REPAIR OR REPLACE: THE PRICE OF AGING WATER/ WASTEWATER INFRASTRUCTURE

BY JASON SPINNATO

Repair or replace? That is a question that has many water/wastewater facility owners and operators seeking an answer. Harsh environments and aging infrastructure are taxing these systems to their limits, forcing owners to make the difficult decision between rehabilitating an aging structure and replacing it with a new structure.

According to the 2013 American Society of Civil Engineers (ASCE) Infrastructure Report Card,[1] which depicts the condition and performance of the nation's infrastructure by assigning letter grades, the U.S. infrastructure currently has a grade point average of a D+. The report goes on to state that the current grade for our national water infrastructure rates no higher than a D. There are nearly 170,000 public drinking water systems and approximately 14,780 wastewater treatment systems serving the majority of the population in the United States. Many of these systems have components, with useful lives of 15 to 95 years, that date back to the middle of the 20th century. To make matters worse, federal appropriations for infrastructure have declined since 2008, putting more financial burden on the state and local governments.[1]

With increased failures of already inadequate systems and the growing costs of providing clean water, owners and operators of these water systems face difficult decisions on whether to repair their aging structures or completely replace them. To be able to properly inform an owner regarding the factors in rehabilitating or replacing a structure, it is important to understand some of the major causes of the deterioration of these structures.

Fig. 1: Severe concrete matrix loss and corrosion of underlying reinforcement due to carbonation

ASSESSMENT OF EXISTING STRUCTURE

The concrete structures in water/wastewater facilities are often exposed to harsh conditions that can lead to rapid structural deterioration if not properly maintained and protected. Prior to determining whether rehabilitation is acceptable or replacement is needed for a particular project, it is important to investigate the conditions of the existing structure and perform a complete evaluation using visual inspection methods coupled with materials testing.

In water/wastewater facilities, one of the major causes of deterioration is carbonation due to high relative humidity and reactions to acidic process fluids. The alkalines in the concrete matrix react with carbon dioxide in the air to lower the pH of the concrete and allow deterioration to occur. It is common for the deterioration to manifest itself in spalling or widespread breakdown of the concrete matrix. If the carbonation is severe, it may lead to corrosion of the reinforcing steel (Fig. 1). Because carbonation cannot be visually observed, it is important to perform testing of the concrete by taking core samples at various locations to determine the full extent of carbonation. Typically, carbonation occurs in the slower-moving open-air structures such as primary clarifiers and aeration basins found in wastewater plants or the flocculation/sedimentation basins found in water treatment plants.

Wastewater treatment facilities often experience deterioration due to exposure to high concentrations of chemicals, such as hydrogen sulfide gas (H_2S) and chlorine. H_2S is a colorless gas with the characteristic odor of rotten eggs and is generated in the turbulent waters of sewage systems. The bacteria in the sewage oxidizes the H_2S and produces sulfuric acid (H_2SO_4). The acid then dissolves the cement paste, creating a layer of soft, deteriorated concrete, which can then be washed away to expose the next layer of concrete, and eventually exposing the underlying reinforcing steel. This chemical process creates a highly corrosive environment for unprotected concrete and exposed embedded steel elements. Severe deterioration due to sulfuric acid typically occurs in sewer structures that are closed-top, such as vaults and pump stations, where the gas is able to remain in contact with the structure for an extended period of time. The highest concentrations of H_2S gas are typically found in the junction structures in the conveyance system and at the front end of the plant at the bar screen and grit chamber facilities.

Deterioration due to hydrochloric acid in water/wastewater plants typically occurs in the chlorine contact basins. These basins are located at the end of the treatment process where gaseous chlorine is added to the treated water prior to discharge. Once the applied chlorine dissolves in the water, it forms hydrochloric acid and begins to reduce the alkalinity of the concrete. This leads to deterioration of the concrete matrix, the loss of concrete cover, and corrosion of the reinforcing steel (Fig. 2).

EVALUATION OF OPTIONS

Once a proper evaluation of the existing structure has been completed, the process of determining whether rehabilitation is a viable option, or replacement of the structure is necessary, can begin. There are several factors that impact the decision and each project must be evaluated on a case-by-case basis. Some factors to be considered include, but are not limited to:

- Condition of the existing structure;
- Capital costs of a rehabilitated versus new structure;
- Availability of space for new structures;
- Impact to ongoing plant operations;
- The age of process equipment; and
- The required operational life of a rehabilitated versus new structure.

Fig. 2: Severe concrete and reinforcing steel deterioration due to hydrochloric acid exposure

The condition of the existing structure is a critical element to determine if it can be rehabilitated or requires replacement. In locations where severe deterioration has been observed to the point that the integrity of the structure has been compromised, the owner may be left with no choice but replacement. In cases where the structure has not been compromised, a careful analysis of the other aforementioned factors must be performed to determine the best course of action for the project.

With the recent decrease in federal funding for water infrastructure projects, plant owners must make difficult decisions regarding the distribution of their limited capital funds. Sometimes, a less expensive rehabilitation option for an aging structure is mandated due to the lack of adequate funding for replacement.

In addition to funding considerations, the day-to-day activities of the plant must be taken into consideration. With the current state of our water infrastructure, many facilities are being forced to operate well beyond their design life due to the fact that they are unable to be taken offline for any length of time. In this case, repairs are often delayed to be scheduled in sequence with the plant's routine maintenance shutdowns.

If space and funds are available to construct a new structure, it may be advantageous to maintain the operation of the existing elements until the new structure is completed and brought online, thus minimizing the disruptions to plant operations.

In some instances, even if the structure is able to be repaired, it may make more sense to replace it due to the age of the process equipment. With many facilities operating beyond their design life, the existing process equipment may have been rendered obsolete due to technological advances in water treatment or due to more stringent regulatory guidelines. In these situations, the owner may determine that a more efficient process system can provide long-term cost and energy savings, even at a greater initial capital cost.

Finally, the age of the existing structure must be taken into consideration. After an aging structure has repeatedly been repaired, diminishing returns are seen in the extended operational life for subsequent repairs. While a structure may be able to be repaired to achieve a 10- to 15-year extension on its useful life, it may be more desirable to build a new structure with an operational life of 50 to100 years, if the cost increase is not significant and the required facility service life requires such.

The engineer's responsibility in this process is to assist the owner in making an informed decision regarding the direction of the project. The input from all major stakeholders (maintenance, operations, and engineering staff) is critical to determine how their individual needs compare. Developing a scoring matrix can be a helpful tool in assessing the needs of the group and determining a recommended course of action for the project. For example, in a recently completed project in north Texas, it was determined that protective coatings for a pump station wet well should be installed during a planned screening equipment replacement project.

During the initial evaluation for this project, it was determined that concrete rehabilitation was required to accommodate the installation of the new equipment. Due to the required repairs, the team investigated the use of protective coatings to extend the service life provided by the repairs. To properly evaluate this option, a scoring matrix was developed to weigh the advantages and disadvantages of installing protective coatings during the current project, rather than deferring to a future project. It was determined that while the coating installation carried a substantial capital cost, it resulted in a reduced life-cycle cost. Plants incur large daily costs during shutdowns, and thus attempt to minimize the number of shutdowns as much as possible. By installing the coatings during the current rehabilitation, the estimated service life of the structure was doubled, allowing the staff to operate the facility for longer periods between major maintenance events.


Fig. 3: Installation of spray-applied repair mortar at vertical repair areas

REHABILITATION

If it is determined that a structure can be rehabilitated, the extent and type of repairs will be dictated by the results of the original evaluation. Many repairs for areas experiencing spalling, matrix loss, or chemical attack can be accomplished using repair mortars. A hand-applied mortar is best suited for small areas, while a spray-applied mortar may be appropriate for large areas (Fig. 3). Form-and-place or pump techniques using relatively fluid repair mortars should be considered for deep repairs or those with heavy concentrations of reinforcing steel.

In addition to deterioration caused by chemical attack, the concrete structures at water/wastewater facilities often experience cracking due to elastic shortening of the concrete (that is, shrinkage) and stress caused by soil and temperature movements or an excessive amount of cyclical loading/unloading. It is critical to quickly identify and repair cracking in these structures in a timely manner to prevent leakage into and out of the basins, and reduce the potential for groundwater contamination or further deterioration. Structural, inactive cracks typically are repaired by injecting an epoxy-based resin into the crack to restore the concrete's structural integrity. Flexible polyurethane grouts are often used to seal leaking and actively moving cracks.

Water/wastewater facilities often consist of large concrete structures that require regular expansion joints to allow movement and relieve the internal stresses in the concrete. Due to the corrosive nature of the process fluids, it is not uncommon for the expansion joint materials to experience severe deterioration over time, posing a greater potential for leakage and contamination. The replacement of joint systems can be a costly item in any major rehabilitation project and must be considered during cost evaluations.

PROTECTION

Regardless of whether an existing structure is rehabilitated or completely replaced, concrete surfaces should be properly protected, especially where the harshest environments occur. There are many products available that are capable of protecting concrete surfaces. However, care must be taken when selecting a protective coating for concrete surfaces, as most have specialized uses and vary widely in cost. Although coatings can have significant impact on capital costs, they can often double the service life of critical infrastructure facilities, easily justifying their return on investment.

Factors to be considered when selecting a coating system for a concrete surface include resistance to physical and chemical attack, NSF-approval for contact with potable water (not critical for wastewater applications) and life-cycle cost. Some coatings typically used in water/wastewater applications are repair mortars; epoxy-based, quartz-reinforced composite overlays (Fig. 4); and epoxy-based liner systems (Fig. 5). Each system has advantages and disadvantages; therefore, determining the most appropriate protection system is critical to ensuring a cost-effective design that maximizes the potential life span of a new or rehabilitated structure.

CONCLUSIONS

With the current state of our national water infrastructure, enormous investments will be required to maintain current systems and provide adequate capacity for population growth. This will need to be accomplished while decreasing federal appropriations are putting a greater burden on local and state governments. Owners are being faced with difficult decisions due to limited capital funds and urgent needs for repair. They are often forced to limit rehabilitation operations, leading to increased and more expensive repairs in the future, which may shorten the useful life of a structure, eventually forcing a costly replacement. However, a properly identified and executed rehabilitation plan can provide owners with a viable option to replacement, offering a legitimate balance between life-cycle cost and available capital funds.

Fig. 4: Application of epoxy-based, quartz-reinforced composite overlay on the effluent trough of a clarifier basin

Fig. 5: Epoxy-based liner applied to surface of a wastewater effluent channel

REFERENCES

1. ASCE, "2013 Report Card for America's Infrastructure," American Society of Civil Engineers, Reston, VA, 2014, www.infrastructurereportcard.org. (last accessed June 17, 2014)

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