Repairs to the Primary Tanks at a Wastewater Treatment Plant

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As part of the City of Grand Rapids, Michigan, Capital Improvement Plan, the city required an assessment of the condition of four of their 16 wastewater treatment plant's oldest primary settling tanks (circa 1954). The condition assessment was to determine the cost for rehabilitative repairs and useful service life.

The primary settling tanks are part of a multi-stage clarification system of wastewater from multiple municipalities in the Grand Rapids area. The B-Section primary clarifier tanks are the third of an 11-step process for clarification of wastewater. The B-Section consists of four rectangular tanks (Tanks 5 to 8) separated by concrete divider walls. Each divider wall has a catwalk of similar width along its top. The main wall between Tanks 6 and 7 has a wider catwalk that serves as the main walkway through the middle of the B-Section tanks. Access to the catwalks between the remaining tanks is blocked by chain link; however, plant maintenance personnel use these catwalks for tank cleaning and equipment maintenance.

The B-Section Primary Settling Tanks include Tanks 5 to 8 with influent and effluent channels at opposite ends of the structure. The overall structure size is 115 x 205 ft (35 x 62.5 m) and constructed with cast-in-place concrete. Each tank comprises three 16 x 90 ft (4.9 x 27.4 m) compartments separated by concrete divider walls. Tank compartments contain mechanical process equipment for cleaning raw sewage in each compartment, and sidewall depth is 12 ft (3.65 m).

Causes of Deterioration

Freezing-and-thawing deterioration of the concrete, from the lack of air entrainment, was the main type of deterioration. Chloride-induced corrosion of the reinforcement was also a contributing factor to the deterioration of the supported slabs. The corrosion was accelerated from cracking in the slab, which allowed the chlorides to intrude directly to the reinforcement. Tank wall deterioration at the surface water line was caused from a combination of freezing-and-thawing and chemical attack. Handrails, grates, and other miscellaneous metal frames deteriorated from corrosion.

Visual Condition Assessment—Slabs

The concrete slab spanning over the influent channel and the auger sludge pit at the south end of B-Section tanks was severely deteriorated on both the top and undersides of the slab. The slab supported motors and controls that operate the mechanical equipment within each tank.

The top surface of the slab had widespread freezing-and-thawing damage and the concrete was severely deteriorated. Cement paste eroded such that the coarse aggregate was significantly exposed, and heavy scaling existed in some areas. Concrete degradation was noticeably evident in numerous

Overall existing project before reconstruction

Original catwalk

Original slab

locations throughout the surface; hence, several bituminous patches scattered over the slab surface. Based on visual observations from coring, layers of horizontal cracks appeared within the top 2 to 3 in. (5.1 to 7.6 cm) of the concrete core. The top layer of slab reinforcing was visibly corroded. This appeared to substantiate the horizontal cracking as observed through the core.

Embedded conduit was exposed in one slab section due to lack of concrete cover. The corroded conduit deteriorated the slab along the entire length of its embedment. Steel gratings allowing overhead access into the influent channel were severely rusted and questionable to their bearing capacity in some locations. An area of heavy scaling and surface deterioration existed just above the grate opening in the influent channel. Debris deposited and moss grew in the gap between the grate and metal support frame.

From the underside of the slab, significant cracking with carbonate stains covering most of the area was observed. Concrete spalls on the slab underside were noticed and the bottom layer of reinforcing was exposed and corroded. Concrete spalls are also prevalent along the bottom edge of the slab support beams that span between divider walls and over the influent weir openings.

The slab surface over the effluent channel along the north side of B-Section tanks exhibited a severely weathered appearance. Some areas along the slab edge had deteriorated to the point of crumbling away from the remaining sound concrete substrate, and heavy scaling appeared along surface areas toward the middle of the slab. It also appeared that deterioration forced both concrete and asphaltic patching material to be placed in numerous locations on the slab surface. Visual observations noted delaminated concrete along the edge of the slab and water leaching through the layers of delamination.

Visual observations in the B-Section tanks were conducted in a staged operation as other tanks had to remain in operation to process required plant flows. Generally, the divider wall and base slabs were in good physical condition having no visible signs of spalling or deterioration. This is mainly attributed to the fact that these walls are constantly under water and do not receive oxygen that is required to begin the corrosion process. Expansion joint sealants were well beyond their useful service life as water was observed to be leaking from full tanks still in operation on the other side of the divider wall.

Visual Condition Assessment—Catwalks

Considerable deterioration also occurred under the portion of the entire catwalk that overhangs the divider wall. Water from the surface leached through existing cracks along the overhang portions. Carbonate stains on the underside of the catwalk overhangs and concrete spalling from the underside of the catwalks had fallen into the process water. Water accumulating on the catwalk surfaces also leached through existing cracks. Existing unmaintained cracks allowed chloride ions to penetrate through and corrode reinforcing bars, which caused spalling. The undersides of the overhangs were continuously moist from the humidity emanating from the process water, as the bottoms of the catwalks are closely located above the water surface line. Coupled with chloride ions brought through existing cracks, the corrosion process was accelerated.

The walking surface of the catwalk contained isolated areas of deteriorated and crumbling concrete. Asphalt material was used to patch areas where significant deterioration left an uneven walking surface and potential trip hazards to the plant staff. Numerous spalls occurred along the top edge of the overhang, especially at the bases of handrail posts where they were embedded into the concrete. The bases of the posts were exposed at spalled locations and the metal severely corroded. The main catwalk was in poor condition and its durability very limited. Much of the cement paste around the aggregate eroded away to the point where aggregate was loose and concrete crumbled in several locations. Edges of the supported catwalk spalled away from the original substrate at various locations along the catwalk overhang.

The handrail extends around the entire perimeter of the tanks and along both edges of the main catwalk. Widespread corrosion was evident on horizontal rails as chlorides from deicing chemicals had corroded the bases of the handrail posts, which also corroded the embedded portion of the post and resulted in spalling the concrete edge of the catwalk and channel slab.

The remaining catwalks between the baffle walls were weathered and the cement paste eroded to the point of exposing the coarse aggregate. There were also locations where the cement paste eroded so severely that the aggregate loosened and crumbled away from sound substrate.

A general observation throughout the network of tunnels was performed to identify areas where significant deterioration occurred. The tunnels generally appeared in good physical condition. Shrinkage cracks occur every so often in this area, but they appear as being typical from when the tunnels were constructed. Leaking was observed through some construction joints; however, none of it was noted to be significant.

Examinations and Test Results

Laboratory examinations and tests were performed on concrete core samples removed during the field investigation. Results of laboratory testing and examinations are summarized as follows. All laboratory materials testing was performed in accordance with ASTM reference standards.

Visual examinations were performed on all concrete core samples removed during the field investigation. Examinations included documenting sample size, condition, and general characteristics.

During construction (forming and steel placement for new slab)

During construction

After examination, cores were selected for more extensive laboratory work.

Petrographic Examinations

Petrographic examinations were performed on cores removed from the influent and effluent channel slab and to evaluate its general concrete condition, durability characteristics, and quality. Results of petrographic examinations verified that the concrete was not air-entrained and

New catwalk

New slab

cracking induced by corrosion or restraint due to thermal contraction was caused by freezing-and-thawing deterioration.

Acid-Soluble Chloride Ion Tests

Tests were performed on concrete powder samples drilled at selected depths from cores extracted from the influent and effluent channel to evaluate the amount of acid-soluble chloride in the concrete. Test results for cores revealed that acid-soluble chloride levels ranged from 0.099 to 0.133% chloride ion by weight of concrete. The commonly accepted corrosion threshold is 0.030% acid-soluble chloride ion by weight of concrete, and this value was exceeded in several samples. Measured chloride concentration for the majority of these concrete samples was less than the corrosion threshold; however, measured chloride concentrations in the samples removed from the supported slab exceeded the corrosion threshold, suggesting ingress of chlorides from deicing salts in the deck.

Repairs

Design

Due to the condition of the B-Section tanks, immediate and recommended future repairs to the section were developed to prolong the life of the tanks. Included were recommended repairs to the Primary Control Building, where conduit had completely corroded at the concrete surface line and exposed the electrical wires. Replacement of the conduit with polyvinyl chloride (PVC) type was completed immediately.

Additionally, full replacement of the influent and effluent channel slabs and main catwalk with a new cast-in-place reinforced concrete slab with long-term durability characteristics was designed. This included full replacement of the supporting beams spanning between divider walls after demolition of the influent slab revealed significant deterioration. Epoxy-coated reinforcing bars, fibers to control microcracking, slag, and a 100% solids sealer was used for further durability to increase the overall service life. PVC conduit was embedded in the channel slabs to feed other areas of the plant as well as motors and equipment that controlled the primary settling tanks.

Repairs to the existing concrete deterioration on the access catwalks over the divider walls were performed. This included edge spalls, delaminating surfaces, existing patches, repairing leaking cracks and joints in the walkway, as well as a cementitious coating to reestablish a sound substrate and smooth walking surface.

Finally, replacement of the entire handrail and other steel operation platforms and ladders at the B-Section tanks was carried out. These were removed and replaced with stainless steel to match other areas of the plant.

The repair system for this project was based on several weighing factors including repair methods, cost, available budget, construction schedule to meet plant and City wastewater flow requirements, and individual material characteristics as they relate to wastewater environmental conditions. These factors where placed into a repair matrix that weighted each item based on its importance.

Repair Process Execution

After demolition, the supported slabs were formed and poured with conventional concrete with 15% substitution of slag and fibers to control shrinkage cracking. Other miscellaneous concrete patching was performed along with waterproofing. New metal grates, frames, handrails, and other equipment were installed.

Special features used in the rehabilitation of the primary settling tanks incorporated durability characteristics in the materials selected to meet the project objective of continuing long-term serviceability of the tanks. Concrete durability included 5000 psi (34 MPa) concrete, slag cement, low water-to-cement ratio, and air-entrainment and corrosion inhibitor admixtures. Reinforcing bars in new or existing slabs were epoxy coated. Polypropolene fibers were used in the concrete to minimize shrinkage cracking.

Embedded ferrous metal used in grating framework, access ports, and handrail posts were stainless steel. Electrical conduits were embedded in the concrete to minimize exposed surface mounted conditions. Conduits embedded were PVC to eliminate corrosion typically experienced from metallic conduit.

Wastewater Treatment Plant

Owner
City of Grand Rapids
Grand Rapids, Michigan

Project Engineer
Walker Restoration Consultants
Kalamazoo, Michigan

Repair Contractor
Rahm Industrial Services
Caledonia, Michigan

Material Suppliers
Sika Corporation
Lyndhurst, New Jersey

EMACO
Livonia, Michigan

Overall completed project