DEWATERING OF DREDGED MATERIAL USING GEOTEXTILE TUBES

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Moninder (Witty) Bindra is the General Manager for Permathene Pty, Ltd., Australia. He has 13 years experience in geosynthetics and contributes articles for the various publications in Asia—Pacific region. He obtained B.E. in Civil Engineering in 1989, M.Tech in Soil Mechanics and Foundation Engineering from the Indian Institute of Technology, Delhi in 1993 and M.B.A. from Massey University, New Zealand in 2002. In 1995, he was awarded the Confederation of British Industry (CBI) Overseas Scholarship in the field of geosynthetics. He has developed numerous erosion control plans for reclamation and development projects in this region.

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ABSTRACT

The ability of geotextiles to retain solids while passing liquid has led to their use in dewatering fine-grained materials. Fine-grained materials such as dredged material from waterways, lagoon sediment or industrial waste products tend to have long and inefficient dewatering periods when allowed to dry by simply leaving the surface open to the atmosphere (Gaffney, Martin, Mahir, and Bennert, 1999).

When fabricated into a tube, geotextiles act to contain the material and provide faster dewatering due to several factors. The objective of this paper is to provide information about the usage of geotextile tubes to dewater contaminated sediments. This new and innovative technology has been successfully used to dewater fine-grained, contaminated dredged material. This is the first successful use of geotextile tubes for dewatering contaminated sediment in Victoria, Australia. This concept of containing contaminated sediments has proven to be construction-practical, technically and economically feasible and environmentally acceptable.

Key words: geotextile tubes; dewatering; consolidation; contaminated material; drainage

INTRODUCTION

Geotextiles have been used during the last 30 years for applications such as sandbags, concrete forms, large soil and aggregate filled bags, hydraulically filled tubes, and mechanically filled containers (Sprague et al., 1998). This paper is an overview of one innovative system used to contain and dewater high water content materials through the use of geotextile tubes.

The geotextile tube uses a predominately passive method of dewatering, although if needed the high water content material can be subjected to mechanical dewatering techniques while contained within the geotextile tube. The geotextile tube works in an indirect form compared to most other dewatering methods because the high water content material is surrounded and encapsulated by the filtration system.

Remediation of the lake in the Rippon Lea Estate in Victoria is a part of the National Trust of Australia

(NTA) Site Remediation Action Plan. The long-term goals of the action plan are to identify contaminated NTA sites, investigate and, if necessary, remediate them within a 40-year period. Several hundred of these sites involve contaminated sediments. Without remedial action the sediments/sludge would cause problems for many decades. The Rippon Lea Estate lake contained approx. 150 m³ of sludge and the size of the lake is 2–3 acres x 1.2 m deep. Several investigations and studies were carried out to determine how and under what limitations clean up could be performed.

An alternative remediation method was selected that involved vacuum dredging and dewatering the sludge using high strength geotextile tubes as filters. The need for improved dewatering technology stems from the basic premise that saturated, fine-grained materials typically bulky, have little or no value in their saturated state, and do not dewater efficiently on their own. Once dewatered the dredged material was to be disposed of in a landfill.

PROJECT DESCRIPTION

Project Design

The concepts to design large, dredged material filled geotextile tubes and containers are not well documented in the industry. In addition to above, geotextile property requirements are not well understood and few details have been reported on the operation of dredging equipment or the performance of various types of dredged materials. In spite of above, installations based upon "reasoned" design techniques have proven to be quite successful. Therefore, these techniques are a starting point to develop more thoroughly researched design approaches (Sprague, Bradley, Toups, and Trainer, 1998).

The geotextile envelope provides fill retention and the structural integrity of a dredged material-filled geotextile tube. For this project, the computer program (GeoCops 2.0) was used to determine the fabric strength and geometry of the geotextile tube. Fabric selection was also based on both opening characteristics, which approximately matched the fill particle size and permeability, and strength, which was sufficient to resist filling pressures. The various computer data and results are in Tables 1–4.

Dredged material-filled geotextile tubes can be filled with any material capable of being transported hydraulically. Clayey and silty dredged materials have been used for containment dike applications, but naturally occurring beach or river sand is the best choice. The engineer should assess the fill material's settling characteristics to help determine the appropriate spacing and frequency of injection and relief ports in the geotextile tube.

Table 1. Computer Input Data.

1. Circumference of tube	4.57 [m]
2. Unit weight of lower layer of slurry	12.00 [KN/m³]
3. Unit weight of upper layer of slurry	12.00 [KN/m³]
4. Unit weight of fluid outside tube, lower layer	10.00 [KN/m³]
5. Unit weight of fluid outside tube, upper layer	0.00 [KN/m³]
6. Specified height of lower layer of slurry, Hin-L	1.0 [m]
7. Specified height of outside lower fluid, Hout-L	0.0 [m]

Table 2. Geosynthetic Design Parameters.

1. Reduction factor for installation damage, RFid	1.30
2. Reduction factor for durability, RFd	1.00
3. Reduction factor for creep, RFc	1.50
4. Reduction factor for seam strength, RFss, in tube's: Axial (longitudinal) direction Circumferential direction	 2.00 2.00
5. Geosynthetic with ULTIMATE strength of 70.00 [kN/m] was specified.	

Table 3. Computer Program Results.

1. Results correspond to a circumference of tube of 4.6 [m] and ultimate geosynthetic strength of 70 [kN/m].	
2. Geosynthetic in CIRCUMFERENTIAL direction: Tensile force at WORKING conditions Required ULTIMATE strength	 18 [kN/m] 70 [kN/m]
3. Geosynthetic in AXIAL direction: Tensile force at WORKING conditions Required ULTIMATE strength	 10 [kN/m] 40 [kN/m]
4. Maximum height of tube, H	1.3 [m]
5. Maximum width of tube, W (Max. width is at height 0.5 [m] from base)	1.6 [m]
6. Ratio H/W	0.795
7. Width of base of tube resting on foundation soil	0.6 [m]
8. Cross-sectional area of lower layer of slurry	1.4 [m²]
9. Cross-sectional area of upper layer of slurry	0.2 [m²]
10. Total storage capacity of tube per unit length	1.6 [m³/m]
11. Net pumping pressure within tube at inlet	20.9 [kPa]

Table 4. Consolidated Geotextile Tube.

1. Unit weight of consolidated (saturated) fill	12.2 [kN/m³]
2. Consolidated cross-section area	1.5 [m²]
3. Final height, H	0.9 [m]

Using the on-site slurry, one can evaluate whether the selected geotextile material will not clog. This performance feature can be determined using ASTM D 5101-90 (Standard Test Method for Measuring the Soil-Geotextile System Clogging Potential by the Gradient Ratio). Typically, clogging should not be a problem if the AOS criteria were used in selecting a type of geotextile. If, however, the slurry will result in a biological activity on the geotextile, the clogging potential then can be evaluated using ASTM D 1987-91 (Standard Test Method for Biological Clogging of Geotextile or Soil/Geotextile Filters). Biological activity is typically a long-term concern whereas the filtration capacity in a tube is usually a short-term (a few months) issue (GeoCops 2.0, 1999).

A filled geotextile tube's cross-section is circular on the edges and flattened on top. Field experience demonstrates that it is possible to fill tubes 70 to 80 percent of the theoretical maximum circular diameter, though 50 to 60 percent is more commonly accomplished. To achieve stability under severe hydraulic conditions like drag, lift and inertia, achieving a relatively high unit weight for a filled unit is essential. The scour apron could be made from the impervious lining material for the municipal dewatering and desludging applications where there is no current or wave action destabilizing the structure.

Dewatering System

In the project under review, a work area was set up off site in the Australian Broadcast Corporation car park nearby. Deployment of both the scour apron and the geotextile tubes were accomplished by unrolling them off a core, supplied with the tubes and apron by the manufacturer. The scour apron was deployed before the geotextile tubes, as it was not attached to the bottom of the geotextile tubes at the fabrication facility. Once the scour apron was fully deployed, positioned and secured, the geotextile tubes were unrolled. They were unrolled into position with the injection and relief ports facing upwards along the top centreline. Once deployed, they were secured to the previously installed alignment stakes/anchors.

The dewatering system consisted of two geotextile tubes; 20 m long and 1.4 m diameter, each fabricated from a high strength woven geotextile. This product has sufficient tensile strength to withstand the stresses associated with pumping. The fabric opening size may seem large when compared to the grain size of the dredged material, and might lead to the question of how efficient retention of solids could occur. The answer partly lies in the fact that a filter cake forms on the inside of the fabric shell, thus creating the equivalent of a two-stage filter. Filtration efficiencies above 98% are not uncommon for fine-grained dredge materials filtered through high strength woven geotextile tubes.

After several fillings, the tube was filled to capacity and allowed to dewater. In an effort to improve the dewatering rate and effluent cleanliness, a small amount of polymer was added to the pump discharge line prior to the sludge entering the geotextile tube. A standard polymer mixture and a dosing unit were used to pump polymer into the discharge line. The small incremental cost of polymer addition may be economically viable since the effluent will be cleaner, the tubes will release water faster, and consolidation will occur sooner (Gaffney, 2001).

The dredged material was pumped into the tubes using a trash pump through a 150 mm discharge line. The water percolated out through the fabric, leaving dense sludge/sediments in the tube. The tubes were pumped until full, reaching heights of 0.8–1.0 m and widths of 1.4–1.6 m on completion. A 20 m long tube contained nearly 25 m^3 of dry sludge material. Total Suspended Solids (TSS) was measured as low as 4 mg/L. Prior to filling the tube, the dewatering area was lined with a lining membrane to prevent local erosion and to collect all the effluent, which was released from the tube.

GEOTEXTILE TUBES

Manufacturing of Tubes

The geotextile tubes are manufactured as per standard ASTM guidelines at the fabrication facility in New Zealand. Before the geotextile tubes and scour aprons are deployed on site, the area is usually prepared using common grading equipment. The location in which the geotextile tubes are to be placed is usually marked off with grade stakes. If required, large stakes or anchors can also be used at predetermined spacing so that the geotextile tube can be fastened to them with straps to assure proper alignment during filling.

Most geotextile tubes will contain several injection ports throughout the length of the tube. The ports are usually located at the top centreline at a spacing of no more than 15 m. These ports are employed for filling and also for relief of excess water. The contractor and/or the engineer, prior to the fabrication of the geotextile tube, must make a determination of the port spacing. Several factors will influence the appropriate spacing, such as overall size of the geotextile tube, size of the dredge pipe, discharge volume of the dredge, type of fill material, and amount of water to be used as a vehicle for transporting the solids. There were two fill ports 10 m apart each, designed for the tubes in this project.

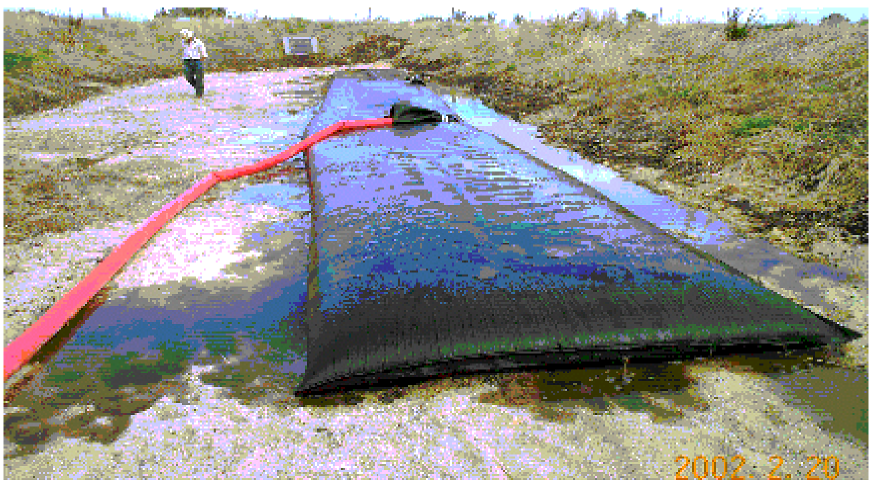
Depending upon the spacing of the injection ports, the composition of the dredged material, and the capabilities of the dredge, some of the injection ports will not be used at all. For example, a 60 m long geotextile tube may contain five injection ports. If the conditions are ideal and the dredge is capable, it is likely that the entire 60 m long geotextile tube could be filled from one injection port located near one end of the tube. The injection port located the farthest away would be left open to allow the expulsion of excess water, acting as a relief port. All of the ports in between would be tied off and left unused. If conditions are not ideal for filling from one port, then the correct intervals in which to move the dredge pipe to continue filling the tube must be determined. Filling operations are performed sequentially by using one port for injection and one (or more) port(s) for relief. As the operation progresses, all ports in completed segments of the tube should be closed to prevent loss of materials from within the tube.

Filling Operations

A pontoon with dredging equipment was designed, constructed and installed in the lake. The dredging equipment system was commissioned and pumps were altered to ensure the most appropriate flow rate of sludge/water mixture was achieved. A flexible pipeline was installed from the dredging unit to the temporary dewatering area and from there to the mobile wastewater treatment unit.

This process takes much longer and is much more complex than simply filling the small geotextile bag or anchor tubes. The dredging equipment was used to fill the geotextile tubes. The discharge pipe (or injection nozzle) of the dredge was placed inside the appropriate injection port of the geotextile tube. The injection ports were fabricated of the same geotextile that made up the tube itself. The ports were 1.0 m long

Photograph 1. Pontoon with dredging equipment.



Photograph 2. Filling operation of the geotextile tube.

and 300 mm in diameter, however, the dredge pipe had only 150 mm diameter. Typically 200 mm to 300 mm diameter dredge pipe are commonly used for this application.

The pipe was inserted approximately 2/3 of the way into the injection port and secured with tension strapping. It was made sure that the pumping pressure does not exceed the net pumping pressure within tube at inlet for this project. At low pressures, a small increase in pumping pressure will result in significant increase in height h. However, beyond a certain value (say, 35 kPa), the increase in height is insignificant (i.e., the tube's section approaches a circle) while the increase in required strength of geotextile is exponential. It should be noted that the pump pressure in a typical dredge line is quite high (300 kPa and more). Without an adequate field control, the pumping pressure may build up toward that of the pump and consequently, can rupture the encapsulating geotextile tube. Hence, to reduce the risk of excessive pumping pressure, a strict control of pressure at the tube's inlet is essential (Leshchinsky, Ling and Gilbert, 1996).

The discharge nozzle and injection port were secured with tension strapping. The discharge nozzle and injection port connection was elevated to a vertical position with a backhoe. The excess water from dewatering system was pumped through the mobile wastewater treatment plant unit and returned to the lake as treated water.

Dewatering and Consolidation

Dewatering and consolidation in the geotextile tube reduced the volume of the dredged material by a factor of 7 to 8 within 2–4 weeks of filling the tube. Thus, 450 m^3 of material was initially dredged and approximately 45–60 m^3 placed at the final disposal site along with the geotextile tubes. The dredged material was highly cohesive and had a high organic content. This stage of desludging was carried out on a small trial section of the lake and it is expected that greater productivity can be achieved in a larger section of the lake. The ideal process rate for the treatment is between 3–5 m^3 per hour.

Photograph 3. Geotextile tube being dewatered.

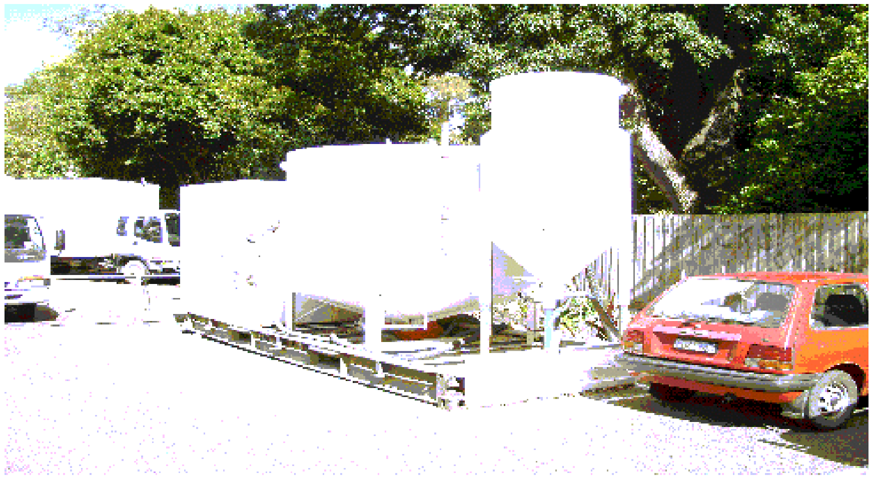
Upon completion of this dewatering operation, the injection ports were secured properly to ensure that they do not become torn with time. The injection ports were secured while allowing enough excess fabric to roll (or fold down) flush to the top surface of the tube. The folded material was then fastened to the tube surface by the use of corrosion resistant compression type fittings.

Filled and closed geotextile tubes continued to dewater and further consolidate the solids for some time. The duration of the dewatering and consolidation period always varies depending upon the type of geotextile and fill material. Typically, coarse material will dewater much faster than fine material such as silty clay. Once the expected amount of dewatering had taken place, the geotextile tube was backfilled and left on the site.

Waste Water Treatment System

The excess water from dewatering system was pumped through the mobile wastewater treatment plant and returned to the lake as treated water. This unit is also known as a Centrifugal Flow Separator (CFS) which is a highly efficient sedimentation/clarification unit forming the base system in plant design. In this unit, liquids to be treated are introduced tangentially into a cylindrical vessel fitted with a cone bottom.

The vessel is designed to control the flow of liquid around its outer wall in a spiral flow. The complex vortex flow patters induced into the flow by the special lid and head frame design cause suspended particles to rotate on their axis optimizing the effect of gravity, so that solid matter rapidly passes to the bottom of the vessel to be continuously discharged as a slurry into a



Photograph 4. Mobile wastewater treatment unit.

sludge thickening tank. Clarified liquid leaves the system from the centre of the top of the separator with any floating matter being held behind a collar.

The system works very efficiently under a hydraulic head of 1 metre or less. The separator is not a hydro cyclone or a centrifuge. When compared with a traditional sedimentation unit the centrifugal flow separator performs better than a traditional plant whilst occupying as little as 20% of the area.

Normal operation results in 95% of the liquid leaving the unit as cleaned flow with the remaining 5% continuously discharging to the sludge thickener. After passing through the thickener the supernatant is returned to the inlet of the system and sludge of around 6% solids is obtained. The duration of the CFS treatment at primary stages with appropriate chemistry package is approximately 2 hours, i.e., before the onset of septicity. This stage removed the following from the effluent:

1. Phosphorous up to 100%
2. Reduce BOD by a minimum 50% and maximum 60%
3. Suspended solids by 90% (minimum) and 98% (maximum)
4. Sulphides by minimum 25%
5. Ammonia by minimum 5%

(*Courtesy: Green Waste Environmental Engineering Pty, Ltd., Australia.*)

CONCLUSIONS

It was concluded that the geotextile tubes were capable of retaining the fine-grained particles. These materials responded similarly to the fine-grained sewage sludge. It was shown that the geotextiles are capable of filtering the contaminated sediments so that the effluent water passing through the fabrics will meet council regulations. It was also concluded that this new and innovative technology is capable of competing economically with other alternative dewatering techniques. This technique is passive and does not require extensive or constant labor and maintenance of equipment.

The project was very successful with geotextile tubes providing a cost-effective solution to a very difficult dredging project. The tubes dewatered the material at a greatly accelerated rate when compared to open-air retention, and eliminated safety issues inherent with disposal pits. The desludging provided a significant increase in the storage volume of the lake to allow for reticulation of the Rippon Lea Estate gardens. This new system provided significant savings and only two tubes were needed for a two-month operation.

Although dredge-filled geotextile tube technology has been used for many years, recent high profile projects have brought attention to the industry. By collaborating with the GRI to document an industry standard specification, the methodology has gained further credibility. The technology and the industry are still young, but newer and better protocols are being realized on a daily basis. The future certainly looks bright for dredge-filled geotextile tubes.

RECOMMENDATIONS

It is recommended that additives such as polymers (flocculents, coagulants or precipitants), fly ash or highly oxidized water, etc., be added during consolidation in the geotextile tubes to achieve rapid dewatering and a greater bacterial reduction (Fowler, Bagby and Trainer, 1996). One alternative is to do nothing and let the dewatered sediments or sludge stabilize naturally in the tube. It is recommended that small to medium size water and wastewater plants consider the use of this new and innovative technology for dewatering sludge.

The future of the geotextile tubes and containment systems is not dependent on need, but on adequate design and installation. The need for dewatering high moisture content materials is evident. Worldwide sales of cross flow filtration equipment and membranes will top $4.7 billion in 2000, with reverse osmosis accounting for just under $2 billion in sales as per The McIlvaine Company in Illinois, USA (http://www.mcilvainecompany.com/webtofc.html).

With the growing population worldwide, there will be more waste and less space to dispose of it. Traditional methods of waste containment include lagoons that require large amounts of space, increasingly difficult environmental permitting and frequent dredging. Traditional methods of dewatering include capital intensive, often low volume, filtering devices that can be unaffordable to small businesses and farmers.

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