PORT OF PORTLAND TERMINAL 5 STRUCTURAL REHABILITATION AND CORROSION PROTECTION

BY STEVE GEIGER

Located 100 miles (161 km) upriver from the Pacific Ocean, Portland is the largest port in Oregon, moving more than $18 billion in goods annually. The Oregon legislature created the Port of Portland in 1891 to dredge a shipping channel from Portland to the sea. Since 1891, the port has grown, and today the port owns three airports, four marine terminals, and four industrial parks. Terminal 5 is located on the north edge of the port's Rivergate Industrial District. The 159 acre (643,459 m^2) terminal features one of the country's highest-volume grain export facilities and a state-of-the-art potash fertilizer mineral bulk-exporting facility.

According to the most recent study, the port generates 32,460 jobs; $1.86 billion in wages, salaries, and consumption impacts; and nearly $1.89 million in taxes. Therefore, it was vital to perform the needed structural repairs in a timely and long-term manner to ensure the continued contribution of the terminal to the state's economy.

PROJECT SCOPE

The port's Terminal 5 potash facility handles about 2 million tons (1,815,000 metric tons) of potassium-based fertilizer feed stock per year. The nearly 1/3 mile (0.54 km) long, 49.85 ft (15.19 m) (maximum point height) elevated conveyor system that transports the potash for bulk loading of export tanker vessels required major structural rehabilitation to ensure further operations. Also, the supporting pier structure along the Willamette River that houses a portion of the bulk conveyor handling system also required major structural rehabilitation.

It was critical to maintain bulk-loading operations during the restoration. As the photographs show, bulk-loading production was maintained during the extensive rehabilitation, thereby having

Project prior to repairs

Deteriorated concrete at Port of Portland

Deteriorated concrete on supporting pier

a minimal impact on operations and port-generated revenue and personnel jobs. Maintaining operations during the restoration required extensive shoring and support systems. The use of a specialized, prebagged structural repair mortar that was able to be applied through the form-and-pump method, combined with the 24-hour strength of 4000 psi (27.6 MPa), was critical to maintain operations.

The scope of the project included, but was not limited to, the removal of the deteriorated and sulfate-contaminated concrete, exposing the full circumference of the reinforcing steel for proper surface preparation and splicing, as required by the contract documents. The project included concrete spall repairs caused by both noncorrosion and corrosion-related deterioration of the following concrete structures with the estimated quantities of repair per item:

- Pier beams: 1432 ft^3 (40.5 m^3) of spall repair;
- Pier girders: 357 ft^3 (10.1 m^3) of spall repair;
- Pier fender blocks: 18 ft^3 (0.5 m^3) of spall repair;
- Abutment: 6 ft^3 (0.17 m^3) of spall repair;
- Conveyor structural support tower leg and lateral support conveyor struts: 957 ft^3 (27 m^3) of spall repair;
- Conveyor double-tee beam between support towers: 110 ft^3 (3.1 m^3) of spall repair; and
- Pier deck: 367 ft^3 (10.4 m^3) of deck surface repair.

Analysis of the existing concrete was also conducted to determine the level of sulfates and overall integrity of the host concrete. It was determined that the host concrete did have a high concentration of sulfates, so the approved, prepackaged, engineered product had to show sulfate resistance—among many other qualifying project properties—to ensure a long-term successful repair.

The original quantities of concrete repair were estimated at 3247 ft^3 (92 m^3). It became apparent once the deteriorated concrete removal process had been executed that the extent of repairs required would be more far-reaching than first calculated. It became apparent that years of aggressive attack by sulfates from the overspill of previous conveyor raw materials led to more extensive deterioration of the concrete than originally estimated. The scope of the project had more than doubled from the original estimates for structural concrete repair, as listed previously, to a completed job total of 7290 ft^3 (206 m^3) of structural concrete repairs.

The prepackaged proprietary material specified was a self-consolidating, shrinkage-compensated, low-permeability, structural, form-and-pour or pump, high-modulus, cementitious repair mortar containing a migrating corrosion inhibitor. The product was supplied in premeasured, prepackaged, three-ply polylined bags with the material label, instructions, and batch code listed for traceability. The product was mixed on site as required with a pretested, locally sourced aggregate to ensure that proper flow, consolidation, and strength were still maintained. Approximately 810,000 lb (367,410 kg) of this prepackaged, engineered structural repair mortar was successfully used to complete the extensive rehabilitation.

It is worth noting that concrete repair as compared to replacement (new) can show a decrease in reducing the carbon introduced to the environment by up to 70%. This reduction in carbon-related emissions truly makes concrete restoration (as compared to replacement) one of the most green, environmentally friendly construction means for true sustainability while not compromising the overall financial integrity of the owner's business.

Each daily application of the repair mortar was sampled on site prior to pumping and tested for compressive strength results. Following the startup procedures and during the ongoing application phase of the project, not one on-site mixed sample was reported to not have achieved the specified compressive strength requirement.

The scope of the project also included the following rehabilitation work:

- 745 ft (227 m) of epoxy injection;
- 650 ft (198 m) of route and seal;
- 1500 ft^3 (42.5 m^3) of concrete deck topping;
- 1691 new or repaired joints;
- 13,650 ft^2 (1268 m^2) of pile sealing;
- 18,785 ft^2 (1745 m^2) of waterproofing coating; and
- 18,785 ft^2 (1745 m^2) of silane sealing.

A proprietary galvanic steel reinforcing protection system and arc-zinc spray were also installed. This corrosion protection system was installed immediately following the repairs to further ensure the longevity of the vital conveyor system. The use of a multi-system approach, engineered repair, and galvanic corrosion protection is by far the most complete method to help ensure the arrest of the deteriorated concrete and corrosion, thereby ensuring the optimal life cycle of investment dollars.

REPAIR PROJECT

Over the years, it became visually apparent that concrete deterioration was active on the elevated concrete conveyor support system and supporting pier. The existing concrete was experiencing spalls and minor-to-severe stress cracks, with many of the stress cracks resulting in loss of structural integrity and reduced load-carrying capacity. The decrease in structural integrity, combined with the maximum elevated height of 49.85 ft (15.19 m) for the conveyor system, created the potential for falling concrete spalls. This became a safety concern due to the potential for injuries. Visual and sound method testing was conducted to estimate the extent of the repairs.

Extensive scaffolding was erected to provide safe access to perform the required concrete restoration on the elevated conveyor system and beam structure. Due to the severe deterioration and the resulting extent of concrete removal, an engineered shoring system was required to avoid any possible safety and operation issues.

Pneumatic chipping hammers were used to remove the deteriorated concrete. The perimeter edge was then saw cut to a minimum of 2 in. (50 mm) in depth to ensure proper coverage and application. High-pressure water blasting was used to remove all loose concrete and concrete dust from the previous operations to help ensure a clean bond profile.

A wood framing system was used around the perimeter of the patch zone as part of the forming.

Extensive scaffolding was required on project

Removing deteriorated concrete

The reason for constructing the forming system using a wood frame, as required by the engineer, was to ensure a minimum embedment depth of 2 in. (50 mm) for the reinforcing steel.

In addition, this type of forming helped facilitate the application of the form-and-pump, self-consolidating, structural prepackaged repair mortar. The use of the wood framing allowed for ease of pumping of the prebagged repair mortar from the bottom up in a nonclosed application, which lowers the propensity to generate voids.

The repair zone was predampened for 24 hours prior to application by filling the watertight formed area overnight with water. After 24 hours, the face board was removed and the water was drained. An appropriate time was given for the surface water to evaporate, leaving the substrate in the proper saturated, surface-dry condition for bonding. The forms were coated with a water-

Framing in place ready for repair material

Column after repair

Project nearing completion

Finished project

based form release agent and reconstructed. The forming board was typically a 1 in. (2.5 cm) thick exterior grade plywood.

The product was mixed and installed using a mixer and pump combination. The product was mixed by a specialized mixer that uses an inline spiral mixer to properly combine the powder and water at the correct ratios on demand. As stated previously, this equipment allowed for the product to be mixed on demand, lowering overall project waste. The properly mixed product was delivered directly to the rotor-stator style pump for delivery to the preset, predampened forming system. The pump was able to deliver the product up to the top of the 50 ft (15.2 m) tower beams and legs without an issue. The two photographs above show the before and after of a typical type of concrete repair done on this project.

After placement, the forms were left on for a minimum of 7 days to allow for proper curing and strength gain. If the forms were removed prior to a 7-day cure time, then the application of an approved membrane-forming curing compound was specified. Compressive strength testing conducted prior to the commencement of the project determined the necessary cure time to ensure structural soundness of the repair zone to avoid damaging the material during form removal. After the removal of the forms, the surfaces received an arc-spray zinc coating for protection. The top surface of the deck was coated with the preapproved waterproofing membrane, whereas the underside of the deck received the penetrating silane sealer.

PROJECT SUCCESS

In summary, using a systematic, well-thought-out, coordinated approach encompassing the technical expertise of many different disciplines led to the successful application of the restoration and corrosion protection systems. The multi-discipline approach, which was coordinated through planning meetings, informal discussions, and openly listening to everyone's suggestions, led to a project with all parties working in constructive tandem, which led to the use of the best means and methods currently available. As a result, this extensive rehabilitation project in which the oldest repairs are nearly 2-and-a-half years old still shows no signs of deterioration.

The overall success, as in most cases, came from the ability of our industry to supply a means and method to prolong the life of a structure while minimizing the impact and/or downtime on current operations, resulting in cost effectiveness to the owner as compared to new construction. This was vital in the final decision-making process to proceed with the rehabilitation of the structure.

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Port of Portland Terminal 5

OWNER
Port of Portland
Portland, OR

PROJECT ENGINEER
Moffatt & Nichol
Seattle, WA

REPAIR CONTRACTOR
Pioneer Waterproofing Co., Inc.
Portland, OR

MATERIAL SUPPLIERS
W. R. Meadows, Inc.
Hampshire, IL

Vector Corrosions Technologies
Winnipeg, MB, Canada