2019 Honorable Mention

Duck Island Wastewater Treatment Plant: Screw Pump Rehabilitation

By Mason Guarino

The Duck Island Clean Water Facility, located in Lowell, MA, is a 32 million gal./day (120 megaliter/day) activated sludge treatment plant. The facility accepts wastewater from several Massachusetts cities and towns, including the City of Lowell and the towns of Chelmsford, Dracut, Tewksbury, and Tyngsborough. The service area includes approximately 220,000 people. The facility has been in the news for the past decade due to its need for massive repairs. During large rainstorms, it dumps thousands of gallons of less than properly treated water into the Merrimack river, which is a drinking water supply for many towns in the area. Starting in early 2018, the city awarded Waterline Industries (WI) a contract for full rehabilitation of the facility starting at the point of wastewater entry and working its way through the plant. Thus, the first-stage of repair would be the Archimedes screw pumps that convey the raw sewage from the sewer system up into the plant. South Shore Gunite (SSG) was retained to help with rehabilitation of the screw pumps, as SSG had worked on dam repair with Waterline Industries years before.

The screw pumps are 9 ft (2.7 m) diameter and 60 ft (18 m) long screw augers that sit in sloped concrete basin at a 45-degree angle. Each pump is capable of moving 30-million gal. (110 megaliter) of water per day. This facility has four screw pumps side-by-side which all required trench basin repair. The basin is a semi-circular shaped concrete

Fig. 1: Finished screw pump basin with tight radius

structure that is approximately 7/16 in. (11 mm) larger than screw flights. The tolerance between the screw and its supporting structure is very tight to ensure efficiency of the pump. The conventional way of repairing this structure is to remove the screw, demolish and remove the old grout lining down to the structural support, reinstall the screw with a 7/16 in. screed rod welded to the screw flights, and use the screw itself to screed the new concrete into place. The screw pumps at Duck Island are some of the largest, longest, and steepest in the country, making them some of the hardest to work on (Fig. 1).

FIRST CHUTE

During the demolition of the screw pump grout, it was found that the existing structure was 10 in. (250 mm) deeper than it should have been because the grouting operation with the screw only works with the grout being 2 to 3 in. (50 to 75 mm) thick. SSG was brought in to help build up the structure to match the 2 to 3 in. thickness that the grout needed. SSG asked WI to provide a plywood form top and bottom with a radius drawn to show where they wanted the shotcrete to stop. WI had all of this information and was able to easily provide SSG the radius and a couple of plywood templates to check the radius along the 60 ft shaft. SSG then drilled small holes in the template plywood every 10 in. along the line, and installed guidewires every 10 in. (Fig. 2). It took 4 days to set up and shoot the first chute. After SSG was done, WI checked SSG's work to confirm how much grout was needed, and was amazed to find that the installed shotcrete was accurate, with no noticeable variation anywhere. Additionally, the 28-day compression test results on the shotcrete came back over psi (55 MPa) with one panel breaking at 12,000 psi (83 MPa). They were impressed.

PROJECT CHALLENGES

In the following days, WI welded the 7/16 in. rod on the flights of the screw pump, reinstalled it, and performed the grout installation per the screw pump manufacturers recommendation. It did not go well. From SSG's shotcrete experience in the area, they knew that the local ready mixed concrete suppliers were not good at making the very-low slump concrete material this job required. The material showed up with mud balls in it and the grout did not stay in place when poured. WI spent 14 hours on site with 12 men struggling to get the screw grout installed, which still needed repair work afterward. A combination of the high-angle of this screw pump, and a concrete mixture that did not perform as needed, made for a very challenging, frustrating, and unrewarding day for WI. That's when SSG got a new request.

SSG was asked to install the shotcrete full-thickness to a tolerance of less than 1/8 in. (3 mm) deviation over 10 ft (3 m) on a radius structure. SSG said yes, but unfortunately, the engineer for the project and the screw pump manufacturer said no during a meeting with SSG, WI, the City, the engineer, and the screw pump manufacturer. Mason Guarino of SSG pools was asked if he could install shotcrete to the required tolerances to repair the screw pump lining and how he would do so. Guarino explained

Fig. 2: Basin walls shot with guidewires in place

the shotcrete process, the benefits, and how we could achieve the desired results, but the engineer and manufacturer did not approve. The head of the plant argued that this process had failed three times in the past 10 years when this application of grout should last 20 years before repairs. The owner then went against the recommendation of the engineer and manufacturer and told WI and SSG to proceed with a full-thickness repair using shotcrete, and they did. In the following weeks, the engineer and pump manufacturer would not return calls or e-mails to WI or the owner.

SHOTCRETE SOLUTION

WI and SSG proceeded to work on repair of the next screw pump following the same procedure as the first one, building the shotcrete to the final finish elevation this time. SSG chose a specific pattern for the shotcrete placement that would ensure accuracy while maintaining production (Fig. 3). It would be easier to manage rebound and work from the top to the bottom of the screw, but the bottom is where all the rebound and water could accumulate, making it difficult to clean with the uneven surfaces from the demolition. The bottom sides were shot first (Fig. 4), along with the bottom middle on the setup day, but only up about 4 ft (1.2 m) to make rebound cleanup easier. Then SSG moved back to the top right, shooting about 10 ft of one side leaving a 3 ft (0.9 m) gap in the middle to provide us an area to walk in for finishing (Fig. 5). SSG then proceeded down from there, occasionally jumping from one side to the other, and skipping small areas where it had guidewire supports. The checkerboard-like pattern kept things moving so overspray was not hitting the finishers and SSG could work in smaller more manageable areas to ensure accuracy. The overall shooting process took 5 days to complete for one screw pump shaft. SSG hung a rubble bucket from a telehandler and set it to bucket down into the hole right where the rebound accumulated, so rebound management was relatively easy and saved the crew from manually carrying buckets of rebound.

Upon completion of the shotcrete work, the screw was installed the following week to check fitment and confirm that the shotcrete solution was the correct decision. When the screw was installed there was an initial concern because the screw was hitting the shotcrete. After further investigation it was found that in the previous repair, one of the 7/16 in. rods was not removed from the fight of the screw. Once removed, the screw spun freely as it was supposed to, and the tolerances appeared just as tight as they would have been with the conventional grout method. Upon testing, the flow of the screw was normal and some plant employees mentioned the screw with the shotcrete appeared to be conveying more water than the other screws.

Fig. 3: Careful trimming of the sides

Fig. 4: Shooting side of basin off middle strip

Once the engineer and manufacturer heard about the success of the shotcrete, they became involved again and were more interested. SSG proceeded to work with WI for about a week every couple months to complete the remaining screw pump repairs. SSG used the dry-mix shotcrete method on this project because dry-mix allows a lower production rate, and facilitates stopping and starting throughout the day. Airplaco 914 mobile mixers were used to produce the material and SSG used a C-10 gunite gun to deliver material to the nozzle. The concrete material used was a dry-mix shotcrete mixture with a silica fume modified cement, concrete sand, and synthetic microfibers. The silica fume modified cement was chosen because SSG wanted to achieve high-strengths within just a few days as the plant was going to place the screw into operation within a week of completing the project. Curing was completed by keeping everything wet while SSG was on site, covering everything in poly plastic overnight and when SSG was not on site. A spray on curing membrane and surface hardener was used at the completion of the individual screw structure.

Fig. 5: Overview of shooting the basin with access down the middle

CONCLUSIONS

Shotcrete really transformed this from a difficult task that may not have performed well to a highly successful project. The monetary savings using the shotcrete method were negligible, but using shotcrete did help accelerate the project by 1 to 2 weeks per screw, and in an active wastewater treatment plant, days matter. When asked how shotcrete benefited this project from the general contractor's point of view, WI responded with "The quality of your final product and the structural integrity of the whole assembly is exponentially better than the multilayered system that has been traditionally done and which frequently needs to be redone due to the cold joints and multiple opportunities for poor concrete and grout conditions during installation." Overall it was a very successful project for SSG, the GC, owner, and shotcrete.

Mason Guarino *started in the pool industry when he was 14, learning how to install reinforcing bars. Since then, he has worked on all phases of swimming pool construction. Guarino has been with South Shore Gunite Pools & Spas, Inc., full-time since graduating from the Wentworth Institute of Technology with his BS in construction management in 2009. Guarino currently serves as Treasurer on ASA's Executive Committee and is an ACI Certified Nozzleman.*

2019 HONORABLE MENTION

Project Name
Duck Island Screw Pump Rehabilitation

Location
Lowell, MA

Shotcrete Contractor
South Shore Gunite Pools & Spas, Inc.*

Architect/Engineer
Hazen and Sawyer

Materials Supplier
LafargeHolcim

Equipment Manufacturer
Gunite Supply & Equipment*

General Contractor
Waterline Industries

Project Owner
City of Lowell, MA

***Corporate Member of the American Shotcrete Association**