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THE USE OF GEOTEXTILE TUBES FOR EROSION CONTROL -

SELECTED CASE STUDIES

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ABSTRACT
Geotextile tubes are a simple, low-cost technology which is a viable option for controlling erosion in wetland or shoreline areas. Geotextile tubes can be filled with available clean material and arranged to form breakwaters and stabilize shorelines. The effectiveness of the geotextile tube to control erosion has been demonstrated in a variety of projects, including the following case studies:
1. The Lake Sinissippi Wetland Protection Project was completed to stop the destruction of a wetland area adjacent to a lake. Approximately 800 lineal feet of thirty-foot circumference geotextile tubes were deployed and filled in the lake to a height of 4 – 6 feet in such a way as to connect two shorelines of the lake.
2. The Wallops Flight Facility Emergency Shoreline Stabilization project was conducted for the purpose of stopping wind and wave erosion of the sand beach on the southernmost shoreline of Wallops Island. Geotextile tubes were placed along the beach to form a breakwater to protect the beach from further erosion.

RESUMEN
Tubos de geotextile son una tecnologia simple y barata que es una opcion viable para controlando erosion en areas de wetlands o costa. Tubos de geotextile peeden llenar con material limpio disponible y arreglado para formar rompeolas y hace muy estable la costa. La eficiencia de los tubos de geotextile para controlar erosion ha estado demonstrado en una variedad de proyectos, incluyendo los casos siguentes:
1. El Proyecto de Wetland Proteccion Lago Sinissippi complete para parar la destruccion de un wetland area adyacente a un lago. Aproximadamente 800 pies lineales de treinta pies circunferencia tubos de geotextile deploraron y llenaron en el lago a una altura de 4 a 6 pies en una manera como conectar dos costas del lago.
2. El Proyecto de Wallops Flight Facility Emergency Shoreline Stabilization condujo por el objeto de parando erosion de viento y ola de la playa en la costa mas sur de Wallops Island. Tubos geotextiles situaron a lo largo de la playa para formar un rompeolas para proteger la playa de mas erosion.

1. INTRODUCTION

Geotextiles have been utilized for many years in a wide variety of applications. With each use and application in a vast industry, innovative methods for geotextile use continue to remain on the cutting edge of technology. With the development of geotextiles sewn in a tubular form, a wide range of innovative applications was established. In addition to standard applications of erosion control, these geotextile tubes were viable options for the collection and dewatering of solid/liquid combinations. These 'slurries' could be transferred into the geotextile tubes which would in turn retain the settling solids while simultaneously releasing the liquids. In specific instances, the geotextile tubes could serve multiple purposes by retaining solids and/or releasing liquids, and once in place with a solid or semi-solid content, providing long term erosion control.

The description of two selected applications to further demonstrate just a few of a wide range of potential benefits that are possible through the use of geotextile tubes are provided herein. In the first instance, a small inland lake association compiled of local lake residents from central Wisconsin demonstrated to the local and state regulating agencies the undeniable benefits of geotextile tube use by conducting a full scale pilot study intended to prevent further erosion of their already rapidly dwindling wetlands surrounding the lake ecosystem. The 2,855 acre man-made lake was increasing in area due to the spawning habits of various non-game species of fish, thereby causing the deterioration of adjoining wetlands throughout the lake. The lake association (Owner) combined efforts with a national sportsperson/conservation club to fund the creation of an in-water geotextile tube breakwater, eradicated the fish, and planted aquatic flora in an attempt to reestablish a deteriorating wetland.

In the second instance, faced with the ever imposing erosion associated with wave action, tides, and storm events on the eastern seaboard of the Commonwealth of Virginia, the National Aeronautics and Space Administration (NASA, or the client) was hard pressed to prevent further damage to one of their rocket launching pads and an adjacent drone landing strip at their Wallops Island Flight Facility. With a brief window of opportunity available between two closely scheduled launches during the dead of winter, the client acted swiftly to arrange for the design and installation of a geotextile tube barrier to prevent further erosion of the beach and adjacent infrastructure. Within weeks, a design was submitted and approved, construction crews were mobilized, and the installation began. Since the completion of the project, not only has erosion been curbed, but sand deposition has continued to accumulate.

2. LAKE SINISSIPPI WETLAND PROTECTION

2.1 Design

As part of a 500 square mile lake basin located at the southern portion of the Horicon Marsh Wildlife Refuge, the stated goal of the Owner is to provide for the restoration, protection and enhancement of the water resources and ecosystem. Part of that commitment to the protection of the lake ecosystem included protecting the already-existing wetlands. Having already secured topographic maps of the lake bottom with sediment in place, and the lake hard bottom, the Owner turned the information over to Infrastructure Alternatives with the challenge of conducting a full-scale pilot study to demonstrate the effectiveness of the geotextile tubes as a means of preventing further erosion, the first step in re-establishing the dwindling wetland.

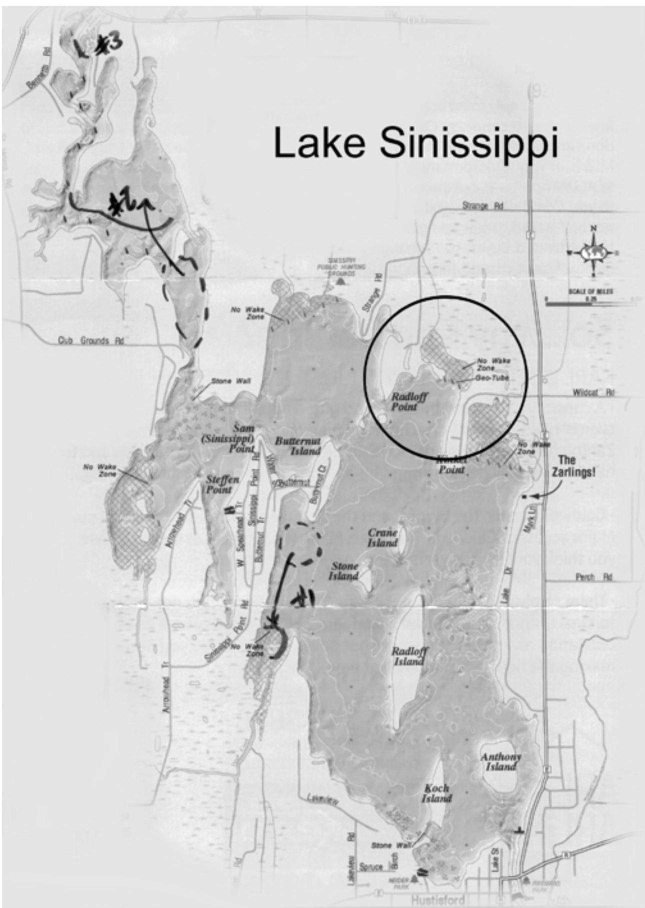


Figure 1 – Lake Sinissippi

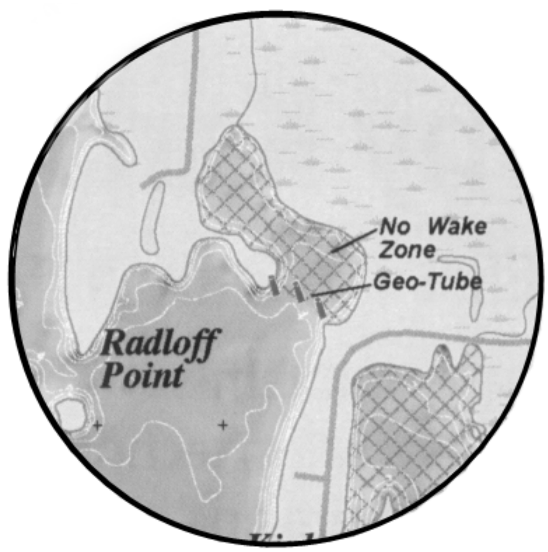


Figure 2 – Project Location

With ice still on the lake, holes were drilled, and core samples of the lake bottom material were collected for bench testing and analysis. Accurate measurements from shoreline to shoreline were collected in an effort to provide an effective placement of the geotextile tubes. Depths of the water from shoreline to shoreline were taken into consideration, and the tubes were sized accordingly. Since the depth of water from shore to shore ranged from 1' to 5', a 30' circumference light fabric was determined as the most effective option, with a total fill height of 6'. At this height, the tube was capable of handling 2 cubic yards of material per lineal foot, and remaining approximately 1-1.5' above the water line. The lighter fabric possessed the following mechanical properties:

Mechanical Properties	Test Method	Unit	Minimum Average Roll Value	
			Machine Direction	**Cross Direction**
Wide Width Tensile Strength (at ultimate)	ASTM D 4595	kN/m (lbs/in)	70 (400)	96.3 (550)
Wide Width Tensile Elongation	ASTM D 4595	%	20 (max.)	20 (max.)
Factory Seam Strength	ASTM D 4884	kN/m (lbs/in)	52.5 (300)	
Apparent Opening Size (AOS)	ASTM D 4751	mm (U.S. Sieve #)	0.425 (40)	
Water Flow Rate	ASTM D 4491	$l/m/m^2$ (gpm/ft^2)	813 (20)	
Mass/Unit Area	ASTM D 5261	g/m^2 (oz/yd^2)	585 (17.3) (Typical Value)	
UV Resistance (% strength retained after 500 hrs)	ASTM D 4355	%	70	

Figure 3 – Geotextile tube testing requirements

2.2 Implementation

Horizontal alignment was established through the use of a transit as the proposed location of the geotextile tubes was laid out. After clearly delineating the work zone for local boaters, metal stakes were placed along the proposed tube line to identify the proposed lay out. The first of two 390' tubes was deployed by suspending the rolled up tube above the ground with an all-terrain fork lift, then pulling the end and unrolling it in the water. In its empty state, the geotextile tube floated on the water, thereby allowing easy positioning and adjustment. Stakes were used to tie the tube off in the proposed position. The 8" polyethylene and flexible hosing transfer piping system was connected from the 8" auger head dredge to the geotextile tube fill ports, and the filling process commenced. As the tube received the sand/gravel/sediment slurry, it naturally began to sink towards the lake bottom.

Figure 4 – Initial tube filling process

Figure 5 – Final tube fill height

The filling process continued until the contents of the geotextile tube were solid, and the top of the tube protruded above the water line. A screened passage was constructed from the end of the tubes to the shoreline at the eastern end to allow water flow and to prevent fish passage. Additional slurry was pumped from the lake bottom to the back side of the geotextile tubes to stabilize the tubes and to promote aquatic plant growth.

2.3 Considerations

The staging and filling of geotextile tubes in water can be a challenging issue. Wind and wave action, currents, precipitation, and the consistency of available fill material, among other factors, impact both the deployment and filling processes. In addition, in freezing climates, the impact of large moving sheets of ice during the springtime melt need be taken into consideration. Furthermore, the tubes need to be clearly identified for winter sports enthusiasts. At Lake Sinissippi, the impact of the sheets of ice after the first winter was negligible or non-existent. The tubes were well marked by the lake association.

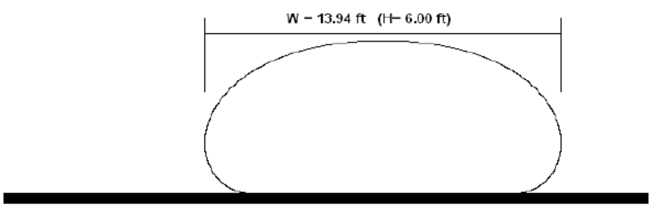
Figure 6 – Tube surrounded by ice

Figure 7 – Aerial view of geotextile tube breakwater

3. WALLOPS FLIGHT FACILITY EMERGENCY SHORELINE PROTECTION

3.1 Design

With a large volume of aerial photographs and topographical information already in place, the design team utilized the existing information as provided by the client to identify the proposed layout of the geotextile tubes, determine sources for makeup water, sand addition, mixing and pumping activities. The client had designated the northern end of the project as a starting point, and required continuous geotextile tube coverage over 4,600 lineal feet. A 34' circumference geotextile tube with a length of 200' and having a final fill height of 6.0' was agreed upon. Each tube was manufactured with six 8" polyvinylchloride flanged fill ports. The recommended geotextile tube fabric was of a heavy polypropylene weave possessing the following characteristics:



GIVEN C = 34.00 ft H = 6.00 ft SPG = 1.60 FS = 4.00

DENSITY OF SLURRY	= 99.84 pcf
TUBE CIRCUMFERENCE, C	= 33.99 ft
EX PRESS -TOP OF TUBE, P	= 1.323 ft (water) 0.5732 psi
WORKING CIRCUM FORCE, Tcir	= 95.57 lbs/in 1146.8 lbs/ft
WORKING AXIAL FORCE, Tax	= 71.33 lbs/in 855.91 lbs/ft
TOTAL HEIGHT OF TUBE, H	= 6.005 ft
TOTAL WIDTH OF TUBE, W	= 13.94 ft
BASE CONTACT WIDTH OF TUBE	= 10.37 ft
END AREA OF TUBE	= 70.76 sq ft 77.00 % FULL
TUBE VOLUME, V	= 2.621 cu yd/ft 529.3 gal/ft
FABRIC AREA TO VOL RATIO,R	= 1.441 sq yd/cu yd
BASE PRESSURE	= 4.737 psi 10.93 ft (water)
REQ'D CIRCUM STRENGTH T	= 382.3 lbs/in 4587.4 lbs/ft
REQ'D AXIAL STRENGTH	= 285.3 lbs/in 3423.6 lbs/ft

Figure 8 - Geotextile tube fill characteristics

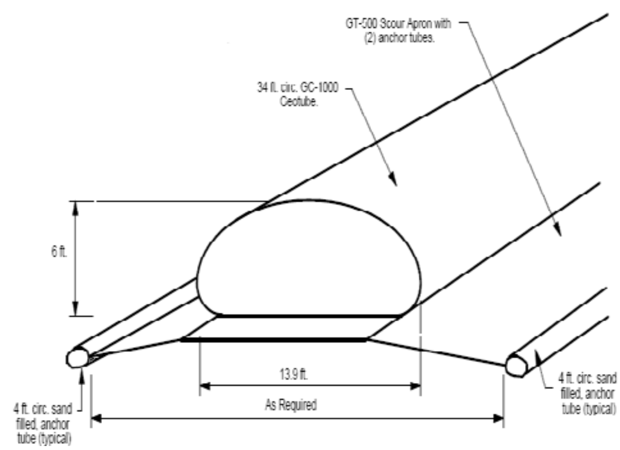


Figure 9 – Geotextile tube, scour apron, and anchor tubes

In addition to the geotextile tubes, a geotextile scour apron, consisting of 210' lengths of a 27' wide apron, bordered on each side by a contiguous 4' diameter anchor tube, all of which was fabricated out of a lighter polypropylene, was agreed upon for installation. The purpose of the scour apron is to stabilize the base material that supports the geotextile tube and prevent undermining of the tube. With constant wave action scouring the sandy beach, the scour apron is designed such that as scouring occurs, the weight of the 4' diameter anchor tubes continues to settle with each scouring cycle. As the anchor tube continues to sink, the material underneath the scour apron, which functions as the foundation for the geotextile tube, is locked in place. The tubes and scour aprons were configured so as to minimize the likelihood of corresponding overlaps, or joints between successive tubes/aprons.

Further design considerations included the sieve analysis of the proposed sand fill material, the required velocity of flow to maintain suspension of solids, the percent solids of the sand slurry, the distance that the sand slurry was to be pumped, the sizing and pressure rating of the transfer pipe, the sizing of the fill ports, the sizing of the makeup water pumps, the sizing of the sand slurry pumps, and the means by which the decant water from the tube filling operations would be sheeted away from the tubes and scour aprons so as to prevent further washout and undermining.

3.2 Implementation

Two slurry pits, where off-site sand was mixed with water pumped from the ocean and/or estuary, were established. The first one, towards the north end of the project site, was adjacent to about 5,000 cubic yards of sand that had been hauled in from off-site and stockpiled. It was positioned such that it allowed a pumping distance of about 300' to the north, and about 1,300' to the south. The second slurry pit, located near the halfway point of the project, allowed pumping to the north for about 800', which met the limits of the southerly pumping from the north slurry pit, and pumping to the south of about 2,300' to the southern end of the project. Nearly 9,500 cubic yards of sand had been stockpiled adjacent to this slurry pit, thereby requiring the majority of the pumping from this pit.


Figure 10 – Aerial view of project site


Figure 11- Initial filling at northern end of project site

The slurry pump that was suspended by a crane in the slurry pit was a 75-horsepower hydraulic drive, abrasion resistant submersible pump equipped with an agitator to assist in maintaining the sand in a suspended state. Two self-priming trash pumps, a 6" and an 8", were used to draw water from both the ocean and/or the estuary, depending on the tide cycle, and transfer the water at a rate of about 1,700 gallons per minute (gpm) to the slurry pit where it was mixed with the sand. A tracked excavator equipped with a 2 cubic yard bucket was utilized to transfer the sand from the stockpile to the slurry pit at a timed rate. With a semi-constant water supply rate of 1,700 gpm, sand was added at such a rate to allow a 10 – 15% solids slurry for transfer through the piping system.

An 8" mechanically jointed SDR 26 high density polyethylene pipe with 25' and 12' long sections was utilized for the header system. 8" x 6" tees were used to reduce to the 6" flexible hosing that connected to the fill ports on the geotextile tubes. Mechanical pinch valves were positioned at each fill port to allow flow control. The transfer piping system was continuously assembled, disassembled, and reassembled as the project progress continued from north to south and from slurry pit to slurry pit. With each length of pipe added or taken away, changing flow characteristics required constant adjustments to pump speed, percent solids of slurry, and number of fill ports on line at any given time. Further reduction of the piping system to 4" was required for the filling of the scour apron anchor tubes. This reduction significantly increased the head pressures experienced thereby requiring further adjustment of pump performance.

Figure 12 – Geotextile tubes shaped around existing structures.

3.3 Considerations

The time constraints on this project may've been the biggest challenge. The site wasn't accessible until after mid-January, and had to be cleared for preparation for the mid-April launch by late March. Pumping exercises commenced on January 22, and were completed by March 29, after countless delays brought on by adverse weather conditions, low tides that prevented drawing water for the sand slurry, and towards the end of the project, miscellaneous down days due to the client's preparations for the upcoming launch.

Other challenges included the wide range of pumping demands. With the same pump, the filling of a 34' circumference geotextile tube through two fill ports at a distance of 200' and the filling of a 4' circumference anchor tube through a single fill port at a distance of 2,300' was achieved. The percent solids of the sand slurry was not completely consistent as water supply rates and /or sand addition rates varied, thereby requiring a full time operator to oversee the sand slurry pump and test frequently with a portable ultrasonic flow and density meter.

The entire project was accomplished with a crew of 5 – 6 men who stood up to the elements, be they rain, wind, sleet, snow, bitter cold wind chill temperatures, or a combination of all of the above. Through it all, safety of the crew was maintained on the highest order as no reportable injuries were incurred. The site was vacated and all crews and equipment were demobilized in time for necessary preparations for the scheduled April launch. Since completion of the project, the client has noted significant sand deposition along the entire length of the project, where, prior to the installation of the geotextile tubes, erosion was occurring at an alarming rate. Not only have the geotextile tubes prevented further erosion, but they have encouraged the re-nourishment of the beach ecosystem. The client intends to fill in the area behind the geotextile tubes with sand, and plant dune grass for stabilization.

Figure 13 – Filled tubes with natural sand deposition on ocean side.

4. CONCLUSIONS

Through the projects described above, and several other projects of various natures, magnitudes, and scopes, the viability of geotextile tubes as an erosion control measure has been proven effective. For the lake wetland protection project, the erosion has ceased completely and the rehabilitation of the aquatic flora is taking a strong hold. The geotextile tube isolation berm is proving effective in preventing further non-game species from migrating back into the isolated area, thereby successfully curbing the erosion process. With the control of the non-game species spawning habits, the natural flora is encouraged to grow and flourish in a non-threatening environment. The lake improvement district has identified numerous additional projects at other areas of the lake that they would like to address using similar technology.

For the beach stabilization project, the geotextile tube breakwater has not only successfully discouraged shoreline erosion, but has encouraged sand deposition for the entire length of the project despite numerous tropical storms that have ravaged the shoreline. Evidence of miscellaneous debris washing up with the surf and coming to rest on or near the geotextile tubes has yielded little or no negative effect on the tubes themselves. Further stabilization has been secured as the client filled in the back side of the tubes with sand and planted dune grass to further control erosion. Neither the launch pad nor the landing strip has experienced any further degradation due to erosion. The client is monitoring the effects of the natural elements on the tubes closely, and has so far been encouraged that the geotextile tube fix may prove to be a longer term solution than initially anticipated.

Given the flexibility of geotextile tube sizes and configurations through manufacturing, the wide range of slurries that can be pumped into the tubes, the solids retaining capabilities of the weave, and the durability and longevity of the polypropylene material when exposed to the natural elements or stressed with high density fill material, the number of challenges that the process can be successfully applied to is virtually unlimited. As additional widely varying applications are completed, only a wider range of applications will result.

REFERENCES

All information presented herein was compiled from the project records, files, photographs, daily logs, and site personnel associated with each of the respective projects. Permission was secured for the reproduction of the information included herein.