

# **Development of Prefabricated Septic and Pump Tank Construction and Installation Standards for North Carolina**

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## **ABSTRACT**

Guidelines which may serve as a basis for the development of standards for prefabricated tanks, including recommendations with regards to prefabricated tank construction, on-site tank manufacturing inspection, tank installation inspections, concrete compressive strength testing and watertightness testing are presented. The basis for these guidelines follow policies of the state-directed tank program in North Carolina and have been refined with the input of regulators, academicians and manufacturers.

**Keywords.** Tanks, Inspection, Concrete tanks, Infiltration

## **INTRODUCTION**

Prefabricated tanks (in this paper, the term "tanks" refers to both septic and pump tanks) are often the most critical components of an on-site wastewater system. Since they are frequently overlooked during system inspections, inferior tanks are often installed. Leakage out of septic tanks can contaminate ground and surface waters; infiltration into tankage can hydraulically overload the soil-based treatment and disposal system (Bishop, 1996); tank components can corrode and break rendering them useless; and poor construction can lead to catastrophic structural failure of the tank. Regulatory tank inspection programs have historically been inconsistent, infrequent and, in the long term, ineffective. Skill development and training for manufacturing and installation staff are often inadequate. The result is that highly-skilled manufacturers and installers often cannot compete financially when cheaper, inferior tanks are regularly installed and approved and that system owners can be stuck with malfunctioning wastewater systems, contaminated water supplies and costly system repairs.

North Carolina has a state-implemented and directed tank program (NC DEHNR, 1997). Minimum standards of septic and pump tank design and construction are established by the state Division of Environmental Health through the On-Site Wastewater Rules and Regulations (15A NCAC 18A .1900, et seq.). The State is responsible for the review and approval of all prefabricated tank designs; maintains a database of approved tanks and manufacturers; conducts training programs for local environmental health staff and workshops for the regulated community; and organizes quality assurance inspections of tank manufacturing facilities in concert with the local health departments which will ultimately inspect and permit installed wastewater systems. The primary responsibility of the local environmental health departments with respect to tanks has been to ensure that prefabricated tanks are constructed according to State standards and preapproved tank plans and specifications prior to approving their installation. Typically this inspection is done at the job site, after the tanks have been installed.

Although vast records of anecdotal information regarding the quality of prefabricated tanks indicate that a high percentage do not meet the minimum acceptable quality standards, there is very little actual data in the literature identifying common tank construction problems. In North Carolina,

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it has been apparent via inspections of tank manufacturing facilities and of failing wastewater systems that inferior tankage is indeed a widespread problem that has led to the malfunction of on-site wastewater systems in the state.

In an attempt to more effectively implement a tank quality control/assurance program in North Carolina, guidelines were developed to assist the regulatory and regulated communities involved in tank manufacture, installation and inspection. A critical component of this effort was to involve all such parties in the policy-making process. An on-going task force composed of local and state regulatory staff, academia and manufacturers was assembled in the summer of 1996 to meet periodically and openly

discuss tank quality, recommend tank program policy and develop revised rules relating to tank manufacture.

## PREFABRICATED TANK CONSTRUCTION

### Construction Materials

Precast, reinforced concrete is overwhelmingly the most popular choice for tank construction in North Carolina. Its advantages include good structural properties, corrosion resistance and cost effectiveness. Tanks prefabricated from materials other than precast reinforced concrete (e.g., plastic such as glass-fiber-reinforced polyester and polyethylene) are reviewed and approved on a case-by-case basis, provided that adequate supporting documentation including third-party testing in accordance with specified standards is provided. Some advantages of plastic tanks are their lightweight construction, increased watertightness potential and corrosion-resistance. However, many commercially marketed plastic septic and pump tanks are not structurally suitable for all applications.

Several appropriate material and construction standards have been adopted into the North Carolina tank policy for review and approval of plastic tanks (ASTM, 1981; IAPMO, 1993; ASTM, 1984; CSA, 1990).

### Producing Quality Precast Reinforced Concrete Tanks

Table 1 lists the typical sequence of precast reinforced concrete tank construction. Detailed descriptions of each step in this sequence are provided in ensuing paragraphs.

Table 1. Typical sequence of precast reinforced concrete tank construction

1.	Clean tank form.
2.	Apply form-release agent to walls of form.
3.	Pre-bend, tie and center reinforcement in form.
4.	Mix concrete or have pre-mixed concrete delivered.
5.	Pour concrete into form.
6.	Consolidate concrete within form (usually done simultaneously with step 5).
7.	Allow concrete to harden in form.
8.	Remove tank section from form.
9.	Allow tank to cure and harden on yard.
10.	Join and seal tank sections.

Concrete. Concrete consists of coarse aggregate (stone), fine aggregate (sand), cement and water. The proportions of these components define the "concrete mix". Critical considerations in the design of the concrete mix for tank construction are concrete compressive strength and watertightness of the concrete.

Concrete compressive strength. The concrete to be used in the construction of tanks to be sold in North Carolina must have a minimum 28-day compressive strength of 24 MPa (3,500 pounds per square inch). North Carolina encourages the use of a higher strength concrete [e.g., 28 MPa (4,000 psi)] to insure that minimum required compressive strengths are attained. The ultimate compressive strength of a concrete mix is primarily a function of water-to-cement ratio and the extent to which hydration has progressed (PCA, 1968). Curing conditions also play a key role in the development of concrete strength.

Water-to-cement ratio. The ratio of the amount of water to the amount of cement by weight in the concrete mix is the most important factor in determining the concrete strength, durability and watertightness. Generally, more water in the mix will result in concrete with a lower strength, durability and watertightness. The use of concrete with an adequate slump (10 to 15 cm) is essential for proper consolidation of concrete within the forms and, in particular, to cast the walls of the tank which may be as thin as 6.4 cm. A common practice is to add water to concrete, beyond the amount specified in the mix design, to improve the workability of the concrete, thus allowing the forms to more easily fill with concrete, resulting in less honeycombing and a better looking tank. This practice greatly weakens the concrete and can result in serious cracking and even structural failure. It is very important that once the concrete is mixed with the predetermined

amounts of cement, water and aggregate, no additional water is added. American Concrete Institute (ACI) standards allow the use of admixtures (e.g., plasticizers) capable of producing high slump concrete (ACI, 1995). Such admixtures should be used instead of adding excess water.

Concrete consolidation. Because of the thin and deep walls of tank forms, it is very difficult to achieve proper consolidation of freshly-poured concrete without the use of a mechanical vibrator. If the concrete is not properly consolidated, excessive honeycombing may occur in the tank walls, corners and along the joint of two-section tanks. Honeycombing weakens the tank and can also make waterproofing the tank very difficult. Use of a 1.9 to 2.5 cm (3/4 - to one-inch) diameter, flexible shaft internal concrete vibrator, or an externally-mounted, bin-type vibrator is recommended. Flexible shaft vibrators are hand-held and placed in the wet concrete at several points around the tank form. These are most effective on rectangular tanks. Bin-type vibrators are placed in mounts located on the outside of the tank forms. They can be used on any shape of tank, but the sloped-top or octagonal-shaped forms commonly used in the coastal plain of North Carolina require this type of vibrator, since it is usually too difficult to get the flexible shaft vibrator to the bottom of the octagonally-shaped forms. Vibrators are readily available and can be purchased or rented from suppliers. Other concrete consolidation techniques include manual vibration of the forms (e.g., rod and mallet) which may cause damage to the forms and is generally not as effective as mechanical vibration.

Watertightness of the concrete. North Carolina rules state that tanks shall be watertight. Production of tanks with watertight concrete faces depends primarily on the water-to-cement ratio of the concrete mix and the duration of the moist-curing period. Tests have shown that concrete with a low water-to-cement ratio (typically 0.5 by weight) and long moist-curing period (typically 7 days or more) have no leakage (PCA, 1968). Other factors that improve the concrete watertightness is having adequate air entrainment in the concrete and controlling cracks and honeycombs.

Hardening. After pouring the concrete into the tank forms, the structure should be allowed to harden for at least 24 to 48 hours prior to removal of the tank section from its form. During hardening and after removal from the forms, the tank should ideally be kept in a warm moist environment. If the tank is allowed to dry too quickly, the concrete will crack and will never achieve full strength. When possible, the tank and forms should be stored in a shaded area, out of direct sunlight, particularly during the hot summer months. Covering the tanks with plastic and/or wetting them down when the weather is dry and hot will make a significant difference in the strength of the concrete, particularly during hardening within the form and the first week after pouring.

Curing. Concrete continues to gain strength with time, although it acquires most of its strength during the first four weeks after pouring. The concrete mixture is usually specified by the concrete compressive strength at 28 days. For example, 24 MPa (3,500 psi) concrete reaches about 10 MPa (1,500 psi) after 3-4 days and 17 MPa (2,500 psi) after 7-10 days, but typically does not reach the full 24 MPa (3,500 psi) until 28 days.

North Carolina regulations require that concrete with a 28-day design strength of at least 24 MPa (3,500 psi) be used and that the tank reach at least 21 MPa (3,000 psi) before it is removed from the place of manufacture. North Carolina regulations also require that each tank be permanently marked with the date of manufacture. If the tank is properly poured and cured, 21 MPa (3,000 psi) can be reached as early as three weeks from the time of pouring. If a higher strength concrete mix or an ASTM Type III (high early strength) cement is used, the minimum installation requirements may be met even sooner. It is to the advantage of the tank manufacturer to keep as large an inventory of tanks as possible to ensure that all tanks have had an adequate amount of time to harden and cure before they are installed. If concrete is properly mixed, placed and cured, nearly 75 percent of the ultimate strength can be achieved after the first 14 days.

Placement of reinforcement. In North Carolina, tanks must be reinforced with a minimum of one layer of 15 cm by 15 cm (6-inch by 6-inch) - W1.4 x W1.4 (10/10 gauge) welded wire fabric throughout all tops, bottoms, sides, ends, and baffle walls. Separate pieces of the reinforcement must be lapped at least six inches and tied securely in place. It is particularly important that the reinforcement be bent through all corners and edges of the tank since the stresses will be greatest in these areas. The reinforcement must be centered as much as possible to provide an adequate concrete cover [2.5 cm (one-inch) minimum recommended] in all places. This is difficult to do; but, by shaping the reinforcement before placing it in the forms, or using reinforcement spacers, the amount of reinforcement that is outlined or exposed through the tank faces will be minimized. Additional reinforcement is required for tanks to be buried over 90 cm (three feet) below grade, tanks to be subject to vehicular loads, tanks with a nominal capacity of 7,600 L (2,000 gallons) or more and for the slabs of one-piece or top-seam tanks.

Sealing joints. For a tank to be properly sealed, as required, the "V" and notch of the tongue-in-groove joint of two-piece tanks must both be properly formed. If there is any honeycombing along the surface of the joint, it must be touched-up beforehand with hydraulic cement or similar material. Joints that are not level, as can happen when the joint-forming ring around the forms is pushed out of alignment by concrete debris around the form, are not acceptable. North Carolina requires that the seams be sealed with a minimum 2.5 cm (one-inch) nominal diameter mastic, butyl rubber or equivalent pliable material that is both watertight and corrosion-resistant. When joining the tank, the tank halves must be carefully aligned to assure that the joint is sealed around the entire tank. It is also recommended that, after joining, the joint area be plastered over with hydraulic cement mortar or other waterproofing sealant. North Carolina requires additional waterproofing for pump tanks because they are more susceptible to groundwater infiltration if not sealed watertight.

## TANK INSPECTION

## Common tank construction problems

Table 2 lists some of the most common tank construction problems identified during routine inspections of tank manufacturing facilities and the percentage of facilities exhibiting the problem.

Table 2. Percentage of approved North Carolina tank manufacturers with specific construction problems identified during State tank yard inspections over an 18-month period in 1994 and 1995.

<b><u>Problem</u></b>	<b><u>Percentage</u></b>
Low concrete strength	52%
Reinforcing not in accordance with approval	50%
Inadequate reinforcing in top and bottom	30%
Inadequate reinforcing in walls and ends	4%
Inadequate reinforcing in baffle wall	42%
Inadequate reinforcing in access lids	50%
Dimensions not in accordance with approved plans	44%
Incorrect dates of manufacture and/or identification imprints	38%
Undersized sealant	33%
Excessive reinforcing wire outlining	29%
Poorly-formed joints	29%
Structural cracks, drainholes	25%
Inadequate pump tank access opening	23%

Inadequate lid handle material and/or size	21%
Forms damaged, out of alignment, leaky, etc.	17%
Excessive honeycombing	13%
Reinforcing wire exposure	13%
Uneven joints on two-piece or mid-seam tanks	13%

### Tank Yard Inspection

A tank yard inspection is typically a detailed inspection of a tank manufacturing facility (known as a tank "yard") including observation of methods of manufacture and inspection and testing of the product. Historically in North Carolina, tank yard inspections have been considered primarily a responsibility of the State. However, although tank yard inspection continues to be an important State activity, adequate quality assurance through State inspection alone is not possible with current staffing levels due to the number of manufacturers with approval throughout North Carolina (approximately 200 different manufacturers have tanks approved for use in North Carolina). Ideally, tank yard inspections should be conducted often enough to inspect and individually approve each tank prior to its being brought to a job site for installation. It is recognized that this would be very difficult. However, periodic (e.g., monthly, quarterly) tank yard inspections by local health departments could weed out bad tanks before they are installed, reveal problems that are not normally visible, and even lead to better understanding and communication between the manufacturer and regulatory agency. In addition to ensuring that tank construction requirements are being met, tank yard inspections can be a very valuable learning experience for the inspector. A number of local health departments across North Carolina have, with assistance from State staff, initiated their own tank yard inspection programs and have typically achieved a high level of success, including substantial improvements in tank quality.

Recommended inspection frequency. Typically, inspections will need to be conducted more frequently just after implementing a routine tank yard inspection program. Weekly or monthly inspections may be necessary at first, particularly if serious problems are noted during the initial inspection, and close monitoring of future tank construction (e.g., inspecting placement of reinforcing prior to pouring concrete) is necessary. Routine tank yard inspections should be conducted monthly, quarterly or at least semi-annually.

In fairness to the manufacturing community, entire tank marketing areas should be targeted for inspection rather than specific manufacturers or counties, so that competing manufacturers are all inspected at around the same time.

Notifying the manufacturer. Typically, a manufacturer should be notified the day of or the day before the scheduled inspection. There must be enough advance notice to give the manufacturer the opportunity to be present, but not enough for him or her to unload an inventory of poorly-constructed tanks. To the extent possible, a time should be scheduled which will allow the owner or foreman to be present during the inspection. This leads to better overall understanding and communication between the regulator and regulated. Staff of surrounding health departments and other relevant regulatory agencies should also be consulted prior to an inspection to contribute, observe and learn, as appropriate.

Follow-up. The tank yard inspection follow-up should include completing an inspection form and/or writing an inspection report. Copies of the report should be provided to the manufacturer and appropriate regulatory agencies (including local environmental health staff who will be inspecting system installations). The inspector should discuss the inspection including problems discovered, possible solutions and follow-up procedures with the manufacturer or his representative at the time of the inspection.

Equipment needed. Needed equipment for an effective tank yard inspection include the following: approved tank plans, steel-toed boots, tape measure, rebound hammer (or other instrument for estimating concrete strength), metal detector, permanent spraypaint, flashlight, mirror, manhole hook/crowbar.

Inspection. The following items should be inspected during a tank yard inspection:

1. Forms: Possible problems include:

- Excess concrete debris around the tank form which may push the joint-forming ring out of alignment, causing the joint to form unevenly;
- Damaged forms (often caused by hammering with mallet to consolidate concrete or to assist in releasing the walls after hardening), which can result in leakage from the forms and honeycombing or production of tanks with varying wall thickness;
- Forms that are not located on level ground (placement on an elevated, level concrete slab is recommended) which may cause varying top and bottom concrete thickness and segregation of aggregate in the concrete;
- The use of excess form-release agent which may run off of the owner's property during storm events and directly contaminate soil, ground and surface water.

2. Tank appearance: This should include a thorough visual inspection of the tanks. Possible problems include:

- Tanks with dimensions or other physical attributes which are not in accordance with their approved plans;
- Illegible identification imprints;
- Illegible, missing or incorrect manufacture dates;
- Lid handles that are improperly constructed or are not large enough;
- Excessive honeycombing, particularly in the edges and joint areas, which can result in structural and/or watertightness problems;
- Excessive reinforcement outlining, particularly in walls, which limits the benefit of reinforcing;
- Reinforcement exposure (steel sticking out of the tank faces), which, in addition to limiting the benefit of reinforcing, also allows water, soil and/or sewage to enter the concrete and corrode the steel reinforcement and concrete from the inside out;
- Drainholes or blockouts on the bottom of the tank;
- Structural cracks (a crack that is visible from both the inside and outside of the tank) in the concrete.

3. Concrete: Concrete strength must be measured using a rebound hammer or other appropriate test equipment. Mix tickets (receipts) provided by the concrete supplier or concrete mix records (for manufacturers which mix their own concrete) must be checked to ensure that concrete with an appropriate strength is being used.

4. Reinforcement: A metal detector may be used to check for the use of reinforcement throughout constructed tanks including tops, bottoms, ends, walls, baffle wall and access lids. Test equipment can be as standard as a "treasure hunting" metal detector with a "sharp shooter" coil or as elaborate as a specialized rebar detector that can identify the thickness of the steel reinforcement and the depth of cover over it. If possible, the inspector should be at the tank yard prior to pouring concrete into the forms to inspect for the proper amount and placement of reinforcing.

5. Joint work: To the extent possible, ensure that a watertight seal can be made. Possible sealing/joint problems include:

- Use of sealant that does not have at least a 2.5 cm (one-inch) nominal diameter (manufacturer's stock of sealant or a representative sample of the sealant must be inspected for verification);

- Joints which are not level (usually a result of forms not being cleaned properly);
- Tank halves which are not properly aligned (sealant should fill the entire seam and be squeezed out of the sides);
- Honeycombed joint areas (minor honeycombing can be touched-up with cement mortar, or equivalent, prior to joining tank sections).
- Thorough, detailed tank yard inspections may also include leak testing of constructed tanks.

Tank rejection. Sometimes it may be necessary to reject tanks which are not constructed properly. Such tanks should be permanently marked with spraypaint so that they will be identified by regulatory staff inspecting a system installation if delivered to a job site.

### Tank Installation Inspection

Installation inspections are performed by local environmental health staff prior to the issuance of an operation permit for any on-site wastewater system in North Carolina. Installation inspections are to include at least a cursory inspection of the tank(s). The scope of the tank inspection is usually limited since the entire system must be inspected and at least part of the tank is usually covered up prior to the inspector's arrival. However, the installation inspection is a prime time to reject poorly-constructed or installed tanks. Rejection of a tank after it has been installed is likely to induce some protest, but it will also send a loud, clear message to the installer and manufacturer and will discourage future shipment of improperly-constructed tanks.

The following are recommendations to assist regulators during their inspection of system installation:

1. The installer should be required keep the tank uncovered until after its has been inspected.
1. As frequently as possible, the following items should be checked:
  - Tank dimensions for comparison against the approved plans including length, width and depth, sanitary tee construction details, and top and bottom slab thickness (top and bottom slab thicknesses can easily be shortened during tank construction by not adding enough concrete to fill up the form);

- Concrete strength, using a rebound hammer;
  - Reinforcement throughout the tank, using a metal detector.
1. The tank and its individual sections must be oriented properly.
  1. The tank must be set on a firm, compact or bedded subgrade and be level in both directions.
  1. Pipe connections must be made at blockouts or specifically designed penetration points. Unused blockouts or penetration points must be sealed watertight and structurally sound. There must be a sufficient drop (typically, at least two inches) between the inlet pipe and the outlet pipe inverts.
  1. Tank access must be sufficient, providing access to each compartment, sanitary tee and pump or other distribution device.
  1. Gas passage between tank compartments must be unobstructed.
  1. The tank may not exhibit excessive honeycombing and reinforcement outlining and/or exposure.
  1. The tank may not have drainholes or structural cracks (it may be necessary to inspect the inside of the tank using a powerful flashlight to ensure that the tank construction is acceptable).
  1. Tank sections must be properly joined and sealed.
  1. Pipe connections must be properly sealed.
  1. The riser connection to the top of the tank must be properly sealed and, after final grading is completed, the ground surface in the vicinity of the access opening must be sloped to shed surface water away from the opening.
  2. Watertightness testing should be conducted.

## CONCRETE COMPRESSIVE STRENGTH AND TESTING

### Field Concrete Compressive Strength Testing

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North Carolina regulations indicate that tanks shall be subject to testing to ascertain the concrete compressive strength. Laboratory destructive testing subjects a concrete sample, which may be a cored sample from the tank or a cylinder sample poured with the concrete used to make a tank, to an increasingly applied compressive load until structural failure occurs. The results of such testing are an actual measurement of concrete compressive strength. Field tests (e.g., Rebound Hammer, Probe tests, etc.) are convenient and can provide estimates of concrete strength. However, these two field tests

are based on empirical relationships between the piece of equipment and concrete compressive strength. Since they do not provide a direct measurement of compressive strength, their results are not as accurate as laboratory methods. Table 3 below provides a summary of the more common concrete strength tests that can be utilized.

Table 3. Summary of concrete compressive strength tests

Test	Advantages	Limitations
Core sample test	<ul style="list-style-type: none"> <li>• Accurate.</li> <li>• Take field conditions into account</li> </ul>	<ul style="list-style-type: none"> <li>• Requires coring a hole in the tank.</li> <li>• Requires specialized equipment and procedures.</li> </ul>
Cylinder test	<ul style="list-style-type: none"> <li>• Very accurate.</li> </ul>	<ul style="list-style-type: none"> <li>• Does not take field curing conditions into account.</li> <li>• Does not directly test the structure in question.</li> <li>• Requires specialized equipment and procedures.</li> </ul>
Windsor Probe	<ul style="list-style-type: none"> <li>• Somewhat convenient, simple.</li> <li>• Somewhat inexpensive.</li> </ul>	<ul style="list-style-type: none"> <li>• Only an estimate of concrete compressive strength. (ASTM, 1982)</li> </ul>
Rebound Hammer	<ul style="list-style-type: none"> <li>• Convenient, simple.</li> <li>• Inexpensive.</li> </ul>	<ul style="list-style-type: none"> <li>• Only an estimate of concrete compressive strength.</li> </ul>

Although it may not be very accurate, the rebound hammer test continues to be a very good field test for estimating concrete strength. All local health departments and tank manufacturers should have and regularly use a rebound hammer or Windsor probe for convenient field estimation of concrete strength. The core sample test is probably the

single best test for assessing the concrete compressive strength of a tank, particularly when there is a question about the strength of an installed tank that cannot be resolved via field testing. Care must be taken in ensuring that the core sample is taken from a place on the tank where it will cause no structural or design problem. The sample should be taken from the top of an interior baffle wall or from the outside wall of the tank where a pipe connection can later be made (for example, at a blockout). Cylinder testing should be regularly conducted (e.g., monthly or as raw material or design mix changes) by manufacturers who are mixing their own concrete to ensure that a quality design mix is being used. However, it should not substitute for field-testing tank specimens themselves, as cylinder testing does not account for the highly variable field curing conditions to which tanks will be subjected.

### Rebound Hammer Testing

Calibration. Rebound hammers should be calibrated every six months for hammers in heavy use and once per year for hammers in less frequent use (ASTM, 1985). Options for calibration include sending to the manufacturer for service, taking to local Department of Transportation (DOT) offices which are typically capable of calibrating rebound hammers or self-calibration. Generally, calibration consists of firing the rebound hammer against a standard test anvil supplied by the manufacturer. Testing against the standard anvil should result in a rebound number of 80 (this number varies according to the anvil used, but is typically around 80 +/- 2 rebound number units). If not, the rebound hammer may be cleaned or adjustments may be made, per the manufacturer's recommendations, for calibration.

Error. Even a recently-calibrated rebound hammer is capable of providing inaccurate results. As indicated above, the calibration method for rebound hammers involves testing against a standard anvil at extremely high rebound numbers compared to those which will be measured on precast concrete tanks. The graph which comes with a rebound hammer typically has the rebound number on the x-axis, the corresponding concrete compressive strength on the left side y-axis and potential error on the right side y-axis, expressed either as "dispersion", a number by which the estimated strength may be in error, or percent error. Expressed as a percentage of the estimated strength, error increases with lower compressive strength readings. At the range of compressive strength typical in precast tank construction, the error of a given reading or set of readings can be as high as 25 percent.

To reduce the amount of error of the rebound hammer test results, a calibration curve may be developed for each rebound hammer at the relatively low range of compressive strength applicable to precast concrete tank construction. To develop such a calibration curve, at least 10 cylinder samples should be constructed using at least 28 MPa (4,000 psi) concrete from a reputable, local concrete plant. The cylinders should

then be laboratory-tested for concrete compressive strength at 3, 5, 7, 10, 14, 21 and 28 days after pouring (enough cylinder samples to test at least two replicates of each sample are recommended). At the same time rebound measurements should be made on the three extra samples and on the samples to be laboratory tested (the rebound hammer should be held horizontally when making a reading). Curing conditions for the lab-tested and rebound hammer-tested cylinder samples must be similar. A calibration curve can then be developed by plotting measured rebound number on the x-axis versus measured concrete strength [which should range from about 10 MPa to 28 MPa (1,500 to 4,000 psi)] on the y-axis. This calibration curve can be used instead of the one provided on the rebound hammer as it should provide a more accurate correlation during the field-testing of concrete tanks.

## WATERTIGHTNESS TESTING OF INSTALLED PRECAST CONCRETE TANKS

Because of the serious problems that may result from infiltration or leakage, no single field test for tanks is more important than the watertightness test. The objective of this test is to assess the entire tank for watertightness, including the concrete structure itself, tank section seams, pipe penetrations and riser connection seams, after it has been installed and all connections have been made.

Either of two tests may be used: 1) static water test, and 2) vacuum test. Under most circumstances, either test should adequately assess the watertightness of a tank. Vacuum testing is generally preferred because it requires a shorter test time, applied forces are equally distributed throughout the inside of the tank (during the static water test, the force on the inside of the tank increases with depth) and it affords an easier, more precise measurement of test results. The major disadvantage of vacuum testing is the somewhat specialized equipment required and the difficulty in sealing off tank access openings.

Regardless of the test employed, a thorough inspection of tank construction and installation are crucial and can often identify potential watertightness problems prior to watertightness testing.

### Static Water Test

#### Recommended procedure.

1. Temporarily seal inlet and outlet pipes.
1. Fill tank with clean water to a point at least one-foot above the pipe connections or the highest seam within the tank or riser, whichever is highest.
1. Allow the tank to sit undisturbed overnight.
1. Refill tank, if necessary, and record *starting water level*.
1. Cover access openings and allow tank to sit undisturbed for at least 24 hours.
1. Remeasure and record *ending water level*.
1. Tank passes watertightness test if the difference between the *starting water level* and *ending water level* is equal to or less than one-half inch or one-percent of the liquid capacity of the tank.

## Vacuum Test

Recommended procedure (refer to Table 4).

1. Temporarily seal inlet and outlet pipes and access openings.
1. Using proper equipment, draw a vacuum to the *starting negative pressure*.
1. Hold vacuum for the specified time and remeasure and record the *ending negative pressure* inside of the tank.
1. Tank passes watertightness test if the difference between the *starting negative pressure* and the *ending negative pressure* is 10 percent, or less.

Table 4. Recommended vacuum testing conditions and criteria

<b>Starting vacuum</b>	<b>Test holding time</b>	<b>Allowable pressure change</b>
8 cm (3 in.) of mercury	One hour	0.8 cm (0.3 in.) of mercury
13 cm (5 in.) of mercury	Ten minutes	1.3 cm (0.5 in.) of mercury
25 cm (10 in.) of mercury	One minute	2.5 cm (1.0 in.) of mercury

## CONCLUSION

Prefabricated septic and pump tanks are critically-important components of on-site wastewater systems. Manufacturing problems are common and contribute to the malfunctioning of on-site wastewater systems by hydraulically overloading the treatment and disposal system due to infiltration, passing solids due to corrosion and disintegration of tank components, contaminating water supply wells due to leakage and presenting safety hazards due to inadequate structural construction.

Guidelines for manufacturers and regulators have been developed to assist in the development of quality control and quality assurance programs in both the public and private sectors. These guidelines, which address prefabricated tank construction, tank inspection, concrete testing and watertightness testing can be used as a starting framework for a nationwide septic and pump tank quality assurance standard.

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