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Bolted steel tanks, HDPE geomembrane linings

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Every third year or so, it seems that a concrete vault or steel tank arrives at our doorstep for rehabilitative lining. The need for new lining may be because of incompatibility between the liquid contained and the container, or because of a leak observed in the container. For information related to the lining of concrete vaults,please refer to recent articles in *GFR* on cast-in liners, (Peggs and Hammer, 1999) and rehabilitation concrete vault lining designed by the author (Steinle and Human, 1993).

Alternative leak repair techniques such as spray-on elastomeric coatings and flexible geomembrane liners are not discussed. This is not to imply that these techniques are not appropriate, but only that space is not available to review them.

Leaking tanks: general

In many ways, bolted steel tanks are like the landfills they frequently serve—they all leak. The engineering challenge then, is to achieve an acceptable level of leakage. Leakage levels are minimized through the use of several basic means:

• Appropriate construction and inspection methods that limit penetrations in the primary tank, and

• Secondary liners or containers equipped with a leak detection system that will not only detect leakage through the primary tank, but also, and more importantly, limit the head acting on the secondary container.

The acceptable level of leakage for a steel tank generally relates to both the value of the liquid contained and its impact on the surrounding environment. Bulk storage steel tanks that contain potable water may be considered acceptable even if the leakage is several hundred gallons per day out of a tank holding more than a million gallons. Such bulk storage tanks are the least expensive tanks and typically have minimal corrosion protection that consists of a two-part epoxy paint finish. This level of performance, however, is not acceptable if the tank contains liquids such as landfill leachate, as in the situation discussed later in this article. For such environmentally sensitive applications, tanks having a glass coating fused to the metal are more commonly used. While more expensive, the glass-lined tanks provide improved corrosion resistance and will typically provide a lower rate of leakage. This article describes leak repair work performed on “bulk” bolted steel tanks installed to store leachate.

Leaking tanks: specific

Three large-capacity bulk bolted-steel leachate storage tanks were constructed at the Delaware County Solid Waste Authority (DCSWA) in Delaware County, Penn. as part of ongoing upgrade of the leachate treatment system. These three tanks had the following dimensions and capacities:

• Effluent storage tanks: tanks T802 and T803 each with an 80-ft diameter, a 32-ft height and a 1.2M gallon capacity,

• Influent storage tank: tank T002 with a 90-ft diameter, a 28-ft height and a 1,302,000 gallon capacity.

All tanks have bolted steel floors, but are installed in secondary containment tanks that have poured concrete floors and bolted steel walls. These secondary containment tanks have sumps that collected all leakage from the primary tank. Rain roofs are installed between the primary tanks and the secondary containment tanks to prevent rainwater from entering the detection system. Such secondary containment systems allow DCSWA to precisely monitor leachate leakage from the primary tanks. **Photo 1** shows the interior wall of the primary containment tanks; note the tank stiffeners and previous sealant application.

Photo 1*: Primary containment tank's interior wall with tank stiffeners and previous sealant applications.*

A complication in tank T802 was the presence of an an effluent aeration/holding tank built inside it. This additional tank, T801, was 10 ft in diameter, 32 ft high, and contained 20,000 gallons. Since these tanks are part of an active leachate treatment system, additional complications were provided by a significant number of pipe penetrations and large manway access ports in all tanks.

The bolted steel tanks were manufactured by Columbia Steel Tank Company, Kansas City, Kan., where they were coated with a Trico bond two-part phenolic epoxy normally warranted for 15 years in potable water applications. The project specifications required all primary tanks to be hydrostatically tested using a full tank of water for a minimum of 24 hours. All tanks underwent an additional "confidence test" that involved draining the tanks after the 24-hour test, refilling them, and then re-running the 24-hour test. The specifications required all leaks to be repaired.

Initial hydrostatic testing of the three primary tanks indicated an acceptable level of leakage, which is interpreted by both DCSWA and state regulators to be approximately 1 gallon per day. However, all tests failed the subsequent "confidence test," indicating that the strain on the tanks during the fill/empty/refill cycles was damaging seals. The initial "excessive" confidence leaks were all less than 100 gallons per day and would probably have been acceptable if the tanks had held potable water.

Columbia provided a tank leak expert, Mr. Sam Washam of Houston, who successfully eliminated leaks from tanks T002 and T803 by tediously retightening all visible seams. He was not, however, able to tighten tanks T801 and T802 sufficiently to satisfy DCSWA or the state. If you will recall, tank T801 was constructed inside T802, so Washam did not have complete access to the bottom of T802. However, the tank within a tank within a tank problem posed by tanks T801 and T802 precluded access to much of the bolted floor. Thus, it was decided that tanks T801 and T802 would require linings to meet performance criteria, so the author was brought in to overview the lining.

Lining alternatives

Initially, three alternative lining systems were evaluated: a sprayed-on polymeric liner, a flexible geomembrane liner and a more rigid HDPE liner. The most promising of the sprayed on polymeric liners appeared to be an asphalt-extended urethane coating provided by CIM Industries Inc. This coating can be rolled-on, squeegeed-on, or spray-applied. It sticks very well to most surfaces. However, its use would have required the removal of a significant amount of sealant applied by Columbia to the interior of T801 in an attempt to stop its leaks. Additionally, there was concern about the ability of the urethane coating to bridge the joint that occurs between the bottoms of T801/T802.

Flexible membrane liners such as PVC and hypalon were investigated, but because of concerns regarding the chemical compatibility of leachate and possible treatment chemicals, no installers were found who were willing to warrantee the repair. Conversely, several HDPE installers felt comfortable with the application and they were willing to warrantee and service the installed liner system. Additionally, installation cost estimates indicated that the HDPE liner was considerably less costly than the sprayed-on elastomeric coating. Based on this, EnviroCon Systems Inc., Houston, Texas, was selected to perform the HDPE liner installation. The resulting liner design is a collaboration between Chris Swires of Envirocon and the author.

HDPE liner considerations

The liner selected for this application was an 80-mil conductive sheet with a co-extruded white surface manufactured by GSE. It was selected because the white coating allows better visual identification of sheet damage than black coating because the conductive properties are useful in locating very minor leaks. Since Envirocon was required to warrantee the liner against all leaks, this was essential.

On the vertical walls of T802, only smooth bolt heads were exposed. This allowed the HDPE liner system to be placed directly against the steel plates. A batten strip bolted through the tank supports the top of the HDPE. Additionally, the HDPE is bolted to the steel side plates at less than 10-ft spacing, as shown in **Photo 2**. The bolts attaching the HDPE to the steel side walls are both provided with plastic washers and cap-stripped to eliminate possible leakage.

Photo 2: HDPE bolted to steel side plates. Attaching bolts have plastic washers and are cap-stripped to eliminate leakage.

Unfortunately, the bottom of tank T802 was penetrated by thousands of bolts which had the sharp, threaded end of the bolt pointed up. Some form of cushion was required to protect the HDPE from these bolts. It was decided to use a cast-in-place concrete slab to cover the bolts on the bottoms of the tank and dense foam (trade name, Ethafoam) to cover similar bolts on vertical surfaces. The floor of T802 was therefore covered with a 3-in. concrete slab, a geonet leak detection system, and finally the HDPE liner system. Note that the presence of the geonet immediately below the liner means that a minor leakage through the liner may not trigger a regulatory response. If liquids are removed before they get to the leak detection system below tank T802, the system remains compliant. The HDPE floor liner was bolted to the concrete slab immediately adjacent to the vertical walls of both tanks.

Connection of the HDPE covering the floor of the tank to that covering the side walls was made by folding the side wall HDPE 90E and using a single extrusion weld. Originally a factory-formed 90E HDPE angle was going to be used for this connection to eliminate field bending of the sheet. However, testing of "creased" samples by Grace Hsuan of the Geosynthetic Research Institute (GRI), Philadelphia, Penn., and Rich Lacey of Geotechnics showed that the crease had very little impact on the yield or break properties of the sheet. The use of the field "crease" eliminated the second extrusion weld, which was of greater concern than the crease.

Pipe penetrations proved to be particularly difficult, because pipes serving T801 must penetrate three lining systems: T802 liner on the interior walls, T802 liner on the exterior of T801, and the interior T801 liner. Pipes entering T801 would require three boots. The pipes serving T802 penetrated only the liner system placed on the interior of T802. Initially, all pipe penetrations were made using conventional field- fabricated boots. In order to install boots for pipes T801, the boots had to be split, therefore requiring an additional seam in the pipe direction as shown in **Photo 3**.

***Photo 3**: Split boots for tank T801, showing the additional seam required for the installation.*

Tank T801 had been built with the rounded ends of the head bolts inside it, so the exterior of the tank had to be wrapped with dense foam to protect the HDPE liner from the threaded bolt ends. This foam was held in place with steel bands. The foam had to be dense enough to ensure that it did not compress significantly under the hydrostatic forces experienced during operations. Foam compression could cause failure because the HDPE sheet might be punctured by the bolts. Alternately, the seams between the floor and wall liners or the seams between the pipe boots and the liner might tear. Fortunately, only the exterior of the small tank required the use of foam cushion.

Liner Testing

Prior to hydrostatic testing on the liner system, EnviroCon performed an electrical survey using the conductive properties of the GSE HDPE sheet to locate minor defects in the sheet or welds. Additionally, they applied a vacuum between the HDPE liner and the respective tank surface. Very minor leaks were detected by a "hissing" sound and the vacuum drew in the foam similarly to how the leachate hydrostatic pressure would in service. This allowed a visual inspection of the flex in all pipe connections and in the seam between the floor and the vertical walls.

Final 24-hour hydrostatic testing was performed without detectable leakage in either the geonet immediately beneath the liner or in the collector beneath tank T802. During the subsequent "confidence testing," minor leakage was observed, as indicated by flow into the geonet collection system.

Concern immediately focused on the boot connections securing all of the pipe penetrations, particularly those that were placed over the Ethafoam on tank T801. The pipes going to the small interior tank were replaced with HDPE pipes using an HDPE/steel transition fitting. This allowed elimination of the longitudinal boot seam and direct welding of the boot to the pipe. With this change made, the HDPE liner passed the confidence test.

Summary

The successful lining of these two tanks came only after extensive meetings between the contractor (Robert Lazarchich of Terre Hill Concrete Products, Terre Hill, Pa.), the owner (Joseph Sebzda of DCSWA), and the tank manufacturer (Don Wagner of Columbia Steel Tank Co.). Their cooperation allowed Chris Swires of EnviroCon, John Gardner, GNRA (G. N. Richardson and Associates), Raleigh, N.C. and the author to focus upon a technical solution.

The final cost for the lining system was approximately $100,000, with only limited delay to DCSWA (compared to the previous time spent trying to "tighten" the bolted tanks). It was a pleasure to do interesting work for good people.

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