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Bridge of Lions Temporary Bridge Movable Span

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1.0 INTRODCTION

Extensive rehabilitation to the existing bridge No. 780074, Bridge of Lions over the Matanzas River in St. Augustine, Florida was in order. But, in order to achieve this endeavor the existing structure will have to be taken out of service for a long period of time. Because of the significance of the road carries by the existing structure, a temporary bridge with a movable span was deemed necessary. Lichtenstein's assignment for this study was to research, gather and analyze all the pertinent information related to the construction of a movable span and develop feasible alternatives from both an engineering, environmental, and economic point of view.

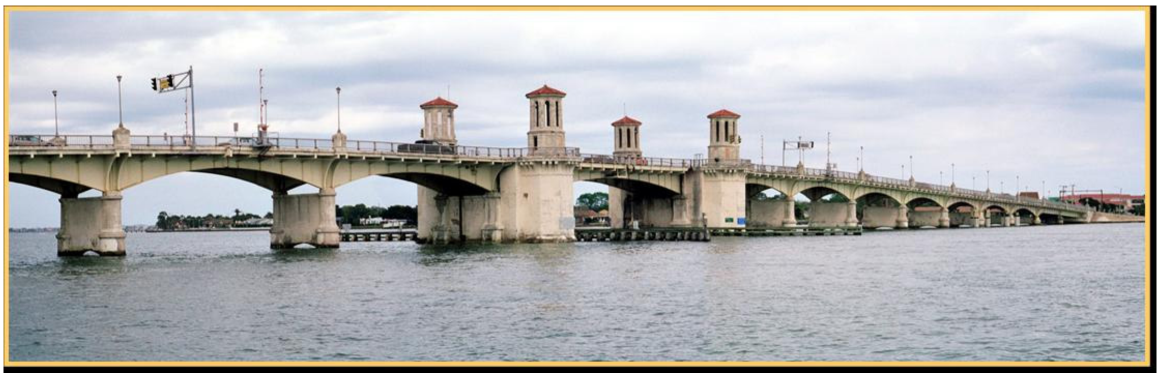

Fig. 1: Elevation View of the Existing Bridge of Lions

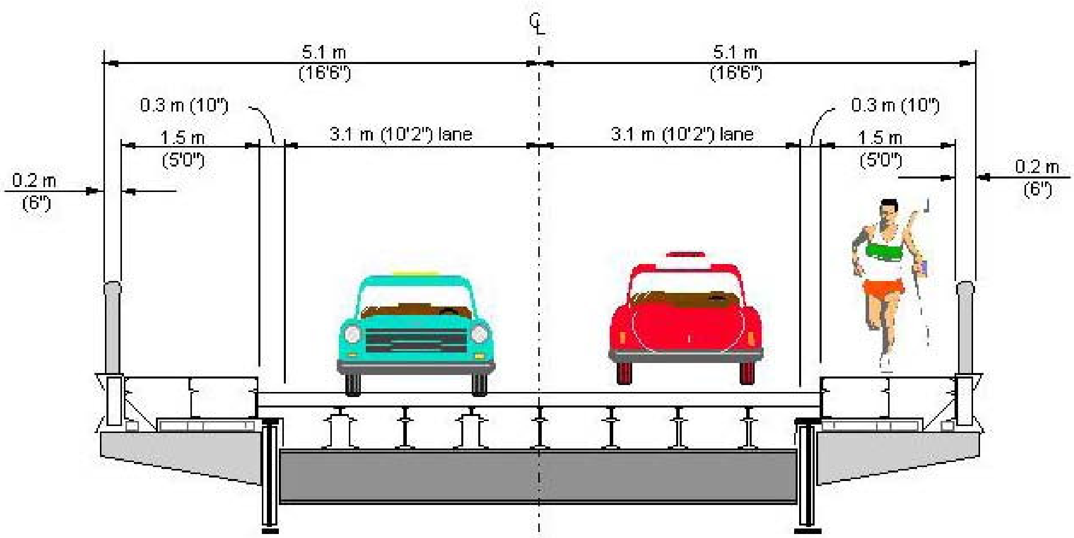

Fig. 2: Existing Typical Section Through Bascule Span

This structure was to be built on the north side of the existing bridge to carry traffic during the rehabilitation phase of same.

A total of four(4) movable span alternatives along with their construction cost estimates were investigated for the 90'-0" clear channel option. The first one consists of a vertical lift with mechanical drive option, the second one is a simple trunnion bascule span with hydraulic cylinders system, the third one is a rolling lift with hydraulic cylinders system, and the fourth one consists of the reuse of the existing temporary 17th Causeway Temporary Bascule Leaf.

A total of three (3) movable span alternatives along with their construction cost estimates were also investigated for the 120'-0" minimum clear channel option. The first one consists of a vertical lift with mechanical drive system; the second one is a double leaf simple trunnion bascule span with hydraulic cylinder system and the third one consists of a double leaf rolling lift with hydraulic cylinders system.

Comparison and evaluation of the alternatives were performed based on preliminary cost estimates, ease of construction and dismantlement, aesthetic, safety and construction impacts.

In evaluating the bascule type alternates for the temporary movable span providing the 90'-0" clear span, only the single-leaf configuration was considered because of the following advantages:

- Required less steel than the double leaf.
- Only one bascule pier will need to be considered.
- Provides a single control and mechanical plant.
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- Offers more flexibility in terms of alignment requirements than the double leaf span.
- Provides better visibility for the bridge operator over a double leaf.

For the 120'-0" minimum clear span option, only double leaf bascule configurations were considered.
Comparison and evaluation of the alternates were performed based on:

- Preliminary construction cost estimates.
- Ease of construction and dismantlement.
- Safety and the ability to meet AASHTO and FDOT requirements.

In the following sections the overall configuration, type and design concepts of each movable span alternate are described.

2.0 DESIGN CRITERIA AND PROJECT OBJECTIVE

2.1 General

All plans and designs were prepared in accordance with the latest standard specifications adopted by AASHTO, FDOT Standard Specifications, Structures Design Guidelines, and the Structures Detailing Manual, except as noted herein. In addition, recommendations and guidance from the State Structures Design Engineer, the Structures Design Office and/or District Structures Design Engineer were fully integrated into the design calculations and plans preparation for the project. The plans and designs were also prepared in close coordination with the Final Environmental Impact Statement.

2.2 Proposed Movable Span Section

The proposed temporary movable span cross section consists of 25'-0" roadway accommodating one lane of traffic in each direction. The roadway is flanked by a traffic barrier on the south fascia and a pedestrian/bicycle railing on the north fascia. A 6'-0" wide sidewalk pedestrian/bike path separated by a traffic railing barrier has also been provided on the north side of the structure. The total proposed movable span superstructure width is 35'-0".

2.3 Clearance Requirements

The first option for the temporary movable span design was to provide a minimum horizontal clearance of 90'-0" between fenders, normal to the axis of the channel. The 90'-0" clear span option for the temporary movable span was based on the opening of the existing bascule bridge. The existing bridge piers were to remain with a clear channel opening of 89'-0".

The second option was to provide a transition across the temporary bridge from 150-0" to 120'-0" minimum horizontal clearance at the south fascia of the temporary bridge. The horizontal fender system was to continue to taper down to the existing channel opening of 89'-0" at the existing Bridge of Lions.

A clear span of 125’-0” between fenders was finally selected for the final design.

The minimum vertical clearance at the main channel was set to 24'-0" from the Mean High Water Elevation with the movable span closed.

2.4 Design Method

The design method for the temporary movable span superstructure was the Service Load Design Metho. The Load Factor Design method was used for the movable span substructure.

2.5 Design Loading

Design loads for the temporary movable structure were as per AASHTO LRFD Bridge Design Specifications. Design load for the movable span superstructure was in accordance with the AASHTO Standard Specifications for Movable Highway Bridges.

2.6 Ship Impact

The piers for the temporary movable span were designed for a basic equivalent static vessel collision force of 125 kips. This collision force provided by the FDOT is based on a Vessel Impact Analysis conducted by same. The location and direction of this force were as per AASHTO LRFD Bridge Design Specifications Section 3.14.14 .

2.7 Fendering System

Our research on this subject revealed that a new fender system incorporating composite materials and engineered for local conditions is considered to be the “state of the art” and are to be used at the Bridge of Lions temporary and permanent structures.

In order to maintain continuity of fender stiffness, the new fenders for the temporary bridge would extend north from the existing bascule piers of the permanent bridge, resulting in a new construction length per fender of approximately 160 feet.

This fender system used both plumb and battered piles composed of composite marine piling, which includes in its composition recycled plastic reinforced with fiberglass rods. The piles are spaced at approximately 5'-6" centers. The four horizontal wales of the system are composite marine timber, composed of similar materials.

The use of composite materials produces many advantages over the standard fender system components:

1. The piles are highly ductile. This increases the energy absorption of the fender due to the ability of the pile to bend. For overloads above the design load, the piles will continue to bend beyond the elastic limit without breaking. If applied loads are within the elastic limit, the pile will rebound to its original shape, minimizing the replacement/repair costs associated with damaged concrete piles.

2. Composite materials do not require treatment with toxic chemicals, such as creosote, which is used to treat timber components.

3. The materials are impervious to marine borers. Timber wales in the splash zone typically require replacement within 5-7 years.

4. Wales of composite construction can be fabricated in much longer lengths than their timber counterparts. This simplifies connections.

2.8 Mechanical Design Options

2.8.1 Design Considerations

The AASHTO standard is typically used for the Mechanical design of permanent bridges. Machinery designed to meet AASHTO requirements typically lasts 50 years or more if the machinery is properly installed and maintained. To apply this standard without modification, to the design of a temporary bridge would have resulted in excess cost both in terms of manufacturing and installation of the mechanical machinery.

For this study, the AASHTO standards were relaxed in an attempt to reduce the cost of the mechanical machinery for the temporary structure. The following changes in the AASHTO standard were considered when evaluating the designs:

- Allowable stresses for machinery components were increased by 25%. This practice has been applied to previous mechanical designs for temporary bridges.

- The counterweight sheave size for wire ropes were reduced from the AASHTO preferred 80 times wire rope diameter to 48 times wire rope diameter (this is the AASHTO preferred size for operating ropes). This significantly reduces the size and cost of the counterweight sheaves. This would result in a shorter service life for the wire ropes but would not impact the wire ropes over the anticipated life of the temporary bridge. The selected ratio between sheave diameter and wire rope size is nearly twice (48 versus 26) the minimum ratio suggested by the wire rope users manual.

- The service factor for the speed reducer has been reduced from 1.5 to 1.2. This is a 25% reduction in service factor.

2.8.2 Trunnion Bascule: Simple Versus Hopkins Type

The trunnion bascule configuration offers two options for span support machinery: Simply supported trunnions and bearings or Hopkins type trunnions and bearings. Each support type has advantages and disadvantages in terms of how the bascule pier supporting the bridge must be designed. As far as cost is concerned for the machinery itself, there is little difference. A Hopkins trunnion is typically longer and requires a larger bearing than a simply supported trunnion. However, two bearings are required for each trunnion for the simply supported type whereas only one is needed for the Hopkins type. The end result is that the machinery cost for each type is comparable and the primary driver in the selection of one type versus the other is the design of the bascule pier that supports the bridge. If the bascule pier can be designed to accommodate either type with minimal cost impact, it is preferable to select the simply supported trunnion type due to the advantages in terms of ease of manufacture and installation.

For either support type, plain bearings, spherical plain bearings or rolling element bearings can be used. Of the three, plain bearings have the lowest initial cost and are therefore preferable for a temporary bridge application.

For all of the reasons mentioned above, only the simple trunnion type bascule was considered in this study.

2.8.3 Trunnion Bascule Versus Rolling Lift Bascule

The primary difference between the trunnion bascule and rolling lift bascule configuration is the span support machinery. Although slight differences may exist in the cost of the two types of span support machinery, any discrepancy would not be sufficient to preclude the selection of one type versus the other.

In a trunnion type bascule bridge, the leaf rotates about a horizontal axis on trunnion shafts supporting the main girders. These trunnion shafts which share the same horizontal center line are typically carried by special bearings built on the bascule piers.

In the rolling type bascule bridge, curved tracks (with squared holes machine into them) are attached to the bottom flange, near the tail of the main girders. These tracks seat on flat horizontal tread tracks anchored to the bascule pier. During opening operation, the curved tracks roll on the flat tracks.

The differences in span support machinery result in slight changes in the requirements for the span drive system. The end result is that for a given channel width, the length of the leaf and therefore the capacity of the span drive machinery for a rolling lift bascule is slightly less than for a trunnion bascule. Because the leaf rolls away from the channel as it opens, its length may be shorter than that of a trunnion bascule system while providing the same channel clearance when fully open.

2.8.4 Hydraulic Machinery Versus Mechanical Machinery

A brief summary of our experience with each of these drive types is presented below:

Mechanical machinery comprised of conventional mechanical power transmission equipment was evaluated for each of the temporary bridge types. Hydraulic machinery comprised of hydraulic cylinders and open loop hydraulic power units was also considered. For the vertical lift bridge configuration, hydraulic machinery of this type is not practical due to the length of cylinder required to raise the span. Therefore, this type of span drive system was only considered for the trunnion bascule and rolling lift bascule configurations.

In general, hydraulic machinery has a considerably lower initial cost (approximately half) than mechanical power transmission equipment where the use of hydraulic cylinders is practical. The installation costs for hydraulic machinery are also generally less than for a mechanical power transmission system. Both systems have proven to be reliable, however, hydraulic cylinders will generally require more maintenance and are less forgiving than the mechanical system when maintenance is not performed. Service life for the hydraulic cylinder system is considerably less than that of the mechanical power transmission system. The vast majority of hydraulic cylinder systems that we are aware of have lasted less than 10 years prior to requiring rehabilitation work or replacement due to leaks. Mechanical power transmission systems typically last for 50 years or more when properly designed, installed and maintained.

Since the temporary bridge structure is anticipated to be in service for less than five years, the service life discrepancy between the two systems is not a major issue. The factors that should be mostly considered for the temporary design are initial equipment cost, installation, dismantlement, and maintenance costs. So, because the hydraulic machinery presents significant advantages in terms of initial and installation costs, it is clearly the preferred option for a trunnion bascule or rolling lift for temporary movable bridge application with an expected service life of three to five years.

The required capacity of the span drive machinery increases with the square of the span length. That is why, the capacity of the mechanical machinery for a single leaf temporary bridge over a 90 ft. channel is more than double the capacity of mechanical machinery required per leaf for a permanent, double leaf bascule bridge over the same channel. As a result the cost of the machinery for the temporary single leaf bridge would be approximately the same as the machinery cost for the permanent bridge. It does not seem to be cost effective to pursue machinery options for the temporary bridge that are equal to the cost of the machinery for the permanent bridge. Therefore, the mechanical machinery options are eliminated from consideration.

2.9 Electrical Considerations Mechanical/Hydraulic Drive System_ Bascule Span

2.9.1. Power Distribution

The following outlines the specific power distribution and control system requirements for the mechanical drive option. The control systems for both options are identical. In keeping with the current FDOT and industry practices the bridge will be operated at 480 volt, 3_phase. The existing Bridge of Lions electrical system is presently operated at this voltage. The 480_volt utilization voltage is the industry standard for industrial power systems and provides the most efficient and economical means of serving the bridge loads. We have proposed Motor Control Center (MCC) construction to house all power electrical components.

2.9.2 Load Considerations

The bascule drive system required 200 HP main drive motors. The estimated connected load for the temporary bridge wasapproximately 220 HP. The minimum service size, based on article 430 of the National Electric Code, is approximately 400 amps. Subsequently, a 400 amp, 480 volt, 3_phase electrical service was proposed. Further, it was recommended that a single main drive motor speed controller be provided to drive the motor or combination of motors for the span. A spare controller was recommended to provide increased reliability.

2.9.3 Emergency Power Considerations

An emergency power diesel driven engine/generator set was recommended to serve the bridge electrical system in the event of loss of normal Florida Power & Light Company (FP&L) power. The estimated bridge generator size was found to be 300 KW. The generator was required to be oversized to accommodate harmonic loading of the non_linear motor loads. The generator was to be connected to the electrical system via a 400_amp automatic transfer switch.

2.9.4 Motor Speed Controllers

Assuming a common secondary reducer design, solid state speed control of the motors was to be accomplished by Variable Frequency Drive Controllers (VFD's).

In bridge applications, the VFD controls motor torque by adjusting the motor's voltage and frequency simultaneously. The VFD varies the speed of an induction motor by varying the frequency applied to the motor. To produce rated torque, the relationship between voltage and frequency is maintained at a constant ratio. As such, the VFD's output voltage varies directly with output frequency. During a "span raise" operation, the VFD sets the voltage and frequency to the motor in response to discrete limit switch inputs.

During a "span lower" the VFD accelerates and controls an overhauling load in motor regeneration. Braking resistors is to be used to dissipate the excess energy. During a "span seating" the motor is to supply a controlled limited stall torque. We have recommended standard VFD's similar to the Allen Bradley 1336 Plus 2 drives to accomplish span speed control and to provide the required span seating torque requirements.

If the system requires operation in a torque share mode, then flux vector controllers (FVC) are recommended. The FVC utilizes the same basic power devices as the VFD. However, instead of controlling the voltage and frequency magnitude, the FVC regulates the flux and torque producing components of current. The FVC operates with rotor position feedback from an encoder that is connected to the motor shaft. This item is critical to designs that require torque sharing. The position information received from the rotor is used to control the flux and load current. These components are added to develop the controlled stator current that produces the optimum speed torque control of the load.

The "span raise" and "span lower" operation are similar to the VFD. However, the FVC can be operated in a master/slave control mode thereby enabling the control system to maintain the motors producing the same torque. The FVC provides continuous full rated torque from base speed down to and including zero speed.

2.9.5 Control System

The bridge control system is to be composed of discrete components and a programmable logic controller (PLC). Since this is a temporary bridge installation it was recommended that the PLC be utilized to provide control of automatic operation of the spans. However, all FDOT standard bridge interlock requirements have been adhered to. The PLC is to also provide the diagnostics, alarm functions and report generation for maintenance personnel. However, in the event of PLC trouble, bridge operation would be possible in a manual mode. Suitable hardwired controls are to be provided to allow the bridge tender to initiate a safe manual bridge operation. The control system is to be comprised of a control desk and main control panel. The control sequence should be semi_automatic in that only the span operation required to be automatically sequenced. Operator interface is to be provided from a FDOT standard operator control console. Controls are to be initiated sequentially from left_to_right to open the span, and right_to_left to close. The individual span drive VFD units are to control the operation of the individual spans. The control system is to provide only run signals while the slow down and stop signals are to be provided by discrete limit switches.

2.9.6 Miscellaneous Electrical

All miscellaneous items such as lockable remote on/off switches and/or local disconnects are to be provided as required by Chapter 15 of the Structures Design Guidelines, Bascule and Bridge Maintainability.

2.10 Electrical Considerations Vertical Lift System

2.10.1 Power Distribution

As with the mechanical drive system, it was recommended that the bridge be operated at 480 volt, 3_phase. The 480_volt utilization voltage is the industry standard for industrial power systems and provides the most efficient and economical means of serving the bridge loads.

2.10.2 Load Considerations

Due primarily to the two 20 HP main drive motors required by the vertical lift system, the estimated connected load for the temporary bridge was approximately 60 HP. The minimum service size, based on article 430 of the National Electric Code, was approximately 150 amps. Based on this information, a 225 amp, 480 volt, 3_phase electrical service is proposed. Individual motor controllers were to be provided.

2.10.3 Emergency Power Considerations

An emergency power diesel driven engine/generator set were recommended to serve the bridge electrical system in the event of loss of normal Florida Power & Light Company (FP&L) power. The estimated generator size was 60KW. The generator was to be connected to the electrical system via a 225_amp automatic transfer switch.

2.10.4 Motor Speed Controller

The proposed mechanical design calls for the bridge towers to be operated independently. As such, electrical skew control is required. A synchro_lock drive controller (SLDC) was proposed to handle the master/slave control requirements for this application. The SLDC was to maintain level lifting regardless of load distribution. The SLDC was to match exactly the speed between the two lifting motors and precisely control the angular position of the motor shafts. This device can effectively replace mechanical line shafts, acting as an "Electronic Line Shaft". This device works in unison with a Flux Vector Controller (FVC).

The FVC utilizes the same basic power devices as a VFD. However, instead of controlling the voltage and frequency magnitude, the FVC regulates the flux and torque producing components of current. However the FVC requires a rotor position feed from an encoder that is connected the motor shaft where the VFD can regulate torque without the use of an encoder. The "span raise" and "span lower" operation are similar to the VFD. However, the FVC can be operated in a master/slave control mode thereby enabling the control system to keep the motors at the same speed. To accomplish skew control of the vertical lift transmission system the flux vector drives is to be operated in a closed-loop pulse counting algorithm.

2.10.5 Control System

The bridge control system was to be composed of discrete components and a programmable logic controller (PLC). Since this is a temporary bridge installation it was recommended that the PLC be utilized to provide control of automatic operation of the spans. As such, the PLC would work in unison with the SLDC. However, all FDOT standard bridge interlock requirements were to be adhered to. The PLC was to also provide the diagnostics, alarm functions and report generation for maintenance personnel. However, in the event of PLC trouble, bridge operation will be possible in a manual mode.

Suitable hardwired controls are required to allow the bridge tender to initiate a safe manual bridge operation. The control system was to be comprised of a control desk and main control panel. The control sequence was to be semi_automatic in that only the leaf operation was to be automatically sequenced. Operator interface was to be provided from a FDOT standard operator control console. Controls were to be initiated sequentially from left_to_right to open the leaves, and right_to_left to close. The individual leaf drive VFD units were to control the operation of their respective leaves. The control system was to provide only run signals while the slow down and stop signals was to be provided by discrete limit switches.

2.12 Aesthetics

Due to the temporary nature of the structure, aesthetics were not considered as a major factor in this project.

3.0 ALTERNATIVE ANALYSIS

3.1 Movable Span Alternatives

A total of four (4) design alternatives (with their construction cost estimates) were developed for the 90'-0" clear span option. Another three (3) alternatives were developed for the 120'-0" minimum clear channel option. Special considerations were given to quick and easy erection and dismantlement procedures, and preliminary construction cost estimates, while focusing on obtaining a structure that meets current structural and geometric design criteria.

A detailed description for each alternate is outlined in the following section.

3.1.1 Vertical Lift Bridge with Mechanical Drive System

Alternate 1a: 90'-0" Clear Span

Alternate 1b: 120'-0" Minimum Clear Span

The 90'-0"clear span (Alternate 1a) consists of a new 110 ft long lift span designed to carry two lanes of traffic as well as provisions for pedestrians and bicyclists on the north side of the structure. The 120'-0" minimum clear span option (alternate 1b) has the same deck configuration as the 90'-0" clear span, but with a 140'-0" long lift span. Alternate 1b would provide a transition across the temporary bridge from 150-0" to 120'-0" minimum horizontal clearance at the south fascia of the temporary bridge. The horizontal fender system was to continue to taper down to the existing channel opening of 89'-0" at the existing bridge of Lions.

The lift span was to be prefabricated modular bridge as per a fixed span bridge (i.e. Acrow or Mabey panel bridge) with the exception that suitable seating devices were to be provided at the ends of the span in addition to providing a means to attach the cables for lifting the span. In the closed position, the lift span is to provide a vertical clearance for navigation of 24'-0" above mean high water, and 65'-0" above mean high water[1] in the open position. This 65’-0” vertical clearance was changed to 80’-0 during construction requiring a redesign of the substructure. The horizontal clearance is 90'-0" for alternate 1a. Alternate 1b was to provide the same vertical clearances. The clear horizontal clearance was to be tapered from 150'-0" to a minimum of 120'-0" at the south fascia of the temporary bridge.
The final horizontal clearance was selected to be 125’-0”.

The weight of the lift span is approximately 200 tons and was to be supported at the four corners. The superstructure consists of a steel orthotropic deck with galvanized checkered plate surface and an anti-skid epoxy/aggregate mixture overlay on the road plate surface. Traffic barriers with a steel contoured plate modeled from the FHWA crash test approved “Jersey barrier” was to be provided at the curblines.

The lift span is to be mounted on four corner towers. Each tower is to be constructed from prefabricated bridging panels and bracing frames. The tops of the towers at each end are joined by a cross beam. A light overhead prefabricated bridging panel gantry was to be constructed to join both cross beams on either end of the lift span for stability of the structure. Sheaves were to be connected to the tops of the towers from which the counterweights are to be moved up and down inside the towers. The counterweights are to be constructed using mass concrete in steel framework.

The control house was recommended to be constructed between the towers on the east side directly above the roadway and was to provide a minimum vertical clearance of 17'-0" above the roadway.

For this alternate, a tower drive configuration with direct drive of the main counterweight sheaves was considered. With this configuration, there are two independent mechanical systems; one drive is provided for each of the towers. This arrangement requires electrical skew control and eliminates the need for a span between the two towers. This type of drive also eliminates the need for operating ropes that can be difficult to adjust and maintain.

[1] As per United States Coast Guard requirements for vertical lift spans over navigable water between Jacksonville, FL and Miami, FL.

The mechanical installation of the tower drive system designed for this alternate is fairly straightforward. The counterweight sheaves and bearing assemblies require precision alignment as is the case with any vertical lift bridge drive design. After this work is complete, the drive installation involves securing the machinery baseplate and installing the floating shafts. All of the machinery on the baseplate can be aligned and installed in the shop. There are no open gears or bearings to align in the field.

Once the lift span is assembled off-site or on a barge on-site, the span can either be lifted or floated into its final position.
The proposed bridge for this alternate was to be equipped with a two gate system or with a vertical resistance barrier. In a two gate system, the first set of gates is to lowered to ensure no vehicles, pedestrians or bicyclists approach too close to the edge of the roadway deck prior to lifting the span. A second set of gates is required as a backup to stop vehicles from reaching the egde of the opening with the lift span raised. With a vertical resistance barrier, the barrier is designed to absorb the energy from an errant vehicle and would therefore not require a second set of gates.

3.1.2 Simple Trunnion Bascule Span with Hydraulic Cylinder System

Alternate 2a: 90'-0" Clear Span

Alternate 2b: 120'-0" Minimum Clear Span

The 90'-0" clear span option (Alternate 2a) consists of a simple trunnion single leaf bascule span carrying two lanes of two way traffic. For the 120'-0" minimum clear span (Alternate 2b), a double leaf configuration was recommended. The deck layout for Alternate 2b is the same as for Alternate 2a. Both options include provisions for pedestrian and bicycle traffic on the north side of the structure. The weight of both the leaf and the counterweight are carried by the trunnions during operation. In this configuration, the trunnions are located approximately at the center of gravity of the mass. These main trunnions which bear on trunnion bearings are in turn supported directly on the bascule pier.

The bascule leaf span length, from trunnion to live load shoe, is 115'-0" for the 90'-0" clear span option (Alternate 2a), and approximately 190'-0" from trunnion to trunnion for the 120'-0" minimum clear span option (Alternate 2b). They are composed of a main girder-floorbeam-stringer system using two (2) welded plate longitudinal girders with varying web depths. For Alternate 2a, the main girders vary (from 8'-6" at the trunnion to 4'-6" at the toe end of the leaf). The flange thicknesses varies from 2 ½" at the trunnion to 1 ½" at the toe end. The space between the main girders is 25'-0" on center. There are seven (7) transverse floorbeams of welded plate or rolled steel construction spaced at 17'-4" on center, and six (6) W14X22 longitudinal stringer lines spaced at approximately 5'-0" on center. The stringers are simply supported between adjacent floorbeams and the overhang brackets using standard shear connections. "X" bracing is used in each floorbeam bay to provide lateral bracing for the leaf. The decking consists of 5"-4 way open grid steel deck.

For Alternate 2b, the main girders vary from 8'-0" at the trunnion to 4'-0" at the toe end of the leaf. The flange thickness varies from 2" at the trunnion to 1" at the toe end. The space between the main girders is 25'-0" on center. There are five (5) transverse floorbeams of welded plates or rolled steel members at 20'-6" on center and five (5) W14X22 longitudinal stringers spaced at 5'-0" on center. The stringers are simply supported between adjacent floorbeams and the overhang bracket using standard shear connection. Similar to Alternate 2a, "X" bracing is used in each floorbeam bay to provide lateral bracing for the leaf span. The deck for Alternate 2b will also consist of 5"-4 way open grid steel deck.
The deck spans across the stringers, instead of resting on the top flanges of the main girders, therefore eliminating fatigue details on these fracture critical members.

For this alternate, the cylinders for the trunnion bascule configuration is mounted in a vertical orientation and pin connected to the moving leaf at the bottom of the bascule girder forward of the trunnion. The cylinder pivots as the bridge opens and return to a vertical orientation with the bridge in the fully open position. Two cylinders are required, each mounted directly below each bascule girder.

3.1.3 Rolling Lift Bascule Span with Hydraulic Cylinders System

Alternate 3a: 90'-0" Clear Span

Alternate 3b: 120'-0" Minimum Clear Span

Alternate 3a consists of a single leaf rolling lift bascule span. Similar to the trunnion bascule span options, the overall deck width is 35'-1/2". The roadway width curb-to-curb is 25'-0 and carries two 11'-0" lanes (one in each direction) with 1'-6" shoulders on each side of the structure. A 6'-0" wide sidewalk pedestrian/bike path is also provided on the north side of the structure for this alternate. The length of the bascule leaf span from center line of roll to the toe end is 106'-0". The bascule leaf is composed of two welded plate main girders with variable web depths, six longitudinal steel stringers and seven W30X99 transverse floorbeams spaced at 16'-4". The total length of the bascule leaf is 137'-6". The first position of roll to the last position of roll(length of roll) is 7'-5". Standard "X" type bracings are used between the floorbeams to provide lateral stability to the structural system. The deck system consists of a typical 5"- 4 way open grid steel deck. The weight of the leaf and the counterweight for this configuration are directly carried by the horizontal tread track, which in turn transfers it back to the bascule pier. The center line of roll is located at the center of gravity of the leaf. The weight of the leaf and the counterweight travel from the first position of roll to the last position of roll on the flat tracks during opening operation.

The hydraulic cylinders for the rolling lift bascule configuration was to be mounted in a horizontal orientation and pin connected to the moving leaf at the center of roll of the curved tread plates. The length of stroke required is equal to the length of roll of the leaf. Two cylinders are required to be mounted outboard of the bascule girders.

The 120'-0" minimum clear channel option (Alternate 3b) using a double leaf rolling lift bascule configuration is similar to the double leaf simple trunnion option, but would operate as described above.

3.1.4 Alternate 4: The Reuse of the Existing 17th Street Causeway Temporary Bascule Leaf: 90'-0" Clear Span

This alternate consists of the re-use of a dismantled steel heel-trunnion single leaf bascule balanced by an overhead counterweight supported by a balance frame. The balance frame is connected to the bascule leaf by a pair of link arms near the tip of the leaf and is supported on overhung trunnions at the top of a pair of “A” frame towers. The bascule leaf, the “A” frame towers, the bascule pier roadway deck, the drive system, the power and control systems are all directly mounted on a common steel support frame.

The Dutch-style bascule achieves proper balance when the gravity line of the counterweight is parallel to the gravity line of the bascule leaf. The link arms maintain the required geometric control by forcing the upper and lower pivot points at the tips of the span to deflect equally.

The bascule leaf span length, from heel trunnion to live load shoe, is 132'-10 ½". The bascule leaf is composed of a main girder-floorbeam-stringer system using two (2) welded plate through main girders spaced at 30'-3" on center, seven (7) rolled steel W 27 x 178 transverse floorbeams spaced at 20'-6" on center, and five (5) longitudinal stringer lines using W 16 x 50 rolled shapes spaced at 6'-3" on center. The stringers are simply supported on the tops of floorbeams, and are braced over same with end diaphragms. “K” bracing is used to provide lateral bracing for the leaf span. The decking consists of 5"-4 way open grid steel deck. The roadway width from barrier curb to barrier curb is 25'-8".

The leaf has a single 5'-11" wide sidewalk located outboard of one of the main girders. An additional sidewalk may be fabricated and attached to the other main girder if necessary.

The balance frame main girders, trunnion girder and counterweight girder consist of open-tub box girders with diagonal braces between the top flanges and thin cover plates to close off the interiors from birds and weather. Rolled steel W-shape diaphragms span between the main girders forward of the trunnion to distribute the load between the girders. In the open position, the balance frame is nearly vertical in orientation, facilitating erection and dismantling.

The link arms consist of steel pipes pin-connected at the ends by clevis bracket assemblies. The clevis brackets welded to the main girders of the balance frame and bascule leaf contain plain spherical bearings to accommodate any slight misalignment between the leaf and the frame and allow for relative lateral displacements between the two due to lateral wind loads. Maintenance free bearings are used to minimize routine maintenance.

The total weight of structural steel in the bascule leaf and bascule frame is approximately 414,500 pounds.

The counterweight mass is provided by cast-in-place concrete poured between the webs of the main girders and counterweight girders, precast reinforced concrete planks keyed together and anchored to steel framework between the main girders via post-tensioned threadbars, and a steel ballast plate bolted to the top of the counterweight girder for fine balance adjustment. The precast planks make for easier erection and dismantling. Internal bracing and stiffening of the counterweight girder allow the placement of cast-in-place concrete without falsework. Approximately 378,100 pounds of cast-in-place concrete are required; 369,000 pounds of precast concrete planks are required; and 54,900 pounds of steel ballast plates are required.

The balance frame is supported atop a pair of “A” frame towers, fabricated from round steel tubing. Each tower is located outboard of the bascule leaf main girders. A longitudinal strut between tower legs at mid height provides additional buckling resistance, and a transverse strut spans between the forward legs of the towers, approximately 18'-0" clear over the roadway deck, to create a rigid frame.

A bascule support frame serves as a common base for support and alignment of the numerous span components, including the bascule leaf heel trunnions, “A” frame towers, roadway deck over the bascule pier, flanking span, hydraulic cylinders and machinery room. The framework consists of main longitudinal girders in line with the “A” frame towers, with cross girders centered at the bascule leaf heel trunnions and at the base ends of the hydraulic cylinders. The longitudinal girders consist of two (2) W 36 x 150 rolled beams tied together with diaphragms. The inclined legs of the “A” frame towers are connected to the top of the main longitudinal girders just inside the cross girders.

The roadway deck over the bascule pier consists of five (5) rolled steel stringers spaced at 6'-2 13/16" on center. These stringers support a concrete filled steel grid deck, which also serves as a roof for the machinery room.

The span is driven by two (2) 12.6" bore - 7.1" diameter rod, clevis mounted, heavy-duty mill-type hydraulic cylinders with power provided by an 80 HP open loop hydraulic system. The cylinders are arranged to pull the span open or push it closed in approximately 70 seconds. The cylinders are mounted with plain spherical bearings to permit slight misalignment in the initial installation and allow for float in the span during operation. The bascule leaf is supported by simple trunnions, located at the heel of each main girder. The 12" diameter trunnions are each supported on a pair of trunnion bearings with bronze sleeve bushings. Each of the bearings are mounted on a common weldment which bolts to the support frame forward of the cross girder, allowing shop alignment of the heel trunnions.

The balance frame is supported on a pair of overhung trunnions framed into the dual webs of the balance frame box girders. These 20.9" diameter trunnions are supported atop the "A" frame towers, each by a trunnion bearing with bronze sleeve bushings. The inboard ends of the counterweight trunnions are provided with three-piece eccentric assemblies to facilitate alignment.

The tip of the bascule leaf has two (2) hydraulic span locks, each driven by a common hydraulic power unit. Combination live load and span guide shoes mount on the rest pier to assure that the bascule leaf rests properly and is aligned with the approach spans.

4.0 EVALUATION MATRIX AND PREFERRED ALTERNATIVE

TABLE 4.1

ALTERNATIVES EVALUATION MATRIX- 90'-0" Clear Span

	Preliminary Cost Estimate	**Ease of Construction & Demolition**	**Construction/ Environmental Impacts**	**Safety/ Maintenance**	**Ability to meet Codes**	**Aesthetics**	**Total (Most desirable)**
Alternate 1a	4	4	4	3	4	1	**20**
Alternate 2a	2	2	2	3	4	4	**17**
Alternate 3a	3	2	2	3	4	4	**18**
Alternate 4	2	3	3	2	3	2	**15**

TABLE 4.2

ALTERNATIVES EVALUATION MATRIX- 120'-0" Minimum Clear Span

	Preliminary Cost Estimate	Ease of Construction & Demolition	Construction/ Environmental Impacts	Safety/ Maintenance	Ability to meet Codes	Aesthetics	Total (Most desirable)
Alternate 1b	4	4	4	3	4	1	**20**
Alternate 2b	2	2	2	3	4	4	**17**
Alternate 3b	3	2	2	3	4	4	**18**

Note: The numerical rating is based on a scale of 1 to 4 with 1 being the lowest and 4 the highest or best rating.

4.1 Discussion

An evaluation matrix was developed for each of the bascule span alternatives included for this study. The matrix is exhibited in Tables 4.1 and 5.2. Among the factors considered in the evaluation of the alternatives include the following: Preliminary Cost Estimates, Ease of Construction and Dismantlement, Safety, Construction or Environmental Impacts and the ability to meet all AASHTO and FDOT Requirements.
The evaluation matrix shows that Alternate 1 (1a or 1b) exhibits the least construction or environmental impacts and offers the easiest and fastest erection and dismantlement procedures.
The ability to meet AASHTO and FDOT requirements is the same for Alternates 1, 2 and 3 and less for Alternate 4. The matrix shows that Alternate 4 would likely require more maintenance than any of the other alternatives due to the fact that it a used structure.
As shown in the evaluation matrix, alternates 1 and 4 present the most adverse effect on aesthetics while Alternates 2 and 3 are aesthetically more desirable.

4.2 Preferred Alternative

Review of the preliminary construction cost estimates indicates that Alternate 1 is the cheapest to construct among all the alternatives while the cost difference between alternates 2, 3 and 4 is minimal. The matrix shows that even though Alternate 1 is aesthetically the least desirable, overall it is however the most preferable. This alternate, because of the modular nature of its components, offers the minimal on-site construction time and labor. Many of the movable span components can be fabricated off-site and either trucked or barged to the site.
Minimizing closure of the channel to marine traffic during construction is one of the additional advantages offered by this alternate. From the time the channel is closed to marine traffic to erect the lift span to when the bridge would open again can be limited to approximately 36 hours.

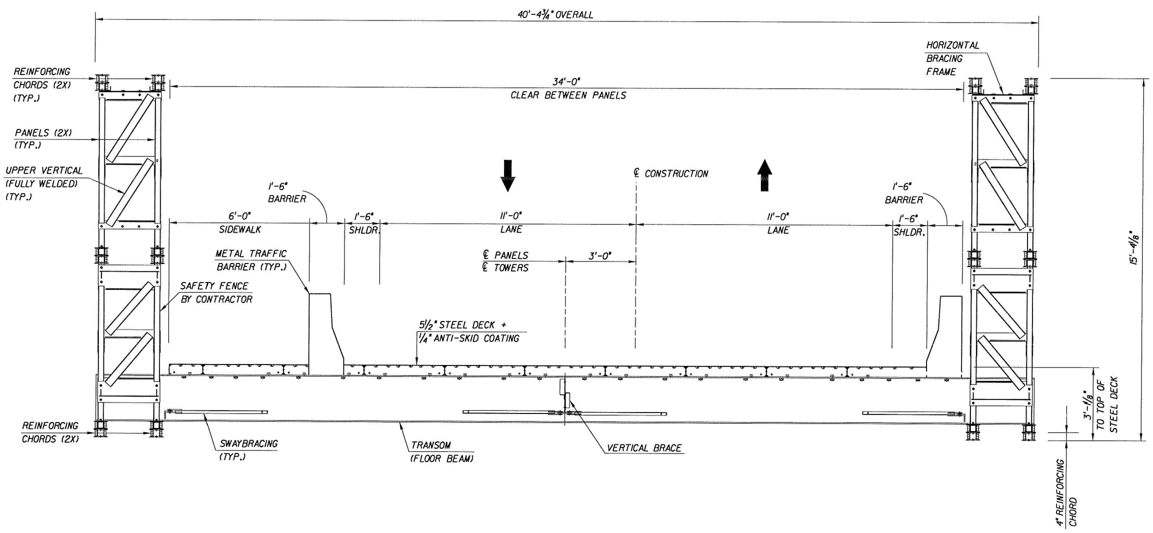

Figure 3: Typical Section Vertical Lift Superstructure

The substructure for this alternate is relatively simple. Two substructure alternatives were investigated. The first one consists of either cast-in-place or precast concrete footings on piles, and the second one was to be constructed entirely of steel. The lift span is mounted on four towers constructed from prefabricated bridging panels and bracing frames at the corners of the span.

This alternate requires the least power for a given speed and the least force for a given channel size than either the rolling lift or trunnion type bascule bridges. This is due to the AASHTO requirements related to wind loading. The vertical lift bridge is designed for a 2 ½ lb/sf. wind on the surface area of the moving span per AASHTO requirements. The bascule type bridges are designed for a 10 lb/sf. wind on the vertical projection of the span per AASHTO requirements. In the full open position the vertical projection is nearly equal to the surface area of the span. The size of the bridge for a given channel opening is similar for the vertical lift and the bascule types. The result of the design requirements and the bridge size is that the wind loading has the largest effect on the capacity of the machinery. Since the wind requirements for the bascule span are nearly four times that of the vertical lift bridge the machinery for the bascule types must have significantly greater capacity than that of the vertical lift bridge.

Maintenance requirements of this design for mechanical components are minimal. Only the counterweight sheave bearings require more than annual maintenance. The other components including couplings, speed reducers, and counterweight ropes require annual maintenance. This drive system has very few components and should prove to be very reliable over the life of the temporary bridge.

The next option which offers minimal erection and demolition time is the reuse of the existing 17th Street Causeway Temporary Bascule Leaf (Alternate 4). However, this alternate, not only would require more maintenance, it is also the most expensive. Also, this existing structure might not be available at the time required for this project, since it was being advertised for sale. Also, this alternate is only feasible for the 90'-0" clear span option

Alternates 2 and 3 are virtually the same. The matrix shows that environmentally they are the most appealing. But, this should not be a controlling factor, since the temporary structure is to be only in service from 3 to 5 years. Also, these alternates would have required more time to construct than any of the other 2 alternatives. This is partly due to the type of substructure which would have been required for a bascule span and the amount of time that would have been needed to fabricate all the superstructure components.

Based upon the above discussion, Alternate 1 was recommended as the preferred alternate for this project. In addition to being the most cost effective, the on site construction time and labor for this alternate would be minimal The vertical lift is relatively simple to assemble due to the modular nature of its components which can be readily made available by Mabey or Acrow. At the end of the project, the span can be salvaged as scrap metal or can easily be reused for another project . Also, at the end of the project, the main span and towers can quickly and economically be dismantled in a matter of days.

Vertical Lift Structure - Preferred Movable Span Option
Opened to Traffic in May, 2006