

Rehabilitation Alternatives for Structures Used on the Flocculation, Sedimentation and Filtration Processes at the Ponce De Leon Water Treatment Plant in Mayagüez, Puerto Rico

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Abstract

The Ponce de Leon Water Treatment Plant located in Mayagüez serves 3,777 clients with a population of 10,085 habitants. It could produce 6 million gallons per day. A visual structural evaluation of the concrete structures and metallic elements on the flocculation, sedimentation, and filtration units was done to assess actual conditions and present rehabilitation alternatives. This research presents the findings and the analysis used to weigh rehabilitation alternatives. Damages found on concrete structures were cracking and spalling. Meanwhile, on metallic elements, general corrosion, and material thickness loss were found. The investigation concluded that the best economical alternative to repair concrete cracks is routing and sealing. For spalled concrete, the recommended alternative is the partial concrete section repair. Finally, the project concluded that the best alternative to treat corrosion on metallic elements at the WTP is the use of protective coatings.

Introduction

After Hurricane Maria in September 2017, the Ponce de Leon WTP was severely damaged, and The Puerto Rico Aqueduct and Sewer Authority (PRASA) requested funds from the Federal Emergency Management Agency (FEMA) to make a complete rehabilitation of the WTP. The intent of this project was to present a structural evaluation and rehabilitation analysis for the concrete structures and the metallic elements on the flocculation, sedimentation, and filtration areas in the Ponce de Leon WTP.



Figure 1

Ponce de Leon WTP Site and its Components

Background

The Ponce de Leon WTP was originally constructed in 1927 and was designed as a conventional water treatment plant for 3 million gallons per day (MGD). In 2005, the WTP was expanded with addition of a metal package plant (Actiflo®) of 3 MGD to produce a maximum of 6 MGD with a Solid Treatment System (STS). The WTP can only produce a maximum flow of 4 MGD due to the actual process configuration. Since that date, no major improvements or expansions have been made to the plant. Only maintenance repairs required by the normal wear and tear of equipment and facilities had been done. Hurricane Maria and other natural events exacerbated the already existing corrosion problems on ferrous metallic plant components and underlying corrosion problems of reinforcement inside concrete. Alternatives to attend these problems are presented on this research.

Problem

The research helped to address the following structural problems found at the Ponce de Leon WTP:

- Concrete floor cracks and spalling that were present on the flocculation, sedimentation and filtration concrete structures' surfaces.
- General and located corrosion on the metallic elements such as: valves, appurtenances, pipes, structural steel handrails, bolts and pipeline supports due to coating failure and contaminant accumulation.

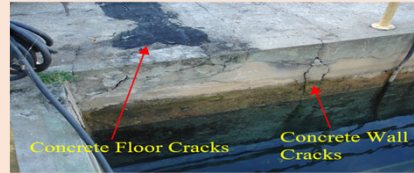


Figure 2
Filter Basin Concrete Wall Cracks

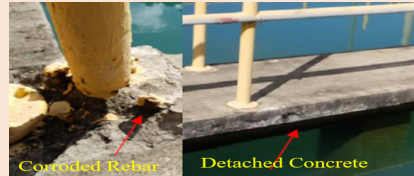


Figure 3
Corroded Rebar and Concrete Detachment at Walkway

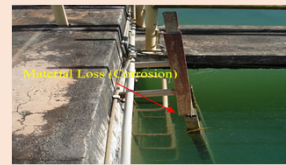


Figure 4
Material Loss Due to Corrosion

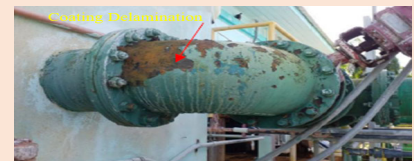


Figure 5

Corrosion and Coating Failure on Pipeline

Methodology

The following methodology was used to evaluate the structural elements and facilities on the flocculation, sedimentation, and filtration processes of the old plant:

- Two site reconnaissance visits to visually appraise the structural damage on the concrete structures and metallic components of the above-mentioned areas of the facility were done on January 11, 2024, and February 06, 2024. Observations were documented in writing and with photographs using a digital camera. No destructive testing or sampling were done; only visual inspection.
- Meeting with PRASA plant operators to gather personal impressions on operational constraints and deficiencies.
- Collection and review of available technical information about the facility such as record as-built drawings, specifications, and other relevant data.
- Concrete surface cracks, concrete spalling, reinforcement corrosion and detachment were evaluated on concrete structures and elements.
- Corrosion, pitting, coating failure and delamination were assessed on structural steel, piping systems, and ancillary assemblies.
- The findings on each category for the flocculation, sedimentation and filtration processes were collected and analyzed to propose different rehabilitation alternatives.
- For each rehabilitation or treatment alternative, a conceptual cost estimate was developed, and an investigation performed to better assess their viability as a potential solution.

The best rehabilitation alternative for each category was selected using a selection matrix with a weighted scoring system.

Results and Discussion

Two methods were evaluated to repair cracks on this research. The first one was the routing and sealing method arbitrarily named Alternative CR-2. As per Table 1, routing and sealing was favored over the other method, the concrete injection grouting with polyurethane resin (Alternative CR-1) in the criterion of cost. The difference on the estimates was not much (\$5,333) and both can be used on the Ponce de Leon WTP. From the constructability and time of implementation perspective both alternatives have the same score. Disruption to plant operations is the same for both alternatives. Final scores were 3.4 for Alternative CR-1 and 3.5 for Alternative CR-2. As told before, both alternatives or a combination of them could be considered to the concrete cracks repairs at the Ponce de Leon WTP.

For concrete spall repair, the two methods considered were: partial depth repair and full depth repair. As it can be seen on Table 2, partial depth Alternative CSR-1 was favored over concrete spall using full depth repair in the criteria of cost and time of implementation. The difference in cost is due to the costs incurred on the demolishing and disposal of concrete debris and the restitution of the complete concrete section. From the constructability and time of implementation perspective Alternative CSR-1 has a better score than Alternative CSR-2. Disruption to plant operations is the same for both alternatives. Final scores were 3.9 for Alternative CSR-1 and 3.3 for Alternative CSR-2. Partial depth repair is considered the most adequate to attend concrete spalling deficiencies found at the Ponce de Leon WTP.

Table 3 presents the evaluation matrix for the three alternatives considered to treat corrosion on metallic elements at Ponce de Leon WTP. The use of epoxy and polyurethane high-performance coatings (Alternative CT-1) had the highest score of 6.9. This alternative is the best in terms of constructability, time of implementation, cost, and aesthetics. It received the highest score on all of those criteria. Compared to the other two alternatives, Alternative CT-1 had the least economic impact. Alternative CT-3 follows Alternative CT-1 with a weighted score of 5.1. Alternative CT-2 (cathodic protection) ranked the lowest with a score of 4.2, being the least favorable mainly due to its highly cost of implementation.

Table 1
Concrete Cracks Repair Alternatives Comparison

Criterion	Weight	Desirability Score		Weighted Score	
		Alternative CR-1 Concrete Injection Grouting	Alternative CR-2 Routing and Sealing	Alternative CR-1 Concrete Injection Grouting	Alternative CR-2 Routing and Sealing
Durability & Resilience	0.3	4	3	1.2	0.9
Cost	0.2	3	5	0.6	1
Constructability and Less Time For Implementation	0.2	4	4	0.8	0.8
Aesthetics	0.1	2	2	0.2	0.2
No Disruption To Normal Operation	0.2	3	3	0.6	0.6
Total	1			3.4	3.5

Table 2
Concrete Spall Repair Alternatives Comparison

Criterion	Weight	Desirability Score		Weighted Score	
		Alternative CSR-1 Partial Depth Repair (PDR)	Alternative CSR-2 Full Depth Repair (FDR)	Alternative CSR-1 Partial Depth Repair (PDR)	Alternative CSR-2 Full Depth Repair (FDR)
Durability & Resilience	0.3	5	5	1.5	1.5
Cost	0.2	4	2	0.8	0.4
Constructability and Less Time For Implementation	0.2	4	2	0.8	0.4
Aesthetics	0.1	4	4	0.4	0.4
No Disruption To Normal Operation	0.2	2	2	0.4	0.4
Total	1			3.9	3.1

Table 3
Corrosion Treatment Alternatives Comparison

Criterion	Weight	Desirability Score			Weighted Score		
		Alternative CT-1 Protective Coatings	Alternative CT-2 Cathodic Protection	Alternative CT-3 Material Change	Alternative CT-1 Protective Coatings	Alternative CT-2 Cathodic Protection	Alternative CT-3 Material Change
Durability & Resilience	0.3	4	4	5	1.2	1.2	1.5
Cost	0.2	5	1	2	1.5	0.3	0.6
Constructability and Less Time For Implementation	0.2	5	2	3	1.5	0.6	0.9
Aesthetics	0.1	5	5	4	1.5	1.5	1.2
No Disruption To Normal Operation	0.2	4	2	3	1.2	0.6	0.9
Total	1				6.9	4.2	5.1

Conclusions

- Based on results, the recommended alternative for cracks repair is the routing and sealing method (Figure 6) with polyurethane sealant and for concrete spalling is the partial depth repair (Figure 7).
- The structural evaluation concluded that cracks and spalling on concrete structures at the Ponce de Leon WTP could be repaired using both alternatives because visually they do not appear to be severe.
- Related to corrosion treatment on metallic elements, the analysis concluded that the best and most cost-efficient alternative was the use of epoxy and polyurethane high-performance coatings. Protective coatings can extend the useful life of metallic structures and mechanical components because they chemically adhere to the metallic substrate and create a barrier against corrosion. For this reason, a good surface preparation is of utmost importance before applying the coatings.

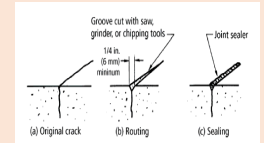


Figure 6
Crack Repair Using the Routing and Sealing Method



Figure 7
Partial Depth Repair



Figure 8
Valves With Protective Coating Applied

Future Work

The following future work could benefit PRASA to save in O&M costs related to concrete and metallic structures:

- Make additional studies to verify extent of concrete delamination and corrosion spread inside concrete (sound testing or ground penetrating radar).
- Core sampling to assess strength and permeability of concrete structures.
- Make a full corrosion assessment on all metallic structures.
- Create a monthly visual inspection checklist for plant operators in where they can grade and document the condition of structures.
- Establish a coating program to be implemented during the year to address corrosion on metallic structures and mechanical components.

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