HEAVY MOVABLE STRUCTURES, INC.
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Small Bridge, Big Challenges
Port Ferdinand Bridge, Barbados, West Indies

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Introduction

Port Ferdinand is an exclusive beachfront marina development in Barbados that will feature 120 berths and 96 luxury condominiums. From an engineering standpoint, a key feature of the development is the construction of a large lagoon in what is currently a ravine separated from the Caribbean Sea by Highway 1, the major road along the northwestern coast of Barbados. To connect the lagoon to the sea, the existing culvert that drains the ravine under the highway is being replaced by a dredged channel spanned by a new bridge. Adjacent connections to local roads and other geometric constraints prohibit the construction of a fixed bridge high enough over the waterway to allow large vessels access to the lagoon. Therefore the new bridge must be of the movable type.

Port Ferdinand SRL and JADA Group are the developer and builder of the project respectively. Through a selective negotiations process, E.C. Driver & Associates, Inc., was contracted as the movable bridge designer, whose scope included performing a scoping study to determine the movable bridge type and establish a construction budget for the bridge, performing preliminary and final bridge design, and providing construction phase engineering assistance to JADA.

The bridge project included several unique elements that are the focus of this discussion; location, size and scale, and management approach. These unique elements presented challenges beyond those of a typical movable bridge that required careful consideration.

First, Barbados is the easternmost island in the Lesser Antilles. The nearest neighbors are the islands of Saint Vincent and the Grenadines, about 104 miles to the east, and Venezuela about 250 miles to the southwest. The United States lies about 1590 miles away and Europe even further, at about 3680 miles. With a land area of only 166 square miles, local resources are limited such that much of the specialty work for a movable bridge needs to be imported.

Second, the required channel width is only 40 feet and the number of travel lanes to be carried only two. Therefore, the bridge is relatively small for a vehicular highway bridge. This creates challenges of scale with regard to space for equipment and maintenance access.

Third, Barbados has only one other movable bridge, so movable bridge construction technology and experience are rare or nonexistent on the Island. In fact, movable bridges are rare in the islands in general. Under similar circumstances most of the other Caribbean islands' movable bridges have been constructed by foreign contractors from Europe or the US. JADA, however, is a large developer with significant engineering skill and marine construction experience so they decided to construct the movable bridge themselves, with engineering support from a US design firm.

Design Criteria

The overriding design criterion for the bridge is that it is to be a focal point of an upscale waterfront development where quality and aesthetics are equally valued. Even the functional elements of an exclusive development must convey and retain quality. The bridge, which functions as both a roadway to convey vehicles to the development and the gateway to the development from the ocean, must display this quality clearly, and do so for the long term, even though it will be constructed in an aggressive salt water environment. This objective was a key consideration in establishing the following criteria for design and construction of the bridge.

Units: The bridge will be designed using the English system of measurement.
Bridge Typical Section: The bridge will carry two 12 foot wide travel lanes and two 5 foot wide sidewalks on a 6 inch high raised curb. No shoulder will be provided between the edge of the 12 foot travel lane and the curb.
Roadway Profile: The elevation of the roadway at the centerline of the road will be at approximately elevation 17 feet at the center of the bridge above the channel.
Design Speed: 35 mph
Channel Clearance: The horizontal clearance in the channel is set at 40 feet. The bridge will provide unlimited vertical clearance over the full width of the channel when open. The vertical clearance between the low member of the bridge and mean sea level is to be 12 feet at the center of the channel.
Channel Depth: The planned dredge depth of the channel is elevation -8.2 feet.
Movable Span Operation: The movable span will cycle from closed to open or open to closed under maximum constant velocity torque (per AASHTO LRFD Article 5.4) in approximately 60 seconds.
Movable Span Operating System: The movable span will be driven by a hydraulic cylinder drive system. The system will have redundancy of major components including drive cylinders and pump/motor groups.
Electrical Control System: The electrical control system will be a relay based system with hard wire interlocking.
Traffic Safety Devices: Traffic signals and oncoming traffic gates will be designed for installation on each approach to the bridge.
Traffic Barriers: A minimum of NCHRP TL-2 tested barrier will be placed at the back of the sidewalk on the bridge and approach slabs.
Design Standards: Six Men's Marina Limited has specified that the bridge be designed for the standards applied to movable bridges in the State of Florida, United States except as noted below. The following standards will apply:

- Florida Department of Transportation Standard Specifications for Road and Bridge Construction
- Manual of Uniform Minimum Standards for Design, Construction, and Maintenance for Streets and Highways
- National Electrical Code (NFPA 70)
- Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD)
- AASHTO LRFD Bridge Specifications and Interims
- AASHTO LRFD Movable Highway Bridge Design Specifications and Interims
- AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, dated 1994
- AASHTO/-AWS-D1. 5M/D1.5: An American National Standard Bridge Welding Code
- Florida Department of Transportation Structures Manual

Exceptions: The following project specific bridge design criteria has been established:

- Ice loading will not apply.
- Seismic loading with an applied ground acceleration factor of 0.375.
- Vessel collision will not apply (piers are located behind the bulkhead).
- The maximum wind pressure for design of the movable span while in operation is 5 psf, corresponding to a 39 mph wind speed with a 1.25 factor for wind gusts and shape.
- The maximum wind pressure for design for holding the movable span in any open position is 10 psf, corresponding to a 56 mph wind speed with a 1.25 factor for wind gusts and shape.
- Wind load on the structure of 150 mph base speed at ground level.

Local Concrete: Local concrete with a 28 day compressive strength, f'_c = 6,000 psi (41.4 MPa) will be used for all concrete placed on site.
High Strength Bolts: High strength bolts, nuts and washers for structural steel connections will be galvanized by the mechanical deposition process.

General Description

The initial phase of the project involved performing an alternatives study to determine the type of bridge and general features of design best suited to the owner's objectives. Alternatives that were developed and evaluated included a swing bridge, a single-leaf trunnion bascule, a single-leaf rolling bascule, a single-leaf trunnion bascule with overhead counterweight, and a double-leaf trunnion bascule. Although not the lowest cost alternative, the owner selected the double-leaf trunnion bascule design for several reasons. In particular, the double-leaf design was given higher marks for aesthetics and redundancy.

The design for the double-leaf bascule bridge resulted in a bridge with an overall length of 99'-2". The Bridge is symmetrical and is composed of a central bascule span flanked on either side by a short pedestrian access span. Each pedestrian span provides a 6 foot wide beach access "tunnel" connecting the private development to the public beach along the Caribbean shore. Locked security gates are provided at the tunnel exit points.

To provide the relatively narrow 40 foot wide horizontal clearance across the man-made channel, the movable span between centerline of trunnions is set at 57'-8". The bascule leaves are configured with a below deck counterweight and a forward live load shoe. The bascule piers are of the enclosed type with a pit and sump pump located below the counterweight. The bascule span, including bascule piers, is 85'-2" long. See **Figure 1** for a half longitudinal section and half elevation of the bridge.

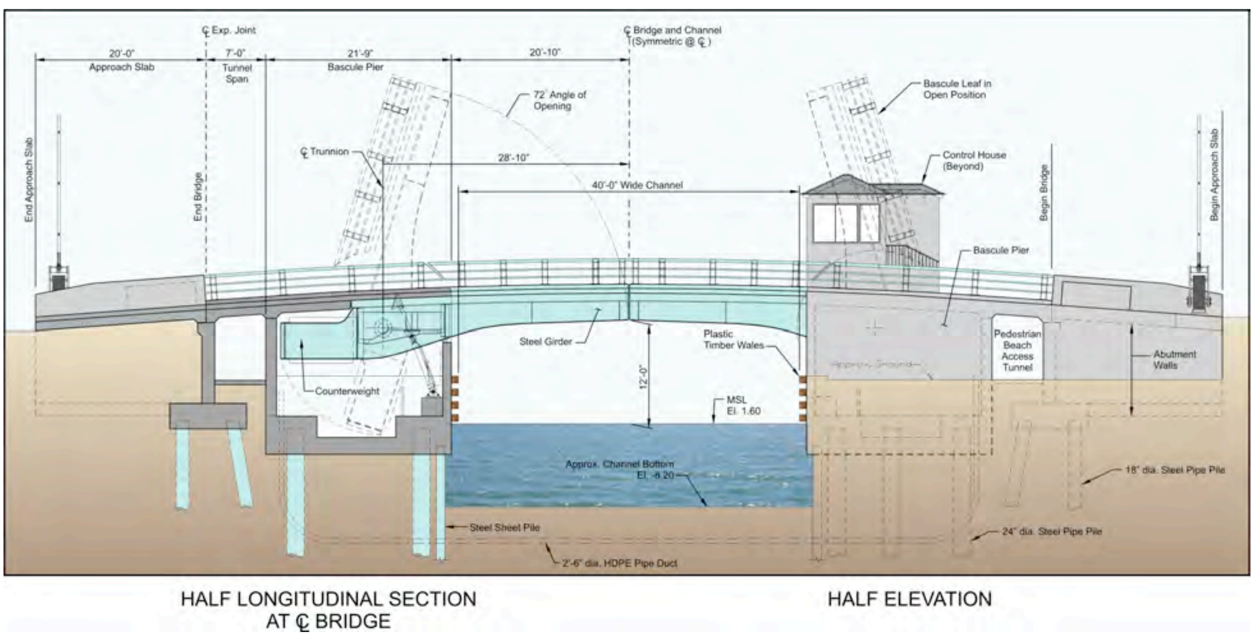


Figure 1

The bascule piers are of conventional cast-in-place concrete construction, supported on 24" diameter steel pipe piles. The piles run as deep as 160 feet due to relatively weak soils and the need to provide resistance for seismic events. Pile supported abutments and cantilever retaining walls on spread footings retain the embankments on either end of the bridge and provide for the beach access tunnels. The bascule pier deck and tunnel span are a two span continuous cast-in-place slab supported on the abutment, the bascule pier back wall and a transverse cast-in-place concrete beam supported on columns within the bascule pier.

The structural system for the bascule span is conventional steel framing with a pair of longitudinal bascule girders, transverse floor beams and counterweight girders and lateral bracing. The bascule girders, counterweight girders and floorbeam FB3, located near the front wall of the bascule pier, are all welded plate girders. The other floorbeams are rolled sections, W24 x 68. Lateral bracing consists of a combination of pipe sections and angles.

The deck on the movable span is an Exodermic Deck® that spans longitudinally between floorbeams. Structural framing is greatly simplified by constructing the sidewalk overhangs of reinforced concrete. This eliminates the need for cantilever brackets, sidewalk bracing, and associated gusset plates and connections. Not only did this turn out to be the more economic solution, it also improves aesthetics by eliminating structural clutter and details that are often prone to corrosion and maintenance. The bridge rails are a combination of the Wyoming DOT TL3 BR and the Florida DOT 42" Vertical Shape barriers. The Wyoming rail, which is a steel post and rail system, is used on the bascule span due to its lighter weight. It is also used on the bascule pier opposite the control house since it provides openings that improve the bridge tender's visibility for approaching vessels. Elsewhere, the concrete FDOT barrier is used. A typical section through the movable span is shown in **Figure 2**.

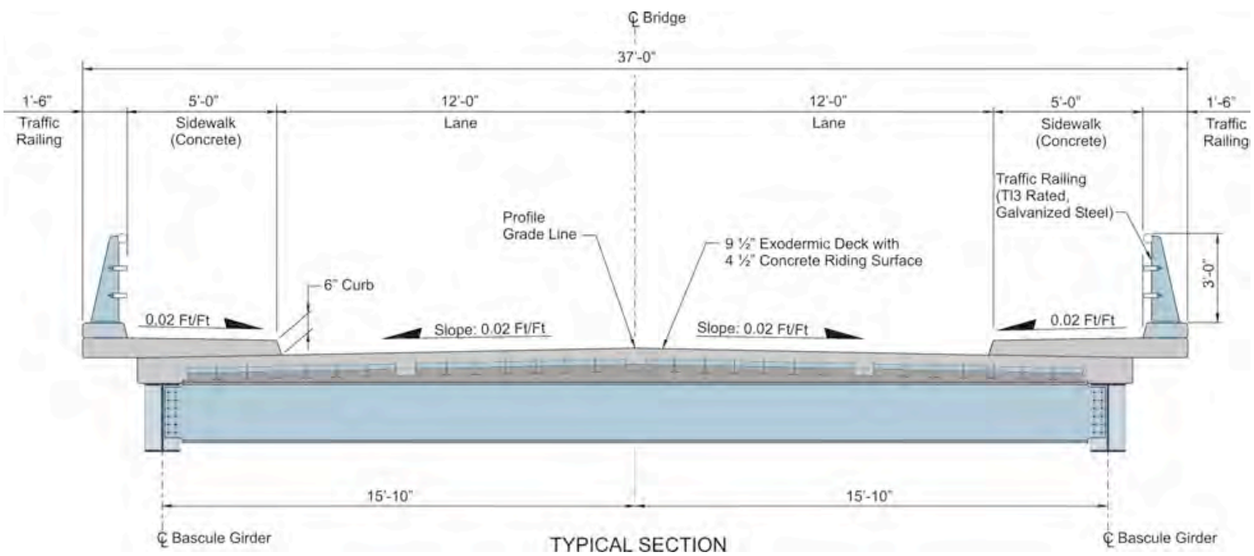


Figure 2

On the east side of the south bascule pier is a control house that provides a station for the bridge tender and houses the electrical control equipment used to operate the bridge. Control equipment includes a control desk with conventional push buttons; relay logic based operating system; two motor control centers; four traffic gates (two on-coming, two off-going); two traffic signals; and associated equipment.

Bridge machinery consists of cantilever trunnions (also commonly referred to as Hopkins Trunnions) and hubs, trunnion bearings, span locks, and clevis attachments for connecting the hydraulic cylinders to the bascule piers and movable span structural steel. Two Cushionlok® span locks are provided to maintain the deck alignment at the center joint. Each lock features a 3” x 5” lock bar. For ease of maintenance, the lock systems are mounted above the deck in the traffic barriers.

A pair of hydraulic cylinders is provided to actuate each bascule leaf. The cylinders are mounted on a machinery platform just inside the front wall of the bascule pier and connect to the underside of cylinder girders on the leaf. The cylinders are normally in the retracted state with the bridge closed and extend to open the bridge. Upon opening, each leaf is rotated 72 degrees, at which the tip of the leaf clears the pier fendering that defines the channel, and unlimited vertical clearance is provided for vessels. Hydraulic power units (HPU) are provided in an equipment room on the east side of each bascule pier. Each HPU features a pair of axial piston pumps driven by a 7.5 horsepower AC motor. Speed and direction control is provided by use of a directional proportional valve.

Unique Elements

Local Materials

Of the major materials required to construct a movable bridge, only concrete is locally produced in Barbados. Other major materials, including structural steel, steel piles, machinery, electrical components, steel grid decking, etc., need to be imported. Reinforcing steel also needs to be imported, but it is available from nearby Trinidad. Given these logistical constraints, every effort was made in the design to maximize the use of reinforced concrete. For other materials the effort was placed on developing logical procurement packages to cost effectively obtain them from abroad.

Even concrete, though locally produced, presented some challenges, particularly with regard to special concrete mixes needed for movable bridge construction. The discussion below focuses on the challenges associated with obtaining the specific concrete mixes desired for this project.

Structural Concrete: With the goal being to construct a bridge that would be durable even in the highly aggressive saltwater environment, concrete was specified using Class IV concrete per Florida DOT’s standard specifications. These specifications require structural concrete to have 18-22% Class F fly ash or 50 to 70% slag (replacement of cement) for salt water environments to reduce the permeability of the matrix.

Unfortunately, neither Class F fly ash nor slag is readily available in Barbados and importing of this type of material can add significantly to the cost of producing concrete. Therefore, the engineer and developer worked with a local concrete supplier on alternative mix designs. Alternatives considered included the use of a local natural volcanic pozzolan, use of blended cements with less than the desired 18 percent fly ash, and use of other chemical admixtures designed to reduce chloride induced corrosion (corrosion inhibitor) in concrete. At the time of this writing the concrete mix design was still in development, but the current thought was to use a corrosion inhibitor in combination with either a blended cement (ASTM C595) having 8-10% Class F fly ash or a blend of Type II (ASTM C150) cement with 25% local volcanic pozzolan. This approach would provide a good durable concrete mix while avoiding importing fly ash or slag.

Counterweight Ballast: One key goal in design was to keep the bottom of the bascule pier footing at an elevation high enough (relative to ground water level) so that it could be constructed without the need for a cofferdam. A major factor in establishing the footing elevation is the length of the counterweight behind the trunnion axis. The longer the distance to the back of the counterweight, the deeper the floor of the pier needs to be and thus the lower the bottom of the footing. One way to reduce the length of the counterweight, while still providing sufficient mass to balance the bascule span, is to make the counterweight denser. This is typically done by using heavyweight concrete, made denser by the use of high specific gravity aggregates such as hematite or steel punchings or by installing steel ballast in lieu of some or all of the counterweight concrete.

In studying this design issue and discussing the availability of local materials for producing a denser counterweight, the owner located numerous scrapped steel rollers that were previously used in sugar mills in Barbados. The size and shape of the rollers varied, with weights in the range of 3.5 to 11 tons, lengths in the 9 to 14 foot range, and diameters ranging from 8 inches to 35 inches. Additionally, the sections were not constant, but varied throughout and included gears and grooved drums. After studying the available rollers, a plan was devised to make use of the rollers as steel ballast. This did require cutting the rollers to lengths that would fit within the dimensions of the counterweight and selecting sizes that could be supported by a given set of steel framing members within the counterweight.

Photograph: Steel Mill Rollers in Barbados

The final design included 16 sections of steel rollers within each counterweight. The resulting effective unit weight of the counterweight concrete, determined by dividing the volume of the concrete plus steel ballast by the weight of the concrete plus steel ballast, is 202 pounds per cubic foot (pcf). A consistent framing system was devised such that the rollers could be set in place and temporarily secured until being fully embedded in counterweight concrete. The framing consists of a series of channels that span across the bottom of the counterweight between two transverse counterweight girders that form the front and back of the counterweight. The counterweight concrete extends below and above the framing such that all structural steel within

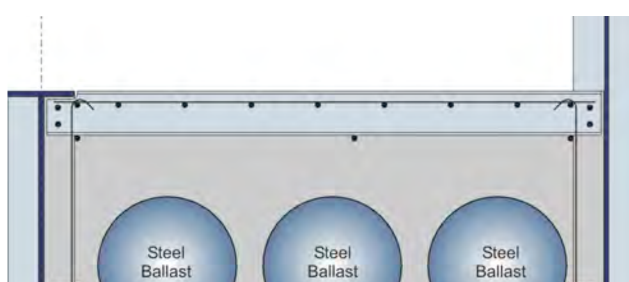


Figure 3

the counterweight (except the counterweight girders and main bascule girders) is fully embedded in concrete as is the steel ballast. A typical longitudinal section through the counterweight is shown in **Figure 3**.

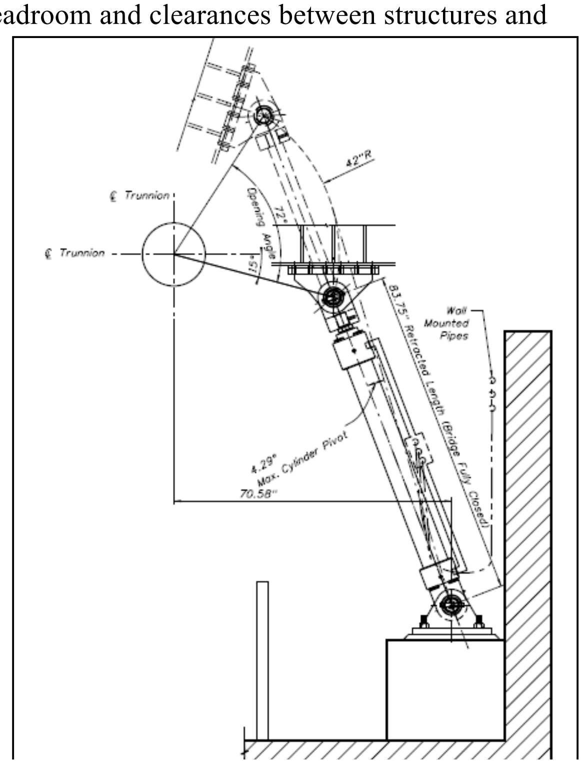
The steel rollers were available locally for purchase at near scrap metal cost. This made them an attractive material for steel ballast and much more economical than importing heavyweight concrete aggregates or importing steel billets.

Structural Lightweight Concrete: The owner expressed a desire to have a solid concrete riding surface on the bridge as opposed to an open steel grid or orthotropic deck. An Exodermic Deck® system with structural lightweight concrete was selected as the most appropriate deck type to provide a concrete riding surface while limiting the deck weight. One drawback of this system at this location was that lightweight aggregates are not available locally in Barbados. However, cost studies determined that the added cost of importing the aggregate was more than offset by savings in the bridge counterweight and machinery.

The exodermic deck consists of a 4.5" thick lightweight concrete slab composite with a grid of WT 6 x 7 main bars spaced at 12" on center. The main grid bars are of ASTM A709, Grade 50 steel and span longitudinally between floorbeams spaced 10'-3" on center. This deck system has an approximate unit weight of 57.8 pcf (unit weight for typical deck excluding haunches, joints and edge beams). If normal weight concrete were used, this value would increase by 10.9 pcf and add 338 kip-ft to the moment to be balanced by the counterweight. This would require either increasing the size of the counterweight, increasing the effective unit weight of the counterweight by increasing the amount of steel ballast, or a combination thereof. As an indicator of the order of magnitude of this impact, the effective unit weight of the concrete in the counterweight would need to be increased by about 42 pcf to balance the additional moment due to using normal weight concrete rather than lightweight concrete. This would require a unit weight in excess of 240 pcf, a value that pushes the practical limits of combinations of steel ballast and normal weight concrete and in this case was found to require extensive counterweight modifications.

Small Movable Bridge Challenges

Just because a movable bridge is small, does not mean that it is easier to design. In fact, a small movable bridge has challenges that result specifically from its small dimensions. Most notable of these is that there are some criteria that are not scalable beyond prescribed limits. Maintenance access clearance is a prime example. When a bridge is scaled below a certain size, headroom and clearances between structures and equipment become overly restrictive.



On a typical trunnion bascule bridge the area for drive machinery is established by the horizontal distance from the centerline trunnions to the front wall of the bascule pier (which is typically a function of the distance from the centerline of trunnions to the live load shoe for a forward load shoe configuration); the front of the counterweight when the bridge is open; and the center to center spacing of the bascule girders. If the trunnions are of the simple trunnion configuration, with a bearing supporting the trunnion shaft on either side of the bascule girder, the machinery space can be further limited by the space occupied by the inboard trunnion bearing and supporting structure. For a typical double-leaf bascule design scaled down to span a 40 foot wide channel this space would be severely limited.

For most trunnion bascule bridges, the bascule girders are set transversely within the bridge section just inside of the curb lines. This arrangement simplifies the geometry of the joints between the movable span and fixed bascule pier. For the Port Ferdinand Bridge, with a roadway width of only 24 feet between curbs, this would result in a center to center distance between bascule girders of only 22 feet approximately. To increase the girder spacing and provide more room for machinery and machinery access, the girders are located just inside the back of sidewalk. This increases the center to center spacing to 31'-8". Not only does this increase the available space between the girders, but it increases the width of the counterweight and improves its efficiency. However, even with this improvement and the use of a significant amount of steel ballast, the clear distance between the front of the counterweight with the bridge open and the inside face of the front wall of the bascule pier is a limited 4'-7" at the level of the top of the handrail on the back side of the machinery platform.

Section thru Bascule Pier at Cylinder

Recognizing the challenges of limited space on a small bridge, it was decided early in the process that the machinery system for the bascule bridge would consist of cantilevered trunnions (often referred to as Hopkins Trunnions) rather than simple trunnions and hydraulic cylinder drives as opposed to gear based machinery. Using the cantilevered trunnion configuration eliminates the inboard trunnion bearing and bearing support, replacing them with an eccentric collar and trunnion girder that are mounted to the bascule leaf and do not restrict the size of the counterweight or obstruct areas that could otherwise be allocated for drive machinery or machinery access.

As a means of driving the bascule span, hydraulic cylinders offer several advantages over conventional machinery with regard to working in limited space. The rack of a conventional gear drive is typically mounted to the underside of the bascule girder. This establishes a fixed position for the rack and the rack pinion. The pinion is often located such that the clearance between the outboard pinion bearing and adjacent bascule pier wall is limited. Hydraulic cylinders can be mounted in a number of locations, thereby providing some additional design flexibility. Furthermore, cylinders are generally significantly smaller in footprint than a comparable gear drive. Just as there is flexibility in locating the cylinders, there is great flexibility in locating the hydraulic power units. Unlike a conventional gear drive that must have the motor and gearing connected by rigid shafting, hydraulic power units and cylinders are connected by piping and hoses that have great flexibility in location.

The advantages gained from the use of cantilevered trunnions and a hydraulic cylinder drive system were critical in developing a design for the Port Ferdinand Bridge that provides adequate clearance for maintenance, despite the bridge's diminutive stature. The cylinders, two per leaf, were located 7'-11" either side of the centerline of the bridge, well clear of the bascule girders. This allowed access stairs to be positioned so that they run just under the bascule girders and provide easy access from the machinery platform level, at elevation 2.50' to the equipment room level, which is located at elevation 7.20' to prevent flooding and allow easy access from the adjacent ground level. The clevis bases that connect the blind end of the cylinders to the bascule pier are positioned on concrete pedestals, close up against the bascule pier front wall. This location elevates the cylinders to a position of easy maintenance access, provides clear access on three sides, and allows for convenient piping runs along the inside face of the front wall.

The machinery platform space is cleared for the cylinders and stairs by moving the HPUs from the machinery platform area to equipment rooms on the sides of each bascule pier. Piping is run approximately 25 feet from the HPU to the center of the machinery platform and then split with runs of equal lengths to the adjacent cylinders. Locating the HPUs in a room on the side of the pier also provides better protection from the environment as the room is partially enclosed. The electrical equipment that supplies the HPU, including motor starters and main distribution panels are collocated in the same room for easy setup, maintenance and trouble shooting.

Typically on double-leaf bascule bridges, the span locks are mounted under the deck such that the forward guides and receivers are mounted either on the webs of the bascule main girders, on the floorbeams, or on the cantilever brackets. The space for this configuration is generally adequate since typical bascule girders have a web depth of at least 3.5 feet. This girder depth provides at least some head room for a crawl space to access the lock equipment. For the Port Ferdinand Bridge, the bascule main girder web is only 2'-2" deep at the tip, not nearly enough space for the equipment alone, much less maintenance access. Therefore, the span locks were located in the traffic barriers, above the deck, at the back of sidewalk. In this location, the lock system is supported within a modified section of the Wyoming TL3 rail. The posts are modified to support the lock guides and receivers as well as the linear electrical actuators used to operate the lock bars. Stainless steel covers are provided to protect the lock machinery from weather.

Packaging the Design for Remote Fabrication

Prior to engaging a design engineer, the owner had already decided to implement a design similar to the movable bridges constructed in South Florida due to the similarity of climates and environmental conditions and the familiarity of both the owner and the reviewing government agencies with those bridges. Early in the alternative study a discussion was held with the owner to determine where best to have the major bridge components fabricated and how to go about procuring those components. In addition to cost, the objective was to optimize procurement with regard to quality and reduction of risk.

With regard to procurement, quality and risk are inversely related such that improvements in quality achieved at the producer, reduce risks at the construction site associated with installation, erection, testing and service. First and foremost, our approach was to select suppliers and fabricators with a reputation for quality and include provisions in the purchase orders for an independent quality control and quality assurance program. This was achieved by requesting quotes only from reputable sources that we had worked with before. Beyond that, however, we also recognized that quality could be improved by having independent audits conducted by the engineer. Furthermore, we recognized that many of the potential quality issues (and therefore risks) were associated not just with one supplier or fabricator, but with the interface between various components or fabrications that may or may not be supplied by the same firm. In these last two items is a commonality that was leveraged in our procurement approach. The fewer suppliers involved the less interface items between suppliers and the smaller the number of shops to be visited for engineer's audits. Thus, fewer suppliers translates into less cost to perform the audits. In other words, reducing the number of purchase orders where it also reduced the number of suppliers/fabricators involved would increase quality and reduce risks. With this general concept, the approach agreed upon for procurement included the following:

1. Break the procurement into packages that would be quoted by select, qualified fabricator/suppliers
2. Obtain quotes for the initial packages
3. Review quotes received and either negotiate purchase orders or repackage by consolidating packages into larger packages to minimize coordination and inspection efforts

The initial procurement packages sent out for quotation included the following:

- Motor Control Center
- Bridge Controls (including control desk)
- Subcable
- Hydraulic Cylinder Drive System (including HPU and cylinders)
- Navigation Lighting
- Traffic Gates
- Structural Steel
- Traffic Rail (steel traffic rail system)
- Trunnion Assembly
- Miscellaneous Machinery (live load shoes, cylinder clevis brackets)
- Span Locks
- Exodermic Deck & Armored Joint Assemblies

In the end, the following purchase orders were negotiated:

- Traffic Gates
- Exodermic Deck and Armored Joint Assemblies
- Structural Steel, Trunnion Assemblies, Misc. Machinery, Traffic Rail and Span Locks
- Hydraulic Cylinder Drive, Motor Control Center, Bridge Controls and Subcable

By consolidating the work into these four packages, not only were the number of purchase orders to be managed reduced, but the number and location of shop inspections was reduced and the interdisciplinary coordination between suppliers was simplified. A significant advantage in coordination of components was obtained by negotiating the same supplier for the hydraulic systems and control systems. This ensured that these components could be tested together in the shop and any interface issues could be debugged prior to shipping overseas. Similarly, having the same supplier for the machinery and structural steel allowed full shop assembly without having to ship components between suppliers. For example, the upper clevis brackets were fabricated and attached to the cylinder girders in the shop for shipment as an assembly. In this manner the positioning of the clevis relative to the trunnion was preset and would only need verification in the field prior to installing final turned bolts.

Photograph: Clevis Brackets Mounted to Cylinder Girder in Shop

In the end, a cost savings in the purchase price on the order of 10 percent was obtained by repackaging. Additional savings were realized through a reduction in the number of required shop visits for independent audits by the engineer.

Each of the purchase orders was negotiated such that the goods were delivered to the Port of Palm Beach from which a commercial shipping company would take possession and ship the goods to Barbados. The selected source for navigation lighting was found to not require a negotiated purchase order and the volume of goods was small enough that this equipment was ordered directly from the supplier and shipped directly to Barbados.

Summary

At the time of this writing, construction of the Port Ferdinand Bridge is well under way. All offsite fabrication has been completed except for the hydraulic systems and bridge controls. Bascule pile driving is complete and the concrete work at the site is getting underway. The project is scheduled to be complete and the bridge open to traffic in April of 2011.

Through careful planning and due consideration of the unique aspects of designing and constructing a small movable bridge in a remote location, an economical and durable design was developed. Although small by movable bridge standards, adequate access has been provided for construction and maintenance of the bridge's operating equipment. By optimizing the use of local concrete and identifying local steel ballast, importing of some materials was avoided. A logical approach to procurement packaging was developed and implemented that limited the cost of imported items while improving quality and reducing risks associated with coordination of remote supply.

Despite the small stature of the bridge, its design provides for the objectives of the owner with regard to quality, aesthetics and durability. The bridge will be a focal point of an upscale waterfront development. The open bascule leaves will form a welcoming gateway for vessels approaching the marina from the ocean. Just as importantly, with careful consideration of the unique aspects of design and construction of a small movable bridge in a remote location, the Port Ferdinand Bridge will be easily maintainable and durable for the long haul.