17th Street Causeway Bridge

FT. LAUDERDALE

OWNER
Florida Department of Transportation

STRUCTURAL ENGINEER
E.C. Driver and Associates, Inc., Tampa, FL

GENERAL CONTRACTOR:
Traylor Bros., Inc., Evansville, IN

STEEL FABRICATOR:
PDM Bridge, Palatka, FL
(AISC member)

STEEL DETAILER
Tensor Engineering Co.,
Indian Harbor Beach, FL
(AISC member, NISD member)

APPROACH SPAN DESIGNER
Figg Bridge Engineers, Tallahassee, FL

STRUCTURAL ENGINEERING SOFTWARE
GTStrudl

When a Florida Department of Transportation (FDOT) study recommended replacement of the 17th Street Causeway Bridge in Ft. Lauderdale with a new movable bridge, local residents called for a "signature bascule bridge" to provide a landmark gateway to the area's renowned beaches and waterways.

In response, the project team designed a one-of-a-kind, double-leaf bascule bridge to replace the existing drawbridge over the Atlantic Intracoastal Waterway. The solution was achieved through graceful form, reduced mass and an uncluttered appearance, without sacrificing structural efficiency and economy.

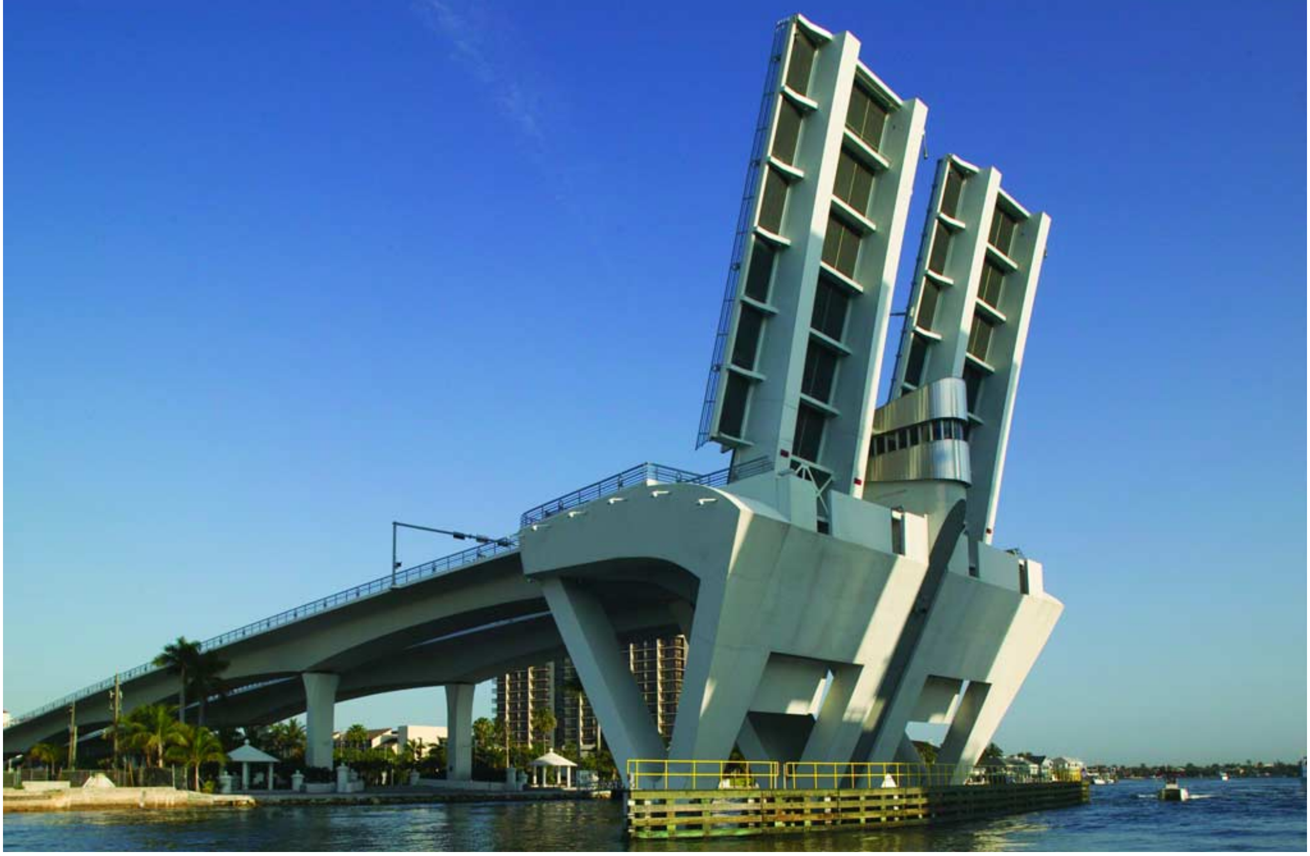
The bridge site is located just north of the ocean outlet at Port Everglades. Ft. Lauderdale is an international yachting center and Port Everglades is a major freight and passenger terminal. Right-of-way acquisition opportunities are limited at all four corners of the site by existing or planned development. Hotels occupy the NW, NE, and SE corners, and the SW corner is the site of a future hotel adjacent to the Ft. Lauderdale Convention Center.

The absence of a vehicle crossing at the port ocean outlet requires all north–south vehicular traffic traveling on SR A1A along the barrier islands to divert inland at this point. The 17th Street Causeway Bridge is the first bridge located north of the outlet and provides the primary-access crossing of the Intracoastal Waterway to Fort Lauderdale's beaches.

Given these conditions, the required horizontal and vertical clearance requirements for a fixed bridge were 125' and 135' respectively. The site could not accommodate a fixed span of sufficient height, since the approaches would dominate the landscape and adversely impact adjacent intersections and commercial properties.

Critical project objectives included:

- Construct a bascule bridge with a minimum horizontal clearance of 125' and a minimum vertical clearance of 55', with the movable span in the closed position (unlimited vertical clearance with the span raised)
- Provide a bascule span with a solid concrete riding surface
- Maintain four lanes of traffic and the navigational channel throughout construction
- Construct the new bridge parallel to, and centered about, the existing bridge alignment
- Give the new bridge FDOT's highest level of aesthetic consideration, Level III.



THE BRIDGE

The new 17th Street Causeway Bridge combines steel and concrete to span 1908' across the mouth of the Intracoastal Waterway. The dominant main span of the bridge is a steel double-leaf bascule span supported on concrete V-shaped piers. The bascule span features variable-depth steel box girders that span 210' between centers of trunnions. Smooth, variable-depth segmental-concrete box-girder spans form the approaches that complete the bridge. The bridge consists of approximately 958 tons of steel.

The bridge has two parallel carriageways. Each carries two 12' traffic lanes, an 8' inside shoulder, a 10' outside shoulder/bike lane and an 8' sidewalk. The out-to-out width of each carriageway superstructure is 53'-5½".

MAINTENANCE OF TRAFFIC

Construction phasing using a two-lane temporary detour bridge maintained traffic during construction, and proceeded as follows:

- Construct a two-lane temporary bascule bridge just south of the existing bridge.
- Divert eastbound traffic to the temporary bridge.
- Shift westbound traffic from the north half of the existing bridge to the south half.
- Demolish the north half of the existing bridge except for the bascule span (must be left in place as it is a two-girder system).
- Construct the north half of the new bridge, including construction of the bascule span above the existing bascule span.
- After completion of the north half of the new bridge, temporarily shift all traffic to the new bridge.
- Demolish the temporary bridge and the remainder of the existing bridge.
- Construct the south half of the new bridge.
- Shift traffic to final configuration.

The temporary bridge in itself was a challenging engineering solution. A single-leaf Dutch-style bascule with overhead counterweight was selected to meet the following criteria:

- Provide horizontal clearance of 100' and a minimum vertical clearance of 26.6' with the bridge closed.
- Provide two 11' lanes of one-way traffic and a 6' sidewalk
- Design for ease of construction with provision to relocate the bridge to another site
- Design for lowest cost, considering salvage value.

AESTHETIC CHALLENGES

The bridge was to be a structure free of ornamentation or artificial color, with the use of natural material finishes. Segmental concrete boxes were chosen for the approach spans and steel box girders for the bascule span. Pedestrian overlooks were to be included at the bascule pier and bridge railings were to have open designs.

The most challenging design elements, which dominated all aesthetic discussion, were the bascule piers. Optimizing the structural efficiency of these critical elements was a means to a design that would contradict the expected mass of typical bascule piers.

Mass is typically provided in bascule pier design to enclose counterweights and machinery as well as for structural purposes. For a bridge of this size, a typical closed bascule pier would have a width of 55'-65'. With a vertical clearance of more than 55', the piers would be massive. This blocky structure would be disproportionate with the bridge superstructure and dominate the remainder of the bridge.

The design team developed a delta or "V"-shaped bascule pier, which fit with the loads and load path associated with support of the bascule leaf and approach spans. The front legs of the pier are positioned between the trunnions and live-load shoes that transfer loads from the bascule leaf to the pier. The rear legs are located under a rear diaphragm, which connects to the approach-span concrete box girder. By making the delta shape integral with concrete box girder approaches, the lower section of the pier could be slender, yet stiff enough to maintain the position of the movable spans. This bascule pier was coined the "Carina" pier, because its shape in the water evokes images of this Latin word for "keel".

Additional advantages of the Carina Pier include improved movable-span economy, pier openness, and additional working space within the piers. With the trunnion centerline offset towards the channel from the centerline of the Carina Pier foundation, the length of the bascule span between centerline of trunnions was reduced from 70 m to 64 m. This reduction translated to cost savings in the movable span, counterweights, and machinery.

Although in a typical bascule pier this height would present a problem of visual mass, in this case height was an advantage. Replacing the mass typical of the lower section with three "V"-shaped elements creates large open areas through the pier. This openness gives an impression of further reduction in mass so the bridge sits lightly on the water. The height and openness features the counterweight as a visual element rather than hiding it. Because the delta shape is wide at the top, it provides adequate space for machinery, electrical systems, and maintenance access. The configuration of the rear diaphragm allows the construction of a maintenance walkway around the perimeter of each counterweight.

The greatest advantage provided by the Carina Pier design is in the bridge proportions and visual continuity of the structure. The resulting bascule span length, measured between centers of the pier legs, is 241'-8". Measured from the center of the pier legs to the adjacent pier, the side spans are 207'-8". The result is an acceptable 0.85 ratio. The depth of the movable span varies from 7'-9" to 11'-2", similar to the depth of the approach structure.

Further, the Carina Pier legs are the same width as the approach pier columns. In most bascule bridges, the movable span, bascule pier and approach spans appear as three distinct elements, but this design provides structural and visual continuity. The main elements are of similar scale, shape and form, and are visually aligned to form a single element with the span closed.

Visual balance is maintained while the span is opened. The mass of the pier is focused at the pivot point of the bascule leaf, forming a focal point for leaf motion. As the leaf rotates above the channel, the counterweight is visible, rotating down between the legs of the Carina Pier.

BASCULE LEAF CONFIGURATION

The movable span consists of twin double-leaf trunnion bascule spans 210'-long center-to-center of trunnions (which are 177'-2" center-to-center of load shoes). Each leaf has an overall length of 144'–4" from tip to tail. The bridge spans a 125'-wide navigation channel skewed to the centerline of the bridge (77°28'05") and provides 55' of vertical clearance at the face of fenders with the span closed, and unlimited vertical clearance with the span raised to its maximum operating angle of 75°.

The 53'-5½"-wide spans are separated by a 13'-1½" open median. The bridge width could temporarily accommodate four 10' lanes and a 5' 7" sidewalk on one of the twin spans to permit phased construction. The bascule span has a closed deck with a 2% cross slope for drainage.

Traffic rides on an Exodermic bridge deck that spans longitudinally across floorbeams, typically spaced at 14'-5" on center. The floorbeams and cantilevered brackets frame into twin-box main girders spaced at 29'-6" on center. The webs of the box girder are spaced 4'-11" on center. The counterweight consists of a steel box shaped to match the Carina Pier and filled with concrete and steel ballast.

Each main girder is supported on simple trunnions that pass through both webs of the box main girders. Live-load shoes are located at the front wall of the pier. Span locks are located inside the box girders at the tip of the main girders. The span is raised via an electro-mechanical drive system with racks secured to the bottom flange of the main girders.

BASCULE LEAF INNOVATIONS

The bridge's innovative bascule-span superstructure displays structural efficiency, economy, and reduced maintenance requirements. Its configuration incorporates the use of steel-box main girders, floorbeams with moment-resisting connections and a lightweight Exodermic bridge deck made composite with the floorbeams and main girders.

Steel box girders initially were proposed for this project because of improved aesthetics. The y eliminate the bottom-flange overhangs and external web stiffeners. The lateral and torsional stiffness of the box girders also eliminate the span lateral bracing that typically clutters the span underside. The box girders reduce maintenance requirements by eliminating external horizontal surfaces where moisture-retaining debris collects. Also, the torsional rigidity of the box girders permit the use of moment-resisting floorbeam connections for efficient load distribution.

Weight savings in the bascule-leaf structural steel and deck translates to savings throughout the structure. To minimize the weight of the bascule leaf, weight-saving details were incorporated into the main girders. Forward of the live-load shoes, the main girders consist of light, open-tub box girders. A combination of transverse and longitudinal web stiffeners minimize the box-girder web thickness. A continuous longitudinal bottom-flange stiffener similarly reduces the thickness of the bottom flange. This weight savings offsets the additional labor cost of the stiffeners. Behind the live-load shoes, where weight is not as serious, the open-tub box girders transition to a closed-box configuration. The closed-box provides a torsionally rigid element near the trunnions, where it is imperative to maintain alignment of the main girders, especially prior to deck construction.

Longitudinal stiffeners are required on one side of the web only, and are placed within the box girders. Although fatigue is typically a concern with web and flange stiffeners, here the longitudinal stiffeners were located either within the compression zone or near the composite-section neutral axis where the stress level is low.

Continuity at the welded connection between the floorbeams and main girders, and the torsional resistance of the main girders provided efficient load distribution. Reduction in distribution of live loads to the main girders ranges from 5% to 12% when compared with simple distribution. The continuity and torsional resistance provides additional structural efficiency by redistributing loads from one main girder to the opposite girder (load sharing). Comparison of main-girder bending moments with and without this redistribution revealed reduction in live-load bending moments in the main girders from 30% to 50%.

EXODERMIC DECK SYSTEM

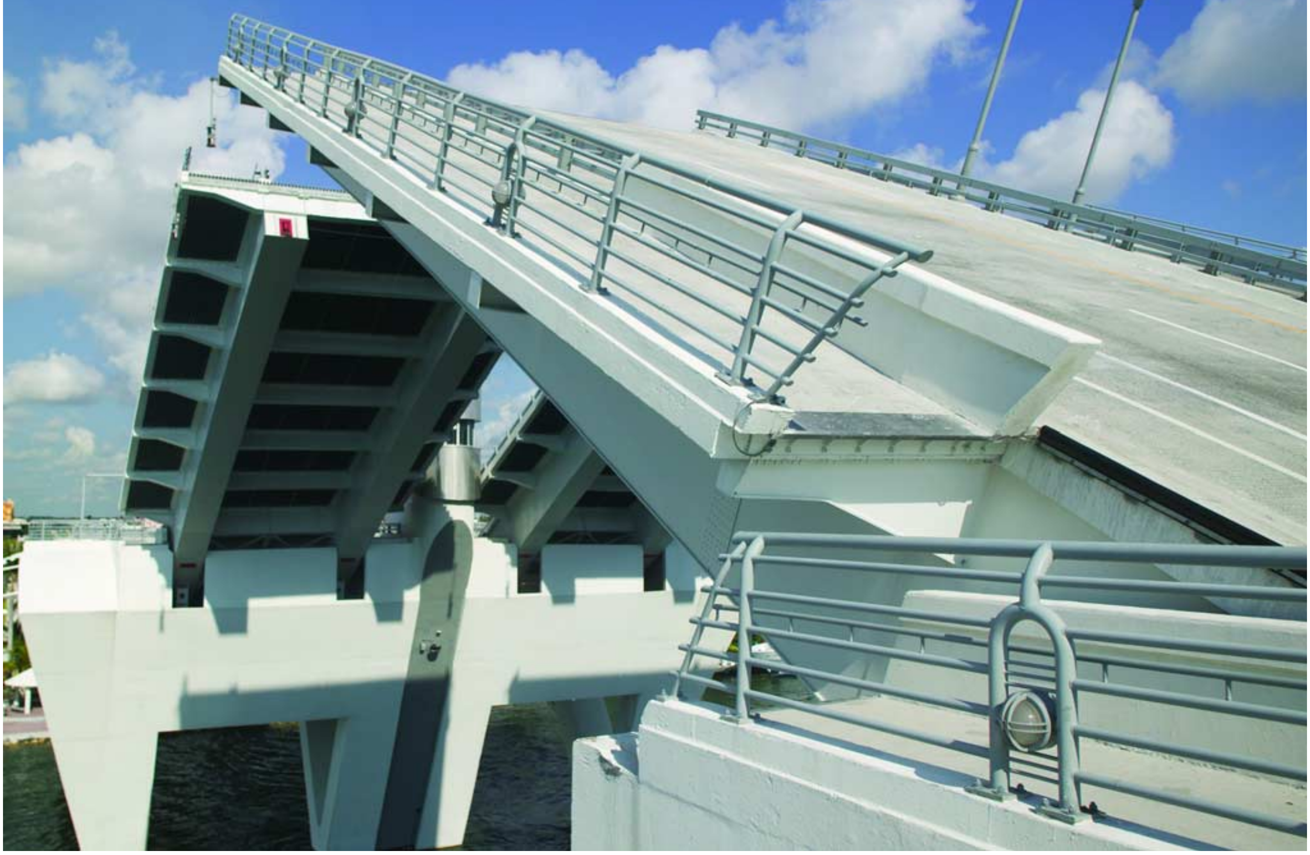
A concrete-deck system provides rideability, skid resistance and minimal traffic-induced noise. An Exodermic deck with sand-lightweight concrete was selected for its structural efficiency. The Exodermic deck mounts a thin reinforced-concrete slab on top of a fabricated steel grid. The Exodermic deck spans longitudinally 14'-5" floorbeam-to-floorbeam, permitting elimination of steel stringers that typically support the deck between floorbeams. This uncluttered design eliminates details (e.g., stringer end connections) typically susceptible to corrosion and fatigue.

The Exodermic deck system consists of a 4½"-thick reinforced structural sand-lightweight concrete slab composite with a 5¼" manufactured steel grid. The lightweight concrete specified has a unit weight of 115 pcf, using expanded-shale lightweight aggregate. Sand is used for the fine aggregate to provide improved wear and skid resistance. Composite action between the concrete slab and the steel grid is achieved through tertiary bars and a grid of studs that extend into the slab. The Exodermic deck is made composite with the floorbeams and main girders for additional structural efficiency. This is the first bascule bridge to make the Exodermic deck composite with the main longitudinal-load carrying members.

Since the Exodermic deck serves as a large diaphragm to resist lateral loads, and the main girder boxes provide large torsional and lateral resistance, permanent lateral bracing for the leaf is not required.

STEEL COUNTERWEIGHT BOX

A steel counterweight box balances the movable-span weight while providing an aesthetic complimentary to the steel box girders and bascule pier. The counterweight box and main girders behind the trunnions are filled with steel ballast and concrete. The bottom soffit of the counterweight box is curved to match the bottom soffit of the bascule pier with the span in the closed position. The front face of the counterweight box



is curved to tuck below the cantilevered machinery floor with the bridge in the open position. Curved internal diaphragms transfer loads to the transverse diaphragms, which carry weight to the main girders. The box also eliminates the need for substantial falsework over the water, since its design supports the weight of the steel ballast and concrete.

The bridge design yields a low unit weight of structural steel equal to 80 psf. The Exodermic deck adds a unit weight of 75 psf, for a total bascule-leaf unit weight of 155 psf. The total weight of each leaf is 1,169 tons. The counterweight, including steel box and concrete ballast, weighs 696 tons.

OPERATING MACHINERY

The FDOT stressed maintaining bridge operation. Criteria were imposed to eliminate single-point failure elements and to implement redundancy.

The structural configuration provides for redundant trunnion bearings. Each leaf rotates about a pair of trunnion assemblies. Each assembly consists of a trunnion shaft that passes through both webs of the box girder and is secured to the webs via hub assemblies. The trunnion shafts are supported on spherical roller bearings. The span can remain operational with either of the inboard bearings removed for repairs, reconditioning or replacement. If an outboard bearing requires work, an inboard bearing can be moved temporarily to the outboard location. The bearings are sized to accommodate the larger reactions introduced with the removal of one of the bearings. The torsional rigidity of the main girder boxes and the rigid frame connections between the main girder, floorbeams and counterweight box is adequate to temporarily resist the inboard end of the trunnion in an overhung trunnion arrangement. The spherical roller bearings contain sufficient rotational capacity to accommodate the structure deformation.

Fully redundant operating drives also are provided. Each independent drive train consists of a 93.25kW, 150rpm, four-quadrant DC motor that drives a pinion through a pair of gear reducers. The pinion engages a rack mounted in a frame secured to the underside of the main girder box. Each independent drive train has the capability of driving the bridge on its own at full speed under maximum design conditions, although the drives work together under normal operation.

A SIGNATURE BRIDGE

The 17th Street Causeway Bridge blends with the natural landscape of the area and enhances the surrounding community. The one-of-a-kind bascule span provides a spectacular view. Pedestrian overlooks were provided on the Carina piers. Soft, energy-efficient lighting was incorporated into the railings. The bridge design includes public plazas in the open areas beneath the new bridge, with public parking and views of the Intracoastal waterway and Fort Lauderdale. The plazas include a circular stairway and walkways to nearby resort hotels.

Of three bascule bridges constructed in FDOT District Four between 1998 and 2002, all with the same span requirements, the 17th Street Causeway Bridge had the lowest bascule-span cost per square meter of deck area. The bridge is also the tallest and longest movable span of the three. ★