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GEOBAG LOADING ANALYSIS

Donald F. Hayes[1], Godson Babu Gummadi[2], and Kiran Kumar Salkuti[2]

ABSTRACT

Geotextile bags are increasingly being used for sediment management. They have been used to store sediments, wastewater sludges, and a variety of other solids; as retention structures for marsh establishment, dredged sediment storage, and island creation; and shoreline protection. Information and data on sediment consolidation and dewatering are available including limited design and analysis procedures. Some limited testing has even been conducted to evaluate contaminant loss during dewatering.

Loading of geobags, however, has received little attention, even though it has widely been recognized as problematic. A variety of stop-and-start loading methods have been used to maximize the initial storage in the bags. Other applications have used gravity thickeners to increase the initial density of sediments and minimize free-water drainage during loading. Even with pretreatment, most loading processes have required multiple loading events to maximize loading. These approaches add significant complications to an already difficult loading process and increase costs. They may also pose safety risks for personnel assisting with the loading process.

This paper discusses fundamental sedimentation processes and how they apply to the geobag loading process. The loading process is defined in a manner that should encourage the development of better analysis procedures. Specific areas are identified where additional information is needed.

Keywords: Dredging, geotextile bag, dredged material disposal, contaminated sediment, water quality.

INTRODUCTION

The Noriega Point project in Destin Harbor, Florida conducted in December of 1991 seems to be the first application of geotextile fabric being sewn into tubes and used to contain dredged sediments in the United States. Geotextile tubes have since been used in a wide range of projects including energy dissipation below dams (Jiang and Li 2008), as retention structures for confined disposal facility and island construction (Fowler, *et al*. 2002a and Fowler, *et al*. 2002b are examples), to reduce coastal erosion (Shin and Oh 2007), to restore coastal marshes (Landin, 1998) and to contain contaminated sediments for large-scale sediment remediation projects (Cretens 2009). Many other examples of geotextile tubes providing viable solutions for difficult engineering problems exist. Today, geotextile containers[3] are used in a wide variety of geotechnical and environmental engineering applications for many purposes.

Since geobags are filled with sediment, dredging sediments and placing them in the bags efficiently is an important part of the process. Some projects have used mechanical means to fill bags prior to the final sewing. However, the majority of projects discharge hydraulically dredged sediments into the geobags. Since hydraulic dredges typically pump sediment at high rates, matching dredge production with the capacity of the geobags is problematic (Bradley 2001). The discharge is often split in a manifold to load multiple bags simultaneously resulting in a manpower intensive and erratic operation that often requires expensive interruptions to dredge operation.

Polymers have also been used to expedite and enhance clarification and, thus, the loading process. Still, the high flow rates often overwhelm the bags as they reach capacity. The result can vary from little or no clarification with

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[1] Director, Institute for Coastal Ecology and Engineering and Professor, Department of Civil Engineering, University of Louisiana at Lafayette, P.O. Box 42291, Lafayette, LA 70504-229; Phone: 337/482-5929, FAX: 337/482-6688, hayes@louisiana.edu.

[2] Graduate Student, Department of Chemical Engineering, University of Louisiana at Lafayette, P.O. Box 42291, Lafayette, LA 70504-229

[3] These containers are commonly referred to as Geotube®, a registered trademark of Tencate. To avoid confusion, the remainder of this paper will use the term *geobag* to refer to tubular or other shapes of geotextile container that may be filled with dredged sediment.

solids discharge from the geobag to less than maximum loading of the bag. Typically, a trial and error approach has been taken to the loading process (SI Geosolutions 1999) whereby discharge into the bag is halted, then restarted after a period of settling. Several cycles are often required to maximize the bag loads.

This paper considers the loading process of geobags with hydraulically dredged sediments as the fill material. A review of basic sedimentation processes will be used to demonstrate historical observations. The results are used to identify areas where additional information is needed and approaches that may increase the efficiency of the loading process.

PREVIOUS STUDIES

The widespread use of geobags for dredged sediment management has resulted in a number of publications describing specific applications and the long-term consolidation behavior of sediments in the porous containers. Landin (1998) provides guidelines for using geobags for wetland restoration. Landin also summarizes a number of successful Corps of Engineers applications. Many other wetland restoration projects have used geobags for retention structures in challenging environments since.

Geobags have also been used in other applications to successfully dewater highly organic sediments. Gaffney and Moo-Young (2000) described the use of geobags to dewater dredged sediment from Nacote Creek in Port Republic, New Jersey. In August 1997, a storm resulted in flooding and a dike breach along Nacote Creek; the flood deposited 18,350 cubic meters (24,000 cubic yards) of sediment into Nacote Creek. To restore the creek to its original depth, the organic mud was dredged from Nacote Creek and placed into geotextile tubes. During the laboratory tests, dewatering and consolidation in the geotextile tube reduced the volume of the dredged material by a factor of 3 to 4 within 2 to 4 weeks of filling the tube. The authors did not indicate that polymer was used in this project.

Bindra (2002) reports even more incredible success while dredging an Australian lake. The cohesive yet highly organic dredged sediment was placed in geobags. Bindra reported that dewatering and consolidation reduced the volume of the dredged sediment by a factor of 7 to 8 within 2 to 4 weeks of filling the geobags. Again, there was no mention of polymer use.

Geobags are becoming popular alternatives for contaminated sediment sites as well, being used in some cases to store large volumes of sediment. Tencate (2006) describes the use of Geotubes® to assist in the remediation of 573,450 cubic meters (750,000 cubic yards) of contaminated sediment from the Lower Fox River (LFR). Some LFR sediments are contaminated with polychlorinated biphenyls (PCBs) released from paper mills over the past 80 years. Dredged contaminated sediments were initially placed in Geotubes® for dewatering, and then later disposed of in a landfill. Tencate (2007) describes a similar project in the Hylebos Waterway. Hylebos sediments were contaminated with a host of metal and organic compounds released from different industries during the past century. Settling ponds and mechanical separation units were used to dewater the dredged material for this project. However, Geotubes® were used to filter the 2.5% solids in the settling basin overflow prior to discharge. Polymers were used to flocculate the fine material before loading it into Geotubes®.

Cretens (2009) describes the use of geobags for dewatering dredged sediment of the lower Asthabula River, Ohio. The soft sediment was contaminated with polychlorinated biphenyls, polycyclic aromatic hydrocarbons, heavy metals and some low radionuclides. The sediment was chemically conditioned with a combination of primary coagulant and anionic polymer to ensure optimal solids capture within the geobags.

Geotextile containers have been used to contain other solids as well. Fowler, *et al*. (2002c) presents three case histories of geobag use for dewatering of sewage and hazardous sludges. In the first case history, the geobags are used to retain the fine-grained sewage sludge. The conclusions show that the geobags are capable of retaining fine-grained sewage sludge while passing water that can meet the discharge requirements. The effluent water passing through the geotextile met the 30 mg/L discharge requirements in less than 11 minutes of drainage time. Geobag data and analysis showed that in 65 days of consolidation, the amount of solids in the tubes increased from 8.0% to 21.4%. In the second case history, municipal sewage was pumped in the geobags for dewatering and consolidation. The initial average percent solids pumped in was 9.7%. The average percent solids prior to opening of the geobags was about 18.7%. The initial bulking factor was 2.4 and was reduced to 1.2 due to geobag drainage and further shrinkage was observed when the geobag was opened and exposed to desiccation drying. In the third case history, the geobags were filled with hazardous waste from a settling pond at Catlettsburg, Kentucky. Approximately 3823 cubic meters of material was dredged from the sediment basin and pumped into five geobags.

In addition to a number of applications, there have also been substantial efforts to formulate models and develop tests to predict the long-term consolidation process within geobags. Gaffney *et al*. (1999) describe the processes by which geotextile tubes retain solids while passing liquid through the porous fabric. Retention, filtration, permittivity, and permeability all contribute to consolidation of solids and subsequent loss of liquid from a sediment filled geotextile bag tube. Retention and filtration are governed by grain size distribution of the sediment and Apparent Opening Size (AOS) of the geotextile. For soils with 50% or less particles by weight passing U. S. No. 200 sieve, the AOS of the geotextile must be less than 0.595 mm. For soils with more than 50% particles by weight passing U. S. No. 200 sieve, the AOS of the geotextile must be less than 0.297 mm. The coefficient of uniformity of the soil (CU = d_{60}/d_{10}) may also be a factor for the retention and filtration capability of the geotextiles. (Gaffney, *et al*., 1999)

Clogging and blinding of the geotextile is also an important factor in affecting the amount of water seepage and the retention of fine particles inside the geotextile tube. Clogging is the movement of soil particles into voids of geotextile, thereby reducing the hydraulic conductivity (also known as permeability) of the geotextile as defined by Koerner (1994) as in Gaffney, *et al*. (1999). The term “clog” implies complete cessation of drainage. Blinding is more apt since soil particles build up a resistive layer on the inside of the geotextile thus reducing the permeability of the geotextile but not eliminating the water seepage. (Gaffney, *et al*., 1999)

Filter cake and the viscosity of the slurry are also two other important issues. When considering consolidation of clay (or extremely fine-grained particles), the water surrounding the particle must deform (Dunn et. al, 1980 as in Gaffney, et al., 1999). This deformation is viscous in nature and the speed of deformation is a function of the magnitude of the load placed on the material. The time lag associated viscous resistance is called viscous lag, and when acting with hydrodynamic lag, form the process by which consolidation occurs. (Gaffney, et al., 1999)

The permittivity of the fabric and permeability of the contained sediment strongly influence water movement and discharge from the geobag. The relationship between permittivity of the geotextile and water flow rate is:

$$\psi = \frac{q}{(\Delta h)(A)}$$

where ψ = permittivity (sec^{-1}), q = flow rate (m^3/sec), Δh = head loss (m), and A = total area of geotextile test specimen (m^2). Permittivity is directly proportional to water flow rate through the fabric when head loss and area are constant.

Consolidation within a geotextile tube depends on the void ratio and hydraulic conductivity of the sediment. Salem, *et al*. (1977) and Gaffney, *et al*., (1999) presented the following relation for coefficient of consolidation and the length of the shortest drainage path,

$$c_v = \frac{T \cdot \lambda^2}{4t}$$

where, c_v = coefficient of consolidation (units), t = consolidation? time (units), λ = length of the shortest drainage path (m), and T = time factor (units). The time factor is a function of the degree of consolidation.

Leshchinsky, *et al*., (1996) as in Gaffney, *et al*., (1999) suggest that, based on the experience, the height of the tube drops while the maximum width changes very little. Average drop in height of the geotextile tube is given by:

$$\frac{\Delta h}{h_0} = \frac{G_s\left(\omega_0 - \omega_f\right)}{1 + \omega_0 G_s}$$

where Δh = decrease in the height of the tube (m), h_0 = initial height of the tube (m), G_s = specific gravity of the solids (unitless), ω_0 = initial water content of the fill material (fraction), and ω_f = final water content of the fill material (fraction).

Several authors have developed testing procedures to assess the performance of the geotextile bags. Koerner and Koerner (2006) describe the hanging bag test initially proposed by the US Army Corps of Engineers. The hanging-bag test simulates the actual loading conditions of a geotextile. Meagher (2008) proposed the Rapid Dewatering Test as a better approach to assess polymer and flocculation performance and the Pressure Gravity Dewatering Test to better replicate the entire procedure of filling and dewatering. Neither of these tests was designed to quantitatively estimate effluent quality during and after loading. Moo-Young, *et al.* (2002) developed a testing procedure using a filtration apparatus with pressure monitoring and the filtrate collecting system to evaluate dioxin lost through the geotextile fabric.

Despite extensive study and reporting on sediment consolidation in geotextile containers, only a few authors have discussed the challenges associated with the loading process. Bradley (2001) states, "One of the biggest problems associated with installing geotubes has been the over capacity of the equipment used to fill the tube." He further explains that often the tube becomes "too full too soon with too much material in the wrong place." Projects for which the geobags are being used for a specific external purpose such as sediment retention or shoreline protection have the opportunity to design the loading operation. While there is still good reason to economize on these projects, the focus on the geobags makes it easier to justify operational adjustments to facilitate efficient loading.

Projects for which the geobags are used primarily to facilitate disposal, however, often have other priorities. Time constraints, processing costs, water quality impacts, and a host of other issues may have priority. Contaminated sediment projects, in particular, must focus on the dredging operation and its effectiveness. Time constraints are also common for contaminated sediment projects. Thus, the geobag loading process needs to function continuously without impeding the dredging operation or project schedule. Health and safety issues may also limit the use of manpower to facilitate a cumbersome loading process. Thus, the use of geobags in these projects hinges upon resolving these loading concerns.

SEDIMENTATION CONSIDERATIONS

Sedimentation behavior in confined disposal facilities is well-understood and has been described in a number of publications. Sediment slurries typically exhibit all four sedimentation processes - discrete particle, flocculation, zone, and compression settling – during the placement process. These same processes occur during the loading of geobags. This section describes these processes briefly in the context of geobag loading.

Discrete Particle Settling

Sand and larger particles typically settle at rates several orders of magnitude faster than fine grained (i.e. silt and clay) particles. Sand mounds form at the discharge point in a CDF, attesting to this disparity in settling rates. Gravel, shell, and rock will be mixed in with this mound if they exist in the dredged sediment, although sand is typically the majority of the coarse sediment fraction. These coarse particles settle individually, i.e. discrete particle settling, at rates reasonably approximated by Stokes' law:

$$v_s = \frac{gd^2(\rho_s - \rho_w)}{18\mu} \qquad (1)$$

where v_s = settling velocity (m/s), g = gravitational constant (9.81 m/s^2), d = particle diameter (m), ρ_s = particle density (kg/m^3), ρ_w = density of water (kg/m^3), and μ = dynamic viscosity (kg/m/s). Although this formulation assumes spherical particles and laminar flow conditions around the particle during settling, the resulting settling rates of 0.4 to 4000 mm/sec are reasonable estimates for sand particles.

Sand not only settles rapidly within a CDF, but to a relatively uniform density of about 1400 to 1800 kg/m^3. Because few fines get trapped within the sand, their coefficient of permeability tends to be in the range of 10^{-1} to 10^{-3} cm/sec. At these rates, the sand tends to drain rapidly to the water table within the remainder of the CDF or geobags.

Flocculent Settling

Silt and clay particles settle several orders of magnitude slower than fine sands. The particles tend to flocculate during their extended stay in the water column, increasing their settling velocity as they aggregate. Flocculation rates, i.e. particle aggregation, vary dramatically with water and particle characteristics. Salinity enhances flocculation and increases settling rates in estuarine and coastal environments. Polymers and other chemicals (e.g. alum) are also often used to enhance flocculation. The cost of flocculants and the controlled mixing necessary for them to be highly effective have limited their use for dredged sediment placement operations. However, flocculants have been used in several geotextile bag applications attesting to the need to expedite settling during the loading process.

Zone Settling

A sediment-water interface forms during zone settling (sometimes referred to as hindered settling) as the rapidly settling particles form a sediment matrix that restricts their settling rate. Flow through the matrix is “hindered” by the tortuous path that the water must follow. The Long-tube Column Settling Test (LTCST) described by the Upland Testing Manual (USACE 2003) consists of filling a settling column with a slurry mixture approximating the inflow total solids concentration to be discharged into the CDF. The solid-liquid interface height is monitoring with heights recorded as it decreases over time. Figure 1 shows an example of the solids-liquid interface and a typical zone settling curve.

Flow through the sediment matrix limits the rate of settling, but tends to leave behind a supernatant layer with a relatively low TSS load. The average solids concentration below the interface can be estimated as:

$$S_t = \frac{h_i S_i - (h_i - h_t) S_s}{h_t} \cong S_i \left(\frac{h_i}{h_t} \right) \tag{2}$$

where S_t = average total solids below the interface (g/L), S_s = average total solids concentration in the supernatant (g/L), S_i = inflow total solids concentration (g/L), h_i = initial slurry height (m), and h_t = interface height at time t (m).

Zone settling usually begins during the first hours and continues for up to 24 hrs. During this time, dh/dt is at its highest and approximately constant; the value of dh/dt over this time is the zone settling velocity. Zone settling continues until dh/dt begins to decrease. The decrease in dh/dt typically occurs rapidly, over a few hours, and is obvious for most sediments. This rapid decrease in dh/dt represents the transition from zone settling into compression settling. The transition concentration for the sediment in Figure 1 is about 1.75 times (h_i/h_t = 7.0 ft/4.0 ft) the inflow solids concentration.

Compression Settling

Compression settling commences after the transition period, typically within twenty-four hours of the initial discharge. The value of dh/dt during compression settling is typically several orders of magnitude slower than the zone settling velocity. Still, compression settling can yield substantial volume decreases within the first few months after loading is complete.

GEOBAG LOADING

As described above, sand and other coarse particles will settle rather quickly after being discharged into a geobag, just as in a CDF. This poses some risk for clogging, although the inflow is usually sufficiently strong to move deposited sand away from the inlet. For sediments that contain mostly fines, sand and coarse particles will remain near the inlet and settle to a natural angle of repose.

Fine sediments will remain in suspension as the slurry moves toward the outlet. Clarification will occur, i.e. zone settling, as long as the Surface Overflow Rate (SOR) is less than (or equal to) the zone settling velocity. SOR is defined as:

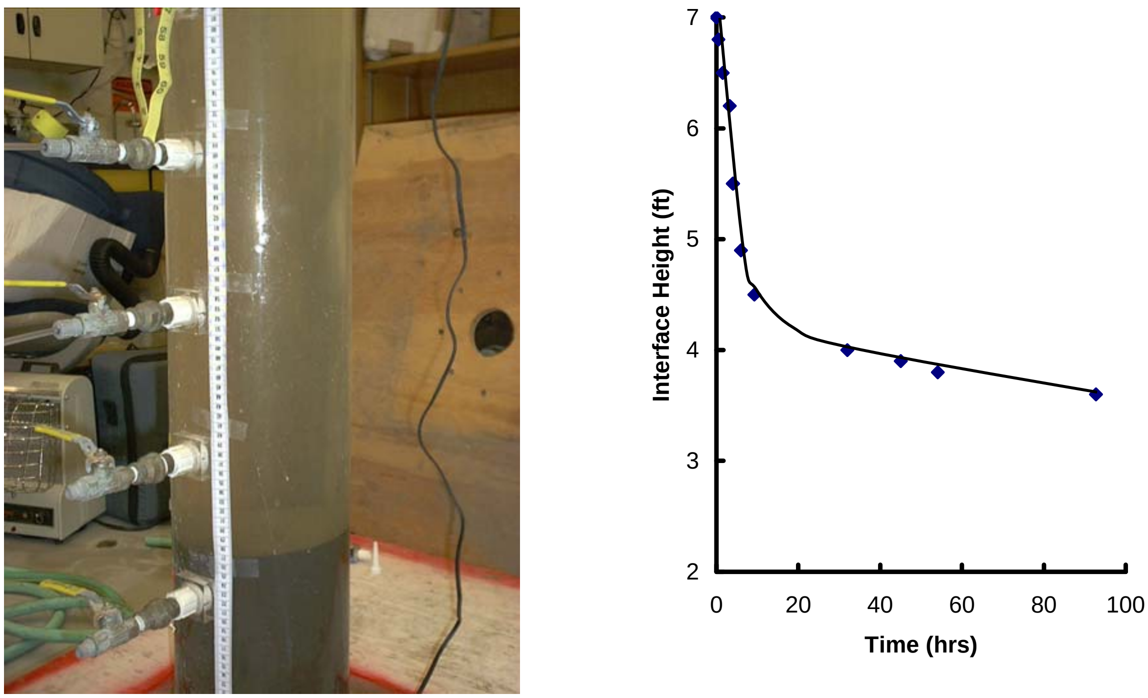

Figure 1. Zone settling column test and typical

$$SOR = \frac{Q}{A_s} \qquad (3)$$

where SOR = surface overflow rate (m/s), Q = inflow rate (m^3/s), and A_S = horizontal area of the geobags (m^2). Most geobags form an elliptical shape with the horizontal axis longer than the vertical axis (Figure 2). The surface

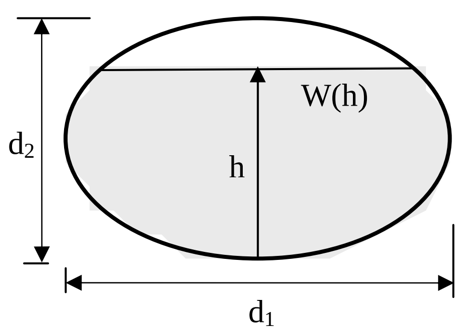

Figure 2. Geobag loading schematic.

area changes as the geobag is loaded since the bag width changes:

$$A_S = W(h)L_b \qquad (4)$$

where W(h) = geobags width as a function of sediment depth, h (m), L_b = length of the geobags (m). Clarification is controlled by the maximum surface area within the supernatant. Thus, as long as the sediment depth is less than $d_2/2$, the controlling width is d_1. Above $d_2/2$, the bag width at the top of the settled sediment controls the area available for clarification:

$$A_c = \begin{cases} d_1 L_b & \text{for } h \le 0.5 d_2 \\ 2L_b \sqrt{\dfrac{d_1^2}{4}\left(1 - \dfrac{4\left(h - \dfrac{d_2}{2}\right)^2}{d_2^2}\right)} & \text{for } h > 0.5 d_2 \end{cases} \tag{5}$$

where A_c = controlling surface area for clarification (m^2). Setting the zone settling velocity equal to SOR gives the maximum allowable inflow as:

$$Q_{max} = A_c V_Z \tag{6}$$

where Q_{max} = maximum total inflow into the geobags (m^3/s) and V_Z = zone settling velocity (m/s). The maximum surface area is $d_1 L_{bag}$ which occurs when h = $0.5d_2$. After that, the surface area for clarification decreases with sediment height in the bag and the maximum inflow rate decreases proportionally (Figure 3).

Figure 3 shows that the inflow rate must be ramped down rapidly once the fill height passes 60% for a typical sediment. Rapid flow reduction is difficult to accomplish in the field; thus, projects often pump until failure, i.e. solids begin to exit the tube near the rate they are entering. Once failure occurs, they stop and allow settling to occur. After adequate settling has occurred, pumping resumes and continues until failure again. Pumping is ceased to allow settling and the process repeated. Some projects complete three or more cycles trying to maximize the sediment volume in the geobag. This cyclic process is time consuming, inefficient, and expensive for the dredging operation.

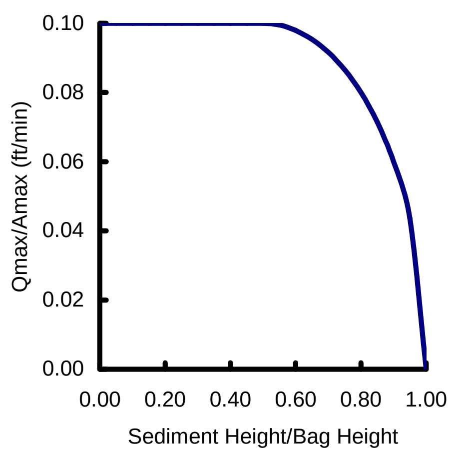

Figure 3. Variation of maximum allowable flow with fill height for an elliptical geobag (10 ft high by 15 ft wide) being filled with a sediment that has a zone settling velocity of 0.1 ft/hr.

In an attempt to expedite the loading process, some projects have implemented a thickener between the dredge discharge and the geobag. Ideally, a thickener would increase the solids concentration from that of the inflow to the transition solids concentration. This would allow sediment to be placed in the geobag at a concentration that will not produce significant supernatant. Thus, the bags could be filled closer to capacity without a cyclic loading operation. The dense sediment, however, is more difficult to pump and not as conducive to the lateral movement necessary for even filling of a long geobag. More inlets are necessary to avoid clogging and assure an even distribution. Sand and coarser materials may also need to be removed prior to the thickener and managed separately.

Continuous flow thickeners would not only have to be quite large, they would also require significant mechanical ability to continuously remove settled solids. The weight and density of settled sediment solids make thickeners challenging and expensive to use in large-scale operations. The project duration is usually not sufficient to overcome the capital costs of the thickener. Thus, it seems unlikely that thickeners will receive widespread use for geobag loading.

WATER MANAGEMENT DURING LOADING

Whether the sediment density in increased in the geobag or in a mechanical thickener, water management is necessary. In all cases, water is expelled as the sediment goes from the inflow solids concentration, S_i, to the transition solids concentration, S_t, via zone settling. Expelled water and any associated solids lost during the process must be managed. This section provides some simple approaches for estimating both.

Water Volume Expelled

The expelled water volume during loading is the volume of water discharged into the geobag during filling minus the residual water in the bag at the end of filling. The most direct way to determine this volume is to first determine the volume of solids in the geobag at the end of loading. The volume of solids in a filled geobag can be computed as:

$$V_s = 1000 S_b V_b f_b / G_s \quad (7)$$

where V_s = volume of dry solids in the geobag at the end of the loading process (m^3), S_b = average solids concentration in the geobag at the end of the loading process (kg/m^3), V_b = volume of the geobag (m^3), f_b = filling efficiency of the geobags (fraction), and G_s = specific gravity of the solids (unitless). The geobag volume is:

$$V_b = \frac{\pi}{4} d_1 d_2 L_b \quad (8)$$

where d_1 = maximum geobag width (m) and d_2 = maximum geobag height (m). The average solids concentration in the geobag at the end of the loading process can be estimated from the zone settling curve. Using either the concentration at 24 hours or that just beyond the transition zone should provide a sufficiently accurate estimate. The filling fraction depends upon the effectiveness of the loading process.

The volume of water in the geobags at the end of loading, assuming saturated conditions, is simply:

$$V_w = V_b - V_s \quad (9)$$

where V_w = pore water remaining in the geobag at the end of loading. The solids volume, V_S, is the same as brought in by the loading process minus any losses:

$$V_s = (V_S)_{load} - (V_S)_{lost} \quad (10)$$

where $(V_S)_{load}$ = solids volume brought in by the loading process (m^3) and $(V_S)_{lost}$ = solids volume lost during the loading process (m^3). Although the solids lost during loading may be significant in terms of effluent quality, they are likely to be insignificant in comparison to the overall loading process. Thus, it can be assumed that:

$$V_s \cong (V_S)_{load} \quad (11)$$

Given that assumption, the water volume placed into the tube during loading can be estimated as:

$$(V_W)_{load} = V_S\left(\frac{G_S}{1000S_i} - 1\right) \quad (12)$$

The total water expelled then is approximately:

$$(V_W)_e = (V_W)_{load} - V_W = \frac{V_S G_S}{1000S_i} - V_b \quad (13)$$

Dividing both sides by the bag volume and simplifying gives:

$$\frac{(V_w)_e}{V_b} = \frac{f_b S_b}{S_i} - 1 \quad (14)$$

Figure 4 illustrates the relationship shown in Equation 14 between the average solids concentration in the geobag at the end of loading and the water volume dispelled in bag volumes. The transition solids concentration, S_t, is a reasonable approximation of the solids concentration at the end of loading unless the loading occurs over a multi-day period.

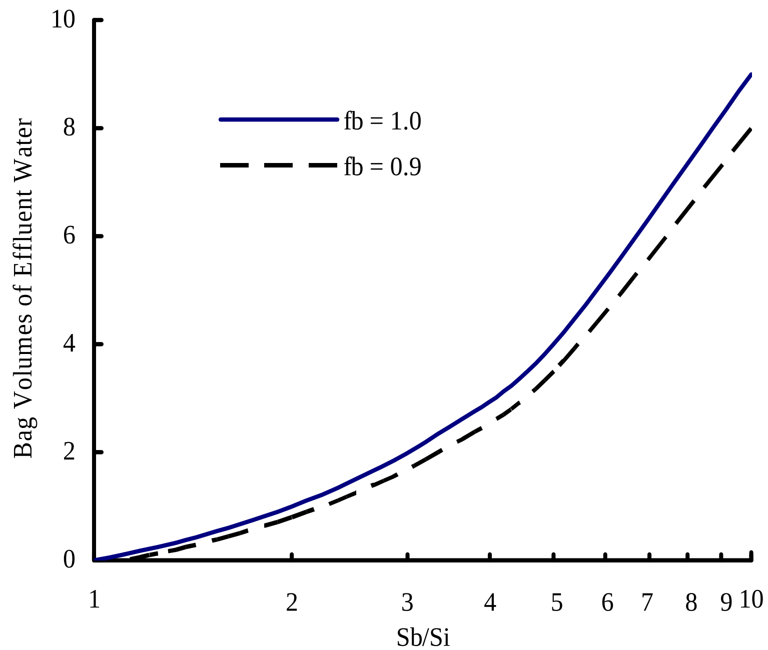

Figure 4. Bag volumes of effluent water as the result of the average sediment concentration in the bag at the end of loading and the inflow solids concentration and the fill fraction of the bag.

Effluent Water Quality

Discharge water quality during loading and long-term seepage through the geotextile is of keen interest. It defines the need, size and processes required to meet effluent requirements. The presence of contaminants exacerbates this interest in a reliable method for estimating the initial water quality.

A few studies have reported effluent water quality measurement when using geobags to store sediments. In most contaminated sediment cases, the effluent water receives additional treatment prior to discharge; Bindra (2002), Cretens (2009), and Tencate (2006, 2007) are examples. Unfortunately, very little quantitative information has been published on the quality of effluent water from geotextile bags. Gaffney and Moo-Young (2000) reported effluent suspended solids concentrations of 1036.7 mg/l from geotextile bags. This seems like a surprisingly high effluent, but the details of the project that led to this discharge are not clear. Mori, *et al*. (2002) conducted laboratory tests to access the dioxin retention capabilities of geotextile bags and the effect of flocculants. Tests were conducted on two samples with different dioxin concentrations using two different flocculants. The suspended solids concentrations in the drained water were strongly related to the dioxin concentrations in the drained water. The geotextile retained greater than 99.8% of the dioxin when flocculants were used. Although this study was limited to dioxins, it suggests that geotextile containers can effectively contain hydrophobic constituents such as dioxins. And, these results seem contrary to those reported by Gaffney and Moo-Young (2000).

Unfortunately, these studies are not sufficient to produce a reliable approach for estimating water quality. In lieu of a better approach, initial supernatant concentrations are probably reasonable basis for estimating the concentration of most constituents during the loading process. Actual concentrations would likely exceed these values, i.e. supernatant concentrations would be *unconservative* estimates, because of the turbulent nature of the loading process. The US Army Corps of Engineers (2003) estimates effluent increases due to wind induced turbulence within a CDF by using a resuspension factor ranging from 1.5 to 2.5. The turbulence experienced during the geobag loading process would likely be greater than wind-induced turbulence within a CDF. Additionally, it would take very little loading failure, i.e. loading to the point where the effluent begins to approach the influent concentration, for these concentrations to increase dramatically. Further research is needed to determine the retention mechanisms and estimate water quality of discharges from geobags.

THE ROLE OF POLYMERS

Many projects where hydraulic dredges pump directly into geotextile bags use polymer addition. Polymers have been proven to enhance and expedite settling of fine sediments. They are widely used in sedimentation operations for water treatment, wastewater treatment, and other solids-processing operations. A wide range of polymers are available. Selecting the best polymer for any given application requires a long series of jar tests to compare performance. Even more jar tests are required to determine the optimal dosage. Polymers are also costly to purchase, manage, and feed. Additionally, performance depends upon specific mixing conditions to ensure even distribution of the polymer and optimal particle-to-particle contact to promote coagulation. Consistently providing the proper mixing intensity and duration in conjunction with the erratic nature of dredging operations can be challenging.

Many project descriptions and reports, including pre- and post-project reports, discuss the “dewatering” advantage of using these polymers and testing for such. However, most of the testing approaches described focus on the settling process, i.e. increasing the settling rate and decreasing suspended sediment concentrations in the supernatant. This confusion in nomenclature is common in the wastewater treatment industry where polymers are commonly used and solids concentrations are far less.

This is pertinent because some polymers can increase bulking in the sediments. Zhou (2004) shows that for some water treatment sludges, polymers increased settling rates and decreased the transition solids concentration. This is illustrated in Figure 5. The average sludge concentration at 140 hours for a 30 mg/L dosage is about half of the sludge concentration at 140 hours for the sludge without any polymer addition.

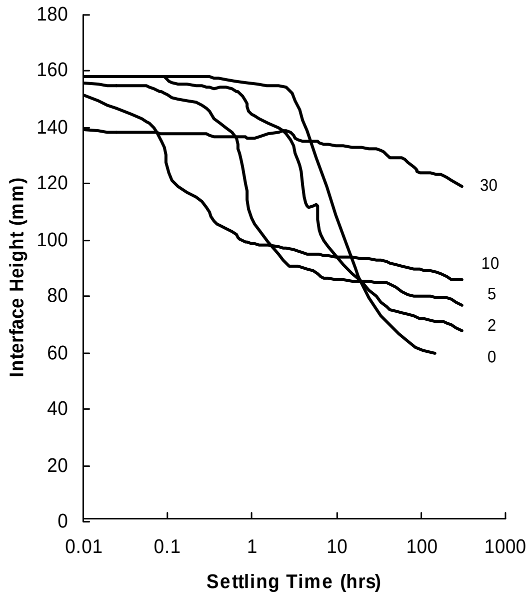

Figure 5. Zone settling curves for polymer additions of 0 to 30 mg/L to a water treatment sludge (modified from Zhou 2004).

The authors are not aware of similar studies conducted on sediments. If a similar phenomenon occurs with dredged sediments being placed in geobags, it would result in substantially decreased average solids concentration at the end of the loading process. This could potentially offset any loading advantages of using a polymer to enhance settling.

SUMMARY AND CONCLUSIONS

Geotextile bags are often used in conjunction with dredging operations. Direct loading of the geobags from hydraulic dredging operations can be challenging. Extensive management of the dredge discharge is often necessary to avoid excess sediment losses during loading. Despite these problems, little attention has been focused on improving the loading approach for geotextile bags. This paper described some of the basic principles that govern the loading process to establish a basis for further improvements.

The information reviewed and summarized in this paper point to a significant need for careful attention and assessment of the loading process when geotextile containers are used as part of a dredging project. Matching the high capacity discharge of a hydraulic dredge with the limited settling capacity of geobags is a challenging effort. Extensive opportunities seem to exist to enhance the process and realize significant cost savings, especially for larger projects.

Some other specific conclusions drawn from this study are provided below.

1. The geotextile bag loading process and the long-term consolidation process are sometimes confused in the current literature. A careful distinction between these processes would be useful. A practical distinction would be:

    a. *Geobag loading*: All efforts and actions associated with placing dredged sediments in a geotextile bag until the sediment reaches the transition concentration. The timeframe for the loading operation would be one day or less.

    b. *Consolidation/Dewatering*: Long-term volume changes that occur after the first day and continue until a final volume is reached.

2. Slurries will settle to the transition solids concentration within the first 24 hours of discharge. The water expelled during this increase in concentration must be managed as part of the loading process.

3. A thickener between the sediment discharge and the geobag could potentially allow sediments to settle to the transition solids concentration prior to placement in geotextile bags. However, transporting the thickened sediment from the thickener to the bag and achieving uniform loading remain concerns.

4. More information is needed to estimate effluent quality during geobag loading.

5. Polymers can enhance the settling process and reduce effluent concentrations, but could result in sediment bulking, increasing the geobag and long-term storage requirements. Additional research is required to evaluate this concern.

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