HEAVY MOVABLE STRUCTURES, INC.
ELEVENTH BIENNIAL SYMPOSIUM

NOVEMBER 6-9, 2006

The Rehabilitation of a Water Control Structure – S310 Navigational Lock

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Background

The S310 Navigational Lock structure is located in the town of Clewiston Florida and is owned and operated by the South Florida Water Management District (SFWMD). The lock structure contains four gates within a chamber that stretches approximately 40 feet wide, 120 feet long and 30 feet deep. It is positioned between Lake Okeechobee and the Industrial Canal, which services the town of Clewiston. The original layout of the S310 Lock had two gates, built in the 1930's, that were strictly for hurricane protection. The structure was modified to become a navigational lock in the mid 1970's. The lock chamber was extended towards the south and two additional locks were constructed. This allows the waterway between the town and lake to be highly traveled throughout the year.

Design

The design phase of the project was completed based on previous inspections that were performed on the lock structure to determine its structural integrity. Underwater inspections were used for this design, as well as a brief dewatering of the lock structure prior to the project commencement. Based on the engineer's design, PCL was able to provide the required submittals, such as detailed shop drawings, mechanical equipment tolerances, and electrical specifications, to allow for owner approval. Construction procedures such as dewatering, environmental protection and spall repair procedures were also submitted for approval. Such items included in the design were steel beam splices, rivet replacement guidelines, new lubrication systems, rehabilitation of the locking mechanism, hinge replacement, fender system upgrades and electrical system overhaul. The design engineer was responsible for field inspections throughout the construction process, as well as making sure the project scope of work was maintained.

Subcontractors

Since the S-310 Navigational Lock project was the first of its kind for Civil Southeast, there was a large amount of time spent selecting the project subcontractors. The most critical subcontractors required were for steel/mechanical repairs and the coating system. The structural steel and mechanical repairs made to the structure were beyond anything that our personnel had performed in the past, so obtaining qualified and quality workmanship was vital. The contractor that was selected for these repairs was the same contractor that performed part of the inspection to determine the scope of the original contract. The contractor was also in high favor with the owner, so having this contractor on our design/build team was helpful to us getting the project.

Another subcontractor that was important to the success of this project was the coating system contractor. Since the most critical components of the lock structure were submersed in water, the quality of the coating system was very important. A unique type of system was desired by the owner, so an experienced and qualified contractor was required. The containment setup was also very important, due to the schedule being somewhat limited, as well as working during the rainy season in South Florida.

The performance of subcontractors will determine the success or failure of a project; therefore selecting the correct subcontractors was a high priority. To relinquish a large amount of liability, we subcontracted out certain aspects of work, such as the structural steel and mechanical work, for this project. This was done mainly due to our unfamiliarity in the given work application, however, this is a common practice when a subcontractor can perform the work for an equal cost or perhaps even if the price is slightly higher than our price.

Schedule

The schedule for the S-310 Navigational Lock Refurbishment was the most critical aspect of the project. The town of Clewiston is a small town that primarily depends on the fish industry and tourism to generate revenue, and the S-310 lock is a vital part of both. This lock system is highly traveled by both commercial fishermen and tourists that enjoy boating and fishing. Because of this, the South Florida Water Management District was adamant about maintaining the 75-day lock closure period. The District scheduled this project during the "slow season" of fishing and tourism in the hopes of minimal impacts to the towns economy. Despite these efforts, the public was not happy about their pathway to Lake Okeechobee being closed. Before construction began on the project, a public information workshop was hosted by the District and PCL to inform the public of what was going to happen to the S-310 lock.

The baseline schedule for the project was completed in a unique way. Since we were given a start date and completion date for the project closure, we had to determine the correct duration for activities and sequence them to accommodate the closure milestones. The critical activities included all repair items that were below the water level and any items that would affect the operation of the lock gates. In order to complete all of the critical work activities within the given closure, we were required to schedule work seven days a week and for some activities 24 hours a day. To better manage the flow of the project, intermediate phase milestones were developed to insure that our overall project deadlines were achieved.

CONSTRUCTION SEQUENCE

The construction sequence of the project was broken down into several key components: dewatering, structural steel and mechanical repairs, coating system and electrical repairs. The timing and schedule on each of these repairs were critical to the project's success. Certain portions of a component of work would need to be completed before another component could be started. This created a challenge for the construction team that required proficient communication between the subcontractors.

Dewatering

The first task in our construction process was the dewatering procedure. Our role in the dewatering process included pumping the chamber dry and removing any remaining material after the dewatering. The South Florida Water Management District has a close working relationship with the United States Army Corps of Engineers, who previously operated the S-310 lock. The U.S. Army Corps services were used to put the bulkheads and sheet piling in place. Once this was completed, we were able to begin pumping the lock chamber dry with two hydraulic pumps. We used a 20-inch and 12-inch diameter pump to remove the majority of the water. Once the water level was around one foot deep, we used two four inch diameter hydraulic pumps to remove the remaining water. The pumps were placed in sump holes located at the ends of the lock chamber. This process took approximately two days.

After the water was removed, debris such as mud and fish needed to be removed. To do this, we lowered a small skid steer and concrete bucket into the lock chamber. We used a series of fire hose lines that were inside the lock to push the mud from behind the gates. We were than able to remove the debris from the main lock chamber with our equipment. It was critical that we remove this material as quickly as possible, as to allow the steel repairs to begin on the first set

of gates. Once these repairs were underway, we were able to remove the debris from the remainder of the lock chamber.

Figure 9: Dewatering and cleanup

The initial dewatering and debris removal process was approximately 8 days long. The dewatering maintenance process, however, continued throughout the project. Due to small leaks in the bulkheads and seepage through the lock chamber floor, water continuously collected within the lock chamber. All of the rainwater runoff from the area drained to the lock as well. This created a great deal of dewatering maintenance, especially when the coating system repairs began. It was key to have a clean, dry chamber floor with no standing water for equipment, such as jacks and rollers, as well as for a quality coating system application. To maintain the insurgent water, we placed a series of small electrical pumps within the lock chamber to move the water toward the larger four inch pumps. All of these pumps were operating the entire project, therefore maintenance of the pumps was necessary.

Gate Repairs

The gate's structural steel repairs started on the two south gates, 2 and 4. The critical repairs here were scheduled to be complete in two weeks. The repairs consisted of 36 vertical "T" columns that were to be replaced at the water line (Figure 10). The bottom twelve inches of each column was removed and new pieces were welded on. The timing in which these repairs were done was very important, due to the fact that the coating system subcontractor was waiting to commence work.

Figure 10: Gates 2 and 4 “T” Column repairs

Once the repairs were completed on the two south gates, the focus then was aimed at the two north gates, which had a majority of the structural steel work to be performed. These two gates, 1 and 3, had to be lifted off their hinges to allow for bushing and casting (hinge assembly) replacement. This was done by a series of six hydraulic jacks that were connected to a main jacking manifold. This ensured that all the jacks were lifting at the same consistency. Once the gate was lifted enough to remove the hinge connection, Hillman Rollers were placed to slide the gate out of its position so the hinges could be removed. Once in place, the gate was blocked in position with wood timbers to insure that the gate could not move.

Each gate has three hinge locations (Figure 11), all of which were being replaced. Each hinge point is made up of a pin, casting and bushing. The bottom hinge location on each gate is the most critical and largest of the three. This hinge also carries a majority of the weight. This hinge has two separate bushings that were replaced, as well as a casting that was resurfaced and machined (Figures 12-15). The two top hinge locations received new bushings only. All three of these hinge points were critical to the project schedule because of the long lead time required for machine work.

Figure 11: Hinge Layout

Each of the bushings required a special mold, that had to be made prior to the bushing itself. The casting for the bottom hinge had three large grooves that had developed over the years of wear and tear. These grooves had to be filled with stainless steel material and then machined to create a smooth wearing surface. This was a long lead item due to the machine work required. All of the material build up and machine work took approximately six weeks. To lessen the time delay of this, the molds for the bushings were made prior to construction. The dimensions for the molds were taken off of original design drawings. This created a significant amount of liability, due to the fact that the drawings were over 70 years old. The bushings, which were made of brass, were not poured until the existing bushing dimensions could be verified to ensure proper replacement.


Fig. 12: Existing lower hinge exterior bushing


Fig. 13: New lower hinge exterior bushing

When the existing bushings were exposed, we found that the original design drawings did not match the current field conditions. The upper hinge bushing had an additional flange that was not indicated on the original drawings, while the lower hinge exterior bushing was half as short as indicated. Fortunately the fabricator was able to modify the molds and pour the new brass bushings without impacting the overall project schedule. The castings were machined, the brass bushings were poured and the hinges were reassembled. The reinstallation of the hinges was the final critical repair performed prior to reopening the lock structure.

Fig. 14: Existing lower hinge casting & interior bushing

Fig. 15: New lower hinge casting & interior bushing

The main contributing factor to why the hinges were in such bad condition was the failure of the three buoyancy tanks in each of the gates. These tanks were designed to act as a float for the gates and relieve much of the pressure from the hinges. Over time the buoyancy tanks began to leak causing them to fill with water. This added a great deal of weight to the gates, causing added strain to the hinges. In the project's original scope of work, the buoyancy tanks were to be repaired so they would hold air, therefore removing the extra strain in the hinges. Due to the severity of the buoyancy tanks and cost savings, the tanks were completely replaced rather than repaired.

To ensure that the new hinges would be maintained for years to come, new lubrication systems were installed on all four gates. There had been a problem in the past where the lubrication system was no longer properly working and allowed the lubricant to leak. To alleviate the problem, a new stainless steel lubrication system was installed.

Other than the major steel repairs, there were several minor repairs that were completed throughout the construction process. All of the access ladders throughout the lock chamber where replaced, due to high corrosion. Originally, the ladders were to be replaced in kind to match the existing material, however, the ladders were changed to be fabricated from stainless steel material. Any material that was to be below the water line was now fabricated from stainless steel, due to the fact that the lake water contained small amounts of tannic acid that would severely corrode materials. The existing wood fender system was replaced with concrete piles and plastic timbers. The existing gate timbers were replaced as well with new plastic timbers. The electrical system for all four gates was completely overhauled. All of the wiring and equipment throughout the structure was updated to meet current electrical codes and replace outdated material.

During certain times of the year, manatees would migrate through the area. During this time, there was a possibility of a manatee positioning itself behind the gate and, if the gate was to close, crush the manatee. To prevent this, manatee fence was installed to keep the animals from entering behind the gates. Manatee sensors were also installed to monitor the area during the gate closings. Environmental concerns were addressed for the duration of the project. During the dewatering phase, the pump intake areas were monitored for manatee and alligator activity. Throughout the construction process, we monitored any manatee activity as well. There were also several instances where alligator removal services were required while working in the water for the new fender system.

Gate Coating System

The gates' coating system was extremely important due to the underwater nature of the structure. The coating process consisted of three major operations: containment, blasting and coating application. The actual coating application for this project had three levels: prime coat, intermediate coat and a final coat. The plan for the coating system was to start on gates 2 and 4, following the structural steel repairs on the gates. The containment was a combination of scaffolding and several layers of tarps, which were constructed to enclose both gates at the same time. The containment system was necessary due to the contract documents stating that lead paint was used on the existing structure. The containment was also used to prevent overspray and reduce the noise from the blasting and coating procedures. All coating procedures followed the Steel Structures Painting Council (SSPC) Guide 6-Class 2A. The coating subcontractor was QP-1 and QP-2 certified for coating and lead abatement.


Figure 16: Gates 2 and 4 containment


Figure 17: Prime coat application

Once the containment system was constructed, blasting procedures began. The blasting process removed all the existing paint from the structure and exposed the metal to a near white finish. Throughout the blasting process, and all coating procedures, a certified NACE inspector monitored and documented all activities. The inspector documented hundreds of measurements that recorded dry film thicknesses. There was a given tolerance that each coating application had to be within. Following the blasting was the application of the prime coat. In this particular system, the intermediate coat and the final were the same product and application. There had to be two separate coats because neither coat could be applied too thick. It was very important that the coats be applied within the given tolerances to create a good bond. The prime coat was applied, allowed the appropriate time to cure, and then the intermediate coat was applied. All of

the coating applications were performed at night or early in the day, to avoid the high daytime temperatures. The product could not be applied when the temperature reached 108 degrees, and inside the contained area temperatures were recorded in excess of 118 degrees during daytime work hours. Upon completion of the intermediate coat, the final coating application commenced. This final coat was the structure's ultimate protection from the elements, therefore accurate application was very important.

From the time of containment construction to coating system completion on gates 2 and 4, was approximately four weeks. During this time, the structural steel and mechanical repairs had progressed according to schedule, so the coating application could now begin on gates 1 and 3. The containment system was removed from the first two gates and installed over the two remaining gates. The coating system process was then repeated on the new gates, however new challenges were presented for this process. Large amounts of rainfall begin to occur on a daily basis, severely hampering the coating system progress. The coating subcontractor rushed to maintain the schedule, while being mindful of the quality of workmanship. Along with rainfall contributing to delays, was the threat of a major hurricane. Preparations for the oncoming hurricane were being made while the final coat for gates 1 and 3 was being applied. There was no time for final thickness readings to be taken, due to the containment system needing to be removed for safety reasons during the storm. Because of this, there were significantly more touch up areas on gates 1 and 3.

Figure 18: Gates 1 and 3 final coat

In the Public Eye

The S310 Navigational Lock is a major artery between Lake Okeechobee and the town of Clewiston. A great deal of local business owners as well as recreational fishermen were affected by the 75 closure to the structure. This was the cause for the critical nature of the closure. Concessions were made to local business owners by the SFWMD to ease the financial burdens. Maintaining the fast paced 75 day schedule was a must to everyone involved.

It was very important for the project staff to maintain the confidence and involvement of the public. PCL was part of a coordinated effort to inform the public prior to the commencement of the project. Since Clewiston was such a small town, the construction team was faced with public perception very often. Local business owners as well as the general public were frequently asking if the project was on schedule and when the lock would be re-opened. It was a daily challenge putting an end to the rumors that would surround the projects status. It was important to ensure the public that the project was on schedule.

Safety

Maintaining a safe work environment is the main priority on all of PCL's projects. Daily pre-job safety instructions were discussed at safety meetings and site inspections were completed weekly. Personal protective equipment, such as hard hats, safety glasses, fall protection, etc., was required at all times will within the project limits. Due to the wet nature of the project, all electrical devices were connected to GFCI's and job hazard analysis were completed for all major work items. An environmental safety plan was implemented for the protection of the surrounding environment. The containment system for the coating system was evaluated and inspected daily to ensure the protection of the environment, the workers and the public. The work zone was surrounded by secure fencing and gates. When workers were not on site, we ensured that the gates were closed and locked to prevent anyone from getting in the work zone.

Challenges

There were several key challenges that we were faced with throughout the S310 project. Maintaining the critical schedule was the most challenging aspect of the project, however, there were challenges associated with the schedule as well. Due to the underwater nature of the structure, many of the repairs were designed based on underwater inspections. Once the structure was dewatered, we found that some of the repair areas required additional attention. This created a major scheduling challenge for our team. Not only did we have planned work to complete, we now had additional unforcen work to complete.

The unpredictable South Florida weather also was a key challenge to our schedule. The afternoon rains disrupted our schedule regularly. There were also concerns with the high

temperatures while applying the coating systems to the structure. We found that when the coating system was applied at high temperatures, the bond within the coating system was not achieved. This required us to modify the work schedule and apply the coating system at night when the temperature was within the products application range. Another weather challenge was dealing with two major hurricane threats. We were required to shut down and secure the project on two separate occasions for major hurricanes. During this time, the United States Army Corp of Engineers overtook operation of the lock structure and worked together with the SFWMD and PCL to secure the lock chamber and ensure the surrounding public was safe during the storms. Although we lost critical time during both of the storm events, no additional time was required for the project.

Project Awards

The S310 Navigational Lock Project was completed on schedule and was very successful. The relationship between PCL and the SFWMD was extremely positive throughout the projects entirety. The project was awarded a National Design Build Award in 2005 by the Design Build Institute of America.