**HEAVY MOVABLE STRUCTURES, INC.**
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# *CHALLENGES OF A DESIGN-BUILD BASCULE BRIDGE REHABILITATION*

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# 1.0 PROJECT OVERVIEW

The NE 14th Street Causeway (Figure 1) is a four lane, two span hydraulic bascule bridge carrying traffic over the Atlantic Intracoastal Waterway in Pompano Beach, Florida. In March of 2005, the Florida Department of Transportation advertised for the design-build rehabilitation of the structure, which included structural, mechanical, and electrical improvements. In response to the Request for Proposal, PCL Civil Constructors, Inc. (PCL) partnered with Hardesty & Hanover, LLP (H&H) and proposed a cost effective design that would provide a low maintenance structure with a long component life. The proposed $4.8 million rehabilitation included replacement of main structural members (Figure 2), refurbished hydraulic cylinders, an overhaul to the electric system, a renovated control tower, and improvements to the existing sidewalk configuration. Along with the proposed reconstruction, the design-build team committed to a 349 day schedule from award to final acceptance. Due to the quality of the Technical Proposal, and the cost effective design, the PCL/H&H team was awarded the contract in August of 2005, upon which the team began its journey to rehabilitating the bascule structure.


Figure 1. NE 14th Street Causeway, Pompano Beach, FL

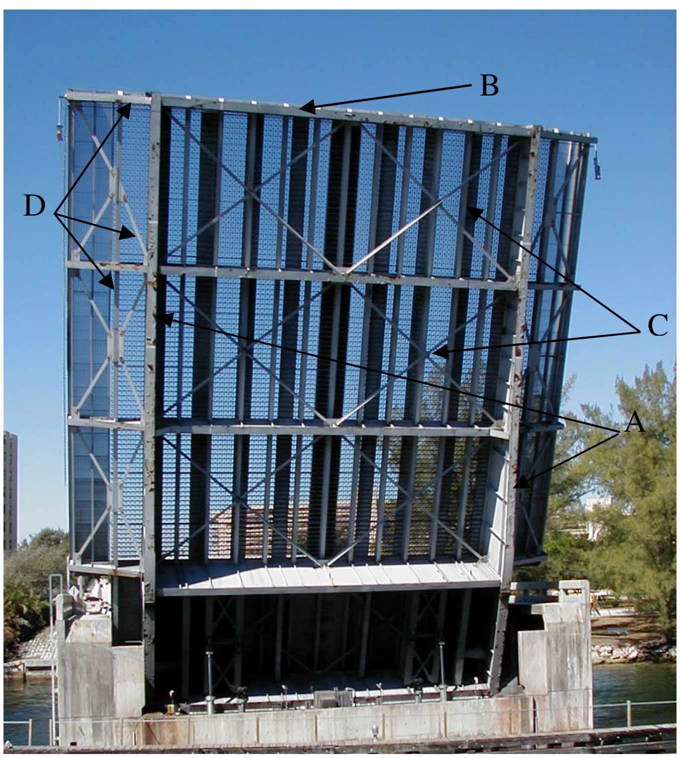


Figure 2. Structural steel components.

STRUCTURAL STEEL COMPONENTS (FIG. 2)

1) Main girders (repairs only).
2) Floor beam (replace three per span).
3) Stringer and lateral bracing (replace)
4) Sidewalk components: overhang bracket, stringer and lateral bracing (replace all).

# 2.0 DESIGN

In preparation for the design of the bascule rehabilitation, the team reviewed the Request for Proposal package, which included a Description of Work, a Rehabilitation Evaluation Report, and several bridge maintenance inspection reports. Various requirements of the RFP could be incorporated into the design and schedule without the need for an analysis for methods of rehabilitation, such as the main mechanical and electrical improvements. Those rehab components that were vague in scope required the design-build team to review documentation, field verify conditions, and create a design that would encompass the full repair.

Review of RFP documents revealed that extensive structural steel patch work would be required to repair the stringers and floor beams on each span. The team decided to propose replacing, rather than patching, these components as the additional initial costs for the new structural steel would be offset by the time saved throughout construction. In addition to the structural steel repairs, the scope of work included a modified cross-section that would remain similar to the existing, with the difference that the median and sidewalk would be reduced in height and a multi-use shoulder would be added.

Figure 3. A snooper truck is utilized to inspect connections.

With a preliminary design complete, the team performed a field verification of existing conditions by the use of a snooper truck provided by the Department during a six hour inspection (Figure 3). In the teams review of project documents, two areas of concern were highlighted: the floor beam to main girder connection and the sidewalk bracket to main girder connection. During the inspection, the team concentrated on these areas to determine an appropriate scope of rehabilitation. As the owner did not allow destructive testing of structural members, it was difficult to ascertain the extent of deterioration located beneath the plates and angles connecting the members to the main girder. The design was completed based on the visual inspection of the members.

In addition to evaluating the existing condition of structural steel members, the balance of the bascule spans had to be considered when creating a preliminary design for the proposal. A trunnion analysis was performed to verify the capacity of the existing shaft and sleeve bearing. The analysis was based on the modified loadings resulting from the addition of weight to the spans by the scheduled rehabilitation. The results indicated that allowable bearing stresses were greater than the theoretical loadings, and no further design modifications were required to this component. As the counterweight pockets were not accessible to survey before the proposal, the design conservatively proceeded under the assumption that there was minimal room in the counterweight pockets for balance adjustment. As a result of this assumption, replacement floor beams were designed with sections similar to those existing. To compensate for weight added by new intermediate sidewalk brackets, flange widths were varied, which saved weight without compromising load capacity. Additionally, the new steel deck was designed with a gap beneath the steel median, whereas the existing grating ran continuous across the bridge.

With the documentation review, field verifications, and design analysis complete, a preliminary design was completed with the following proposed scope of work:

Structural Steel:
- Replace six of eight floor beams and all stringers
- Replace open deck grating and add lightweight concrete wheel paths
- Install new "Minnesota" steel traffic rail between sidewalk and roadway grating
- Add intermediate sidewalk brackets to accommodate attachment of "Minnesota" rail
- Install aluminum pedestrian railing on outside face of the approach and bascule span

Roadway:
- Remove old and install new concrete traffic barrier
- Install 280 ft. of new guardrail
- Remove and replace concrete median

Electrical:
- Install three new roadway lights supported by new concrete pilasters
- Install new flashing warning light at roadway intersection east of bridge
- Modify existing lightning protection system
- Replace all magnetic proximity limit switches with lever arm type switches
- Install new hydraulic pump motor and starters, overload coils, disconnects and breakers
- Modify the PLC program and leaf control

Mechanical:
- Refurbish 8 each hydraulic cylinders
- Refurbish span lock system
- Install heating/cooling and filtration loop
- Install new 25 hp motor and pump assembly
- Replace existing hydraulic hoses

Control House:
- Replace roof with barrel tile
- Replace windows with new bullet resistance glass
- Replace exterior doors
- Add black aluminum balcony rail
- Add pecky cypress outriggers
- Add raised stucco trim.

# 3.0 SCHEDULE

The Request for Proposal allowed a maximum of 500 calendar days to complete the project. The team reviewed previous projects of similar scope, analyzed historic data on production rates, and phased construction activities to determine a construction schedule. This information was added to the teams design phase and a preliminary schedule was created entailing finishing the project in 349 days.

Once awarded the contract for the rehabilitation, the team began analyzing the preliminary project schedule. The requirements of the contract allowed for a one time, continuous 30 day closure. This closure was to be utilized to rehabilitate those members of the structure that could not be altered under vehicular traffic. These activities included replacement of floorbeams, stringers, lateral bracing, and deck grating. The scheduling of this work was based on the timeframe allowed for the 30 day closure. Due to heavy vehicular traffic during the peak season in south Florida (November though April), the closure was restricted to occur between May 1, 2006 and November 1, 2006. As Florida's hurricane season begins June 1st, and with the recent high number of tropical systems, the team decided the ideal window for the 30 day closure would be May of 2006.

With the closure date chosen, the next step was to determine what components of work would be completed before May 1st. Because the new design detailed connecting the sidewalk brackets through the main girder to the floorbeam, the team decided that the sidewalk work would be completed before the May 1st closure. This would expedite the connection of the floorbeams inside the closure as the new holes for the connection to the main girder would be drilled during sidewalk reconstruction. Based on past work experience, the team determined that 60 days would be adequate time to remove and replace the sidewalk components on each span.

Along with the steel work, the team decided that the hydraulic cylinders should also be refurbished before the May 1st closure. By completing the cylinder repairs by May 1st, the hydraulic and electrical subcontractors would be allowed to complete the rest of the mechanical improvements without effecting vehicular traffic. As each set of four cylinders (two from each span) required 30 days for refurbishing, a 60 day time period was also required to complete the hydraulic cylinders.

Based on the 60 days required for the steel and hydraulic work to be completed before the may 1st closure, the team set a construction start date of Feb. 6, 2006. From this date, a schedule of design and shop drawing milestones was created. SSB of Sarasota, Inc., the steel fabricator contracted to supply the structural steel for the project, required 100 calendar days from initiation of shop drawings to delivery of material. These shop drawings would be the critical submittals on the project because the steel reconstruction drove the schedule. Based on the phasing of structural steel work, a sequence chart was created to depict the order and date for which the steel would be required on site. The chart set milestones of shop drawing initiation, fabrication start dates, and required delivery dates. The team set a date of Feb. 6, 2006 for delivery of the first steel components required on site, the north sidewalk components. In order to meet this date, shop drawings for these components needed to be initiated no later than the beginning of November, 2005. As the project was not awarded until August of 2005, the 90% contract drawings were not submitted until Sept. 29, 2005. Because steel delivery was critical for construction operations, the team directed SSB to begin detailing shop drawings based on the 90% design drawings. This reduced the time required for final detailing once 100% plans were received.

Because the contract drawing and shop drawing approval process was a critical aspect of the project, a partnering session was held to help identify means by which the project team could expedite submittal turnaround time. All parties associated with the project were invited and each was able to express their concerns with different aspects of the project. Through the groups discussion, goals were set for submittal dates and review times, which ultimately led to the critical timely approval of contract plans and steel shop drawing approvals.

Signed and sealed drawings were approved by the owner on Jan. 19, 2006. As details could not be finalized until the signed and sealed drawings were received, the steel fabricator was left only 36 days to meet the required ship date for the first set of deliveries, which included the sidewalk overhang brackets for the North span. Due to the extensive efforts of the design-build team, the owner's representative, EC Driver & Associates, and SSB, shop drawings were approved and the first steel delivery made it to site by the Feb. 24, 2006 deadline.

# 4.0 CONSTRUCTION PLANNING

Throughout the design and shop drawing submittal phase of the project, the team was also planning different aspects of construction. Equipment analysis, crew assembly, and work plans had to be completed to ensure a successful project.

## 4.1 EQUIPMENT AND CREW SELECTION

A critical aspect of the project was determining which type of lifting equipment would be used to remove and replace the structural steel. The lifting loads required for the sidewalk reconstruction would be significantly less than those for the roadway reconstruction. Also, the equipment used for the sidewalk reconstruction would have to work with live traffic on the bridge whereas this would not be a concern for the work occurring inside the closure. It was evident that two different pieces of equipment would be needed for these two phases of the project.


Figure 4. Carry deck crane placed inside lane closure.

The team determined that three factors would affect the choice of equipment to be used for the sidewalk reconstruction. Load capacity, size, and mobility had to be investigated to ensure the proper piece of equipment would be utilized. The equipment would have to be capable of fitting inside a 12 ft. wide lane that was closed to traffic, and also have the ability to rotate in order to execute lifts of approximately 1,500 lbs. The equipment would have to be mobile to allow for relocating off the bascule spans quickly when bridge openings were required. After analyzing different types of equipment, the team determined that a carry deck crane would best suit this construction phase. It would be small enough to fit inside a 12 ft. lane closure, had enough capacity to lift the larger sidewalk brackets from multiple angles, and could easily be moved off the spans when bridge openings were required (Figure 4).

Upon completion of the equipment analysis for the sidewalk reconstruction, the team moved forward to investigating how lifts would be made inside the 30 day closure. The controlling lift would be the floor beams, each weighing approximately 8,000 - 10,000 lbs. Two options were explored: making use of a crane placed on a barge in the intracoastal channel, or utilizing a crane placed on the approach span.

Option one, placing a crane on a barge in the channel, would reduce the radius required to make a lift, and thus lower the required capacity of the crane. It would allow more storage space on the approach span and eliminate the need for an analysis to ensure the approach span could support the loading from the crane. One concern with this option was that it would require double handling of material. The new steel would have to be unloaded from trucks and placed in an area accessible to the crane on the barge. This would require an additional piece of equipment to assist with unloading of material. Another concern was that this option would introduce two factors that would reduce the capacity of the crane: barge list and crane list. Accounting for these factors would offset the benefit of the shorter radius when calculating capacity.

Option two, making use of a crane set on the concrete approach span, would eliminate the need for a tug and barge, thus making it a cost effective method compared to option one. It would also make the lift analysis simpler as the crane and barge list factors would not have to be considered. Another benefit of placing the crane on the approach span was that material deliveries could be stored in locations to allow lifting directly from trucks to its final location, eliminating double handling of material. The concern with placing the crane on the approach span was that the longer radius to the outer floor beam created the need for a high capacity crane, thus creating a heavier load for the approach span to support. To address this concern, the crane was sized based on the controlling lift. Information on outrigger loading of the required crane was obtained from a local crane company and the design-build team checked the loading on the approach span. Making use of crane pads to distribute the load from the outriggers, the team determined that the approach span would be adequate to support the required crane and thus selected this option (Figure 5).

Figure 5. 120 ton crane rigged to floor beam during 30 day closure.

As critical as equipment selection was to the project, crew selection would be equally important to ensure the success of the project. The structural steel work to be performed would be complicated and require experienced ironworkers familiar with the scope of rehabilitation. Additionally, ironworkers would be required to work in a non-typical environment that required workers to be aware of their surroundings at all times (Figure 6). In order to ensure a safe and successful project, the team decided ironworkers would be transferred internally from other projects. Utilizing this strategy would ensure that workers were familiar with the company's safety policies and procedures in place to ensure a safe working environment.


Figure 6. Ironworkers install a sidewalk bracket standing on steel beams over the Intracoastal water.

## 4.2 WORK PLANS

With the equipment and crew assembly analysis complete, the team moved forward with work plans for different phases of the project. There were many aspects of construction that were unique and required extensive planning for access, tool selection, and communication. Each phase of construction required a separate work plan as each was constrained by different requirements of the contract and work. In planning for the reconstruction, five areas of concern were identified: continuous vehicular traffic, bridge openings scheduled every 30 minutes, boat traffic in the channel, access and the safety of the workers.

### Vehicular Traffic


Figure 7. Crew constructs temp. steel barrier with modified base.

As discussed in section 4.1, the sidewalk components were scheduled to be removed and replaced with one lane of traffic in each direction across the bridge. Along with equipment selection, this posed a challenge to drop off protection because the existing traffic barrier was connected to the existing sidewalk brackets. In order to remove the sidewalk components, a temporary traffic barrier would be required on each side of the bascule span. This barrier had to meet Florida specifications for crash tested barriers. A concrete traffic barrier could not be utilized because there would be no means by which to adequately anchor the barrier to the deck for bridge openings. The team decided to make use of the new permanent steel barrier by designing a temporary base that would connect to the steel deck grating (Figure 7). Along with the temporary barrier, Type II barricades would be required on the bascule spans to delineate lane closures. To eliminate constant relocating of the barricades for bridge openings, it was decided that the legs of barricades would be tied to the steel deck grating with tie wire.

## Bridge Openings

In order to allow marine traffic to pass, the bridge was scheduled for a two span opening every 30 minutes. To accommodate the construction schedule, the team knew it would be necessary to obtain a modified bridge opening schedule. As done on previous projects, a request for modification of the operating schedule was submitted to the U.S. Coast Guard. The requested schedule modification had two phases. The first would allow single span openings every 30 minutes, and allow two span openings with a four hour notice to the bridge tender. The second phase (30 day closure) would modify the openings to single span only. These two operating schedules, which were approved by the Coast Guard, would allow the team to work on one span of the bridge for extended periods of time during sidewalk reconstruction, and accommodate locking down a span during the 30 day closure.

Figure 8. Ironworkers anchor down pieces of steel removed from the bascule span to maintain longitudinal balance of the span.

Along with its affect on scheduling, bridge openings would also require each span to stay in balance throughout sidewalk reconstruction. With the schedule of construction activities completed, superintendents worked with engineers to generate a sequence of removing and replacing structural steel. From this sequence, a construction balance plan was created which detailed where weight would need to be placed, relocated, or removed in order to maintain the longitudinal balance of the span. In most cases, the demolished structural steel would be temporarily located on the span the same distance from the trunnion as it was in its original location. This would ensure an equal moment would be placed on the trunnion. Once the new steel was in place, creating an equal moment and thus maintaining the balance, the temporary steel would be removed. The steel to be used as temporary weight on the structure would have to be anchored to the span to allow bridge openings when required. Along with anchoring the steel to the span, vehicular traffic had to be protected from the temporary weight; therefore the steel would have to be placed behind the temporary traffic barrier in a 5 ft. wide area (Figure 8).

To complete the extensive amount of work required inside the 30 day closure, the team determined that continuous balancing of the span would not be an option. With a large quantity of steel being removed and replaced in a short period of time, monitoring the balanced condition of the span would be difficult, and continuously relocating weight would be time consuming. The team decided to use a tie down system used on previous bascule rehabilitation projects. This system would lock one span in the down position not allowing for two span openings, which was the reason for the phase two request submitted to the

Coast Guard. Once again, superintendents worked with engineers to create a sequence of steel removal and replacement occurring during the 30 day closure. The engineers determined a threshold for how "light" the span could be at any given time and this was used to assist in sequencing of construction. Once sequencing was finished, an analysis was completed to determine the force to be resisted by the tie down system. With this force known, the tie down system was designed for the structure and, once in place, balancing of the span would not be a concern (Figure 9).

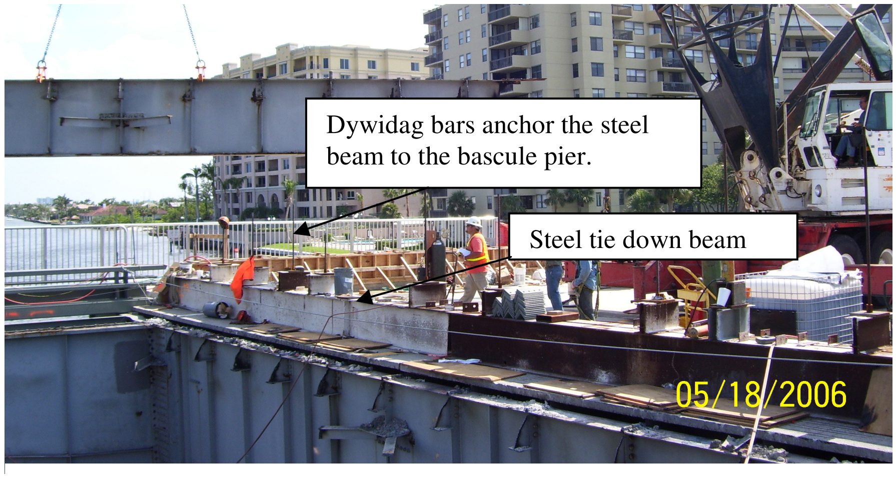


Figure 9. Existing steel is removed. The tie anchors the span in the down position.

## Boat Traffic in Channel


Figure 10. Sparks from torch cutting fall to the waterway below.

Another issue restricting construction operations was that torch cutting would be required for structural steel demolition. The team recognized that torch cutting of the steel would produce sparks creating a hazard to marine craft passing underneath the bascule span (Figure 10). To ensure the sparks from the torch cutting did not damage any vessels passing below the structure, the team decided that each day, two workers would have the responsibility of "boat watch" during cutting activities. These persons would be responsible for alerting ironworkers of marine traffic passing below, at which point the torch cutting would be discontinued until the waterway was clear.

## Safety and Access

For the safety of the workers, communication on the continuously operating structure would be critical. As part of the contract requirement, the design-build team would be responsible for bridge tender operations throughout the duration of the project. The team contracted with The Florida Drawbridge Company, Inc. to have bridge tenders supplied on a continuous basis. These bridge tenders would carry the same responsibility as the bridge tenders who normally operated the bridge, but have the additional responsibility of communicating with team members to ensure workers would be aware of bridge openings. To eliminate the possibility of miscommunication, the team decided that the bridge would not be opened until the superintendent, or an assigned worker, gave permission to the bridge tender. This would prevent the bridge tenders from unknowingly operating the bridge with workers on a span. Also, tenders would provide a five minute warning when a span was going to be operated. This would allow workers the opportunity to clear the spans of any tools, materials, etc. before bridge openings.

In addition to continuous communication and other safety precautions on the bridge, safe access, fall protection, and air filtration would be critical to ensure the safety and health of the workers. Based on site visits, the team knew access would be a challenge during construction. From previous work experience, the team had systems designed to allow safe access for workers. A system of wood floats (Figure 11) and aluminum pick boards connected to steel cables (Figure 12) would be utilized to provide access. This system would work with regular bridge operations as the platforms would be anchored to the spans.


Figure 11. Ironworker torch cutting on access float wears harness tied off to safety cable above while also wearing respirator to protect from lead.

Due to the scope of work and location of the project, workers would continuously work near leading edges where fall distances to the water would be a concern (Figure 11). The team procured harnesses and anchorage devices and created plans for where and how workers would tie off when working around areas where fall protection would be required. Also, air filtration was a concern as the existing steel to be demolished was coated with paint containing lead. The team determined that individuals torch cutting on the existing steel would be required to where a full hood respirator (Figure 11) to prevent inhalation of the lead. In addition to the respirators, the ironworkers' blood would be tested before and periodically during the rehabilitation to ensure their lead levels were at normal levels.

Figure 12. Wood floats and aluminum platforms hang from the raised span.

# 5.0 CONSTRUCTION EXECUTION

With the design complete, submittals and work plans ongoing, it was time to commence construction. The team mobilized as scheduled on Feb. 6, 2006 and the crew was ready to begin rehabilitating the bascule bridge.

## 5.1 SIDEWALK RECONSTRUCTION

Figure 13. The team removes the first sidewalk bracket.

Upon arrival of the first steel delivery and completion of the temporary steel barrier, the team began demolishing the existing sidewalk components on the north span. The first existing sidewalk bracket was removed on Feb. 28, 2006 (Figure 13). After removing the bracket, an ironworker pointed out severe deterioration (100% section loss) on the main girder, which had been hidden by connection plates (Figure 14a and 14b). The superintendent requested the Project Engineer and Project Manager to examine the deterioration to determine if there was cause for concern. Because the point of deterioration was located where the fracture critical floor beam framed into the main girder, PCL contacted the owner (FDOT) and the Engineer of Record (H&H) to request an investigation into the extent of deterioration. The group conducted multiple visual inspections revealing flexing of the girder web and severe deterioration on the fracture critical weld connecting the floor beam to the main girder. As a result of the investigation, the bridge was immediately closed to vehicular traffic to ensure the safety of the public was not compromised.

Figure 14a. Existing connection plates conceal deterioration on the main girder.

Figure 14b. Sidewalk bracket removed exposing main girder deterioration.

After closing the roadway, H&H calculated a conservative connection capacity based on the estimated deterioration of the fracture critical weld, and the section loss in the girder web. The calculation revealed that the connection was marginally adequate to carry vehicles. The parties involved in the investigation held a meeting and decided it was prudent to ascertain the condition of each of the fracture critical floor beam connections prior to reopening the bridge.

In order to investigate each connection to the extent necessary, the team had to remove each sidewalk bracket to allow inspection of the main girder. Because reopening the bridge was critical, an accelerated schedule was created to have all sidewalk brackets removed as soon as possible to allow an investigation of deterioration, and creation of a repair procedure. Three issues would control the accelerated schedule:

1) Modifying the schedule to remove the entire sidewalk components at once meant anchoring down a large quantity of temporary weight to the span, on both the north and south (Figure 15). This temporary weight would have to be removed, or relocated behind temporary barriers before reopening the bridge, which would be challenging due to the minimal space.
2) To remove the temporary weight from the spans, the new steel would need to be installed to maintain the balance. The new brackets could not be reinstalled until a repair procedure was created and the material procured.
3) The schedule for steel delivery did not require steel for the south to be delivered until March 20, 2006. This steel included the temporary traffic barrier required for the removal of the existing material.


Figure 15. Existing sidewalk components placed on roadway for temporary weight.

To address these concerns the team created a schedule of milestones that had to be met before reopening the bridge. The first of the milestones was creating a repair procedure to address the deteriorated main girder webs. PCL and H&H worked together to produce a procedure that would minimize impacts to the original design and have a quick material procurement time. After meeting with the owner for approval, the following repair procedure was created:

1. Remove existing sidewalk bracket.
2. Power tool clean main girder web to expose extent of steel deterioration/corrosion.
3. Engineer of Record inspect deteriorated/corroded main girder web to determine limits of 3/8" thick cover plate.
4. Drill 15/16" diameter holes in main girder web for cover plate connection.
5. Fill pitted areas of main girder web to be covered by plate with FDOT approved metal epoxy compound.
6. Apply zinc primer to area of main girder web to be covered by 3/8" thick plate.
7. Install 3/8" thick steel cover plate.
8. Install new sidewalk bracket.

Placing a repair plate on the main girder meant modification to the original design as the additional 3/8" thickness had to be accounted for in other connecting members. An analysis was completed to determine the members that would be impacted by the repair plates and the team worked with the steel fabricator to revise shop drawings, and have new pieces fabricated and expedited to site.


Figure 16. An additional crane is brought to the site to allow work on the north and south simultaneously.

The next milestone was to set a date which to have all sidewalk bracket locations inspected and repair plate material procured and installed. Based on material delivery, the team set a date of March 28, 2006 to have the north and south main girder remediation completed to allow reopening of the bridge to traffic by March 29, 2006. The team new this would be challenging as it meant double the scope of work (removing and replacing both the north and south sidewalks) would be completed in the amount of time originally slated to reconstruct only one side. To accomplish this task, an additional crane was brought to site (Figure 16) to allow work on each side simultaneously. The ironworkers were split in to two teams to work on each side, and worked extended shifts to make up for the smaller crew size. The team was able to complete the required repairs by March 28, 2006, and the bridge was safely reopened to vehicular traffic on March 29, 2006 (Figure 17).


Figure 17. The roadway is cleared for the reopening of the bridge on March 29, 2006.

## 5.2 CYLINDER REFURBISHMENT

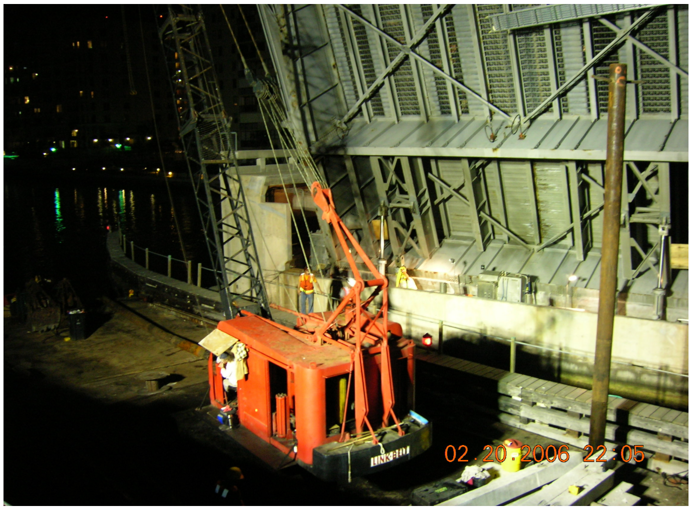


Figure 18. The barge is positioned to allow removal of two cylinders on the west span.

The first four cylinders (two from each span) were schedule to be removed Feb. 20, 2006 during a one night closure. During this one night closure, a crane on barge was brought to sight to remove the cylinders (Figure 18). To allow the cylinder removal to occur within one night, the cylinders were disconnected and un-pinned prior to the night closure. This allowed the team to remove four cylinders, two from each span, in only five hours.

Upon removal, the cylinders were shipped to Hydradyne Hydraulics, LLC for refurbishing. Once disassembled, the owner's representative, along with Hydradyne Hydraulics, conducted an internal inspection of the cylinders. This inspection resulted in two issues arising with the cylinders:

1) Two areas of damage caused by flame cutting were discovered on one of the cylinder rods (Figure 19).

2) Two of the four cylinders had additional machining on the piston to allow oil on the cap end of the cylinder to vent out the cap port (Figure 20). The two cylinders without this machining completely covered and thus sealed the cap port. This trapped fluid at the bottom of the cylinder, preventing full retraction of the cylinder.

Figure 19. Damage to cylinder rod.

Figure 20. Machining on piston allowed fluid to cap port.

To resolve the issues, the team met with the owner to discuss possible repair procedures. It was determined that the damage to the rod thread did not compromise the structural integrity of the cylinder rod and no further action was required. To repair the other damaged area of the rod, the team decided to feather the edges of the plating and damaged substrate such that there would be no sharp edges to exacerbate delaminating of the plating. The team also determined it would be necessary to machine two pistons to match the two pistons previously undercut to allow fluid to pass.

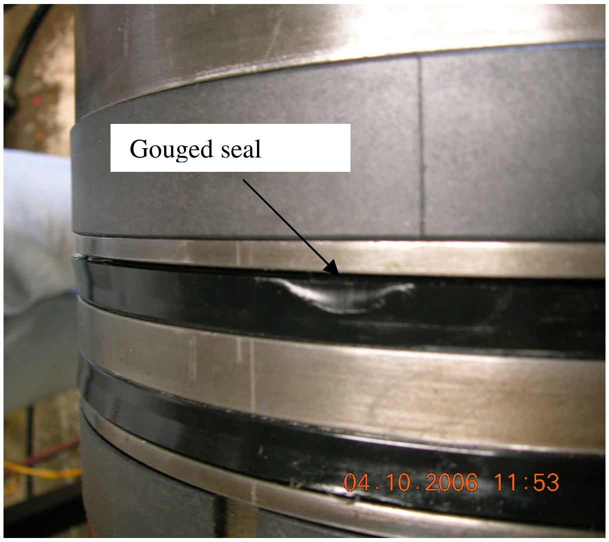


Figure 21. Refurbished seals display gouging after testing of the cylinders.

Once the four cylinders were refurbished, including the additional repairs necessary due to the unforeseen conditions of the cylinders, final testing was performed to ensure the cylinders were operating properly. During this testing, excessive leakage was witnessed in each of the four cylinders. Hydradyne Hydraulics again dissembled the cylinders to try to determine the cause for the leakage. Upon disassembly, gouging of the piston seals was revealed (Figure 21). Hydradyne determined that the damage to the piston seal was caused by sharp edges in the cylinder tube where the rod port and rod gauge port enter the tube. This was another unforeseen condition that had to be repaired by rounding the edges of each port hole in the tube and again replacing the piston seals. Once this work was completed, the cylinders were re-tested and approved for reinstallation.

The multiple unforeseen conditions of the first four cylinders delayed reinstallation from March 21st to April 24th, which in turn did not allow the last set of cylinders to be removed until April 27, 2006. Based on the conditions of the first four cylinders refurbished, the team knew the second set would need two of the pistons to be machined, and each port hole to be rounded in addition to the original scope. Once the last four cylinders were removed, two additional unforeseen conditions were discovered:

1) Heavy longitudinal scoring of the cylinder barrel and piston circumference was discovered on two of the cylinders (Figure 22).

2) On one of the cylinders with longitudinal scoring, the nickel-chrome plating had failed in three locations on the cylinder rod, exposing the substrate beneath (Figure 23). In addition to the failure, several other areas displayed plating delaminated from the substrate resulting in a “bubble” in the plating.

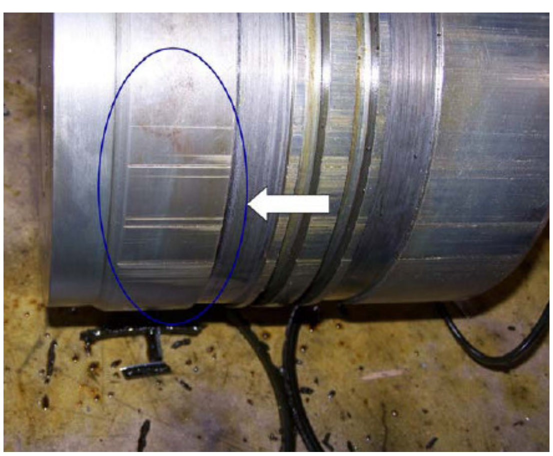

Figure 22. Scoring of piston.

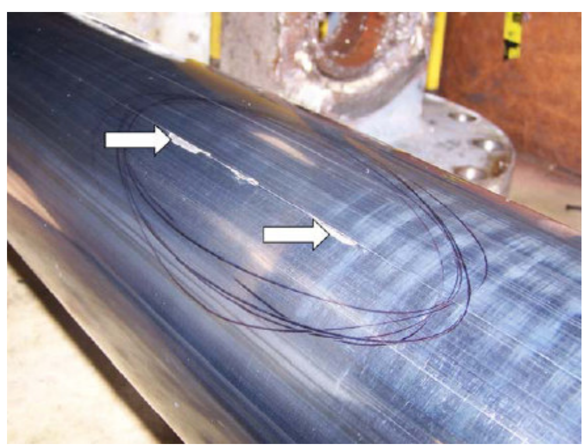

Figure 23. Nickel-chrome plating damage.

To resolve the final two issues with the cylinders, the team again held discussions with the owner to determine a repair. The group decided to hone the damaged cylinder barrels, which would increase the barrel inside diameter by a minimum of 0.03 in. and thus require new oversized pistons and seals for the cylinders to operate properly. Of greater concern was that the cylinder rod with nickel-chrome damage would need to be re-plated. The nickel-chrome required for the re-plating has a minimum (30) week lead time, which would not allow the repair to be completed before the contract end date. The team is currently working with the owner to determine the extent to which this rod will be repaired.

## 5.3 (30) DAY CLOSURE

Figure 24. The last piece of crane boom is connected on the east span of the bridge.

The 30 day bridge closure began May 2, 2006. As the contract included an incentive/disincentive clause for completion of the 30 day closure, the team worked on accelerating the schedule in order to make part of a bonus, which awarded the team for finishing up to ten days early. The accelerated schedule detailed completing work on each span in ten days. The team knew this would be a challenge, even more so as additional repair plates were now required on the main girder due to the unforeseen deteriorated conditions. In order to ensure that the schedule was met, the team set daily milestones that had to be met before construction activities were done for the day.

Figure 25. The first piece of deck grating is removed the second night.

The crane was set up and the tie down installed by the end of the second day (Figure 24). The team began removing the first piece of grating that night (Figure 25). The team worked through construction one bay at a time. In order to keep the force on the tie down below its capacity, the new steel was constructed after each bay was demolished (Figure 26). During the reconstruction of the roadway steel, various unforeseen conditions had to be dealt with. In order to expedite resolving these issues, Hardesty and Hanover made site visits whenever necessary to create a solution to the problem at hand. Due to the teams hard work and extensive planning, the team was able to complete the roadway reconstruction in only 22 days, reopening the bridge on May 23, 2006.


Figure 26. Bay 1 steel is erected after bay 2 was demolished.

## 6.0 SUMMARY

Throughout reconstruction of the NE 14th Street Causeway, PCL and H&H were faced with many design and construction challenges. Major issues included submission and approval of contract drawings and shop drawings in time to allow for fabrication of critical structural steel, an emergency bridge closure due to unforeseen deteriorated steel conditions and additional repairs required to the hydraulic cylinders. Because the team maintained continuous communication both internally, and with the owner, issues were resolved in a timely matter with minimal impacts to the contract value, and the original schedule. Due to the teams extensive planning and hard work, the project was completed within the original 349 day schedule and as the team originally proposed, the Department of Transportation was provided a low maintenance structure that will service both vehicular and marine traffic for many years.