WATERTIGHTNESS OF PRECAST CONCRETE WASTEWATER TANKS

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ABSTRACT

Precast concrete wastewater structures are essential components of onsite wastewater systems all over the world. Although most of the significant wastewater treatment occurs downstream in secondary treatment systems and the drainfield, what happens in septic tanks is critical to the success of the system. A key performance aspect of these tanks is their ability to hold in wastewater and keep outside stormwater and groundwater from getting in. It is essential for installers, inspectors and regulators to understand the keys to precast tank watertightness to help avoid issues in the field.

INTRODUCTION

Since the advent of concrete wastewater treatment tanks, these important vessels have undergone a remarkable evolution. Designs have evolved to provide maximum treatment and improve effluent quality. Innovations have enabled enhanced treatment inside the tanks and advances in precast tank manufacturing have produced longer lasting tanks that can efficiently withstand anticipated loads and severe environments.

With more than one in five households in the U.S. depending on individual onsite systems (U.S. EPA), manufacturers and installers are increasingly busy. Precast concrete tank manufacturers must exercise diligence in ensuring quality control is involved at every stage of production (NPCA). Raw materials are tested and then added in precise, sequential amounts to achieve the desired mix design. Batching, casting, consolidating and curing the concrete is performed under the watchful eye of a quality control manager.

Precast tanks are engineered products that do not rely solely on the installation to be effective, as is the case with any product some installation errors can alter functionality and impact performance. It is important for installers to understand how tanks should be bedded, backfilled and connected so the watertightness of the vessel is not negatively impacted.

Watertightness

Merriam-Webster defines the term watertightness as “of such tight construction or fit as to be impermeable to water except when under sufficient pressure to produce structural discontinuity”. (Merriam-Webster Dictionary) That can be a tall order when there are a series of pieces joined together, sometimes blending different material types. For example, the system may be a precast concrete tank with plastic risers and PVC pipe. All these components must interface to form a seal that keeps fluids in and out while buried underground and potentially subjected to movement. This has been done successfully for many thousands of installations throughout North America for many years. Watertightness of a precast concrete tank can be broken down into 4 rules.

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4 Rules of Watertightness

When it comes to precast concrete composite structures and achieving watertightness, there are four main rules that should be followed:

1. Use an appropriate mix design for the product and its end use.
2. Follow quality manufacturing processes.
3. Execute joints and penetrations carefully.
4. Follow proper installation procedures.

1. Use an appropriate mix design for the product and its end use.

When discussing watertightness of concrete, we must consider the two P's: porosity and permeability.

Porosity is the ratio of the volume of voids to the total volume of the material. A sealer can be added to the concrete surface to help prevent water penetration. It's practically impossible to make completely nonporous concrete where water won't penetrate even a fraction of an inch. However, we can control the size and distribution of pores and limit the permeability.

The pores, which are tiny voids, reside in the cementitious paste and can be subdivided into two types: gel pores and capillary pores (Figure 1). The gel pores exist in every system and are part of the glue that forms around the aggregate to make concrete what it is. Gel pores are very small and do not hinder the quality of the concrete. Capillary pores on the other hand are larger and depend almost entirely on the water-to-cement (w/c) ratio of the concrete. If too much water is added to the mix, the excess water will remain after hydration of cement. Eventually, when the remaining water evaporates, capillary pores are formed. Depending on their size and distribution, these pores can be interconnected, influencing our second "P" – permeability.

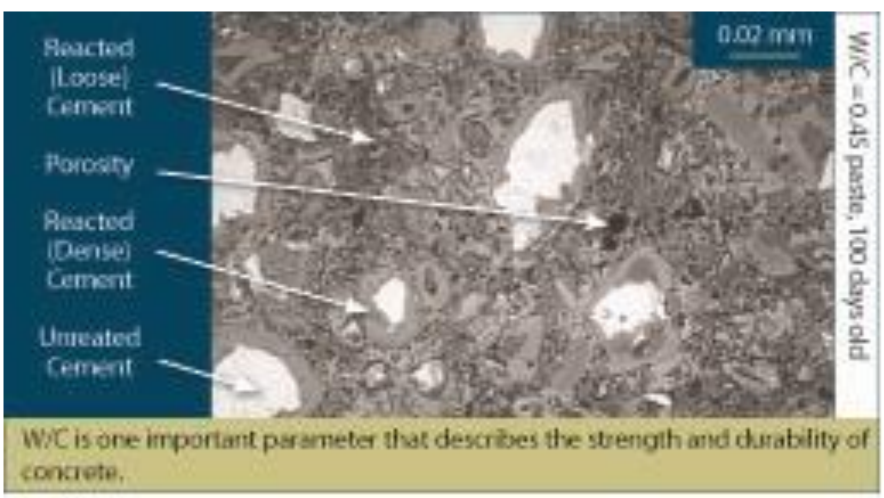

Figure 1 – Scanning Electron Microscope Image Showing Cement Paste Components and Paste Porosity (Courtesy of National precast Concrete Association)

Permeability is the measure of the ease with which fluids can flow through a porous material. Permeability is expressed in terms of speed (in./s or mm/s) whereas porosity is expressed in volume per volume ($in.^3/in.^3$ or mm^3/mm^3). Porosity refers to the quantity of voids within concrete while permeability refers to the ease with which water can travel through the pore system.

Permeability also depends on factors such as aggregate gradation and density. In high-quality concrete, infiltration is very slow, around the order of 3.94×10-11 in./s (1.00076 x 10-12 m/s). (PCA) To provide an idea of how slow that is, it would take about 4,800 years for water to breach a 6-in.-thick concrete wall.

One of the keys to keeping porosity and, consequently permeability, low is the w/c ratio. The w/c ratio is the most important factor in concrete design. The water content in a mix controls the moisture's rate of entry and the movement of water during the freeze-thaw process. A mix design for durable, watertight concrete should have a maximum w/c ratio of 0.48 and require a well-graded mixture of fine and coarse aggregates (NPCA). This information can be obtained from the precaster.

Densification of the concrete can be improved with admixtures. Many different admixtures can be used to improve concrete's densification and can also be used to improve workability and durability as well. Water-reducing agents can be used to control water content while trying to maintain workability. Air entrainment agents can also be used, as they produce near-microscopic independent bubbles that improve the watertight performance of hardened concrete. Air entrainment also improves concrete's freeze-thaw performance and overall durability in addition to easing the placement process.

Rich concrete mixes (that is, those with higher cement contents) provide a denser, more impermeable and superior finished product. Consequently, a minimum cement content needs to be used depending on the exposure conditions. The use of supplementary cementitious materials such as fly ash, slag and silica fume can also increase concrete's density, thus reducing capillary porosity and permeability.

Aggregates comprise the majority of the concrete mix both by volume and by weight. Gradation of the aggregates is a most important factor and should be of primary consideration. Shape and texture of the particles will also affect workability. Aggregate moisture needs to be accounted for when adjusting the mix design so that additional surface water from aggregates does not contribute to a more porous hardened product. Concrete mixtures that are not well-graded can permit water to pass through the finished structure.

2. Follow quality manufacturing processes.

Quality concrete manufacturing processes are critical to the production of durable, watertight concrete products. Proper attention to important pre-pour activities such as maintaining prescribed mix proportions, form cleanliness and specified reinforcement placement and minimum concrete cover are very important. For concrete products permanently exposed to earth or moisture, increased concrete cover as specified in ACI 318 is recommended to ensure corrosion protection and proper bonding of concrete and reinforcement (ACI). Adequate consolidation of freshly placed concrete is an extremely important factor to produce a high-quality, dense concrete. Added emphasis on consolidation is required for a particularly low w/c ratio concrete, as it requires a higher consolidation effort unless self-consolidating concrete (SCC) is used.

Concrete must be adequately cured if its optimum properties are to be developed. An adequate supply of moisture, either by covering or other means, is important to ensure full hydration and reduced porosity.

It is essential for precast concrete manufacturers to have a quality control plan in place. This plan must contain the procedures for procuring raw materials, batching, casting, finishing, curing, inspection and testing.

3. Execute joints and penetrations carefully.

Care must be taken to determine that tank sections installed on site have been properly sealed.

Joint Seals

For maintaining watertight joints, high-quality preformed joint seals should be used at the tank joints and access riser joints. Surfaces should be clean during installation. Seals should meet minimum compression and other installation requirements as prescribed by the sealant supplier. Ambient temperatures below 50˚ F (10˚C) sometimes affect the compressibility of some sealants during installation; therefore, the proper sealant suited for that lower temperature must be used.

Inspecting the joint area to determine that the tank sections have been properly sealed helps prevent soil materials from entering the joint area during backfilling. Manholes and risers should be properly sealed to prevent infiltration. If butyl sealant is used, it is important to check that butyl sealant sections are not simply butted up against each other or left with a gap (Figure 2). Even testing of overlapping the sealant has revealed small holes where water can penetrate (Figure 3). The best way to get the maximum efficiency out of the sealant is to knead the joining ends together to form a homogenous, continuous length of sealant.

Figure 2 – Gap in Joint Sealant Application (Courtesy of Concrete Sealants Inc.)

Figure 3 – Overlap of Butyl Sealant (Courtesy of Concrete Sealants Inc.)

It is also important is to make sure the adjoining sealant ends are not connected at the corners. Rather the sealant should be brought around the corner at least 12 inches and kneaded into the next section (Figure 4).

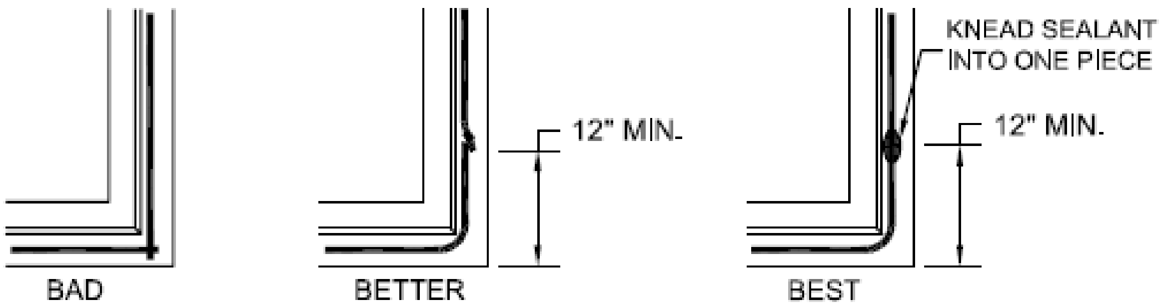

Figure 4 – Best Practices on Connecting Sealant (Courtesy of Concrete Sealants Inc.)

The sealant should be placed as close to the middle of the wall as possible. Placing it near the outside edge will result in a section of the sealant oozing out when the tank sections are joined. Any sealant that ends up outside of the tank is rendered ineffective. The goal is to have the entire area of the sealant within the tank envelope (Figure 5).

The sealant used should adhere to the requirements of ASTM C990 - Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants (ASTM).

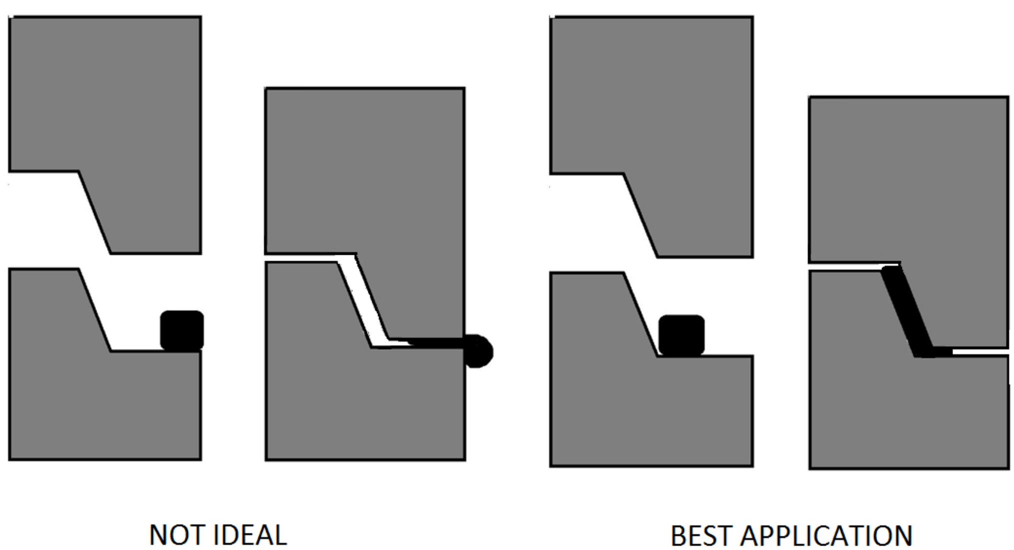

Figure 5 – Best Practices on Applying Sealant Closer to Middle of Tank Wall (Courtesy of National Precast Concrete Association)

Flexible Connectors
Preferably, local specifications will require a flexible connector for the inlet and outlet pipes. Flexible mechanical connectors use expansion rings or tension bands to compress and seal the resilient rubber material. A compression seal, on the other hand, uses pressure between the outside pipe diameter and tank opening to confine and seal the connector. A cast-in boot connector is embedded into the tank wall during forming and casting operations and can have a compression or mechanical seal. It is best to follow manufacturers' recommendations to properly attach the pipe through these connectors. Connectors should conform to ASTM C1644 - Standard Specification for Resilient Connectors Between Reinforced Concrete On-Site Wastewater Tanks and Pipes (ASTM).

Riser Sections
As more and more regulations call for tank access to be at or near grade, access risers or manhole sections are being increasingly used to provide access to the tank. Risers can be concrete or plastic. The most important consideration is ensuring that the riser assembly is stable and will not move from the opening in the tank lid. Also, the riser assembly must be watertight to prevent infiltration. Many precast tank manufacturers are now casting an adapter or the first riser section into the top slab to make it easier in the field to maintain a watertight seal.

4. Follow proper installation procedures.

Proper tank installation is critical for ensuring structural integrity and watertightness. Many of the problems experienced with leakage can be attributed to incorrect installation procedures rather than to poor precast production practices. In addition to damage to the tank, improper installation techniques could pose a safety hazard.

The installation site must be accessible to a large truck weighing up to 80,000 pounds. The construction area should be free of trees, branches, overhead wires or parts of buildings that could interfere with the delivery and installation of the tank. Most trucks must get within 3 to 8 feet of the excavation to be unloaded. Prior to excavation, all buried utilities should be located and identified. Occupational Safety and Health Administration (OSHA) regulations governing excavation work should always be followed. Excavations should be sloped, benched or shored to comply with all construction safety requirements. Care should be taken to ensure the heavy delivery truck does not travel over the intended site for the soil absorption system as it will cause severe compaction and ruin the portion of the drainfield that it traverses.

Bedding
Proper use of bedding material can extend the service life of an on-site wastewater treatment system. Imported bedding material should be used as necessary to provide a uniform bearing surface. A good base will ensure that the tank will not be subjected to adverse settlement. Unless otherwise specified, use a minimum 4-inch thickness of sand or granular bed overlying a firm and uniform base. Tanks should not bear on large boulders or rock edges. Sites with silty soils, high water tables or other "poor" bearing characteristics must have specially designed bedding and bearing surfaces. In the presence of high water tables, structures should be properly designed to resist flotation. Proper compaction of the underlying soils and bedding material is critical to

eliminate later settlement, which can ultimately occur in all tank installations regardless of the tank material. Potential tank settlement is measurable, predictable and preventable. Proper evaluation of the original soil, bedding materials, water table, backfill materials and potential soil-bearing stresses reduces the likelihood of tank settlement.

Worker safety is of primary importance. If it is necessary to have a worker enter the excavation to check elevation or compact bedding materials, proper excavation methods should be used to prevent the sidewalls from collapsing. Alternatively, trench boxes may be used.

Tank Placement
The tank's orientation should be confirmed prior to placement in the excavation. Check the bedding material and ensure that inlet connectors face the residence. After placement, the tank should be checked to verify it is level. The tanks must be set level to provide the proper elevation drop from the inlet to the outlet. The slope of the sewer line and tank elevation should meet local plumbing and building codes. Lifting apparatuses such as slings, lift bars, chains and hooks should be verified for capacity and an adequate safety factor for lifting and handling products should be confirmed. A factor of safety of at least 5 is recommended for lifting apparatuses.

Backfilling
Local regulations may have specific backfilling requirements. In the absence of such regulations, place backfill in uniform layers less than 24-inches thick. Backfill should be free of any large stones or other debris. This debris could concentrate loads on the tank and become an issue over time (Figure 6).

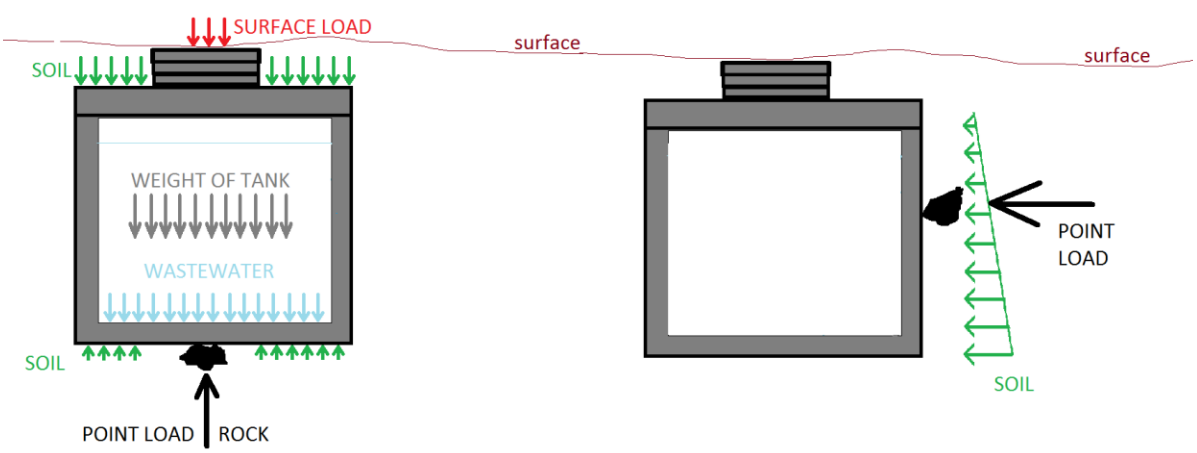

Figure 6: Illustration of Point Loads on an Underground Tank (Courtesy of National Precast Concrete Association)

CONCLUSION
Wastewater structures are engineered products that require skill and care in manufacturing and installation. Precast tank manufacturers must adhere to the engineered design, use quality materials, and exercise quality control throughout the manufacturing process to ensure the tank is acceptable as it leaves the yard. However, a well-designed and manufactured tank can be

compromised by a poor installation, so the installer, too, must adhere to proper procedures. It is the responsibility of the people in the field to complete the process of quality installation. Designers should rely on precast manufacturers in their local areas for guidance. Only when all involved adhere to strict quality standards can the tank be watertight and perform to its intended and expected long life cycle.

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