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Dewatering sewage sludge and hazardous sludge with geotextile tubes

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ABSTRACT: Three case histories of using geotubes to dewater sewage sludge and hazardous waste are included in this paper. The first two case histories describe municipal sewage placed in geotextile bags to evaluate the dewatering and consolidation capabilities of large geotextile tubes and effluent water quality. A proposed ASTM test method for determining the flow rate of suspended solids from a geotextile containment system for dredged material was used to conduct tests to determine the efficiency of different combinations of geotextile filters. The quality of pore water or effluent passing through the geotextile container systems proved to be environmentally acceptable for discharge and/or return to the treatment plant. The third case history describes the application of the Dry DREdge™ technology coupled with geotubes in the dredging and dewatering of hazardous sediments. The paper describes the project objectives, the Dry DREdge™ and Geotube technologies, and the results of applying this technique. The Dry DREdge™ was jointly developed and tested by DRE and the U.S Army Corps of Engineers, Waterways Experiment Station (WES), Vicksburg, MS, under the Corps of Engineers Construction Productivity Research Program (CPAR). The results of these case histories indicated a significant reduction in the sludge volume in the geotextile tube.

1 FIRST CASE HISTORY INTRODUCTION

In the first case the United States Environmental Protection Agency and the Mississippi Department of Environmental Quality had restricted the use of many types of waste lagoons such as those operated by municipal drinking water and sewage wastewater treatment facilities. The regulatory agencies had issued orders to restrict the use of these facilities, but had failed to provide an economical solution for future waste disposal. Dewatering applications for fine-grained soil from navigation dredged material maintenance projects and sludge lagoons had been limited. Geotextile containers filled with dredged material offer the advantage of ease of placement and construct-ability, cost effectiveness, minimal impact on the environment, and confidence in containment. In addition to filling with sandy materials, geotextile containers filled with fine-grained maintenance dredged material provide the opportunity for beneficial use, storage, and subsequent consolidation of this material in dike construction and wetland construction. It has been demonstrated that these geotextile containers retain about 100 percent of the fine-grained maintenance dredged material, therefore retaining the contaminants. The purpose of this demonstration test was to evaluate the dewatering and consolidation capabilities of large geotextile tubes for municipal sewage sludge and the water quality of the effluent passing through the geotextile filter fabric. The scope of this paper is to present the results of the laboratory and field tests, to evaluate the filling methods and techniques, and to evaluate the consolidation and dewatering behavior of a geotextile tube filled with sewage sludge.

1.1 *Background and Geotube Case Histories*

Since the late 1980's, several thousand geotextile bags, tubes and containers ranging in sizes from 1 to 3000 cubic meters have been successfully filled with a variety of fill materials in the Netherlands, Germany, France, Japan, Brazil, Australia and the United States and used as submerged stability berms, groins, sill structures for controlling thalweg erosion, scour protection around piers, contraction dikes, dredged material containment and disposal of clean and contaminated materials. For example, geotextile tubes filled hydraulically with fine-grained sand were used extensively on the northern shores of the Netherlands for barrier dikes for subsequent hydraulic fill behind the dikes (Krystian 1994).

In 1992, the U. S. Army Corps of Engineers (USACE) demonstrated that geotextile tubes 4.6 m (15 ft) wide and 152 m (500 ft) long and 1.5 m (5 ft) high could be filled with fine-grained dredged material for potential use by the Corps of Engineers for dike construction and wetland creation at Gaillard Island Dredged Material Disposal Island, Mobile, AL. Vegetation growth through containers was very promising; natural propagation occurred after the tubes were filled and the material began to consolidate. The dredged material, at an initial wet bulk density of 1.3 g/ml in the geotubes, consolidated 70% from an initial height of about 1.2 m (48 in.) to about 0.4 m (15 in.) in about two months.

Geotextile containers, which are dumped either from dump trucks or split hull, bottom dump hopper barges, have been used successfully to construct underwater stability berms, closures for repair of breached dikes, groins, and thalweg scour protection. (Duarte *et al.* 1995) These containers have been hydraulically and mechanically filled inside split hull, bottom dump hopper barges, moored in place, and dumped. Design concepts for material tensile strength, seaming requirements, and properties with regard to creep, abrasion, ultraviolet protection, tear, and puncture were documented under the Construction Productivity Advancement Research program at WES.

1.2 *Sewage Sludge Dewatering Tests*

Geotec Associates and TC Nicolon Corporation have successfully demonstrated that large geotextile bags and geotubes can filter and dewater sewage sludge and retain almost 100 percent of the fine materials. This was achieved in August 1995, when lime and aluminum sulfate wastes from the Eagle Lake and Culkin Water Districts, Vicksburg, Miss., disposal lagoons were placed in two geotextile bags and one geotube (donated by TC

Nicolon Corp.) and closely monitored for filtration and consolidation testing.

The US Environmental Regulatory Agency has required wastewater managers under 40 CFR, Part 503 Regulation and Specific Guidelines, to find other alternatives for dewatering and disposal of sewage sludge, preferably beneficial alternatives, such as combining green waste, fly ash, kiln dust, and/or lime waste and dewatered sewage sludge for land applications. Wastewater managers have been directed to discontinue use of lagoons and submit alternative methods of disposal for approval.

1.2.1 *Bag Test Results*

There was limited control over the percent solids for filling the bags on any given day from the sludge digester. (Figure 1 shows two hanging bags used for the filtration test). However, there did not appear to be much difference in the time of dewatering of the lower or higher percent solids content materials. The higher moisture content sludge material took about 5 days and the lower moisture content materials took about 4 days to achieve about 90 percent consolidation. There also did not appear to be a significant difference in the dewatering capabilities of the non-woven polyester, Bag 1, versus the polypropylene inner liner, Bag 2. The percent solids, moisture content and wet density approached approximately the same density in about the same amount of time regardless of the initial sludge properties. After a soil filter cake built up on the fabric, the total percent suspended solids (TSS) for both bags stabilized. The initial percent solids in Bags 1 and 2 was 6.6 to 14.9%. The maximum percent solids increase for Bags and 1 and 2 was 31% and 33%, for 128 and 132 days, respectively. The TSS passing through the non-woven polyester geotextile fabrics, Bag 1, performed slightly better than the non-polypropylene fabrics, Bag 2. TSS for effluent water passing through the polyester fabric was less than 26 mg/l after 11 minutes of drainage and consolidation time. Bacterial fecal coliform count decreased to less than 100,000 colonies per 100 ml or to a class A material in less than 29 minutes. These tests are non-conclusive and it is recommended that a battery of tests be conducted under a more controlled environment.

Figure 1. Hanging bag filtration test.

1.2.2 *Heavy Metal Tests*

Heavy metal content tests were conducted on the effluent water samples passing through the inner liner and outer fabrics for Bag 1 (polyester non-woven inner liner) and Bag 2 (polypropylene non-woven inner liner). The results of these tests indicated that arsenic was 1.4 to 1.52 mg/l in the un-filtered sludge and was 0.008 mg/l to non-detect (ND) after passing through the geobag fabrics. Chromium was 1.9 to 4.8 mg/l in the un-filtered sludge and ND after filtration through the geobag. Nickel was 3.2 to 5.8 mg/l before and 0.13 m/l to ND after passing through the geobag. The detection limits for arsenic, chromium and nickel were 0.005, 0.04 and 0.01 mg/l respectively.

1.3 *Geotube Tests*

The outer bag liner consisted of TC Nicolon Geolon GT 500, which is a woven polypropylene fabric that was initially used in geotube construction. Contractors had problems with failure of these fabrics because they neglected to monitor the inlet pressure during filling. The woven polypropylene fabric had an ultimate wide width tensile strength of 70 kN/m (400 pli) in the warp and weft. The tests were conducted using ASTM D 4595 (ASTM 1986) and ASTM D 4884 (ASTM 1990). The maximum strain was 20 percent in the warp and weft, respectively. The Apparent Opening Size (AOS) was a U. S. Standard sieve number 40-70.

The inner geotube liner consisted of a 5.3 N/m^2 non-woven polypropylene geotextile fabric. The polypropylene inner liner has an average thickness of 185 mils. The average grab tensile strength for the polypropylene was 61 kN/m (350 pli). The purpose of the non-woven fabric was for retention of the fine sludge material. The AOS for the polypropylene non-woven fabric was a US Standard sieve number 100.

The woven polypropylene fabric seams for the geotube was about 44 kN/m (250 pli) in the warp and weft. All seams were "J" seams. Seams consisted of type 401, double lock stitches that were sewn with a double needle, Union Special Model #80200 sewing machine. The machine is capable of sewing two parallel seams about 0.6 cm (0.25 in) apart. The thread was a 2 ply 1000 denier passing through the needles and 9 ply 1000 denier passing through the looper.

1.3.1 *Geotube Data and Analysis*

A 15 cm (6 in.) high wooden frame was constructed to form a box 4.9 m (16 ft) wide and 9.7 m (32 ft) long. The box was lined with a 4-mil thick visqueen liner to contain the effluent water from the geotube. The required pressure, 207 Pa (0.3 psi), to fill the geotube to a height of 1.5 m (5 ft) was determined using a computer program, GEOCOPS. (Figure 2 shows the geotube filled to an height of 5 ft) Using geotechnical consolidation theory and an initial measured percent solids of 8 percent, an assumed specific gravity of 2.5, the wet bulk density was determined to be 1.05 gr/ml. After 32 days, the wet bulk density was 1.13 g/ml and the percent solids was 19.2%. After 65 days, the wet bulk density was 1.27 g/ml, and the percent solids was 21.0%.

Figure 2. Shows the geotube filled to an height of 5 ft

Volume loss and flow rates during the primary self weight consolidation of the sewage sludge in the geotube averaged about 0.06 m^3 (15 gallons) daily. After about 26 days loss rates decrease as the geotube accumulates solids during consolidation (Figure 3). The geotube held about 2 cubic yards per linear foot for a 4.6 m (15 ft) wide tube or approximately 45.4 m^3 (12,000 gal), whereas a 1.2 m (48 in.) circumference bag 1.5 m (5 ft) long only held 0.18 m^3 (48 gallons). The geotube held about 1.5 m^3 (404 gal) of sludge per foot. The results from the bag tests may not be used directly to predict geotube performance.

Figure 3. Geotube after 26 days of consolidation.

Initially, the geotube was 8.0% solids with a height of 1.5 m (60 in.), and the contents settled to 21.4% solids at a height of 0.44 m (17.5 in.) after 65 days of consolidation. The geotube was 0.4 m (15 in.) high after 120 days. Ninety percent consolidation occurred in the geotube in about 26 days versus 4 to 5 days for the geotextile bags. Based on past experience it was estimated that the geotube would subside to about 0.4 m (15 in.) as a result of self-weight consolidation or about 23 percent solids or a reduction of about 75 percent of the initial volume.

1.4 *Conclusions and Recommendations*

It was concluded that the geotextile bags and the geotube were capable of retaining the fine-grained sewage sludge and that these materials respond similarly to the soil characteristics of maintenance dredged material. It was shown that geotextiles are capable of filtering the sludge so that the effluent water passing through the fabrics will meets the 30 mg/l discharge requirements in less than 11 minutes of drainage time. It was also concluded that this new and innovative technology is capable of competing economically with other alternative dewatering techniques for sludges. This technique is passive, and does not require extensive or constant labor and maintenance of equipment. This technique is capable of increasing the percent solids to about 22 to 25 percent in relatively short periods of time. This concept of containing sewage sludge has proven to be construction-practical, technically and economically feasible and environmentally acceptable to other disposal alternatives.

It is recommended that additives such polymers, fly ash, or highly oxidized water etc., be added during or after consolidation in the geotubes to achieve a greater bacterial reduction. One alternative is to do nothing and let the dewatered sludge stabilize naturally in the tube. It is also recommended that small to medium size water and wastewater treatment plants consider the use of this new and innovative technology for dewatering sludge. Transportable geotubes have been developed for 6.1 to 12.2 m (20 to 40 ft) long dump trucks and/or trailers. The geotubes can be loaded onto the trucks after dewatering. Current research is being conducted to further substantiate this research effort with polymers through an actual full-scale project in New Orleans.

This new and innovative technology has been used successfully to dewater fine grained, contaminated dredged material that contained dioxins, PCBs, PAHs, pesticides and heavy metals for the Port Authority of New York and New Jersey, the Miami River Marine Group and the Port of Oakland, CA (Fowler *et al.* 1995). This is the first successful use of geotextile tubes for dewatering sewage sludge for beneficial uses in the United States. Research using this process for dewatering pork and dairy farming waste, paper mill waste, fly ash, mining waste, chemical sludge lagoons and several other waste streams is being conducted at the University of Illinois.

2 SECOND CASE HISTORY INTRODUCTION

The second case history describes the placement of municipal sewage from the Kansas City Sewage treatment plant into geotubes to evaluate the dewatering and consolidation capabilities of large geotextile tubes and effluent water quality.

Enviro-Klean, Inc. conducted one of the largest sewage sludge dewatering projects in the world in 1999 using geotubes for dewatering and consolidating sewage sludge at the Kansas City Municipal Sewage treatment plant. Enviro-Klean has utilized many innovative geotextile concepts for treatment and disposal of municipal wastewater sewage sludge. The sewage sludge was place in large geotubes to dewater and consolidate, to improve effluent water quality, and to pass the paint filter test for landfill disposal. One of the primary purposes of this exercise was to reduce the weight of the sludge, therefore, reducing the cost at the landfill.

2.1 *GEOTUBES*

Nineteen very large geotubes were used to dewater about 1700 cubic meters of digested sewage sludge that had become trapped in one of the sewage digesters. The test results of the sediments indicated significant consolidation and reduction in the water content and volume of the sludge in the geotubes. There was also a significant reduction in the bacterial count in the effluent water. The quality of pore water or effluent passing through the geotextile container systems proved to be environmentally acceptable for subsequent discharge and or return to the sewage treatment plant.

2.2 *GEOTUBE LAYOUT*

Of the nineteen geotubes, ten were 9.1 m in circumference and nine were 13.7 m in circumference. The geotubes were placed on an asphalt parking area that was covered with a 6-mil thick polyethylene liner to collect the effluent water (Figure 4).

The effluent water from the geotubes was returned to the plant for treatment. The geotubes were filled with a 10 cm diameter submergible hydraulic dredge to a height of about 1.7 to 1.8 m (Figure 5). The pump was equipped with water jets to loosen the material. There was a considerable amount of plastic debris, rags, and paper that interfered and slowed dredge production. The geotubes lengths varied from 9.1 to 45.7 m. The storage volumes varied from 5.2 to 9.5 cubic meters per linear meter. The geotubes were allowed to drain to more than half of their initial height and then re-filled 3 to 4 times to maximize their storage capacity.

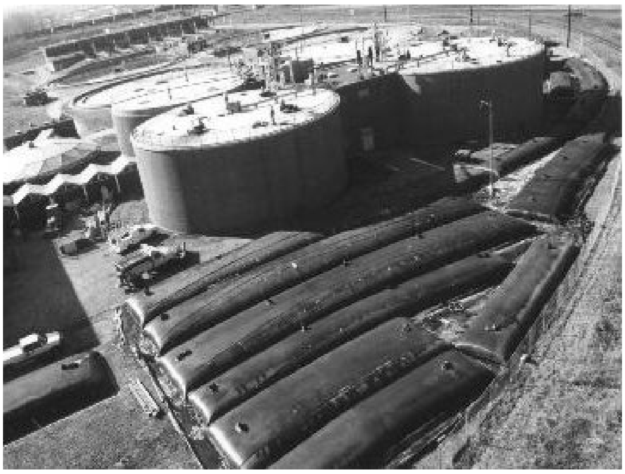

Figure 4. Geotube layout in asphalt parking lot.

Figure 5. Geotubes initially raised to 1.7 to 1.8 m.

2.3 *GEOTUBE SLUDGE PROPERTIES*

The initial average percent solid of the sludge in the digester was 21.9 and the volume was 1700 cubic meters. The initial average percent solid after filling the geotubes was 9.7 and the volume was 2027 cubic meters. The final average percent solids prior to opening the geotubes was about 18.7. The maximum percent solids was 27.2 in the geotube. The initial bulking factor from the digester to the geotubes was 2.43. After drainage, the bulking factor from the digester to the geotubes was 1.2 and further shrinkage occurred after the geotube was opened and exposed to desiccation drying. Desiccation drying caused 5 to 10 cm wide surface cracks about 15 to 30 cm deep and a volume reduction of about 10 percent. The sludge material hauled to the landfill had a bulk density of 1.17 gr/ml and a percent solids of 24.8. The material from the digester that was hauled to the landfill had a bulking factor 1.07. Approximately 1824 cubic meters or 1068 kg of sludge was hauled to the landfill.

2.4 *CONCLUSIONS*

This work has led to research at Clemson University and the University of Georgia using this process for dewatering pork and dairy farming waste. This work also led to geotube dewatering for paper mill waste, fly ash, mining waste, chemical sludge lagoons, and several other waste streams. This innovative dewatering concept is currently being implemented at the New Orleans East Wastewater Treatment Plant. Geotubes are being pumped with aerobically digested sewage sludge and polymers to enhance dewatering in the geotube.

This concept of containing sewage sludge has proven to be construction-practical, technically and economically feasible, and environmentally acceptable. This project was significantly more economical than other dewatering techniques such as belt and plate presses. This work will have a significant impact on solid waste management worldwide.

3 THIRD CASE HISTORY INTRODUCTION

The third case history describes geotubes that were filled with hazardous waste from a settling pond at Catlettsburg, KY. Ashland Inc. had operated a hazardous waste landfill as part of its refinery operations in Catlettsburg, Kentucky since 1976. The landfill is located in Boyd County, Kentucky, approximately 4.8 kilometers south of Catlettsburg, Kentucky. In September 1998, the Kentucky Division of Waste Management was notified that the 8.1 hectares, head of hollow, single cell landfill would be closed by December 1999. Approximately 1.35 million cubic meters of petroleum refinery waste had been landfilled at the site during the past 22 years.

As part of the landfill operation, a wastewater treatment unit was constructed to control surface water discharges. The purpose of the wastewater treatment unit was to collect and treat surface water runoff and leachate that was generated from the landfill during operations. The wastewater treatment unit consisted of a concrete sedimentation basin and water treatment process, which involved chemical precipitation, ozonation and granular activated carbon processes. The water discharge from the wastewater treatment unit was discharged to a nearby creek and it was monitored under a Kentucky Department of Environmental Safety (KYDES) permit.

The Kentucky Department of Environmental Protection (KYDEP) had requested that all sediments from the concrete basin be removed prior to closing the landfill. In April 1999, it was estimated that approximately 3823 cubic meters of sediment was contained in the basin. Since the sediment was collected from a hazardous waste landfill, the material was considered to be a listed waste. Analytical testing indicated the principal chemical constituents were semi-volatile organic compounds (i.e., phenanthrene, chrysene, and naphthalene). In April 1999, the KYDEP indicated that it would be feasible to dispose of the sediment from the basin in a local landfill during closure and prior to final capping. This option provided a cost-effective alternative to off-site disposal. The only requirements that KYDEP required for disposal was the material needed to pass the paint filter test and no free liquids could remain.

Since the KYDEP approved disposal of the sediment from the basin into the local landfill, it was necessary to evaluate several sediment removal alternatives. Management of contaminated surface water and controlling discharge from the 16.2 hectares watershed during sediment removal was one of the principal factors in evaluating sediment removal technologies. This was significant because runoff could not be diverted around the basin during removal and access to the basin was limited because it was considered a confined space. As a result of the evaluation process, the project team selected The Dry DREdge™ technology combined with in-place, Geotube, dewatering of the wet sediment as the preferred method.

3.1 *Material Properties*

Three composite samples were obtained from the basin for geotechnical testing. Particle size distribution and hydrometer tests were conducted to characterize the dredge materials. Other geotechnical tests conducted included Atterberg Limits (liquid limit and plastic limit), natural water content, specific gravity, and geotechnical description. From these test results, the void ratio and the saturated wet unit weight were computed.

The dredged materials were classified as fine-grained dark gray plastic clay (CH to CL) with a trace of sand. Particle size distribution testing showed that composite sample 1 had 90 percent passing a 200 sieve and samples 2 and 3 showed that 99 to 100 percent passing the 200 sieve.

Atterberg limit tests indicated that the dredged material had liquid limits ranging from 45 to 60 and plastic limits ranging from 22 to 25 with the plasticity index varying from 23 to 35. (Atterberg limits are index values determined from soil moisture content.) The specific gravity of the soil material varied from 2.75 to 2.78. The natural water content ranged from 64 to 104 percent with the void ratio ranging from 1.76 to 2.89. The saturated wet unit weights for composite samples 1, 2 and 3 were 1.28, 1.5 and 1.46 gr/ml respectively.

The dredged material exhibited water content values greater than the liquid limit, indicating that the material would act as a fluid mud. The dredged material was very soft in consistency and exhibited very low shear strength. When the fine-grained dredged material was clam-shelled from the sedimentation basin and placed into the positive displacement pump hopper, it flowed to the bottom of the hopper.

3.2 *Dredge Description*

Conventional excavation methods, such as, hydraulic dredging and mechanical dredging with clamshells or draglines typically suffer from several serious limitations. These limitations include significant re-suspension of sediments at the point of excavation, imprecise excavation of hot spots, and free water entrainment in sediments requiring expensive dewatering and return water treatment.

The Dry DREdge™ incorporates a specially designed, sealed clamshell mounted on a rigid, extensible boom (Figure 6). The open clamshell is hydraulically driven into the sediments at low speed, minimizing sediment disturbance and re-suspension. The clamshell is then hydraulically closed and sealed, excavating a plug of sediment at its in situ moisture content.

Figure 6. The Dry DREdge™ is shown removing sediments

The sediment is deposited in the hopper of a positive displacement pump. Depending on the application, the hopper can be equipped for debris screening, size reduction, vapor emission control, sediment homogenization, and blending of additives to modify flow properties or stabilize contaminants. The sediment is pumped in a plastic flow regime through a pipeline to its appropriate disposition. The discharge has the consistency of toothpaste (Figure 7). Depending on the in situ moisture content and degree of hazard posed by the sediment, the disposition may be direct feed to a dewatering process, thermal treatment or stabilization process, direct feed to on-site land disposal, or direct feed to a transport vehicle.

Figure 7. Photograph showing toothpaste consistency of dredged material.

The most unique advantage of this dredge is its ability to deliver sediments at high solids concentration corresponding to the in-situ moisture content. High solids content sediment delivery can offer major economic advantages through the reduction or elimination of dewatering and return water treatment. This dredge has pumped solids concentrations of up to 70% by weight (Parchure et al. 1997). Other advantages include the following: Excavation is accurate and precise. The azimuth, declination, and extension of the clamshell are electronically displayed in the operator's cabin and available for electronic input to a programmable controller. Therefore, the operator can easily control the extent of the excavation (length, width, and depth). The programmable controller can be configured to completely excavate the area within range of the dredge by systematically making a grab, depositing the material in the pump hopper, and returning to make another grab immediately adjacent to, or overlapping, the last grab.

The clamshell-boom configuration allows the dredge to work around rocks and pilings. It is not limited to rectangular excavation patterns as are horizontal auger dredges, or the inverted cone excavation patterns of rotating basket dredges. These excavation capabilities are ideal for hot spot remediation.

Excavation is achieved with minimal re-suspension of sediments. Hydraulic dredge cutter heads agitate the sediments in the vicinity of the pump suction. Conventional clamshells are allowed to free-fall in order to impact the bottom with enough force to penetrate. Draglines are pulled randomly through the sediments. All these operations disturb the surrounding sediments, re-suspending particles and contaminants. Re-suspension is a major concern when dredging is conducted in bodies of flowing water such as estuaries. The dredge is intrinsically sound for debris management. Unlike hydraulic dredges, the pump suction is above surface allowing visual inspection of debris by the operator. Debris can be removed or shredded and pumped. The decision-making capability is critical for certain types of debris.

3.3 *Geotube Design*

The design requirements were for a geotube that had a circumference of 27.4 m, a height of 1.5 m and a length of 48.8 m (Figure 8). A maximum wet bulk density of 1.6 gr/ml was used in the design analysis. A factor of safety of 5.0 was used in the design, which included factors of safety of 2.0 for seams, 1.5 for creep and 1.5 for biological degradation. The geotube design was determined using a computer program, Geosynthetics Applications Program (GAP), (Palmerton 1998). This program assumes that the geotube is filled with a fluid and does not have any shear strength. The ultimate strength of the geotube is directly dependent on the available wide tensile strength of the seams. Since the seam strength available is 52.5 kN/m width and the required seam strength is 45.4 kN/m from the design analysis then the geotextile fabric selected is satisfactory.

Figure 8. Geotube after filling with hazardous material.

3.4 *Geotube Construction*

This project consisted of three, 27.3 m circumference geotubes, 48.8 m long, constructed from 4.6 m wide panels of a woven polypropylene fabric. Laboratory test have shown that this woven geotextile fabric has an ultimate breaking strength in the warp of 70.0 kN/m width and in the weft directions of 96.3 kN/m at 10 percent elongation for both the warp and weft. These tests have also shown the seam strength to be 52.5 kN/m for both warp and weft at 10 percent elongation (ASTM 1986). The Apparent Opening Size (AOS) for the geotube fabric, which is also equivalent to US Standard sieve size number, was about 50 (ASTM 1987).

The geotubes were manufactured by the TC Nicolon Corporation, in Pendergrass, GA and shipped to the project site in a protective covering. Two rows of inlet ports with 0.5 m diameter, 1.5 m long sleeves were provided every 7.6 m along the top of the geotube. Nylon anchor straps sewn to the geotube perimeter every 3.0 m that were used to secure the geotube prior to and during filling. A 5.3 N/m^2 non-woven polypropylene fabric was placed beneath the geotubes to facilitate vertical and lateral drainage during consolidation of the dredged material in the geotube.

A very small amount of fines, less than 5 to 10 mg/l, were evident in the decant water passing through the geotube during the initial filling but this water became very clear as the geotube was filled to the design height of 1.5 m. The decant water looked to have a very light tan to clear color and it was felt to be a insignificant loss of dredged material.

The 4.6 m panels were sewn perpendicular to the longitudinal axis of the geotube. All factory seams were sewn with double stitched butterfly seams. All seams consisted of type 401, double lock stitch that was sewn with a double needle Union Special Model #80200 sewing machine. The machine is capable of sewing two parallel rows of stitching about one quarter inch apart. The thread was a 2 ply, 1000 denier passing through the needles and 9 ply, 1000 denier passing through the looper.

3.5 *Conclusions*

The project was started in April 1999 and completed in June 1999. Approximately 3823 cubic meters of material was dredged from the sediment basin and sequentially pumped directly into five geotextile tubes located on the side of a mountain. Filtrate was routed from each dewatering pad to the existing runoff collection system and returned to the basin. Random sampling of collected sediment indicated the majority of the material would pass the paint filter test within 7 days. Limited measurements indicated a free water loss of approximately 20 percent. Observation would indicate the bulk of this water is interstitial. Thus, the use of the Dry DREdge™, geotube technology, and onsite disposal resulted in cost savings of approximately $1.0 million dollars.

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