By Jay Wolcott Sample

An evolving method of coastal erosion control

The design, development and implementation of coastal structures of all types provides a multitude of challenges, not the least of which is the protection of the project work area during the initial site excavation and product implementation phases. Whether a "Nor'Easter," an overnight Gulf storm, or a full-blown tropical storm or hurricane, the impact of an unanticipated storm event can be disastrous during the implementation stages of a coastal project. The author has been involved in the design and installation of sand-filled geotextile erosion control containers in the coastal arena of Florida since 1980. Numerous storms adversely impacted the installation process on multiple projects until 1985. Impacts included loss of production, equipment, materials and profits.

Initial efforts at protecting project work areas centered on the design, development and implementation of geotextile dike covers. Various combinations of geotechnical fabrics with parallel seaward and landward ballast tubes were employed as covers over triangular earthen dikes formed from the excavated project sand materials. The fabric-covered dikes required a wide beach face to allow for a gentle slope on the seaward face of the earthen dike structure.

In 1985, my crews installed a multi-tier sand-filled erosion control system along the Gulf coast of Florida on the extremely narrow beach fronting a condominium. We accomplished the site excavation, graded a 3:1 slope, and laid out several hundred feet of filter-cloth foundation materials on the slope. Installation of the strap restraint system and crest anchor tube proceeded well, as did the installation of the empty geotextile containers. We ended the day on an upbeat note, anticipating the next morning's sand-filling operations.

We awoke to emergency storm conditions, which had materialized overnight without warning. The narrow protective earthen dike had been entirely washed away and much of the sand had been swept into the excavated, prepared filter-cloth covered project area, burying all of the geotextile components beneath tons of wet sand. Attempts at careful re-excavation of the slope to recover the geotextile components proved futile, costly and ineffective. We tore the tattered fabric remnants from the post-storm beach profile and transported them to the dump. New project materials had to be ordered, fabricated and shipped to the project, all at my expense.

Photo 1: **The first beach erosion-control solution, a round water-filled geotextile tube cofferdam, posed design challenges.**

The design challenge

In an effort to develop more effective methods to protect my own coastal project work areas, I conceived a water-filled protective tube approximately 6 ft. (1.8 m) in diameter. My experience prior to that time was primarily with porous fabrics formed into a pillow shape, incorporating sewn seams around the perimeter. I recognized the need for impermeable geotextile materials which incorporated heat-sealed seams, so I decided to call on the experts in the field. Upon contacting a company in the northeastern United States that fabricated space suits, I was informed that a 300-ft. (91.4-m) "water-fillable tube" fabricated from impermeable geotextile materials would take 18 weeks from design phase to delivery, would cost approximately $70,000, and would likely not fill to a height of more than 2 ft. (0.6 m). Obviously the time schedule and costs were prohibitive.

In desperation, I sought local expertise in the Sarasota area, near the swamped project. I was fortunate to locate a fabricator with expertise in thermal welding of impermeable PVC fabrics.

The two of us worked non-stop from Friday morning until Saturday evening to cut and thermal weld the components of a 300-ft. (91.4-m)-long unit. Sunday was filled with a trip across the state to round up 10-ft. (3-m) sections of 8-in. (20.3-cm) PVC pipe and 2-in. (5-cm) nylon strap restraints, and with fabricating two aluminum clamp brackets to restrain the tube ends.

Solution # 1

Bright and early Monday morning we deployed the first ProTecTube I™ unit on the narrow beach fronting the previously swamped project. The PVC pipes were jetted into the beach face on the landward side of the water tube. The 2-in. (5-cm), 10,000-lb./in.^{2} straps were employed as circumferential restraints to tie the water tube to the vertical PVC pipes. Multiple 4-in. (10.2-cm) pumps pulled water from the Gulf to inflate the flexible cofferdam. By mid-morning the tube was filled to optimum cross section with the seawardmost portions of the tube measuring close to 5 ft. (1.5 m) in height, tapering up the beach to the end restraints where the height was approximately 2.5 ft. (0.8 m) in height. We employed pumps to handle seepage/dewatering on the landward side of the water tube. Our coastal erosion-control project was completed without further incident in spite of repeated additional small storm events. Upon completion, the tube was deflated, rolled up and transported to the next project.

During the weeks of initial monitoring, we noted design challenges in the rounded, elliptical shape of the water tube cofferdam. The round cross-sectional shape was unstable and would roll seaward unless continuously restrained. Waves impacting the convex seaward face split into a dramatic upward component, which occasionally overtopped the tube, and a downward component, which created a scour trench along the seaward side. Over time the tube settled downward into the scour trench, reducing its effective height and related protection levels. Once the tube had settled to the approximate cross-sectional midpoint, all wave forces were deflected upward and no further scouring was evident. Lastly, the single-layer PVC fabric could conceivably be punctured by sharp, wave-borne debris, again putting the project in danger.

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Photo 2: The eroded shoreline of the Longboat Key condominium before installation of the wedge-shaped geotextile-tube erosion-control structure.

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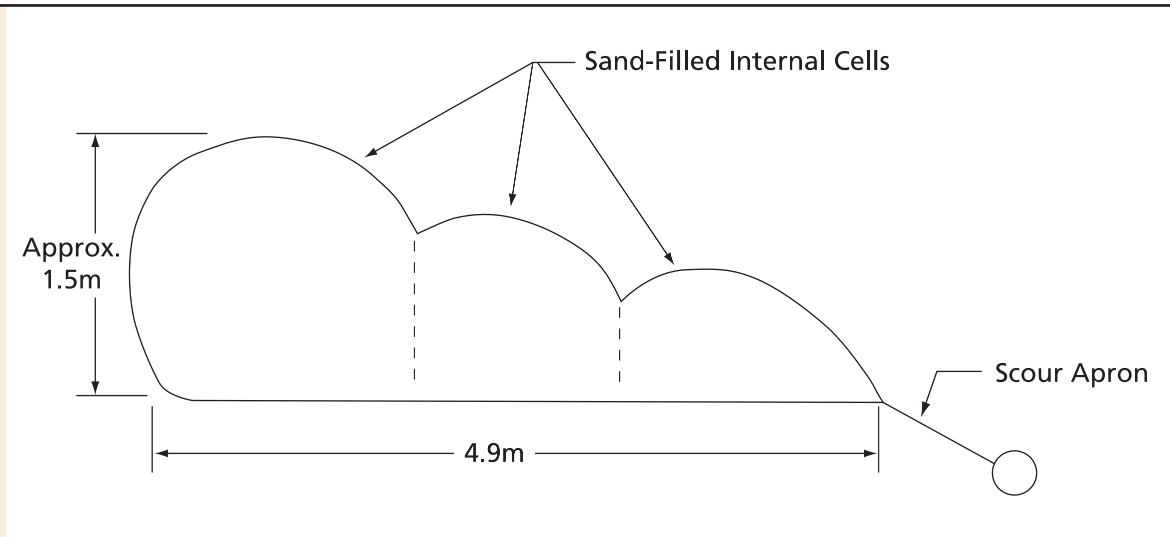
Photo 3: The progressively increasing tube heights of the wedge-shaped geotextile-tube structure, here shown installed in the beach of the Longboat Key condominium, deflect wave forces upward.

Solution # 2

The solution to these challenges proved to be a series of parallel geotextile tubes, each larger than the previous, incorporating a flat, wide stable base to increase stability and rolling resistance. However, holding multiple separate sand- or water-filled parallel tubes together in any semblance of uniformity proved to be a complex and difficult feat in a static environment, much less the turbulent coastal arena. The optimum design configuration evolved into a single factory-assembled unit of predetermined length, which was comprised of multiple parallel tubes, all sharing the same top and bottom, but separated horizontally by internal vertical dividers (or “webs”). The resultant wedge-shaped ProTecTube II™ proved to have much greater inherent stability and rolling resistance than the single elliptical geotextile tubes.

The initial installation was accomplished in Longboat Key on the west coast of Florida in 1988. Monitoring by the Army Corps of Engineers, the Coastal Planning and Engineering firm, and others documented the project’s performance. When periodically uncovered by storm events, the majority of the wave forces were deflected upwards, gradually dissipating wave energy across the progressively increasing tube heights, through distance, time and space, against gravity. Upward wave deflection has proven to have none of the negative effects of horizontal wave reflection. Pedestrian traffic was not impeded when the tube structure was temporarily uncovered by storm events. The gradual slope of the wedge design has allowed repeated natural sand recovery, to the surprise of many within the coastal engineering field.

Figure 1: A cross-sectional drawing of the wedge-shaped geotextile-tube erosion-control structure.



Geotextile materials developed

Just as the nonstop round-the-world flight of the Voyager was impossible until the development of space age composites, the development of this patented device became feasible as a result of the development of job-specific fabrics. The author, working with a textile manufacturer, co-developed and field-tested numerous evolutions of proprietary geotextile fabrics designed to provide superior performance within the harsh environment of the coastal arena. Experience proved a need for a minimum of two separate fabrics—an inner case material designed to contain the fine sand particles, and a separate outer armor layer specifically designed to contend with the problems inherent in the harsh coastal environment. The combination of the two-fabric composite structures has proven to be superior in field testing over many years and multiple projects since the mid 1980s.

Although continuing to evolve to this date, the state-of-the-art geotextile fabric is comprised of a series of dacron polyester fibers woven into strands of predetermined strengths, which are then extrusion-coated with a proprietary formulation. The resultant coated strands are then woven into specialized heat-set geotextile fabrics with inherent design characteristics intended to provide superior fabric performance in the areas of puncture, abrasion, tear and tensile strength, and ultraviolet protection. An optional aesthetic enhancement is the ability to color code the materials to match the project-area beach sand. Kevlar® fibers may be incorporated in the armor layer in a "rip-stop nylon" configuration.

Benefits

Although designed for annual high-frequency, low-magnitude storm events, the installation has exceeded performance expectations by providing significant storm protection during several low-frequency, higher-magnitude storm events in the project area. This was documented by the Army Corps of Engineers Engineering Technical Letter #1110-2-353, published on December 31, 1993.

The benefits of the wedge-shaped geotextile tube device include improved performance during storm wave attack and minimal adverse environmental impacts to the natural dune system, the sandy recreational beach amenities, or adjacent coastal properties. Extremely fast deployment can provide the coastal client with immediate emergency protection when water filled, then higher levels of long-term storm protection when sand filled, covered and vegetated with plants.

Future applications

The next step in the evolutionary development of this technology employs sand-filled geotextile tube devices in conjunction with specialized patented concrete modules to create a composite offshore reef structure. These artificial reefs will be adorned with live coral to create living fringe reefs and underwater breakwaters that reduce erosive wave impacts on beaches and provide enhanced swimming areas. **GFR**

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Jay Sample is a marine structures designer and president of Advanced Coastal Technology Inc., Topton, N.C. He holds the patent for the technology discussed in this article (U.S. Patent # 4,966,491).