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CONCRETE TANK INSPECTIONS

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The objective of a tank or reservoir inspection program is to help owners keep the facilities in operation as long as possible with minimal downtime. That means identifying defects that can result in contamination or failure of the structure.

Effective repairs begin with a thorough inspection. With careful planning and preparation, condition surveys provide valuable information about the causes of deterioration and distress. The appropriate remedy can only be applied when the problem is identified.

Prior to inspection

Specialized structures, such as concrete water tanks or reservoirs, present unique challenges. Plant personnel, with their extensive knowledge of the facility, are an integral part of the inspection process. Their involvement from the earliest stage on is crucial. Downtime for inspections must be limited because of the importance of a tank or reservoir to communities they serve. So when establishing an inspection program, several practical issues need to be considered.

Availability: Because of service demands, especially during peak periods (summer months), inspections often have to be done during the winter. Given the added complications of cleanup, access, lighting, safety, and confined space entry requirements (see below), adequate lead time must be provided for organizing the operation and bringing together the necessary personnel.

Construction: The configurations and ages of the structures vary. Many were built under the guidelines of obsolete codes or out-of-date design/construction standards. Often, little background or data on the history of a structure are available.

Dewatering: Emptying the tank is not always a simple procedure. Nor is it something that can be done quickly. In some instances, base slabs may not be designed for high ground water conditions. The appropriate time for emptying a tank designed in this manner needs to be determined by rainfall as opposed to seasonal water demands. After dewatering, tanks must be adequately cleaned to facilitate a proper inspection. Silt, sand, or other contaminants are often present and must be removed. Often a facility cannot be entirely dewatered because of plant operations. Since a dry tank is not always possible, appropriate preparations (hip boots, laydown areas, etc.) must be made well in advance to avoid delays.

Safety: State and federal requirements for confined space entry must be met. Ventilation and air quality must be evaluated prior to entry. Dangerous areas, such as sumps or a sudden drop, must be cordoned off to prevent accidents. The distance between roof and base slabs can often exceed 20ft (6m). Provisions such as rolling platforms, scaffolds, ladders, or other means must be provided to facilitate inspection of the ceilings.

Classroom instruction and certification in safety issues are necessary. All members of the inspection team, from photographers to engineers, must learn proper entrance procedures, the use of fall protection devices and oxygen equipment, as well as how to identify unsafe conditions.

Tank Environment: It is usually damp (almost rainy) and cold within the structure, which makes it very difficult to write or draw sketches. The high humidity often makes cameras and other equipment malfunction. Backup equipment for documentation should be on hand to prevent costly downtime. In addition, provisions for adequate lighting and power must be made prior to entering the facility.

Clothing: Appropriate clothing (boots, safety harnesses, protective jumpsuits) must be worn by all personnel entering the tank or reservoir.

> Many problems occur due to poor detailing. The lack of proper expansion joints, improperly placed control joints, and insufficient roof slopes are quite common.

Inspection preliminaries

A review of available drawings, reports, and other facility documentation is recommended prior to entry. A thorough knowledge of existing construction and potential problems will result in a more efficient and safer inspection effort.

Ideally, an initial inspection should be performed to become familiar with the facility and identify potentially dangerous areas. Plans, as well as wall elevations, should be prepared prior to performing the inspection to document findings during the inspection process. An examination of the tank or reservoir's exterior for signs of structural distress can be used later to correlate internal findings.

Should initial cursory observation indicate a tank may have foundation-related problems and/or excessive cracking, topographic and elevation surveys may be in order. These studies can establish criteria to monitor future movements of the structure.

It is often helpful to perform limited structural computations, if adequate data are available, to determine the adequacy of the original design. The results can be used to target areas for potential problems.

Minimizing downtime should be a priority in all inspections. If material testing is to be included in the evaluation, determine, in advance, what personnel and equipment will be needed onsite.

A materials testing program may include the following tasks:

- Extraction of cores for petrographic analysis, compression strength, and other tests to evaluate the condition and strength of the concrete.
- Extraction of cores through cracks to determine the extent and nature of cracking.
- Extraction of reinforcing bars for testing.

- R-meter testing to determine location and depths of existing reinforcing.
- Impact echo testing to determine if there is internal cracking or voids in the concrete.
- Swiss hammer or Windsor probe to estimate concrete strength.
- Chloride analysis to determine if calcium chloride as an additive was used during original construction. Sounding of the concrete surface with a chain drag or hammer to detect internal delamination.

Also, plan for necessary cleanup or efforts to repair destructive testing. Patching core holes and cavities where reinforcing bars were removed can add to the length of an inspection.

In some cases, the tops of buried reservoirs must be uncovered to evaluate the stab, underdrain systems, waterproofing membranes, and expansion joints. Arrangements for excavation equipment and personnel must be made prior to the inspection.

Onsite inspection

Whether the purpose of the inspection is to evaluate the general condition of the facility, determine benchmark criteria for comparison during subsequent inspections, or gather data for upgrades or maintenance and repair programs, the required tasks are basically the same. What is likely to be found during an investigation is the following:

Cracks: Two of the most serious issues, leaks and contamination, are the direct result of cracks. Primarily, buried tanks are not subject to the same thermal movements that structures exposed directly to the weather are. They are less likely to experience cracks (and leaks) than above-ground or partially exposed tanks. Tanks with above-grade walls, however, are prone to leaks.

Diagonal cracks are found most often near corners, and vertical cracks appear more frequently along the length of the tank (Fig. 1). Generally, both types of cracks are not structural in nature - they're due to volumetric changes in length. Cracks in walls are less likely to be a source of contaminate infiltration. Instead, they tend to be sources of leaks from the tank (see photo on p. 62).

Figure 1 - Moving cracks on exterior wall of reservoir.

Cracks in base slabs do not usually pose a contamination problem, although when tanks are empty, base slab cracks can allow contaminants to infiltrate. More often, water reservoirs are at least partially full, creating leakage conditions for cracks in base slabs.

Most cracks in exposed tank walls move and change in width with seasonal temperature changes. Tanks with moving cracks will leak more in the winter than in the summer, when the cracks tend to close. As a result, it is common to see ice forming at the cracks in colder months.

The most common cause for cracking in the top of exposed tanks is due to thermal stresses. Many of the structures lack expansion joints. Because of the immense size of these reservoirs, structural components exposed to the weather, especially the top slab, go through significant temperature changes. If the resulting stresses are not properly accommodated (i.e., through properly designed expansion joints), cracks will develop to relieve the stresses. These cracks are major sources for the infiltration of contaminants, which is obviously a serious concern for tanks that hold potable water.

A majority of these structures are flat slabs with capitals and columns about 20 to 25 ft (6.0 to 7.5 m) on center. The crack pattern, leading to leaks, is typically observed in the following manner: a) diagonal from the corners, and b) perpendicular to the exterior walls around the perimeter contiguous with cracking in the walls. Essentially, nature is furnishing the expansion joints and control joints not properly provided in the original construction (Fig. 2)

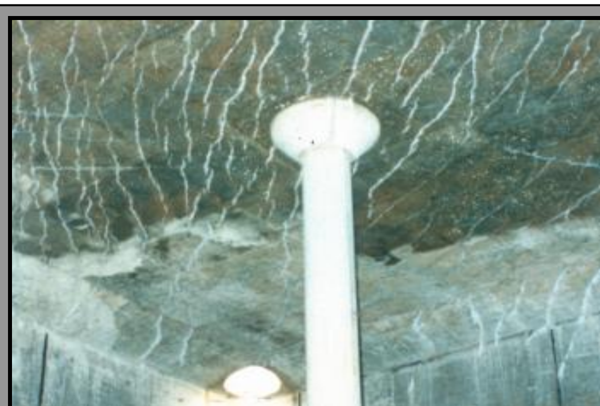

Figure 2 - Cracks through top slab of reservoir due primarily to shrinkage and temperature changes.

Deteriorated concrete: Freeze-thaw damage at the water line, especially with older tanks lacking air entrained concrete, is very common. Delamination due to corrosion of the reinforcing, however, is not a major problem in these facilities.

Poor roof drainage: The regulations regarding roof drains for potable water storage facilities are quite stringent. Drain piping cannot be exposed to the water below for fear of contamination.

Most often when drains exist, they are placed within the columns. However, they frequently are not effective. Deflection occurs in the slab areas between columns where water accumulates until it can evaporate (Fig.3). If any cracks are present within these low areas, water will eventually penetrate the slab unless sealants or membranes are provided to alleviate the problem.

Figure 3 - Ponding water on roof deck drains are located over columns as opposed to low points of slab.

Poor detailing: Many problems occur due to poor detailing. The lack of proper expansion joints, improperly placed control joints, and insufficient roof slopes are quite common. Very serious structural problems can result if adequate overflows are not provided in the structures. Should an accidental overflow condition occur, internal pressures pushing against the underside of the top slab can result in punching shear failures (Fig. 4).

Figure 4 - Punching shear failure at capital of reservoir.

Maintenance/previous repairs: The improper application of repair materials can lead to problems that weren't originally there. Often, moving cracks are mistakenly injected with rigid epoxy. As a result, a new crack forms directly adjacent to the patch to relieve the pressure.

Another incorrect repair procedure is the use of non-breathing membranes applied to the top surface of reservoir roofs. Eventually, the build-up of moisture on the underside of the membrane and resulting vapor drive causes the membrane to fail.

Failed waterproofing: An evaluation of the condition of the waterproofing system is an important part of any tank inspection. Be on the lookout for materials, such as sealants and membranes, that have exceeded their useful life. Signs to look for include peeling or worn membranes on top surfaces. Debonded, cracked, or gummy caulking indicate the sealant is no longer functional.

Obsolete design: Often, older tanks and reservoirs that may have been state of the art at the time of construction, don't meet current design standards - a reservoir built in 1922 had a 900 ft (274 m) long buried water reservoir that incorporated a three-way flat slab structural system. Although the structure had sufficient strength to support the 2 ft (0.6 in) of soil above, it had inadequate shrinkage reinforcement across the column strips. As a result, the top slab cracked longitudinally at the center of each column strip, allowing contaminant infiltration.

Preparing a report

When conducting an inspection, all findings should be documented on plans and elevations, along with notes. Photographs are mandatory. Video taping may also be useful.
Upon completion of the evaluation, the problems unique to each facility should be thoroughly addressed in a report. The report should be organized to present information to enhance recordkeeping and decision-making by the owner. Below is a suggested report format:

- Executive Summary
- Inspection Methodology
- Construction Description
- Findings and Observations (Classified by component)
- Conclusions (Classified by component)
- Recommendations
- Engineering Opinion of Cost
- Captioned Photographs

Conclusion

The objective of the inspection and resulting report is to assess the existing condition of the structure and make recommendations about how best to extend its useful life with minimal service interruptions through either maintenance or repairs.