

Long Key Bridge Pier Replacement

V-pier replacement at 12 expansion joints



by Dennis Fernandez, Florida Department of Transportation and Dr. Luis Vargas, Bolton Perez & Associates

Precast concrete replacement pier in storage at precaster's facility in Tampa, Fla. Photo: Kurt Podoll, Standard Concrete.

The first real bridge construction across the Florida Keys began in April 1905 when a 100-ft-long drawbridge was put in place. The first important long bridge was the Old Long Key Bridge, which consisted of 2.7 miles of concrete arches. This was one of the first major trestle-type structures completed and it withstood, without damage, the most disastrous storm on record in this part of the state, the Hurricane of 1909.

The Old Long Key Bridge was removed from the state highway system in 1982 after the existing Long Key Bridge was opened. The existing Long Key Bridge is located in the Florida Keys (MM 63.2)

and was completed in 1981. It was the first post-tensioned concrete segmental bridge built in the state of Florida. At 12,152 ft long, it serves as the only route into the Florida Keys.

Existing Bridge Description

The bridge was the first precast concrete, segmental box-girder bridge in the world to be erected using the span-by-span method of construction with external tendons. The bridge is prestressed longitudinally using post-tensioned external tendons and the deck is transversely prestressed using pretensioned strands. The bridge was constructed using the dry joint construction method. All non-

prestressed steel reinforcement is epoxy-coated.

There are 13 continuous units, with each unit consisting of seven or eight spans. A typical unit is 944 ft long between expansion joints. Movement was accommodated at the base of the existing V-piers. Thermal, creep, and shrinkage movements take place about the neutral point at the middle pier of each eight-span unit. The bridge foundations are drilled shafts, designed to carry longitudinal forces exerted by the stiffness of the bearings, V-piers, and superstructure interaction. The bridge works as a fully integrated system.

profile

LONG KEY BRIDGE PIER REPLACEMENT / MONROE COUNTY, FLORIDA

PIER REPLACEMENT DESIGN ENGINEER: HDR, Miami, Fla.

PIER REPLACEMENT DESIGN PEER REVIEW: Corven Engineering Inc., Tallahassee, Fla.

PRIME CONTRACTOR: Johnson Brothers Construction, Lithia, Fla.

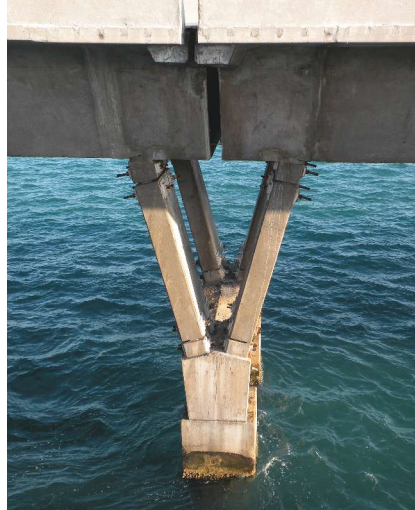
PRECASTER: Standard Concrete, Tampa, Fla.—a PCI-certified producer

CONTRACTOR'S SPECIALTY ENGINEER (DESIGN AND DETAILING OF FALSEWORK, MEANS AND METHODS): A2B Engineering LLC, Tampa, Fla.

CONTRACTOR'S SPECIALTY ENGINEER (FIELD SERVICES): BMA Consulting Engineers, Hollywood, Fla.

CONSTRUCTION INSPECTION: WSP|Parsons Brinckerhoff, Tampa, Fla.

Each pier foundation consists of two 42-in.-diameter concrete drilled shafts with cast-in-place caps that were connected by a precast concrete tie. Longitudinal movements of the bridge due to long-term deformation, thermal, and horizontal loads were accommodated by shear deformation of bearing pads at the bases of the interior V-piers. At the expansion joint locations, the V-pier legs are hinged at the top and bottom.



Side view of original V-piers with Freyssinet hinges at top and bottom. Photo: Luis Vargas.

Existing Bridge Condition

The bridge had a National Bridge Inventory (NBI) rating of 4 (poor condition) due to the condition of the 12 piers at the expansion joints. By contrast, the NBI superstructure rating for this bridge was 6 (satisfactory condition). The Florida Department of Transportation (FDOT) policy is to repair or replace bridges with an NBI rating of 4 or less. Bridges of this age were designed to achieve a service life of 50 years. In order for this bridge to reach its service life of 50 years, repairs were needed.

The 12 piers at the expansion joints were designed to accommodate the longitudinal expansion and contraction of the concrete segmental superstructure due to thermal fluctuations by allowing rotation about the Freyssinet concrete hinges. Somewhere during the design process, steel rods were added to pass through the center of the hinges. These rods effectively limited the rotation of the hinges, causing the piers to crack.

These piers are located in an extremely aggressive (saltwater) environment. Water entered the cracks in the pier concrete causing deterioration and corrosion of the reinforcing steel in the vicinity of the hinges. The piers were subsequently reinforced by temporary

plates and external post-tensioning bars in order for the bridge to continue functioning. FDOT has been aware of the condition of the piers since 1990, and several unsuccessful attempts have been made over the years to fund the replacement of the 12 piers at the expansion joints.

If the bridge continued to deteriorate without repairs, the bridge's load-carrying capacity would have decreased, which would have



Photo of the existing V-pier with the 1908 arch structure in the background. The galvanized compression plates installed shortly after construction are visible. Photo: Luis Vargas.



Precast concrete replacement pier ready for transportation from precaster's plant in Tampa, Fla. Photo: Kurt Podoll, Standard Concrete.

eliminated many of the overweight permit loads that businesses in the area currently depend on and load posting may have been required. This would have had a negative effect on commerce and prosperity of the region. If the bridge was not repaired the damage also could have spread to other parts of the structure, and may have ultimately reached a point where temporary closure was needed to facilitate more extensive repairs. The cost for replacing the Long Key Bridge was approximately \$150 million and the cost to replace the 12 V-piers at the expansion joints was about \$14.4 million.

Replacement of V-Piers

The replacement project encompasses the 12 V-piers at the expansion joints and has the following requirements:

- Keep the same original appearance.
- Maintain uninterrupted traffic on the bridge at all times since it is the only evacuation route of the Lower Keys during hurricane season.
- Meet stringent environmental requirements of the Florida Keys National Marine Sanctuary.
- Do not allow construction activities to interfere with the nearby historic Old Flagler Bridge.

FLORIDA DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Hilman Rollers, Marlboro, N.J.; and VSL, Hanover, Md.

BRIDGE DESCRIPTION: This 12,152-ft-long single-cell segmental concrete box-girder bridge was the first segmental bridge built in Florida and is one of the series of bridges in the viaduct serving the Florida Keys. It was built in 1982 using span-by-span construction to erect 722 segments. The structure carries two lanes of traffic and a major utility—the drinking water supply line. It is the only concrete segmentally constructed structure to use transverse prestressing and a pretensioned deck.

REHABILITATION STRUCTURAL COMPONENTS: Precast concrete V-piers with grouted connections, cementitious grout, and high-strength post-tensioning bars

BRIDGE CONSTRUCTION COST: \$14.4 million for the pier replacement



Special lifting and handling procedures were established. Photo: Kurt Podoll, Standard Concrete.

- Select a structural system that accelerates construction resulting in minimum inconvenience to the public.

Several design considerations were incorporated into the engineering of the replacement project. Since the bridge already had 30 years of service, most long-term deformation due to creep, shrinkage, and steel relaxation has occurred. Therefore, the proposed system only needed to accommodate thermal movements and lateral loads. This was accomplished by using a precast concrete inverted delta-frame that closely resembles the appearance of the existing bridge piers.

The precaster carefully designed the forming system to facilitate removal



Temporary devices used to lock expansion joints during pier replacement. Photo: FDOT.

of the interior core forms and to use self-consolidating concrete. Lifting and handling procedures were established by the project team to meet the FDOT requirements to minimize cracking. These prefabricated elements were manufactured in Tampa, Fla., and shipped to the project site.

Elastomeric bearing pads located on top of the delta-frame support the segmental concrete box girder and accommodate lateral forces and longitudinal displacements. The new precast concrete V-pier has a pier cap, which is designed with a special moment connection (similar to other accelerated bridge construction [ABC] connections in high seismic areas) to the existing drilled shafts, providing continuity to the foundation similar to the original design.

The replacement required slight modifications to the appearance of the V-piers without affecting the remaining members of a bridge unit. Since connection of the V-pier legs to the superstructure was no longer monolithic, the bridge is transversely restrained by a shear key that was introduced between the delta-frames. Also, the inclination of the V-pier leg in the original monolithic detail introduced a compression force in the bottom flange of the box girder that reduced the service-load moment by 8%. Since the new V-pier detail does not produce precompression in the box girder, the service load moment was no longer reduced. Analysis indicated that these structural changes were not detrimental to the performance and load carrying capacity of the bridge.



Temporary support system supporting spans as existing V-pier is being removed. Photo: FDOT.

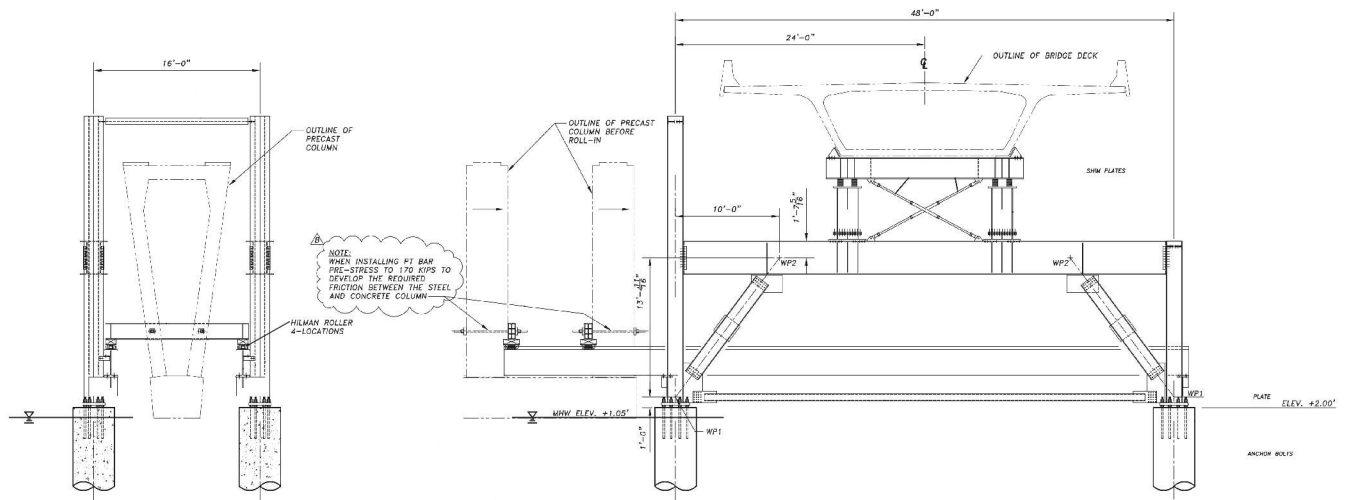


Reinforcing bar cage, grouting tubes, and steel duct for connection between drilled shaft and replacement pier. Photo: Kurt Podoll, Standard Concrete.

The temporary support system (TSS), envisioned and engineered to support the box girder during the replacement of the V-piers, consisted of an innovative steel structure that was unique, safe, and efficient. It was designed with the characteristics of a permanent structure as it carried the bridge and traffic while the substructure was being replaced. The TSS was supported on temporary drilled shafts and included a sophisticated jacking and monitoring system to transfer all dead and live loads from the superstructure without perceptible displacements. As the replacement work was done within the ecologically sensitive Florida Keys National Marine Sanctuary, the TSS avoided special permitting requirements by being independent of the existing bridge (not



Temporary support system spanning between temporary outboard drilled shafts supporting the bridge after the V-pier has been removed. Photo: FDOT.



Shop drawing excerpt from temporary support system frame showing replacement scenario. Figure: A2B Engineering LLC.

using the existing bridge for support). The TSS addressed several aspects of constructability: it was reusable, accommodated existing foundation and superstructure conditions, and allowed for all assembly and disassembly operations to be done above water.

The construction activities started in March 2013 and ended in December 2015. The average V-pier replacement took approximately 1 month. The construction sequence was as follows

1. Install temporary drilled shafts.
2. Install the temporary support system.
3. Install stabilizing system to the existing V-pier.
4. Restrain expansion joint pier

segment of adjacent units with post-tensioning devices.

5. Preload jacking devices with 80% of jacking loads.
6. Monitor deflections and possible settlement for about 6 hours.
7. Jack the structure to transfer superstructure reactions to the temporary support system.
8. Saw cut or burn (or both) connections at the hinges (top and bottom).
9. Disconnect and remove the existing V-pier cap and footings by wire cutting at the top of existing drilled shafts.
10. Slide in and level the new V-pier.
11. Drill holes in the existing drilled shafts; install and grout steel bars.
12. Install bearing pads and retract jacks to transfer load to new pier.

Conclusion

Replacing the 12 piers at the expansion joints was by far the most prudent use

of state funds. The replacement of the piers eliminated the existing structural deficiency, making it possible for the bridge to achieve its service life of 50 plus years. ▲

Dennis Fernandez is the structures maintenance administrator at the Florida Department of Transportation, District Six in Miami, Fla. Dr. Luis Vargas is chief bridge engineer at Bolton Perez & Associates in Miami, Fla., and former engineer of record with HDR when the rehabilitation was completed.

EDITOR'S NOTE

See the article in the November-December 1980 PCI Journal by Thomas Gallaway for more information on the original design and construction of this bridge. Portions of this article are based on a paper by Vargas for the 2015 National ABC Conference.



New pier seated in temporary support system and ready for side launch into permanent position. Photo: FDOT.



With the new V-pier in position, anchor holes were used as drilling template for establishing connections into drilled shaft. Photo: FDOT.



High-strength bar installation and cementitious grouting operations using ABC connection details. Photo: FDOT.