HEAVY MOVABLE STRUCTURES, INC.
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Gasparilla Island Swing Bridge Replacement

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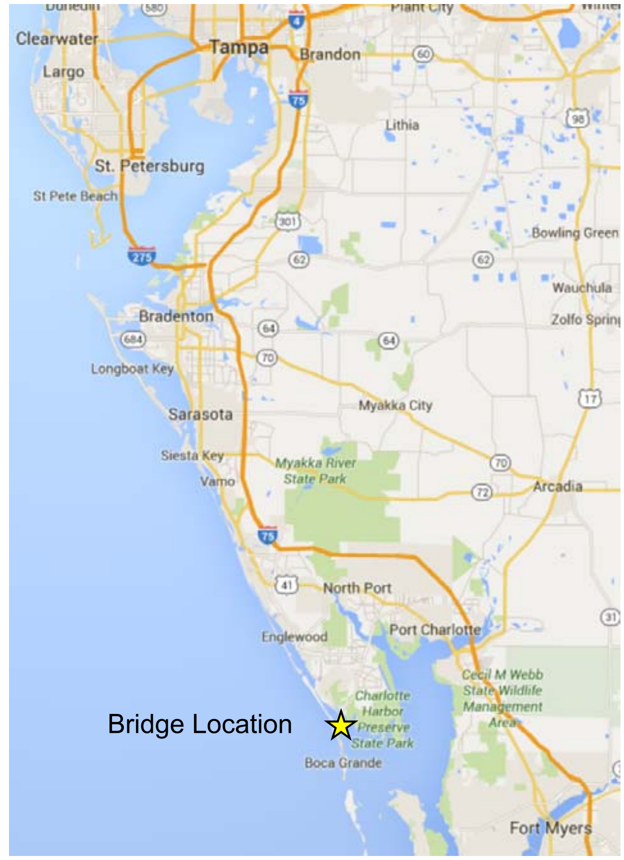
Introduction

The Boca Grande Causeway, CR 771, located in Placida, Charlotte County, Florida, separates Placida Harbor to the north from Gasparilla Sound to the south, and provides access from the mainland to three barrier islands - North, Cole and Gasparilla Islands. The causeway consists of three bridge structures. The northernmost structure is the Gasparilla Island Swing Bridge (a.k.a. North Bridge) over the Gulf Intracoastal Waterway between Placida Harbor and Gasparilla Sound. The other two structures are the Center Bridge and South Bridge. The Gasparilla Island Swing Bridge is not on the National Highway System and is owned, operated and maintained by the Gasparilla Island Bridge Authority (GIBA), which is a State of Florida Independent Special District. It is designated as a "Critical Bridge" by the Florida Department of Transportation (FDOT) because it provides the only access to and from the barrier islands. The replacement project was needed due to the substandard load carrying capacity, structural deterioration, substandard safety appurtenances, narrow roadway width, unreliable operational systems, and vulnerability to vessel collision and storm wave loading.

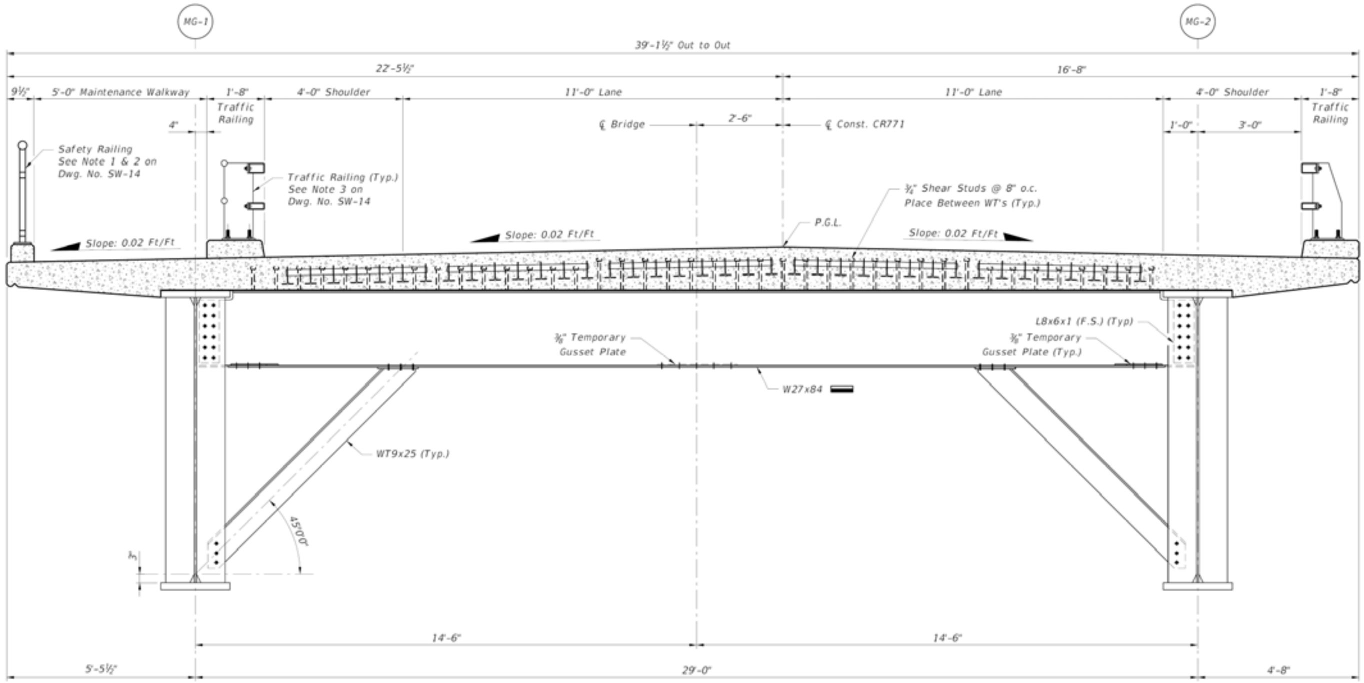


Site Plan

The original Gasparilla Island Swing Bridge, built in 1958, had a total length of 600' and is on a straight alignment. The bridge comprised a swing span over two 80' wide navigation channels skewed at an 80.89 degree angle to the bridge axis. Both the north and south approach spans were 192' long and consisted of four 48' simply supported spans with precast prestressed concrete girders. The 213' long swing span consisted of a steel "fish belly" plate girder superstructure with riveted built-up sections (flange angles with cover plates and web plates). The bridge had a narrow 22' roadway width for two 11' travel lanes with no shoulders or sidewalks.

Original Gasparilla Island Swing Span

The new bridge has a length of 678' and is on an offset alignment shifted 57'-6" center to center from the existing bridge with horizontally curved approach spans and approach roadway. The bridge consists of a 225'-0" swing span, two 117'-9" south approach spans, and two 108'-9" north approach spans. The typical section provides two 11' lanes, two 4' shoulders, and a 5' maintenance walkway on the west side for a total width of 39'-1½". The approach superstructure consists of Florida-I prestressed concrete beams (FIB) supporting a cast-in-place concrete deck. The swing span superstructure consists of steel plate girders of welded construction with similar "fish belly" shape to the existing swing span, supporting an Exodermic® deck that spans longitudinally between a series of floorbeams, which is the first application of this configuration in Florida.



New Swing Span Section

Project Need

The existing post-tensioned concrete beams were of an older vintage that lacked the required shear reinforcement per current design standards, and thus required monitoring for safety. There were weight restrictions with posting of 17 Tons for 2 Axles (single-unit truck) and 20 Tons for 3-Axles (combination truck). Despite a rigorous maintenance program, the swing span operational reliability was becoming more difficult to maintain. Additionally, the low lying bridge and pile bent substructure were vulnerable to collapse from vessel impact and wave loading from coastal storm events. The narrow roadway width with no shoulders did not permit passage of vehicles in both directions in the event of a disabled vehicle on the bridge. The narrow roadway width and substandard bridge railings were potentially hazardous to motorists. These vulnerabilities were heightened since the Gasparilla Island Swing Bridge is part of a critical evacuation route for residents of the barrier island communities. The bridge also provides the only access for emergency response, including police, ambulance and fire rescue.

Design Challenges

The design team was faced with numerous design constraints and challenges. Each would need to be overcome in order to achieve a permittable, buildable, cost effective and durable facility.

SHPO Requirements

The original Gasparilla Island Swing Bridge was designated as part of the State Historic Registry. In order to mitigate the loss of the cultural resource it was agreed that the new bridge would be of the same basic type and general appearance as the original. As a result, the new bridge would be a swing span type movable bridge with a “fish belly” steel plate girder configuration. The team was charged with the first design of this bridge type in Florida since the original, but with all modern requirements and systems. The construction of a new swing span immediately adjacent to an existing swing span, while maintaining vehicular and navigation traffic throughout construction, was a significant challenge.

Coast Guard (USCG) Requirements

The Gasparilla Island Swing Bridge traverses the Gulf Intracoastal Waterway and therefore the design must maintain navigation traffic during construction and meet the US Coast Guard (USCG) navigation requirements. It was determined that the new structure would have two channels, each 80’ in width similar to the existing bridge, and a minimum vertical clearance of 21’. The USCG also allowed for temporary narrowing of the navigation channel and closure of one of the two channels during construction.

Sensitive Environment

The waterway is part of the connection between Lemon Bay and Gasparilla Sound Aquatic Preserves, which is part of the greater Charlotte Harbor State Aquatic Preserve and Estuary system. In order to receive permits from the Southwest Florida Water Management District, US Army Corps of Engineers, and the US Coast Guard, the bridge alignment needed to avoid impacts to protected mangroves, sea grasses and essential fish habitat, by minimizing the offset from the existing alignment. Phased construction of portions of the approaches would be required to maintain traffic during construction.

Safety and Evacuation

The Charlotte County Comprehensive Plan indicates that the Southwest Florida Regional Planning Council’s Hurricane Evacuation Study 2001 identifies Charlotte County as the county in southwest Florida most vulnerable to impacts from hurricanes and tropical storms. It also states that the County’s evacuation problem is greatest in the West County Planning Area, which includes all of the subdivisions platted on the Cape Haze Peninsula and the County’s barrier islands. Transportation in the West County

Planning Area is based on three major roads: State Road 776 and County Roads 771 and 775, (which carries the Gasparilla Island Swing Bridge).

As mentioned earlier, the swing bridge is part of a critical evacuation route for residents of the barrier island communities, and is also the only access for emergency responders. The existing weight restrictions prohibited large trucks from travelling over the bridge, which presented problems during evacuations. As a result, the Gasparilla Island Swing Bridge is designated as a "Critical Bridge" by FDOT. This designation greatly heightened design requirements, including vessel impact loading and coastal storm wave loading.

Vessel Impact

The new Gasparilla Island Swing Bridge is the first swing bridge to be constructed over the Gulf Intracoastal Waterway in Florida since 1958. In accordance with FDOT design procedures, an AASHTO Method 2 Vessel Impact Probabilistic Risk Analysis was required, which accounts for asymmetric northbound and southbound vessel traffic and two navigation channels, which is inherent to swing spans. The bridge foundations were required to be designed to resist large lateral loads associated with a 10,000 year collapse return period for a "Critical Bridge", while minimizing the swing span length and project costs. Teamwork between the coastal, geotechnical and structural engineers was necessary to quantify the effects of scour, wave loading and errant vessels, while safely proportioning the resisting scour protection, foundation, substructure and superstructure systems.

Hydraulic Models

The team developed models to estimate the effects of scour and wave crests from coastal storm events. Wave crest loading can impart large lateral and overturning loads on the superstructure and substructure. Because the forces from wave loading are substantial, and applied at the level of the superstructure, there are significant challenges in designing a bridge to resist such forces. As such, it is desirable to locate the superstructure a minimum of 1 foot above the 100-year maximum wave crest. The wave crest elevation for the statistical 100-year storm event was estimated to be Elevation +16.20.

The FDOT inspection reports indicated that the bridge was scour critical, and unstable with a 3 rating. The hydraulic models also estimated that the substructures would see 100-year storm scours of 20' below the channel bottom. This required that the bridge's concrete pile foundations were driven deep enough to include significant embedment depth to maintain lateral stability and sufficient strength to resist flexure for these significant scour depths. Load cases were required to include vessel impact from tug and barge tows at half of these scour depths.

Maintainability, Durability and Reliability

The coastal Florida marine environment is extremely harsh on bridge structures. FDOT requires that the superstructure be located above the "splash zone", which is 12' above mean high water. In addition, salt water run-off on the deck from towed boats is also extremely corrosive.

As it provides the only access to the barrier island communities, reliable operation of the swing span is critical. Reliability requires that the operating equipment be redundant with features that permit the bridge to continue operating while portions of the equipment is removed for service, and/or otherwise made as durable as practical to maximize service life and reduce the risk of premature failure. Reducing the number of times that the bridge is required to open minimizes the wear to the mechanical systems. The existing bridge had a low vertical navigation clearance of only 8' and required openings for most vessels on a very active channel. The team endeavored to reduce the number of openings by at least 50% by maximizing the vertical clearance to the maximum extent practical. The proximity of the toll plaza to the north of the bridge limited the amount the bridge could be raised.

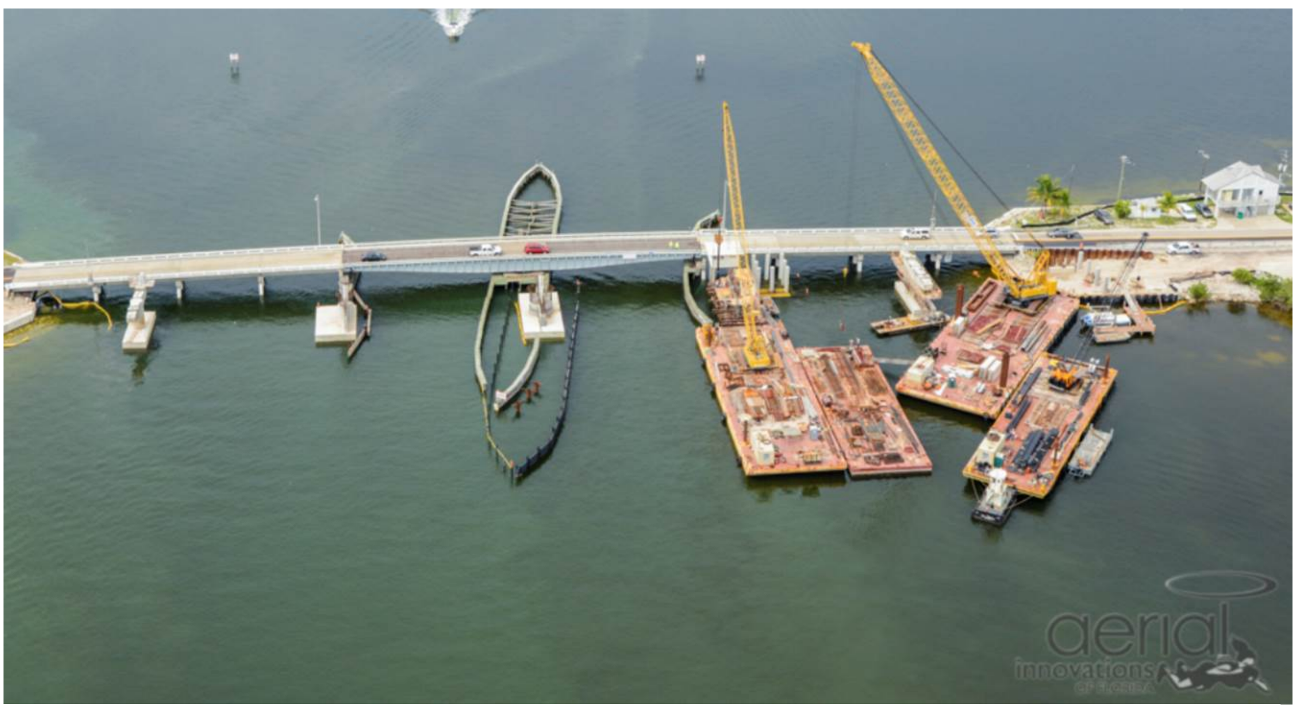
Design Solutions

The challenges and constraints described above were addressed in a holistic manner since many of the solutions and effects are intertwined.

Geometry

In order to minimize environmental impacts and meet permitting agency commitments, the new bridge alignment was held as close as possible to the existing bridge. The edge of the new swing span was located approximately 21’-6” to the east of the existing swing. This location also accommodated the existing and new tender house locations. The approach span and roadway alignment include reverse horizontal curves to tie back to the existing alignment and to align with the toll plaza. Phased construction of the mechanically stabilized earth (MSE) retaining walls was used to maintain traffic during construction while minimizing the offset at the bridge ends.

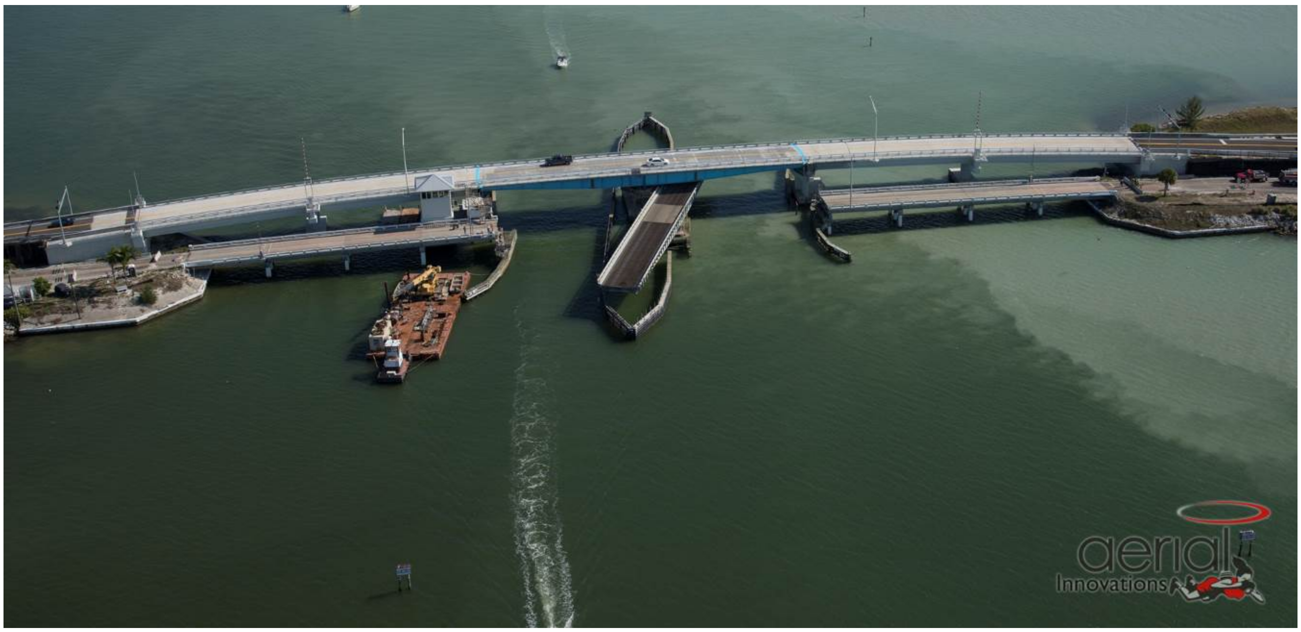
Although the channel widths for the new bridge would match the existing, it was not possible for the alignment of the new channels to match the existing. It is a nuance of swing bridge design that the bridge width affects the bridge length and channel location. The center fender system that protects the swing span when open and delineates the channel limits is set by the swing span width. To accommodate the wider swing span and corresponding center fender system, and to address the offset of the new swing span along the skewed channel, the North Channel was shifted 20’-0” to the north. The north channel would be temporarily reduced to 60’ during construction, as permitted by the USCG, because the existing swing span opening angle was limited by the new swing span pivot pier.



New Foundation Construction Showing Offset Center Fender

The geometry of the bridge results in an overlap of the existing and new swing span circular operating circles with a diameter equal to each of the swing span lengths. In order for both bridges to operate during construction, the new bridge needed to be constructed high enough to clear the existing bridge. Setting the minimum clearance of the swing span to 22'-4" allowed for all of the constraints to be satisfied:

- Meets the USCG minimum vertical guide clearance
- Allows the bottom of the new swing span to clear the existing swing span during operation
- Allows the minimum low member to stay well above the coastal storm wave crest
- Maximizes the clearance above the extremely aggressive saltwater for reduced exposure
- Reduces openings by approximately 50%
- Allows for the roadway to touch down at grade prior to the toll plaza



Existing Swing Span Opened Under New Swing Span

Vessel Collision

This project was the first application of FDOT pier design procedures, which is based on the AASHTO Method 2 vessel collision probabalistic risk analysis, for a swing span on the Gulf Intracoastal Waterway in Florida. Adding to this challenge is the "Critical Bridge" designation, which greatly reduces the allowable frequency of collapse, and consequently increases the pier design loads. The design team had to interpret the spirit and application of the code to best proportion the collapse risk and loading for each of the water piers. The design was particularly challenging for the rest pier design since the channel widths and corresponding swing span length are increased if the pile array size is increased. The cost of the swing span and the overall project was highly sensitive to the length of the swing span. The design team minimized the span length by minimizing the rest pier pile arrays through the use of pile batter and offsetting the pile array away from the channel relative to the rest pier column and cap. The two rows of piles centered on the rest pier were designed for the strength and service loads while the entire array with two additional rows of piles away from the channel were designed for the extreme vessel collision loads.

The new fender systems adjacent to the pivot pier and rest piers utilize fiberglass reinforced plastic wales and polymeric piles.

Corrosion Resistance

Corrosion resistance was provided by way of increased concrete cover on the substructure and MSE wall panels, concrete material with calcium nitrite (which counteracts corrosion), and fly ash admixture (which increases impermeability).

The swing span steel members are protected by maximizing the clearance over the water, with the use of a deck with a solid concrete surface, and a three-coat paint system with a zinc-rich primer that cathodically protects the steel. Steel field connections utilized mechanically galvanized bolts.

Closed Lightweight Deck

The use of closed lightweight deck systems has become standard for new Florida movable bridges. Closed decks with a concrete surface provide a more durable solution by protecting the supporting steel superstructure from corrosion and provide a consistent riding surface, similar to the rest of the bridge, with good skid resistance. The design team chose to use an Exodermic® deck, which is a thin reinforced concrete slab made composite with a hot dip galvanized steel grid. The lightweight deck system provides a lower mass that significantly reduces the swing span weight, inertia and corresponding power requirements. This is the first application of an Exodermic® deck on a steel plate girder swing span in Florida. Use of this system has the added benefit of reducing the number of supporting elements. The efficient design of the Exodermic® deck allows the deck to span greater distances. The deck spans 13’-6” between floorbeams, which eliminates the need for stringers. The deck also serves as a horizontal diaphragm that, in combination with floorbeam knee braces, eliminates the need for permanent lateral bracing. Temporary bracing is provided to assist in the stability and alignment of the steel framing during construction. The Exodermic® deck is made composite with the main girders and floorbeams by way of welded headed stud shear connectors to increase the strength and stiffness of the swing span steel framing.


Swing Span Solid Deck

Lightweight concrete was used with a specified equilibrium unit weight of 115pcf. The Contractor elected to place the Exodermic® deck concrete in the field by pumping the lightweight concrete. This approach required that the swing span tips were allowed to deflect with the placement of the concrete. Jacks were used to control the tips but still allow them to deflect while the screeds placed the concrete in a balanced fashion from the tips toward the pivot. When pumping lightweight concrete, it is important to perform advanced testing of the proposed mix design using the proposed pumping equipment, and confirmation field testing during placement to confirm the physical properties of concrete, including unit weight, as the pump pressures can force excess water into the lightweight aggregate, which can effect the properties.

Span Support Systems

The Span Support System consists of the Pivot Bearing, Balance Wheels, Live Load Rollers, Span Locks and the End Lifts. These elements combine to support and stabilize the swing span superstructure with vehicular traffic on the bridge and are of robust, durable construction

Pivot Bearing and Balance Wheels

The Pivot Bearing supports the entire 800-ton dead load of the swing span on the pivot pier and permit the swing span to pivot when driven by the operating machinery. The pivot bearing is bolted to the underside of the swing span pivot girder and is anchored to the pivot pier. Shims are provided to adjust the height of the swing span. The pivot box houses circular bronze (upper) and steel (lower) disks in an oil bath to reduce friction. Covers with seals are provided to contain the oil and prevent contamination. The circular disks include matching convex (upper) and concave (lower) curved interface surfaces, which experience minor deformation under dead load. The matching curved surfaces allow the swing span to find a stable equilibrium position after minor initial wear. Jacking points on the pivot girder are provided to lift the span for future maintenance of the pivot bearing.

The balance wheels consist of an array of eight diametrically opposed steel wheels with lubricated bronze bushings bolted to the underside of the swing span above a circular steel track on an 8’-4” radius centered about the pivot bearing. The wheels and track are tapered to eliminate sliding of the wheels. The track is integral with the curved rack gear segments. The wheels are set with a 0.05” gap above the track under normal operation using shims. The balance wheels come into contact with the track and provide a righting reaction when the swing span leans during operation from wind or imbalance.

The Live Load Rollers are an additional pair of steel wheels below the main girders in line with the pivot girder that engage ramps when the bridge is in the closed position. These rollers act to stabilize the swing span in the transverse direction and transfer vehicular live load to the pivot pier while the swing span is in the closed position. This minimizes truck loading on the Pivot Bearing. Like the Pivot Bearing and the Balance Wheels, the Live Load Rollers are passive devices that do not require actuators, which reduces the maintenance burden.

Live Load Rollers

Both the Span Locks and End Lifts are actuated components supported on the Rest Pier near the tip of the swing span. The End Lifts deflect the tips of the swing span upward so that the swing span deck meets the deck on the approach spans. They also impart a positive reaction that prevents uplift at the supports due to vehicular loading on the opposite half of the swing span. The end lift configuration utilizes an eccentric wheel, as opposed to a wedge system, to reduce the operating loads. The end lift wheel can accommodate a greater variation in tip movement and provides increasing mechanical advantage at the end of the stroke where the greatest force is needed. The end lifts deflect the ends of the swing span upward a total of 2” in order to reverse the dead load and thermal gradient deflection. The end lifts are sized considering the stiffness of the composite section properties of the main girder and Exodermic® deck. A total stroke of 6” provides clearance for the swing span to pivot over the end lifts during operation. The end lifts are powered by a 7.5 HP electric motor that drives through a worm gear reducer.

End Lift

The Span Locks do not transfer live loads from the swing span tips as would be expected with a double-leaf bascule bridge. Rather, they provide lateral supports in high winds and function to center the span during the closing sequence. The lock bar is driven into a receiver on the swing span using an electric linear actuator.

Span Lock

Span Operating Systems

The swing bridge is controlled by a relay-based control system with PLC monitoring. This combination of robust and easily maintainable elements with an augmentable monitoring system has been the preference of owners throughout Florida. The electrical control systems are located in the lower level of the Tender House. The bridge is outfitted with a full array of modern safety interlocks, communication and visibility tools.

Span Operating Motor, Brakes and Reducer on Machinery Platform

The swing span has two independent drive trains, each mounted on the swing span above the Pivot Pier. The redundant drive trains permit the bridge to remain in operation using a single drive train while the other drive train is temporarily removed for service. Each drive train includes a 10 HP vector duty squirrel cage electric motor controlled by a flux vector drive, a 341:1 right angle speed reducer, and a pinion gear mounted on a vertical shaft below the reducer that engages a rack gear mounted on the Pivot Pier. The drive machinery is located more than 27’ above the water, covered by the swing span closed deck, and enclosed by the main girders and floorbeams (pinion girders), greatly reducing exposure to the corrosive marine environment, and improving durability.

Pinion

Summary

The Gasparilla Island Swing Bridge presented numerous challenges requiring innovative solutions, which were achieved through a holistic and collaborative approach. Most notably, the geometrics that were developed allowed for construction of a new swing span immediately adjacent to an existing swing span, while maintaining vehicular and navigation traffic throughout construction. The end result is a new, context sensitive bridge that maintains the character of the barrier island community, was constructed with minimal environmental impacts, provide increased reliability and maintainability, and addresses the vulnerabilities to coastal storms and vessel collision. The Gasparilla Island Bridge Authority and residents of Placida and North, Cole and Gasparilla Islands once again have a safe and reliable bridge that will serve the community for many decades to come.

New Swing Span West Elevation