the temporary casing is extracted. The City and VDOT specifications require the reinforcing steel to be corrosion resistant reinforcing, (CRR). The contractor chose to use MMFX steel for all the structural reinforcing on the project. The MMFX alloy is a low chromium, low carbon, high strength, corrosion resistant reinforcing steel. The concrete used for the drilled shafts is self-consolidating concrete, (SCC) with a 28-day design strength of 4,000 psi (27.6 Mpa). This type of concrete was chosen due to high pumpability, and the fact that it does not need to be vibrated in place.

The Chesapeake Bay is a very environmentally sensitive region. It is the largest estuary in the United States and home to many endangered species. For this reason the drilled shaft operation requires 100% capture. This means that all the drilling spoils & polymer slurry must be captured during the drilling operation. The drilling spoils are collected in a dump barge. On a regular basis the barge is transported by tug, the spoils are excavated and the material is hauled off site. In addition, when the concrete is being pumped into the shaft the polymer slurry is pumped back into a holding tank on shore. The recharge of the slurry saves the contractor money as well protecting the environment from any overspills. The chart, in figure 3, below is an average of 30 compressive strength test cylinders from the SCC drilled shaft concrete. Compressive strength breaks were recorded 7 and 28 days. The strength curve for the concrete was very important for the contractor to maintain their construction schedule. Drilling on an adjacent shaft could not begin until the concrete reached a minimum of 2,000 psi (13.8 Mpa)

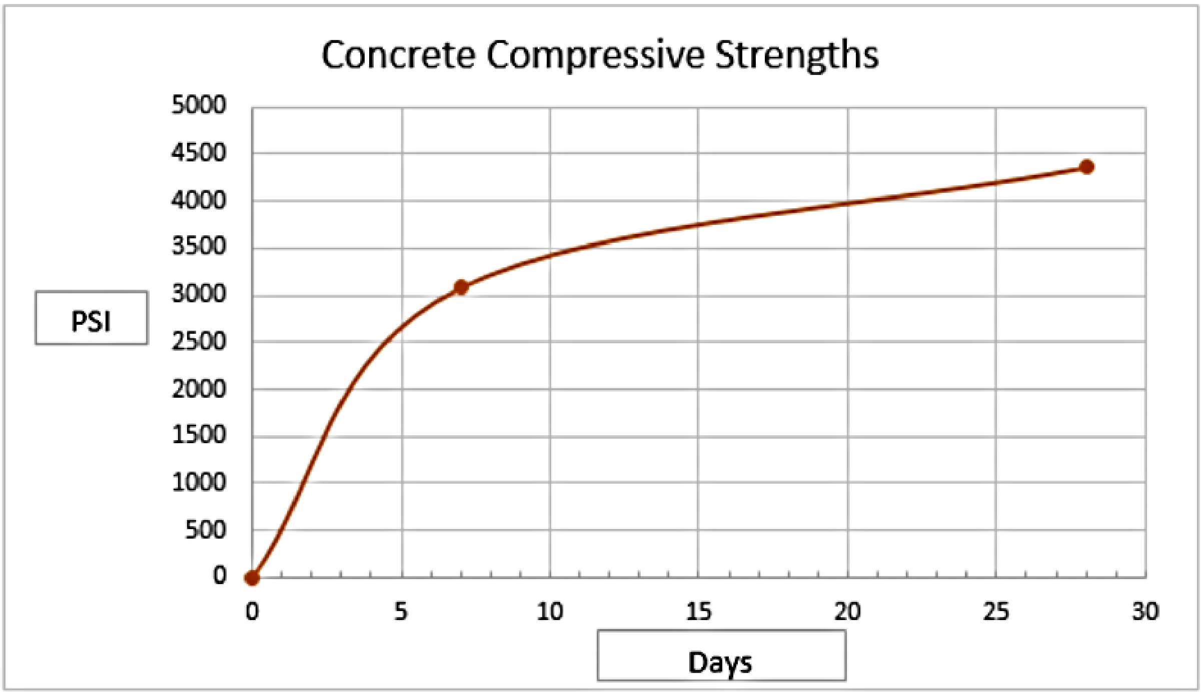


Figure 3- Drilled Shaft Average Compressive Strengths

SUBSTRUCTURE

Another structural component of the design is the cast in place concrete substructure. The substructure is made up of two components, the footings and the columns. Each bridge is supported by two end abutments and nine footings. Three of the footings were constructed on land and the other six were constructed in the water. There are three different types of footings as shown below:

Type 1 footings

- Constructed on land
- 160 CY, (122 CM) of low permeable concrete
- 25,000 lbs (11,340 Kg) of MMFX reinforcing steel
- Supported by 4 drilled shafts

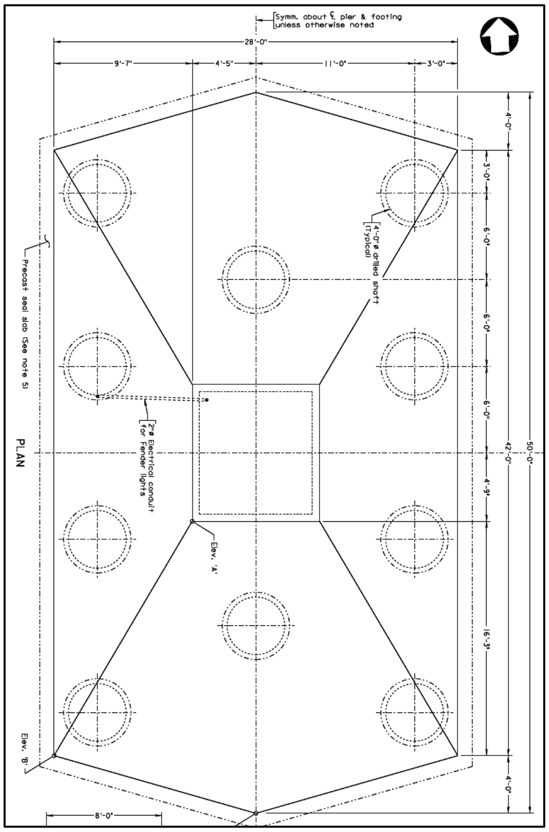
Type 2 footings

- Constructed in shallow water
- 275 CY (210 CM) of low permeable concrete
- 37,000 lbs (16,780 Kg) of MMFX steel.
- Supported by 5 drilled shafts

Type 3 footings

- Constructed in deeper water
- 390 CY (300 CM) of low permeable concrete
- 65,000 lbs (29,480 Kg) of MMFX reinforcing steel.
- Supported by 10 drilled shafts

The type 3 footings are adjacent to the channel span and are designed for vertical load condition, punching shear, and horizontal loads to withstand ship impact. The diagram for a type 3 footing is shown in figure 4, on the following page. During the concrete placement of footings great care was taken to avoid any accidental concrete being introduced into the Bay. Several concrete capture containers were placed alongside the footer forms during concrete pumping operations. These containers were required to capture any loose concrete that may spill into the bay during the concrete pumping activity. Two different methods of concrete placement for water footings were utilized. The first method was crane and bucket, where the buckets were filled on land and transported by barge and then lifted at the point of placement by a crane at the footer location. The second placement method for the footings in shallow water was to place the concrete using a concrete pump with a 140’ (42m) hydraulic boom.



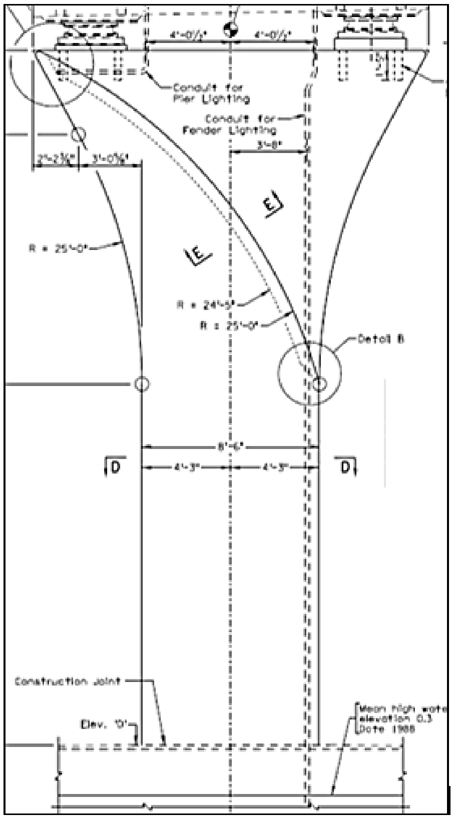


Figure 4 - Type 3 Footer

Figure 5 - Pier Column

The columns are cast in place in a monolithic concrete placement with no horizontal construction joint. During concrete placement the contractor closely monitored the placement rate to ensure that they did not exceed the fluid pressure in the forms. The pier columns, as shown in figure 5, range from 26'– 41' (8m – 12.5m) in height. The columns are designed for the significant dead load, the largest reaction loads during construction will be 1,781 kips, as opposed to a much lower service load for the live load once the bridges are open to traffic. In order to accommodate the large reactions during construction, the top of the columns are designed with 5 – 1-3/8" (3.5cm) post tensioned bars. These bars are 150 ksi steel and are stressed to 120 kips each. These bars are horizontal and run transversely in orientation approximately 9" from the top of the column. This stressing force puts the concrete into compression in the transverse direction and withstands the tension force from loading during construction. The concrete for the columns has a design strength of 4,000 psi (27.6 Mpa) and is required to meet a low permeable standard. The reinforcing steel is MMFX steel which meets the corrosion resistant reinforcing specification requirement. A striking aesthetic feature of the column will be an arced recess that will house a string of LED lights which will cast up lighting on the top of the column flare section.

SUPERSTRUCTURE

The most complex element of the two bridges are the individual pre-cast segments. There are a total of 168 segments in each bridge. The segments are being cast at Atlantic Metro Cast, (AMI) in Portsmouth, Virginia. AMI has two casting beds, as shown in figure 6, which can be adjusted to create each segment needed for its exact position in the bridge. The concrete used for the segments ranges from 6,000 psi to 8,000 psi (41.4Mpa – 55.2Mpa) and is required to be low permeability, less than 1000 coulombs. The reinforcing steel is also MMFX steel.

Figure 6- Segment Casting Bed

Figure 7 – Segment being lifted out of the Casting Bed

The segments are cast using the short line match-cast process. The match-cast process involves each segment being cast next to the previous segment in the span, as shown in figure 8 below.

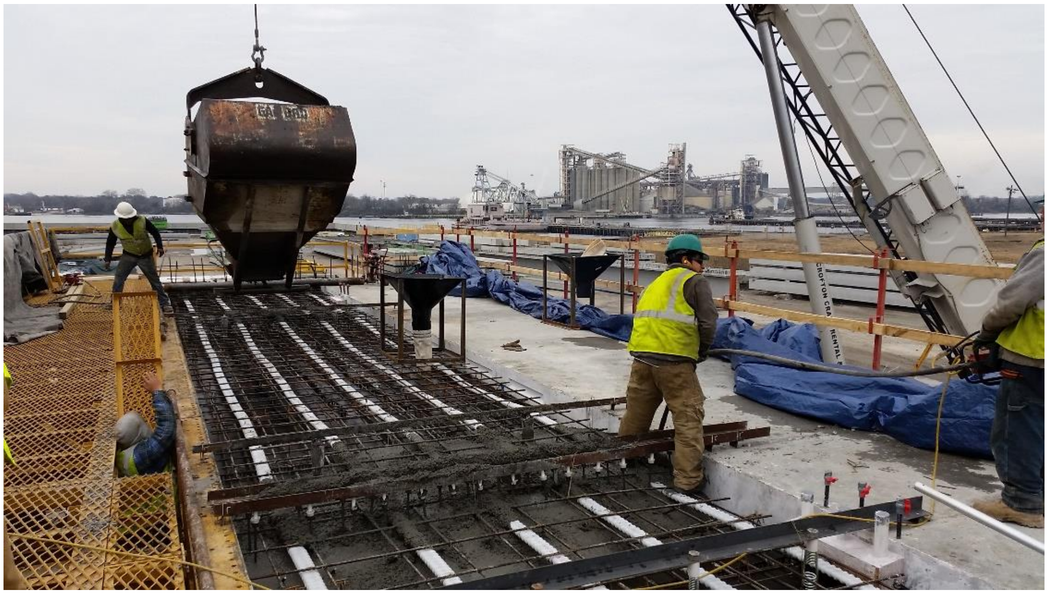


Figure 8 – Segment match cast process

A bond breaker is applied to the previously cast segment to allow the segments to easily separate. This bond breaker is a mixture of talc and soap. This ensures that when the segments are erected at the project site they will fit together perfectly. Prior to the segment being cast, the form bed is surveyed and adjusted to values generated by a geometry control program. Then following the segment casting, the segment is surveyed and the "as-cast" data is entered into the program. The program then generates the set-up values for the next segment in the span. Each one of the segments are then picked and stored using a special straddle lift, as shown in figure 7. When the casting of each span is complete, the geometry control program generates a "casting curve". This curve establishes the horizontal and vertical values that the segments will be erected to at the bridge site.

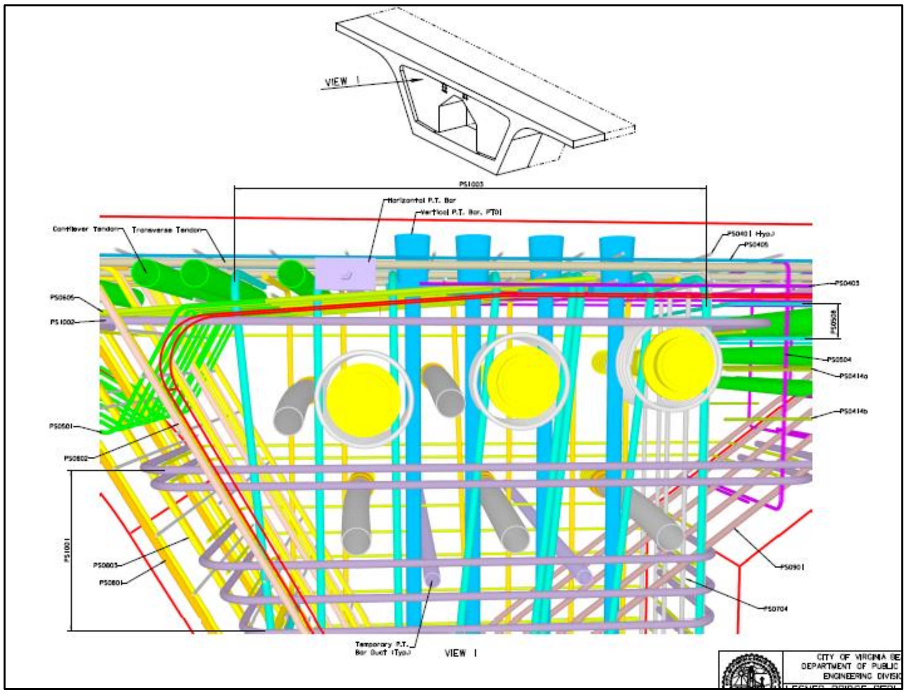


Figure 9 - Multi-color 3-D Reinforcing Steel Detail

The design for the reinforcing steel used 3-D modeling to achieve integration of the post tensioning elements. This design feature also utilized multi-color drawing as shown in Figure 9.

At each abutment sits the expansion joint segment. These segments are positioned on either end of the bridges and are designed to house the expansion joint assembly. They are the most complicated to construct because of the top block-out for the expansion joint. Atop each of the nine pier columns there is a pair of pier segments. Due to the incredible combined weight of over 180 TN, the pier segments were cast in two halves. Without this accommodation the pier segments would be too heavy to transport and would exceed the lifting capacity of the overhead gantry crane used to set the segments in place. Nine of the ten spans are made up of 14 additional segments spanning each of the pier columns for a typical span length of 150' (45.7m). The typical spans are designed to be erected using span-by-span erection method, using either an under slung or overhead truss. The channel span length at 225' (68.6m) cannot be erected using this erection method. Instead, it had to be constructed using cantilever method as pictured in Figure 10.

Figure 10 - Cantilever Main Span

Each span of segments is held together using post tensioning strands. These groupings of strands are referred to as “tendons”. The material properties of a single strand is .6” (1.5 cm) diameter, low relaxation, 270 ksi tensile strength steel. The post tensioned tendons are stressed using a hydraulic jack to create a compression force across the face of the segments. The number of strands in each tendon and the force that is applied to each tendon is dependent on its location in the structure. During the stressing operation a calibration chart is used to correlate the correct force to be applied to the tendon with the correct gauge pressure for each specific gauge and jack. Then the force is checked by measuring the elongation using the formula below.

$$\frac{P\ (force)\ \times L\ (length)}{A\ (area) \times E\ (Modulus\ of\ Elasticity)}$$

In addition to using the above formula, losses in the post-tensioning system must also be accounted for as well. These losses include the change in the tendon profile path and friction. The post tension “tendons” are encapsulated by a high performance cementitious grout that is

Figure 11 - Grouting Mock-Up

pressure injected into the post tensioning ducts. This grout not only protects the strand from the harsh environment, it also provides shear transfer by locking the strands in place and not allowing them move or slip. The grout is mixed using a high shear colloidal mixer. This is the only type of grout mixer /pump that may be used with this material. Prior to any production grouting the contractor was required to construct a full size grouting mock-up of a 150’ (45.7m) tendon with vertical deviations matching the profile of some of the tendons in the bridge, as shown in figure 11. The purpose of the mock up was for the contractor to demonstrate that the tendon could be grouted successfully. The grout crew personnel were required to use the same equipment, the same mixing procedure, and the same grout as they would during the actual bridge grouting. After the grouting for the mock-up was complete, the grout had set, and the mock-up tendon was cut into sections, as shown in figure 12 above. The sections of grouted duct were then analyzed to ensure that there were no voids, no segregation, and no bleed water from

Figure 12 – Grout Tendon Cut for Investigation

the grout as observed. The City of Virginia Beach Supplemental Specification considered the grouting mock-up a success as long as the following three conditions were satisfied:

1. The contractor's methods and materials must completely fill the tendon to the owner's satisfaction.

2. There are no air voids over 0.5" in diameter in the inclined length of tendon.

3. There is no observance of bleed water at either end of the tendon.

The mock-up test was a complete success and prepared the contractor for effective grouting of the in-place post-tensioned tendons in the new bridges. If the grouting mock-up test had not been successful the contractor would have been required to remedy the deficiencies prior to the beginning post-tensioning activities.

MSE WALLS

Figure 13 – MSE wall pre-cast panels

On the roadway design of the project, the approaches to the bridge are supported by 4 mechanically stabilized earth walls on each end of the project. An MSE wall is a retaining wall that has pre-cast concrete panels, as shown in Figure 13, with a galvanized metal strap that extends back into the fill. As the wall gets taller and the soil is compacted, the straps become locked into position due to the compaction and weight of the soil above the straps. There was a concern that during construction these 20' (6m) tall approaches would experience prolonged settlement due to soil consolidation. In order to expedite this consolidation, wick drains were installed to create closely-spaced artificial vertical drainage paths permitting the pore water to flow upward. These artificial drainage paths allow for significant settlement to occur in months rather than years. A typical wick drain is a free-draining water channel, surrounded by a thin geo-synthetic filter jacket and is approximately 4” (10.2 cm) wide, 1/8” (3.2 mm) thick and comes in rolls up to 1,000’ (305m) in length. The wick drains installed in a 5’ x 5’ (1.5 m x 1.5m) grid pattern and were drilled in 65-75’ (19.8m-22.9m) deep. In order to verify settlement had occurred, pore pressure monitors, transducers and settlement plates were installed in the fill on both sides of the approaches.

ROADWAY

The City of Virginia Beach made a commitment to the Shore Drive Community to preserve an effective level of service for the 40,000 average daily traffic traveling through the project. To achieve this commitment, one of the primary tenants of the project design was to maintain four lanes of traffic at all times on Shore Drive (Route 60). Multiple traffic shifts during different phases of construction allowed the four lanes to remain open. This includes travel on two east bound lanes, two west bound lanes, and maintaining entrances and exits to all surrounding businesses in and adjacent to the project limits. A pedestrian path was also maintained throughout the project limits during the entire construction process.

CONCLUSION

In 2017, residents and visitors to Virginia Beach will be able to utilize and enjoy all aspects of the new Lesner Bridges. With aesthetic lighting, a multi-use pedestrian path and new landscaping, Shore Drive’s newest bridges will be dramatically updated and improved. This locally administered project is an excellent example of Federal Highway Administration, Virginia Department of Transportation, and the City of Virginia Beach joining together to fund a successful $116M project. The 100-year design life and high performance materials provide a sustainable long term solution for the Lynnhaven Inlet crossing. Designers Clark Nexsen and FIGG Engineering, McLean Contracting, CEI Consultants RS&H, WR&A, and Quinn, are collaborating their efforts to replace the existing bridges while protecting the Chesapeake Bay’s environment. The new twin Lesner Bridges will be signature structures enhancing the scenic Shore Drive community in Virginia Beach, Virginia.

References

1. Price, Russell., "*PTI Frequently Asked Questions – Field Elongation Measurements*," Issue No. 6, July 2007
2. City of Virginia Beach *Lesner Project Plans* "FIGG, Inc. Engineer of Record" 2013