# HEAVY MOVABLE STRUCTURES, INC. TWELTH BIENNIAL SYMPOSIUM

November 3-6, 2008

Innovative Solutions to Complex Challenges NW 12<sup>th</sup> Avenue Bascule Bridge Replacement George C. Patton, P.E, M.S.C.E. E. C. Driver & Associates, Inc.

> CARIBE ROYALE RESORT ORLANDO, FLORIDA

## Introduction

Replacement of any bridge in a congested urban setting most always poses challenges, but replacement of the NW 12<sup>th</sup> Avenue Bascule Bridge in downtown Miami over the Miami River posed more than its fair share for the design team and Contractor. This paper discusses the numerous challenges the project team faced and the innovative design and construction solutions developed to address these challenges.

Among these challenges were:

- Replacement of an existing 60' wide, four-lane bascule bridge with a new 110' wide sixlane bascule bridge with limited available right-of-way.
- Extremely congested and active urban roadway network with the need to maintain four lanes of traffic along NW 12<sup>th</sup> Avenue throughout construction. (NW 12<sup>th</sup> Avenue, a.k.a. SR 933, is a major urban arterial that provides direct access across the river between the Latin Quarter and East Havana residential neighborhoods and business districts including the Orange Bowl Stadium to the south and the Allapattah neighborhood and business district including the Jackson Memorial Hospital, Cedars Medical and University of Miami Hospital and Medical Center, Miami Civic Center, Miami-Dade Justice Center to the north. The presence of the hospitals and medical centers immediately north of the bridge made the need to maintain traffic imperative for life-safety reasons. NW 12<sup>th</sup> Avenue is also a vital link to important transportation facilities including the Dolphin Expressway and several Metro Rail Stations.)
- Very active commercial waterway with the need to maintain navigation traffic throughout construction with only a maximum eight-hour closure of the river permitted. (The United States Coast Guard working with the Miami River Marine Group dictated the restrictions on river closures. The Miami River is considered the fifth largest port in Florida with more than \$4 billion of commerce annually, primarily from cargo traffic between the United States and the Caribbean, Central and South America with vessels ranging from 50 feet in length and less than 500 ton displacement to 300 feet and more than 2,500 ton displacement.)
- Significant increase in the vertical clearance beneath the bridge (from the existing 10' at the face of fenders to the proposed 25' at face of bulkheads) that was required to reduce the number of openings. (Each bridge opening has a significant impact on the congested downtown road system. Because of intersections with nearby cross streets at both ends of the bridge the new vertical profile was severely constrained.)
- Significant increase in horizontal clearance (i.e. from 85' between fenders to 150'-0" between bulkheads) required to improve navigation safety and commerce.
- An aesthetic and economical bridge design. (Although the Florida Department of Transportation had limited available funds to build the project, in order to mitigate the loss of the existing 75-year-old historic resource and to reduce impacts on the adjacent historic Spring Garden neighborhood and other adjacent landmarks they had committed to the community to construct a bridge with a high level of aesthetics with a number of specific features including a double-leaf bascule bridge with a concrete riding surface and steel box main girders, low profile and visually open traffic barriers, decorative pedestrian railings, arched approach span girders and octagonal pier columns reminiscent of those on the original bridge, and distinct twin octagonal control towers similar to the nearby historic Hindu Temple.)

Innovative solutions to the above challenges discussed include:

- Development of the geometric and phased construction solutions.
- Details of the economical twin staggered double-leaf bascule span configuration with skewed bascule piers.
- Details of the structurally efficient bascule leaf design including steel box main girders, integral moment resisting floorbeams, lightweight precast Exodermic deck made composite with the main girders and floorbeams, and steel counterweight box.
- Details of the push-pull tandem hydraulic cylinder drive system.

## Background

Following an in-depth Preliminary Development and Environmental (PD&E) study completed in 1998, the Florida Department of Transportation District 6, concluded that the existing 70+ year old NW 12<sup>th</sup> Avenue Bridge over the Miami River in downtown Miami, Florida had reached the end of its useful service life and was in dire need of replacement. The bridge contained existing numerous deficiencies and was no longer meeting the city's transportation needs, and thus a new bridge was needed to improve mobility within downtown Miami. The bridge was identified as "structurally deficient" with a sufficiency rating of 46.9 with more than half of the bridge structural components in poor condition and unreliable bridge operation due to the deteriorated operating equipment. The bridge also had substandard roadwav horizontal and



FIGURE 1: Location Map

vertical geometry, roadway width that was too narrow for the high volume of vehicular traffic (AADT greater than 34,400 with 5.4% trucks), low 10' vertical clearance over NW 8<sup>th</sup> Terrace, and narrow 4' wide sidewalks that do not meet ADA requirements. A narrow horizontal clearance of 85'-0" beneath the bridge made tow of large cargo vessels difficult, with ever increasing risk of impact by an errant vessel. The high volume of navigation traffic, low vertical under-clearance of 10' at the fenders and 17' at the center of the span, high volume of vehicular traffic, numerous signalized intersections along NW 12<sup>th</sup> Avenue with insufficient turn lane storage resulted in:

- An average of 22 and maximum of 40 bridge openings per day on weekdays and an average of 27 and a maximum of 50 bridge openings per day on weekends.
- Approximately 13% of all daily vehicles that experienced a delay due to a bridge opening.
- An average of six (6) traffic signal cycles required to normalize traffic flow.
- A significant accident history directly related to the frequent bridge openings.

The existing bridge was 627'-1" long and contained a 157'-7" long double-leaf trunnion bascule span (measured back to back of piers, 120'-7" center-to-center of trunnions) and 12 concrete approach spans ranging from 30' to 44' in length. The bridge carried two northbound and two southbound travel lanes with a clear roadway width of 48'-0" with no median separator and original 5'-2" wide raised sidewalks on each side of the roadway reduced to less than 4' due to installation of guardrail along the curb.

The existing bridge was originally constructed in 1929, is located near the historic Spring Garden neighborhood and



PHOTO 1: Existing Bridge – Looking South

immediately adjacent to the Merrill-Stevens Dry Dock & Repair Co. (Florida's oldest continuously operating yacht services company.) The bridge was eligible for listing on the National Register of Historic Places before it was removed from service and included a number of distinct aesthetic features including architecturally distinct octagonal columns and decorative pedestrian railings.

The preferred alternative from the PD&E study called for a new 110' wide bascule bridge that accommodated four 12' through lanes, 11' southbound and northbound right turn lanes, median barrier, 2'-6" inside shoulders, 8' outside shoulders, two 6' sidewalks, traffic barriers between the roadway and sidewalks, and pedestrian railings at the back of sidewalk. The bascule span included twin 55' wide double-leaf trunnion bascule leaves with closed rectangular piers and an overall length of 341'-0" measured back to back of bascule piers and a span length of 265'-9" center-to-center of trunnions. This included 15' wide walkways between the river and bascule piers to accommodate implementation of the Miami River Greenway (an ongoing riverfront enhancement program intended to restore access along the river to the public by constructing a linear park system along the river and river corridor.) The front wall of the pier was proposed to be inclined toward the river to reduce the span length slightly. The new bascule span was to provide a minimum horizontal clearance of 150' between bulkheads with piers located outside the limits of the river, which provided improved navigation safety. The new bascule span was also to provide a minimum vertical clearance of 25' at the face of the bulkheads with the bascule leaves lowered, unlimited vertical clearance for a horizontal width between leaf tips of 110' and a

minimum vertical clearance of 75' (minimum vertical clearance of the lowest fixed bridge along the river) at the face of bulkheads with the bascule leaves raised. With this clearance envelope, the United States Coast Guard did not require a separate fender system. Composite plastic rub rails were bolted to the face of the bulkheads in the event an errant vessel strikes the bulkhead.



PHOTO 2: Miami River Navigation Traffic



FIGURE 2: Replacement Bridge General Plan and Elevation

## **Bascule Span Solution**

### **Cost Reduction Strategies**

During final design, strategies were investigated to reduce the cost of the project while still meeting the commitments made to the community during the PD&E Study. As the cost of the bascule span is by far the largest component of the overall project cost, the focus on cost reduction strategies was primarily on the bascule span. Cost saving opportunities can be found throughout the bascule span and ultimately is the sum total of all of the individual cost savings.

### Reduction in Span Length:

Because the cost of the bascule span increases exponentially with the span length, strategies that reduce the span length were found to provide the greatest opportunity to reduce cost.

The bascule span length was reduced 30' by moving the walkways for the Miami River Greenway from between the river and bascule piers to below the spans immediately behind the piers and placing the face of the bascule piers just behind the face of the bulkheads. This was found not to significantly deviate from the Miami Greenway Action Plan for this part of the river where the Greenway is primarily along the adjacent road system.

The roadway alignment for the new bridge is such that the bridge crosses the river at a  $15^{\circ}$  skew from normal requiring a longer span length. However, the bascule span length was reduced an additional 15' by staggering the twin bascule leaves. To minimize the change in appearance of the bridge with this configuration, the bascule pier front and rear walls were skewed parallel to

the river rather than staggered with the bascule leaves. In space, the skewed pier walls are not visually obvious and actually appear more visually appropriate with the skewed waterway. A three-dimensional computer model of the proposed staggered bascule leaves with skewed bascule pier walls was developed to demonstrate to the Department and the community that the appearance of this configuration did not deviate significantly from the originally proposed non-staggered leaves with rectangular pier walls.

Finally, the bascule span length was reduced an additional 20' by reducing the distance from the trunnion to the front wall of the pier. The distance from the trunnion to the live load shoes at the front wall of the pier is typically 10% to 15% of the length from the trunnion to the tip. This distance is usually designed to ensure that there is no net uplift on the trunnion bearings. The significant weight of a bascule leaf with a closed deck and short, heavy counterweight results in relatively large dead load trunnion reaction and thus a shorter distance between the trunnion and live load shoe could be used without concern with uplift on the trunnion bearings.

Ultimately, it was possible to reduce the bascule span length from 265'-9" to 200'-0" center-tocenter of trunnions (a reduction in bascule span length of 65'-9") and 341'-0" to 281'-0" from back-to-back of bascule piers (a reduction in overall bascule span length of 60'-0") without significantly impacting the bridge appearance or the commitments made to the community with significant cost savings.

#### Reduction in Bascule Pier Length and Depth:

As bascule piers amount to a significant portion of the overall bascule span cost, there are significant opportunities to reduce the cost of the bascule piers during the bascule span design and development.



FIGURE 3: Bascule Pier Front Elevation

The length and depth of the bascule pier is a function of the length bascule leaf tail. A reduction in the length of the bascule leaf tail results corresponding in a reduction in the length of the bascule pier walls, footing, pier deck, and access platforms; the wider and taller the pier, the greater the reduction in these items. Similarly, a reduction in the length of the bascule leaf tail yields a reduction in the height of the bascule pier walls and columns, depth of the cofferdam sheet piling and excavation, and thickness of the seal. The length of the bascule leaf tail can be reduced with a corresponding increase in the weight of the counterweight. An increase in weight of the counterweight requires either an increase in volume or increase in As the counterweight density.



FIGURE 4: Bascule Pier Side Elevation

volume is usually restricted vertically by the bascule pier deck, when the leaf is lowered, and machinery platform, when the leaf is raised, it usually is not practical to increase the counterweight weight by increasing the counterweight volume. As such, a significant increase in counterweight weight is typically accomplished with an increase in counterweight density, which is usually accomplished with either a combination of steel ballast and normal weight concrete or heavy weight concrete. On the NW 12<sup>th</sup> Avenue Bridge, an optimization study was performed comparing the reduction in bascule pier cost to the corresponding increase in counterweight cost for different lengths of bascule leaf tail. The volume of the counterweight was maximized for each case within the available geometry and the density was varied from normal weight concrete (unit weight of 150 pcf) to a sold steel counterweight (unit weight of 490 pcf.) Ultimately, a shorter bascule leaf tail with a counterweight unit weight of 320 pcf (50% concrete and 50% steel) was determined to be most economical.



FIGURE 5: Longitudinal Section thru Bascule Pier

As the depth of the bascule pier is also a function of the length of the bascule leaf tail (i.e. the bottom of the counterweight pit is typically established to accommodate the pivoting counterweight) there are strategies to further reduce the depth of the pier. The bottom of the counterweight pit is typically the top of the bascule pier footing and the footing thickness is typically designed to transfer the loads from the bascule pier walls and columns to the foundation piles. As the walls and columns are typically around the perimeter of the pier, there are no significant loads in the center of the counterweight pit and thus the piles need only be distributed around the perimeter of the pier and can be eliminated within the limits of the counterweight pit. On the NW 12<sup>th</sup> Avenue Bridge, the bascule pier footing is 7.5' thick. A 5.5' thick portion of the footing, within the limits of the counterweight pit where there are no piles, was removed leaving a nominal remaining thickness of 2' above the seal to span this opening and provide for a counterweight pit sump. This removal of footing concrete permitted the footing to be raised 5.5' with corresponding reductions in the height of bascule pier walls and columns, depth of the cofferdam sheet piling and excavation, and thickness of the seal. As the subsurface material to be excavated contained hazardous material and material to be removed consisted of limerock, the reduction in the depth of the bascule pier resulted in a significant corresponding reduction in rock excavation and hazardous material collection and treatment.

Innovative Solutions to Complex Challenges: NW 12th Avenue Bridge Replacement



FIGURE 6: Bascule Pier Plan at Machinery Floor Level

There are also features of the bascule piers that will reduce long-term maintenance costs. All walls, columns, access platforms and structural framing were constructed using cast-in-place reinforced concrete requiring no maintenance painting and minimizing potential the for steel The pier configuration is corrosion. designed with ample access to the sides and tail end of the bascule leaves for inspection and maintenance. The machinery platforms that support hydraulic cylinder manifolds and plumbing are protected by overhead concrete platforms to reduce the exposure of equipment to the weather. Hydraulic power units are located in an environmentally controlled room within each pier and centrally located between the two leaves.



PHOTO 3: Bascule Pier during Construction

#### Reduction in Bascule Leaf Weight and Future Maintenance:

It is well accepted that savings in the weight of the bascule leaf translates to savings throughout the bascule span. Reduction in the bascule leaf weight forward of the trunnion translates to a corresponding reduction in counterweight weight equal to two to three times that of the bascule leaf weight. A significant reduction in the overall bascule leaf weight can translate to corresponding reductions in the trunnion shaft, hub and bearing design and reductions in the bascule leaf drive machinery, bascule pier trunnion columns, foundations, etc. In addition, attention to detail and simplification in the bascule leaf details reduces maintenance costs.







FIGURE 8: Bascule Leaf Framing Plan and Longitudinal Section

The design of the bascule leaf on the NW 12<sup>th</sup> Avenue Bridge is a refinement of the innovative design developed for the award winning 17<sup>th</sup> Street Causeway Bridge in Ft. Lauderdale, Florida. The design consists of twin steel box main girders, floorbeams and floorbeam cantilevered brackets with moment resisting welded end connections, an Exodermic deck made composite with the main girders and floorbeams and a steel counterweight box. The design is a structurally efficient, lightweight bascule leaf that requires less maintenance than traditional bascule leaf designs and yields a clean, uncluttered understructure appearance.



FIGURE 9: Section thru Bascule Leaf

The 55'-0" wide bascule leaves provide adequate width to proportionately accommodate the steel box main girders with a balanced framing configuration with main girders at 31-6" on center and symmetric 11'-9" long floorbeam cantilevered brackets. At the front wall of the skewed bascule pier front wall, the bascule leaves required additional staggered cantilevered brackets midway between the floorbeams at this location.

The Department committed to providing a bascule span with a concrete riding surface for reduced noise, improved ride and skid resistance and the Exodermic deck provided a lightweight, structurally efficient solution. The Exodermic deck consists of a fabricated steel grid made composite with a sand-lightweight (115 pcf with 5,500 psi minimum compressive strength) reinforced concrete slab mounted on top of a steel grid. The steel grid consists of a series of inverted structural tees (WT 6x7 spaced at 8" on center) connected by a series of cross bars (<sup>1</sup>/<sub>4</sub>" x 2" bars spaced at 6" on center)



FIGURE 10: Exodermic Deck Isometric

inserted through holes in the stems of the tees and located such that the top of the cross bars are 1" below the top of the stem of the tees. The concrete is formed by steel sheet metal forms resting on the top of the cross bars. The concrete is made composite with the steel grid by way of  $\frac{3}{4}$ " diameter punched holes in the top of the stem of the tees that extends into the concrete slab. A single two-way mat of reinforcing steel (No. 4 bars at 4" on center transversely and No. 6 bars at 4" on center longitudinally) rests on the top of the tees.

The Exodermic deck spans longitudinally across floorbeams spaced at 13'-2" on center allowing for elimination of stringers traditionally used on bascule leaf framing and simplifying the framing. On each leaf there is a series of steel grid panels ranging in width from 3'-4" to 6'-8". Each panel is the length of two floorbeam bays, but the steel grid is made continuous the length of the leaf by way of bolted field splices. The steel grid panels are temporarily supported on leveling bolts on top of the top flanges of the steel framing. Composite action between the Exodermic deck and the steel framing is achieved by welded headed studs and formed concrete haunches on the top flange of the main girder, floorbeam and floorbeam cantilevered bracket top flanges.

Exodermic deck is generally more efficient than concrete filled steel grid deck. Both systems utilize a fabricated steel grid and lightweight concrete, but the Exodermic deck makes more efficient use of these materials with the concrete placed on top of the steel grid instead of within the limits of the steel grid. This results in additional strength and stiffness for same weight due to the increased eccentricity. In addition, the Exodermic deck steel grid is somewhat simpler fabricate to than conventional concrete filled steel grids and thus are generally lower in price.

Although the Exodermic deck concrete is in tension due to the cantilevered structural configuration of the double-leaf bascule, the wide effective top flange width and significant stiffness of the steel box main girders acts to minimize the tensile stress in the concrete and the combination of the primary reinforcing steel and the continuous steel grid main bars act to control cracking.



PHOTO 4: Bascule Leaf Raised

The leaf structural design takes advantage of the stiffness of the steel box main girders and the composite section properties of the Exodermic deck to reduce the amount of structural steel and the overall weight of the bascule leaf. The steel box main girders have vertical, variable-depth webs and an open tub configuration with split top flanges from the tip of the leaf to a location just forward of trunnion where the top of the box slopes downward toward the tail to clear the bascule pier deck and transitions to a fully closed box where the Exodermic deck becomes non-composite with the girder. Where the girder has an open tub configuration, the Exodermic deck completes the box section. Although each box girder contains two webs, the increased weight is offset by the reduction in web depth and thickness. Web thickness is controlled by minimum thickness requirements and diaphragms within the box at each floorbeam/floorbeam cantilevered bracket stiffen the webs so additional transverse web stiffeners are not required. Longitudinal stiffeners act to reduce the web minimum thickness requirements where the box section is deeper closer to the bascule pier. The weight of the wide bottom flange is offset by a reduction in flange thickness. Due to the structural efficiency of the box section, the bottom flange thickness is controlled by minimum thickness requirements and a single longitudinal bottom flange stiffener acts to reduce the minimum thickness requirement. The increased labor cost of the web longitudinal stiffeners and bottom flange stiffener is more than offset by the steel weight savings and the corresponding savings in counterweight.

Because a double-leaf bascule span acts as a cantilever, the stiffness of the main girders is important to minimize live load deflections. As the main girders include two webs per box, a wide bottom flange and the composite Exodermic deck top flange, they are typically much stiffer than traditional bascule leaf framing systems with plate girders with a non-composite concrete filled steel grid. This additional stiffness results in a significant reduction in the live load deflections with corresponding decrease in wear to the span lock equipment and live load shoes. The significant increase in stiffness of this structural system permits a shallower structure depth than traditional bascule leaf structural systems, which permits the vertical clearance beneath the bridge to be maximized.

The increased cost of fabrication of steel box main girders is offset by the significant simplification in the steel framing. Therefore, the unit cost of the steel fabrication is lower than traditional bascule leaf fabrication.

Although the floorbeam and floorbeam cantilevered bracket welded connections are considered a Category E fatigue detail, the composite behavior of the Exodermic deck with the steel box main girders acts to raise the neutral axis of the section and the main girder live load stress range at the depth of the floorbeam/floorbeam cantilevered bracket welded connections is relatively low and thus the fatigue design does not control the design of the main girders. Similarly, fatigue does not control the design of the floorbeams and floorbeam cantilevered brackets. The composite behavior of the Exodermic deck raises the neutral axis of the section such that the welded connection is completely below the neutral axis; because the connections are subject only to negative live load moments the live load stresses remain in compression.

Torsional stiffness of the steel box main girders and moment continuity between the floorbeams and main girders, achieved by welded end connections of the floorbeams to the main girders, provides more efficient load distribution throughout the bascule leaf. This continuity more equally shares load between the main girders by way of load redistribution and thus yields significantly lower main girder shear and bending moments than a comparable bascule leaf with torsionally flexible plate girders with simple shear end connections.

The lateral and torsional stiffness of the steel box main girders and the lateral stiffness of the Exodermic deck adequately resist lateral wind loads and maintain the alignment of the leaf during operation. As such, lateral bracing found in traditional bascule leaf framing is not required in the permanent structure. However, as the Exodermic deck becomes non-composite with the main girders in the region directly forward of the trunnions lateral bracing is provided in this region only. Elimination of lateral bracing reduces the weight of the bascule leaf. Temporary bracing is provided during bascule leaf erection until the Exodermic deck concrete is cured.

The bascule leaf design reduces the maintenance of the structure. Minimal main girder bottom flange overhangs and elimination of the lateral bracing and stringers found in traditional bascule leaf framing significantly reduces the surfaces that typically accumulate moisture-retaining debris and significantly reduces the number of connections that usually require maintenance. The closed deck eliminates the concern of debris falling through the deck and accumulating on the horizontal surfaces of the leaf framing as commonly found on bascule leaves with steel open grids. Span locks are located within the limits of the steel box main girders reducing the exposure of this equipment to the weather and eliminating the need for separate span lock access platforms.

The clean lines of the steel box main girders and elimination of stringers, lateral bracing and span lock access platforms improves the appearance of the bridge by significantly reducing the understructure clutter.

#### Bascule Leaf Operating Equipment:

Each bascule leaf pivots about a pair of trunnion assemblies each supported by two spherical roller bearings in a simple trunnion configuration (i.e. one bearing on each side of the main girder.) The low friction bearings significantly reduce operating loads and thus reduce the power required to operate the bridge; the larger and heavier the bascule leaf, the greater the impact the low friction value has on the operating system design. The spherical roller bearing has a friction coefficient of only 0.003 compared to a value of 0.12 for a traditional bronze sleeve bearing resulting in a significantly lower corresponding frictional resistance.



FIGURE 11: Section thru Bascule Pier Showing Operating Machinery

The NW 12<sup>th</sup> Avenue Bridge utilizes a newly developed push-pull tandem hydraulic cylinder arrangement that is significantly more efficient than a push-open cylinder arrangement traditionally used on bascule bridges throughout Florida and the United States. This design provides equal flows for raising and lowering the bridge, thereby allowing for optimization of hydraulic components. The push-pull tandem configuration operates with higher operating pressures and lower operating flows than the push-open configuration. As system inefficiencies are mostly attributable to flows, the balanced, lower flows of the push-pull tandem arrangement yield greater system efficiencies with more economical component sizes. On the NW 12<sup>th</sup> Avenue Bridge, the push-pull tandem cylinder arrangement resulted in a 30% reduction in the horsepower required to operate the bridge due to these efficiencies. Other advantages of the push-pull tandem system realized in the hydraulic system design, detailing and maintenance include:



FIGURE 12: Push-pull Tandem Hydraulic Cylinder Drive System

- Reduced hydraulic piping sizes due to the lower flows.
- Essentially constant reservoir fluid levels, eliminating the need for large, maintenance intensive desiccant breathers to filter water vapor out of the exchange air.
- Identical valves for raising and lowering flow, thus reducing the types and sizes of components and making spare parts interchangeable.
- Net reduction in the forces acting on the bascule leaf and bascule pier structure and reduction in the cylinder lower clevis connection to the pier due to the balancing of the tandem cylinder force vectors.

The advantages listed above not only reduce the initial construction cost, but also reduce maintenance costs and improve reliability.



PHOTOS 5 & 6: Hydraulic Cylinder Drive System

#### **Geometric Solutions**

#### Bridge Height and Vertical Profile:

A bridge height study performed during the PD&E study determined that a minimum vertical clearance of at least 25'-0" was desired to reduce the number of openings and corresponding impacts to vehicular traffic. However, as an adjacent at grade intersection at NW 11<sup>th</sup> Street to the north and a combination of a crossing over NW 8<sup>th</sup> Terrace and at grade intersection at NW 7<sup>th</sup> Street to the south introduced conflicting constraints on the vertical profile, several innovative solutions were needed to achieve the desired clearance.

In order to achieve the desired vertical clearance with minimal impacts to the immediately adjacent intersection at NW 11<sup>th</sup> Street, it was clear that the steepest practical approach grades would need to be used. Due to the need to meet the requirements of the Americans with Disabilities Act of 1990 (ADA), the maximum permissible roadway grade was determined to be 7.14%. Recent litigation has confirmed that ADA requirements apply to the sidewalks on bridges. The Code of Federal Regulations (28 CFR 36, ADA Standards for Accessible Design) defines any accessible route with a slope greater than 1:20 (5%) as a ramp. These standards require that ramps include 5' level landings at the top and bottom of the ramp, a maximum slope of 1:12 (8.33%) and a maximum rise of 30 inches. Although the sidewalks can accommodate the ramp requirements, it is not practical to accommodate a sawtooth profile on the roadway. Even with an approach grade of 7%, the close proximity of the intersection with NW 11<sup>th</sup> Street still required raising the intersection approximately 4'.

The conflicting constraints of the adjacent cross streets resulted in the bascule leaf asymmetrically located on an asymmetric vertical profile. With twin staggered leaves and skewed bascule piers, this roadway geometry would normally significantly complicate the detailing of the bascule leaves and bascule piers. However, an innovative detailing solution greatly simplified the bascule span design and construction.



FIGURE 13: Main Girder Geometry

In order to simplify leaf detailing, the web geometry was made identical for the eight main girders of all four bascule leaves. The web geometry was established relative to a horizontal

reference line through the center of the trunnion and was set such that the top of the web generally follows the profile grade line after setting the centerline of trunnion for each leaf to a different elevation and rotating each leaf a different amount about the trunnions so that the north and south bascule leaves match at the centerline of the bascule span. (See FIGURE 12.) This required that the trunnions of all four leaves be located at different elevations. As the leaves on the south side of the river were from approximately 3'-2" to 3'-9" higher than the leaves on the north side, the south leaves were rotated about the trunnions downward while the leaves on the north side were rotated upward. The magnitude of the rotations was relatively small, varying from approximately 0.4 to 1.6 degrees. Slight differences in ordinate values between the top of the web and the actual profile grade, due to the varying locations of each bascule leaf along the profile grade line, were found to be negligible (i.e. less than  $\frac{1}{4}$ ) and were addressed by varying the haunches slightly over the main girder top flanges. As the deck on the bascule span has a constant transverse cross slope of 2% for drainage, in order to minimize the thickness of the deck concrete haunches over the girder flanges and reduce the leaf weight, the two main girders of each leaf were set at different elevations (i.e. the inboard main girder was set  $0.63' = 31.5' \times 0.02$ higher than the outboard main girder.) As the trunnions are located on a common axis, the trunnion assemblies pass through the two main girders vertically at different locations.

The bascule leaf floor system and steel counterweight box for each leaf are located identically relative to the main girder horizontal reference line prior to leaf rotation and thus the detailing of these components and the connections to the main girders are the same for all four leaves, which greatly simplified detailing and balance calculations. The small leaf rotations were inconsequential in the balancing of the leaves given overall leaf rotation of 72 degrees during leaf operation.

Despite the asymmetrical placement of the bascule span on the vertical profile, the north and south piers were detailed nearly identical to each other with the following distinctions:

- The piers are identical in plan dimensions rotated 180 degrees relative to each other.
- The footings of both piers were set at the same elevation making the design and detailing of the cofferdams, seal and footings nearly identical for both piers. Because the north leaves are at a lower elevation than the south leaves, the footing elevation was set relative to the lower north leaves. Only the bumper block pedestals were different for the two footings accounting for the difference in trunnion elevation and difference in leaf rotation.
- The machinery level, trunnion level, operator's house entry level and control level floors were set at similar relative elevations for the two piers with the north pier elevations set 3'-9" below those on the south pier. The difference in height between the two piers was made by use of two different column and wall heights between the footing and machinery level platforms. Minor differences in the elevation of the approach span beam seats, trunnion bearing, live load shoe, and hydraulic cylinder lower clevis supports were made with slight adjustments in the support pedestal concrete.
- The roadway and sidewalk deck was set to match profile grade and thus there were slight differences in the height of the walls and columns between the trunnion level and deck level floors.

### **Construction Considerations**

#### **Bascule Span Phased Construction:**

With the much wider replacement bridge and limited rightof-way, there was not adequate space to construct the entire replacement bridge in a single phase while maintaining four lanes of vehicular traffic on the existing bridge. However, acquisition of a limited amount of rightof-way and a new improved roadway alignment, that eliminated the existing substandard horizontal break in roadway alignment, provided an opportunity to offset the new bridge a sufficient distance to permit construction of half of the bascule span, north approach spans and north approach roadway while four lanes of traffic were maintained on the existing bridge. Half of the new bridge provided adequate roadway width (45'-6" clear roadway between median barrier and traffic barrier) to temporarily accommodate four lanes of traffic while the existing bridge was demolished and the second half of the new bridge was constructed. Because of a more significant overlap between the existing and new approach spans on the south end of the bridge, half of the new south approach spans had to be built in multiple phases. Adequate right-of-way was available to construct enough of the south approach spans to temporarily accommodate two northbound travel lanes on the new bridge while two southbound lanes are maintained on the existing bridge and while portions of the existing bridge are demolished to make room for the remaining portion of the first half of the existing bridge.

The bascule piers were designed with consideration of the phased construction including such details as water stops, shear keys, and bar couplers at construction joints. The construction joint between the first half and second half of the piers was detailed so that slightly more than half (3'-0") of the first half of the bridge was constructed to accommodate an approach span beam line and pile line along the centerline of construction. In addition, the construction joint in the north bascule pier was staggered around the existing bridge control house to minimize the shift in the alignment of the new bridge thus reducing the required right-of-way acquisition and maximizing the space available for construction access and staging.

The bascule pier deck and access platforms at the trunnion level and machinery level, which in the ultimate condition are part of a continuous span configuration, were temporarily cantilevered and required a series of temporary supports that extend below to the bascule pier



PHOTOS: 7, 8 & 9: Bascule Span Phased Construction

footing and that were in place until the second half of the bascule piers were constructed. As the hydraulic power units are centrally located within the pier between the two leaves, only slightly more than half of the supporting slab was available for this room during the first phase of construction. As such, the hydraulic power units had to be temporarily located within the room with temporary hydraulic plumbing until the second half of the pier was constructed. As the sides of the piers were temporarily open until the second half of the piers were constructed, temporary walls (timber framing with plywood sheathing and plastic sheeting for weather proofing) along the hydraulic power unit room were required to protect the hydraulic power equipment and associated controls from the weather.

Because of the temporary roadway configuration with four lanes of traffic on half of the new bridge, temporary traffic gates and signals were required. The permanent warning gate assemblies were used with temporary, shorter gate arms and paired with additional temporary warning gates located along the median side of the roadway. The permanent traffic signal was used for northbound traffic while a temporary post-mounted traffic signal was used for southbound traffic.

#### Precast Exodermic Deck:

As the Department committed to providing a closed deck with a concrete riding surface on the bascule span and because of the restrictions on river closures, it was necessary to develop a lightweight deck system that could be constructed with only a maximum 8-hour closure of the river. A precast Exodermic deck system was selected because:

- Exodermic deck offered a relatively lightweight, structurally efficient solution that could be made composite with the bascule span main girders and floorbeams.
- The system of grid panels provided for rapid modular construction and span balancing. The bascule leaves could be lowered to install, level, align and secure the precast panels with subsequent raising of the leaves for navigation traffic using the permanent hydraulic cylinder drive system. The leaf balance could be maintained throughout the bascule leaf construction with the addition of ballast to the counterweight box following installation of each panel.



PHOTO 10: Precast Exodermic Deck



PHOTO 11: Exodermic Deck Panels

• The small quantity of concrete within the closure pours could easily be placed within the limited 8-hour river closure while it would be a challenge to place and finish a large section of cast-in-place deck within this limited closure period. Unlike a large deck pour, the closure pours did not require an elaborate screed system (e.g. razorback or

Bidwell screed) to place and finish the concrete. The closure pours utilized a much smaller quantity of high-early strength, lightweight concrete (1,200 psi compressive strength in 6 hours.)

• The precast deck did not have concerns with temporary support of the deck reinforcing steel while the bascule leaves were raised and lowered.

Although precast Exodermic deck has been used on numerous fixed bridges over the past 25 years and cast-in-place Exodermic deck has been used on a number of bascule spans over the past 10 years, this was the first use of a precast Exodermic deck on a bascule span. Because this was the first installation of this type, there were a number of unique details that had to be considered for this installation including the following:

- Details for temporary support, leveling and alignment of the precast panels prior to placing the closure pour concrete needed to allow adjustment of the panels with the leaf in the lowered position while also restraining the panels with the leaf in the raised position. In addition to the normal leveling bolts used to level and align the panels, the panels included temporary clip angles bolted to the bottom of the panels that bear against the edge of the floorbeam flanges to keep the panels from shifting during leaf operation.
- The steel grid panels were detailed with field bolted splices to maintain the continuity of the main bars so that their section could be considered in the composite section properties of the main girders. The steel grid panels were provided with end plates the full width of the panels and welded across the ends of the main bars.



PHOTO 12: Closure Pours

- Both the transverse and longitudinal reinforcing steel in the deck were detailed with overlapping hooked bars that extended beyond the faces of the precast concrete into the closure pours to splice the transverse and longitudinal reinforcing steel. The width of the closure pours was detailed to accommodate the required lap length. The panels for an entire leaf were required to be set-up in a shop with the reinforcing steel placed with a staggered alignment to ensure that the there was no interference between the hooked bars of adjacent panels. The longitudinal hooked bars at the closure pours that contained the steel grid panel bolted field splices required temporary field bending of the reinforcing to permit access for field bolting operations. Additional straight bars were provided within the closure pours.
- The closure pours were detailed with consideration of the forming of the concrete haunches over the main girder and floorbeam flanges.
- The deck thickness and steel armored joint assemblies were detailed to permit profiling and grooving the deck after the panels were erected and the closure pours made. The panels were also detailed with a uniform concrete deck thickness of 4½" for control of the deck weight and leaf balance. Because of inherent tolerances in precast panel construction, it was anticipated that the riding surface would not be uniform after initial construction and thus a sacrificial thickness of ½" was included in the deck thickness to permit profiling of the surface and to provide a smooth riding surface with a uniform appearance.

#### Steel Counterweight Box:

Use of a steel counterweight box filled with a combination of concrete and steel ballast provided a number of advantages on this project over a traditional cast-in-place, reinforced concrete counterweight as it:

- Eliminated the need for extensive formwork.
- More easily accommodated balance adjustments during bascule leaf erection.
- Accommodated a greater quantity of steel ballast allowing for a shorter bascule leaf tail with corresponding savings in pier length and depth.
- Reduced the risk of interference with adjacent pier walls and columns due to tolerances in concrete forming.

#### Bascule Leaf Detailing:

The bascule leaf structural steel framing was designed and detailed with small, manageable components that could be quickly erected so as to minimize the impact to navigation traffic. The main girders were provided with a field splice located behind the existing fender system to allow the tail half of the leaf to be fully erected and aligned with the bascule leaves in the lowered position.

#### Summary

The NW 12<sup>th</sup> Avenue Bridge project demonstrated how good engineering design can solve the technical challenges of replacing a bascule bridge in a heavily congested downtown location while maintaining both vehicular and navigation traffic throughout construction. The project also demonstrated how it was possible to use innovative engineering design to create an economical, landmark structure that will enhance the Miami riverfront community for years to come.

#### **Bridge Facts**

Bid Price: Bid Date: Acquisition Duration: Construction Duration: Start Date: Scheduled Completion Date:	\$63,723,862 June, 2005 350 days 930 days August, 2006 June, 2009
Acknowledgments	
Owner:	Florida Department of Transportation – District 6
Designer:	E. C. Driver & Associates (Prime Consultant – Overall Concept Development, Roadway, Bascule Span Design, Operating Machinery, Fluid Power Systems, Electrical Power and Controls)

HNTB Corporation (Major Subconsultant – Drainage, Roadway Lighting, Approach Span and Wall Design, Bascule Pier and Control House Detailing)

General Contractor:	Kiewit Southern Corporation
Steel Fabricator:	Kiewit Offshore Services
Machinery Fabricator:	Hardie-Tynes
Exodermic Deck Fabricator:	LB Foster
Hydraulic Supplier:	Bosch-Rexroth
Electrical Subcontractors:	Southern Power
Construction Inspectors:	Pinnacle Consulting Enterprises Bermello, Ajamil and Partners