REHABILITATION OF WET WELL AREAS OF THE PUMP STATIONS

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The Monterey Regional Water Pollution Control Agency (MRWPCA) typically seeks joint solutions to the wastewater collection and treatment needs of its member communities. It serves the cities of the Monterey Peninsula, the city of Salinas, a few small towns, and unincorporated areas that include approximately 250,000 people. Each day, the Regional Treatment Plant (RTP) processes approximately 20 million gal. (75,708,000 L) of wastewater that is collected primarily from 10 pump stations (and several smaller lift stations). Most of the treated water is further treated by the recycled water facility and supplied to the surrounding 12,000 acres (48.6 km^2) of farmland. The remaining portion of the treated water from the RTP is discharged into Monterey Bay through its ocean outfall 2.5 miles offshore (4.0 km) (refer to Fig. 1). The original construction was very similar for all pump stations, which vary in age between 28 and 35 years. Figure 2 shows the partial schematic plan and elevation views of the area near the influent channel.

Due to the age of the pump stations exposed to an aggressive environment, four stations were selected for rehabilitation, which included removal/replacement of corroded sluice gates, permanent removal of the flapper gates from the wet well areas, and repair of the deteriorated concrete in and around the inlet channels. Because the concrete in the influent channel of the pump station is exposed to an aggressive environment that includes acid and hydrogen sulfide attack and erosion caused by cavitation, some deterioration of the concrete is expected. In addition, corrosion of the embedded reinforcing steel can accelerate, causing structural concerns. A long-term solution to protect these important structures requires a systematic approach to repair the damage and extend the life of the structure. This article describes only the work related to the concrete repair.

CONDITION SURVEY

After conducting and evaluating observations of the preliminary survey of the pump stations, two stations were selected for a detailed condition

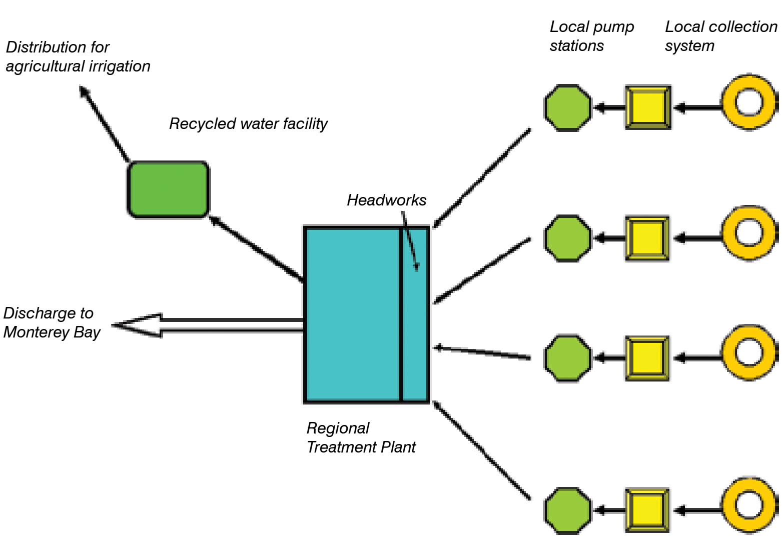

Fig. 1: Schematic of the partial MRWPCA system network

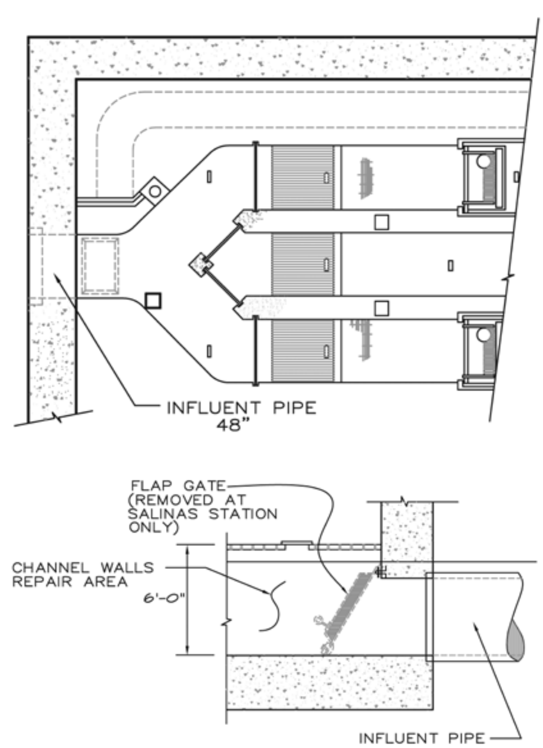

Fig. 2: Partial plan and section views of the inlet areas (Note: 1 in. = 25.4 mm)

survey. The survey included observing and locating the embedded reinforcing steel in the concrete, drilling and removing the concrete cores, and testing the cores for compressive strength and microscopic examination.

OBSERVATIONS

Figure 3 shows the overall view of the wet well area facing the north wall. At the time of the visit, the corroded sluice gate was removed from the influent channel. The top of the channel is covered with a grate. The north wall concrete above and near the gate area had eroded severely, exposing large aggregate. Figures 4 and 5 show a close-up view of the distressed concrete. At one of the stations, the same area showed severe concrete erosion with exposed, corroded reinforcing steel both in the wall and the slab. Assuming that there was a 2 in. (50 mm) concrete cover over the vertical reinforcing steel, total erosion of the concrete was at least 5 in. (127 mm) in the wall. The exposed reinforcing steel in the wall was not only corroded but also experienced significant section loss. Observations did not indicate significant cracks in the wall or the concrete slab.

EMBEDDED REINFORCING STEEL IN THE WALL

Reinforcing steel in the wall was located using an electronic detector. In areas of exposed steel, there was no need to use the electronic detector. Information obtained from locating the reinforcing steel was used to map out the core locations. Embedded steel was in good condition with an absence of corrosion stains. Average spacing in the wall was approximately 12 in. (305 mm) on-center in both directions. The vertical and horizontal bars were 3 and 4 in. (76 and 102 mm) from the surface, respectively.

REMOVAL OF CONCRETE CORES

To determine the compressive strength of the concrete, 4 in. (102 mm) diameter cores (approximately 8 to 10 in. [203 to 254 mm] deep) were drilled and removed from the wall. In addition, partial-depth cores were drilled and removed at the intersection of the reinforcing steel to observe their condition (refer to Fig. 6). The interior reinforcing steel was in good condition. No cores were removed from the vertical walls of the channel due to lack of safe access. All core holes were patched with a low-shrinkage, fast-setting mortar prior to leaving the site.

COMPRESSIVE STRENGTH OF THE CONCRETE

Three cores from each pump station were tested for compressive strength. The samples were tested

Fig. 3: Overall view of the wet well area

Fig. 4: Deteriorated area showing the exposed corroded steel above the wet well channel

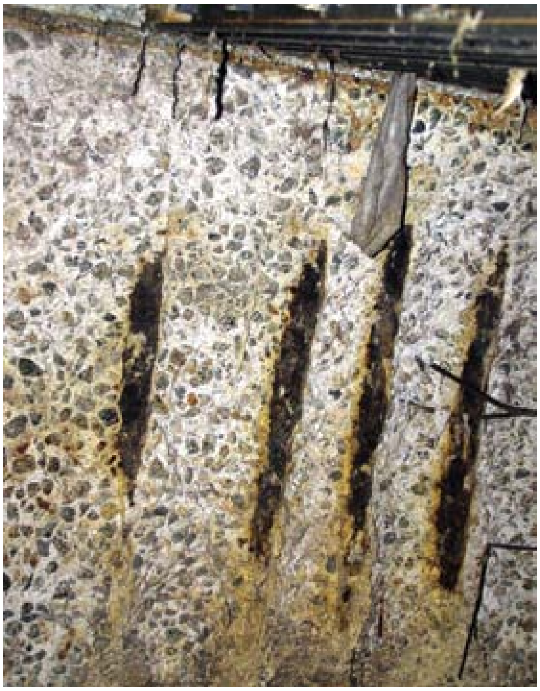

Fig. 5: Close-up view of concrete erosion and corroded reinforcing steel

Fig. 6: Partial-depth core showing interior reinforcing steel with minimal corrosion stains

Fig. 7: Concrete carbonation depth of 0.75 in. (19 mm)

Fig. 8: Thin section of the deteriorated portion showing cracking and porous nature of concrete as indicated by the blue dye-mixed impregnated epoxy

according to ASTM C42/C39 test procedures. The strength of cores varied between 5460 and 6610 psi (37.6 and 45.6 MPa) with an average compressive strength of 5907 psi (40.7 MPa).

CARBONATION DEPTH

Carbonation is a reaction of the concrete with the carbon dioxide. Carbonation lowers the pH of the concrete, resulting in less protection in preventing the corrosion of the reinforcing steel. Carbonation depth on the concrete cores was measured using a phenolphthalein solution. The bright pink color indicates areas with no carbonation; no color indicates areas with carbonation. The depth of carbonation was found to be variable between 0.25 and 1 in. (6 and 25 mm) on the exterior portion of the cores (refer to Fig. 7).

MICROSCOPIC EXAMINATION

The exterior surfaces of the cores showed light brown discoloration with severe alterations and decomposition and erosion. The broken ends (interior concrete) of the cores showed sound concrete. The paste was soft and severely altered in the deteriorated section (top 0.75 in. [19 mm]), but it was dense and hard in the sound concrete. The depth of carbonation had extended up to 2.25 in. (57 mm) from the surface. The cores from different pump stations showed similar severe deterioration of concrete due to chemical attack by the sulfuric acid generated by the hydrogen sulfide gas. The attack has resulted in softening of the concrete with increased porosity and microcracking (refer to Fig. 8). The chemical attack extended 0.75 in. (19 mm) deep from the exposed end, with a complete loss of calcium hydroxide component of the cement paste. The deteriorated portion of the concrete also showed severe microcracking. Figure 9(a) and (b) shows X-ray diffraction analysis graphs for the good and deteriorated portions of the concrete, respectively. Chemical reactions generated abundant deposits of secondary gypsum in the deteriorated portion.

RECOMMENDATIONS FOR CONCRETE REPAIRS

Concrete at the influent pipe entry area near the wall and the vertical walls of the influent channel were severely deteriorated at both the pump stations. The concrete was eroded away mainly by the sulfuric acid generated by the hydrogen sulfide gas. The chemical attack would continue to degrade the concrete further until a remedial action was taken.

A detailed repair specification was prepared that included routine repair strategy of removing contaminated concrete, cleaning or removing/replacing corroded reinforcing steel and protecting it with anti-corrosion coating, and applying the repair mortar to the concrete substrate and protecting it with a coating material. It was anticipated that a minimum of 2.5 in. (63.5 mm) of concrete would need to be removed from the vertical walls of the channel. Because it was absolutely essential to minimize downtime, the repair material, including the protective coating, needed to have high early strength, be compatible with the moist substrate, have sufficient application and finishing times, and have a minimum curing time. The selected repair materials, one for hand-applied and one for the "form-and-pour" application, consisted of two-component, polymer-modified cementitious, non-sag mortars. The protective coating consisted of trowel-applied or spray-applied 100% solids—two-component polyurethane material resistant to hydrogen sulfide and acid attack. The minimum thickness requirement for the coating was 0.25 in. (6 mm).

Quality control procedures included on-site supervision, a high-voltage spark test (NACE RPO 188-99 or ASTM D5162), and adhesion testing (ASTM D4541) for the protective coating material. Voltage for the spark test was to be adjusted to detect the holiday, and the repair procedure was outlined to repair the areas with holidays. Adhesion tests required the use of a 0.75 in. (19 mm) diameter (minimum) dolly and a minimum adhesion strength of 200 psi (1.4 MPa).

REPAIR WORK

Four pump stations were chosen for the repair work. In addition to the concrete repair work at the pump stations, work also included the removal/demolition, disposal, and replacement of corroded steel sluice gates and the permanent removal of fiber-reinforced polymer (FRP) flapper gates (which appeared to be concentrating H2S gases at the wall-influent channel interface) in the wet well areas. Construction sequencing, short-duration shutdowns and other constraints for each pump station were outlined in the specification. Because the inlet channels had to essentially remain in service all the time, it was necessary either to furnish a temporary "pump-around" bypass system or to install inflatable, flow-through plugs in the pump station influent pipes. MRWPCA opted for the latter, thereby eliminating the need to design and implement a "pump-around" bypass system to intercept incoming wastewater at the influent manhole (just upstream of a given inlet channel) and pump-around to the wet well. Such "pump-around" systems are costly, require considerable redundancy and 24-hour attendance, and can be too noisy for use in suburban areas. The use of flow-through plugs, however, had its own specific challenges.

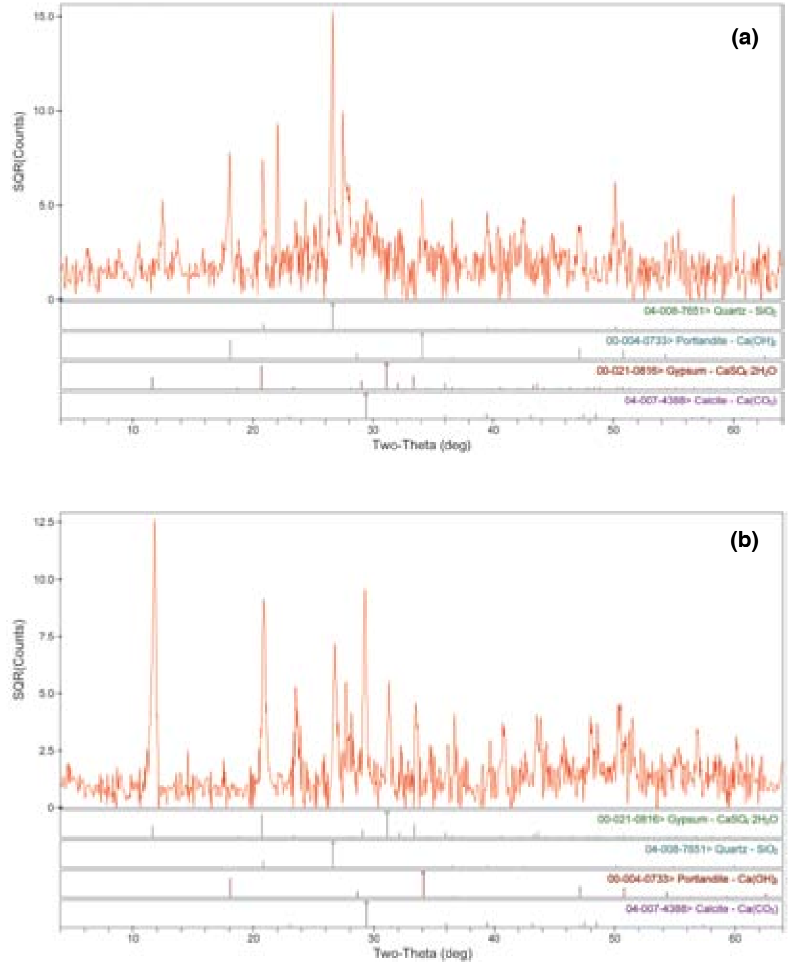

Fig. 9: (a) X-ray diffraction pattern of good portions of the concrete-absence of gypsum deposits; and (b) X-ray diffraction pattern of deteriorated portions of the concrete-abundance of gypsum deposits

A planned daily sequence of plug installation and removal was required to provide access to the repair areas. The plugs needed to be installed during low-flow periods (typically by 2:30 a.m.) and removed by 7 a.m. (as the flow-through diameter was significantly smaller than the influent pipe and could not handle peak morning or evening flows). In addition to shortening work shifts to 4.5 early morning hours, the plugs were extremely unwieldy and their daily handling, installation, and removal introduced several additional safety considerations. In addition, precautions were taken to prohibit construction debris and other objects from falling into the flowing wastewater to avoid damaging downstream equipment such as grinders and pumps. Also, the work area was designated as a "confined space," and the entry permit procedures had to be followed.

A CHALLENGING BUT SUCCESSFUL REHABILITATION

This project posed many challenges to the contractor and the owner: the work, which

Fig. 10: Corroded reinforcing steel

included various simultaneously coordinated areas, was done under difficult access conditions and shortened work hours. Performing this type of work in sewage pump station influent channels, manholes, and limited portions of piping (which are intended to always remain in service) is inherently difficult on several levels. Some of the specific challenges and difficulties of this project were as follows:

- It was difficult to plug the influent piping. The plugs were unwieldy and difficult to install and remove, especially due to the presence of hydrogen sulfide gas and limited access. The collection system can hold approximately 5 hours of flow before risking a sewage spill upstream.
- The work hours were shortened. Work was typically carried out early in the morning (between 2:30 a.m. and 7 a.m.) when low-flow conditions exist.

Fig. 11: Replaced reinforcing steel

Fig. 12: Blisters in the protective coating

Fig. 13: Completed repaired area with the sluice gate in place

- Extra manpower was required to carefully monitor the pump station operations.
- Difficulties were encountered when applying the protective coating. Once deteriorated concrete was removed, corroded reinforcing steel in the wall needed to be replaced (refer to Fig. 10 and 11). It was difficult to properly apply the protective coating. Heated air blowers had to be used to dry the moist substrate. Many times, after the initial application of the protective coating, several blisters appeared on the surface (refer to Fig. 12), and the contractor needed to remove and reapply the coating. Spark testing showed several pin holes that required localized repair of the coating material. Once the protective coating passed the spark testing, however, adhesion testing showed more than 200 psi (1.4 MPa) bond strength. Although the rehabilitation took longer than estimated, the quality control and assurance procedures that followed resulted in a satisfactory repair. Figure 13 shows the repaired area with the sluice gate installed at one of the stations.

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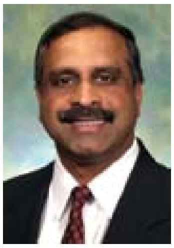

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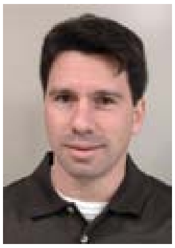

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