Geomembrane containers for storage of liquids

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ABSTRACT: Liquids are increasingly being stored in large geomembrane containers. These liquids may be water, wastewater derived from municipal, industrial and agricultural processes, or hazardous liquids. The cost of building geomembrane containers, or geotanks, is very much cheaper than a similar sized tank made of concrete or steel. This paper describes some design and construction aspects of geomembrane containers for the storage of liquid, and presents two case histories. A brief cost comparison is presented and the future potential of these structures due to environmental awareness and carbon credits is described.

1 INTRODUCTION

Geomembranes have been used for some years to form large containers for the storage of a variety of liquids; such as water, municipal and industrial wastewater, and agricultural processing wastewater (Sadlier & Taylor, 2002 and Frobel & Sadlier, 2009). More recently, geomembrane containers have been used to store hazardous liquids for mining applications.

Typically, a geomembrane container is formed by constructing an earth bund around the sides of the container, lining the bottom of the container with a geomembrane and then floating a geomembrane cover over the top of the contained liquid. The size of the containers, or geotanks as they are sometimes called, is typically about 1 hectare in area with a depth of about 5 metres. They typically store about 50,000 m^3, or 50 megalitres, of liquid. Large geomembrane containers have been formed with areas of 10 to 30 hectares, storing about 1,000,000 m^3, or 1 gigalitre, of liquid.

The cost of building geomembrane containers is very much cheaper than a similar sized storage tank made of concrete or steel. This is leading to the storage of more valuable, and also more hazardous, liquids in this way. This paper describes some design and construction aspects of geomembrane containers for the storage of liquid.

2 CONTAINER COMPONENTS

The sides of the container are usually formed by constructing earth bunds, although sometimes the sides are formed with reinforced concrete retaining walls. The bottom liner and the top cover of the container are then formed with geomembranes.

2.1 *Side Walls*

Earth bunds are easier and cheaper to construct than concrete retaining walls. Also, it is often easier to install the liner and the floating cover on a sloping earth bund rather than a vertical retaining wall.

2.2 *Liner*

The liner can be designed along much the same principles as for solid waste landfill liners. If leak detection is required, then two geomembrane liners can be installed, with a geonet leak detection layer in between. However, the design head of liquid will be more than for a landfill, probably requiring a higher performance geonet and possibly supplementary pipes.

2.3 *Floating Cover*

The design of a floating cover is quite challenging. The geomembrane has to be shaped so that it can accommodate the change in surface area of the liquid, as it rises and falls. This allowance in shape must take into account the full range of levels between when the container is full of liquid and also when it is emptied for maintenance.

The cover needs to incorporate correctly designed ballast and floats to keep it in place as the contained liquid rises and falls. It will also require walkways, for man access, inspection hatches and gas vents. In some situations, the top cover may comprise two layers of geomembrane with an insulation layer in between.

Depending on the intended in-situ treatment of the contained liquid, the floating cover may need to contain escaping gases or allow them to escape in a controlled manner.

2.4 *Treatment of Contained Liquid*

Because the liner and cover exclude air, the contained liquid is usually treated using a self propagating anaerobic process. An anaerobic process usually generates gas such as methane, which can then be harvested for its fuel value.

If aerobic treatment is desired then this is often performed with surface aerators outside of the covered portion of the container. Aerobic treatment under the cover is theoretically possible by injection of air in conjunction with a system to extract the resultant gas.

2.5 *Pipes, Pumps and Instrumentation*

Pipes and pumps are designed and installed to facilitate filling and emptying the container, the abstraction of leak detection fluids, and the removal of rainwater from the floating cover.

Instrumentation is required to measure the quantity of stored liquid, and to automatically switch pumps on and off. In the case of hazardous stored liquid, it is advisable to install instrumentation to prevent over filling of the container.

3 GEOMEMBRANE MATERIAL TYPE

Typically, the base of these containers is lined with a high density polyethylene (HDPE) geomembrane. Sometimes, they are lined with a geosynthetic clay liner (GCL) covered with soil, and occasionally a composite liner comprising a GCL under a HDPE geomembrane.

Several types of polymeric geomembranes have been used for the cover systems. The cover system is required to sustain dynamic movement and flexural fatigue caused by varying fluid levels, wind uplift, edge restraint, gas pressures, temperature changes, and maintenance. Additionally, the cover must be durable in the presence of the chemicals in the contained fluid and ultra-violet (UV) light.

With these different design situations, cover systems have been constructed with both reinforced and unreinforced HDPE, LLDPE, chlorosulphonated polyethylene (CSPE), metallised polyethylene (MPE), ethylene propylene diene monomer (EPDM), polypropylene (PP), ethylene interpolymer alloy (EIA), and composite combinations of these materials.

The more durable cover systems are based on polyethylene materials, but most cover situations will not allow the use of HDPE for the whole cover because it is too stiff. One option is to construct the whole cover in a flexible reinforced PP, EPDM or EIA. Another option is to use a hybrid of more flexible materials, such as LLDPE or reinforced MPE, placed in the flex zones of an HDPE cover. This hybrid cover gives the stiffness and security of an HDPE cover with flexible zones where they are required.

4 CASE HISTORIES

Two case histories are presented to illustrate the different types of container for different stored liquids. One is for the storage of a wastewater and the other is for the storage of a hazardous liquid.

4.1 *Storage of Wastewater*

In this case the contained liquid was a combined stream of municipal and industrial wastewater. Five plants were built with each comprising two geomembrane containers for anaerobic processing. They are situated in areas of high groundwater table, and extensive dewatering was deployed to construct the base liner; comprising a GCL covered with concrete.

The floating covers (fig. 1) were then built in the partially filled lagoons, using a combination of HDPE and LLDPE geomembranes as well as a special highly flexible metallised polyethylene (MPE) material with a woven scrim reinforcement.

The cover design incorporated a primary ballast and float system to control the cover shape and movement, a secondary ballasting system for gas control and a secondary floatation system under the cover to provide gas release paths and facilitate gas harvesting.

Figure 1. Wastewater container cover system.

4.2 *Storage of Caustic Soda*

Geomembrane containers, or geotanks, have been used to store caustic soda for the mining industry. In one location, four geotanks have been constructed on an area of reclaimed land over a mangrove swamp, near a coral reef, for the storage of caustic soda being unloaded from ships. For environmental reasons, the prevention of leakage from the geotanks was essential.

The rectangular geotanks were constructed with earth bunds around all four sides, with geomembrane base liners and floating covers. Each geotank was about 150 m long by 60 m wide by 4.5 metres deep, giving a total storage capacity of about 160,000 m^3, or 160 megalitres.

The earth bunds were formed on the surface of the reclaimed land with traditional earth moving equipment. The base liner and floating cover system were constructed inside the earth bunds.

The environmental security concerns led to the adoption of a substantial lining system, with a GCL placed on the reclamation and earth bunds, overlain with two HDPE geomembrane liners, with a geocomposite leak detection layer in between (fig. 2).

Figure 2. Construction of geotank base liner.

Figure 3. Construction of geotank cover system.

The floating cover, built in the empty lagoons, comprised two layers of HDPE geomembrane with a foam insulation layer in between. Walkways, handrails and inspection hatches have been provided for maintenance personnel access, and gas vents and rainwater extraction troughs have been constructed (fig. 3).

Extensive quality assurance (QA) and quality control (QC) measures were employed during both the manufacture of the geomembranes and the construction of the geotanks. A hydrostatic test was carried out with water in each geotank before putting them into service.

The oldest of these geotanks has now been in service for five years and it has performed very well, as have the younger three. A little maintenance was required to remove some light vegetation growing in the rainwater extraction troughs on the cover (fig. 4), but the tank has already exceeded its design life based on capital cost return.

Figure 4. Caustic soda geotank in service.

5 COST COMPARISON

5.1 The municipal and industrial wastewater geomembrane containers were constructed as cheaper alternatives to traditional concrete tanks, for one quarter of the cost.

5.2 The caustic soda geomembrane containers were constructed as cheaper alternatives to traditional steel tanks on piled foundations. These geotanks are flexible and they required no foundations to deal with the settlement of the soft marine clays under the reclamation. In comparison, traditional tall steel tanks require a firm foundation of deep piles with concrete pads. Each geotank was constructed for one seventh of the cost of a steel tank. In order to be cost effective, they need to remain in service for only four years. The oldest of these geotanks has already been successfully in service for 5 years.

6 FUTURE POTENTIAL

There is considerable future potential for the use of geomembrane containers to store valuable liquids at a cheaper cost than traditional tank material alternatives, and also to harvest gases from some of the contained liquids for conversion into energy.

Candidates for these opportunities include high organic wastewater producing enterprises such as piggeries and abattoirs, breweries, palm oil, starch and other foodstuff producers.

Under the umbrella of the Kyoto Protocol and the United Nations Framework on Climate Change (UNFCC) a number of methods have developed that allow funding of greenhouse gas friendly projects under Clean Development Mechanisms (CDM). These mechanisms allow gas harvesting projects to be implemented with funding provided as carbon credits.

A typical small pig farm with 1,000 breeding pigs will produce about 200 megalitres of high organic content wastewater per year. In the anaerobic conditions inside a geomembrane container this will produce about 400 megalitres of gas per year, with a carbon dioxide equivalent in excess of 3,000 tonnes per year. The typical return period on investment based on power generation from the gas would be about 10 years, which with carbon credits can be reduced to about 5 years.

7 CONCLUSIONS

Geomembrane containers have been successfully used to store liquids, such as water, wastewater and hazardous liquids, in a variety of situations.

They can be considerably cheaper to construct than traditional steel or concrete tank alternatives.

With increasing harvesting of gases generated from agricultural processing wastewaters, driven by climate change considerations and carbon credits, there is a large future potential for these geotank structures.

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