Lessons Learned From the Failure of Geotextile Erosion Control Tubes

by G.N. Richardson

ABSTRACT: Large circumference sand fill geotextile tubes were used to stabilized the beach on a small private island facing the Atlantic. The tubes were stacked to provide a low profile erosion resistant barrier to shoreline erosion. The geotextile tubes were used in place of concrete or sheet pile revetments because of a State law that limited the used of 'hardened' structures on the coastline. This paper reviews two design concepts for the tube erosion barrier system and chronicles the installation of a regulatory driven compromise system. Additionally, the paper describes the eventual failure of the regulatory system and makes observations regarding the performance of such systems.

KEYWORDS: Geotextile, Erosion Control Tubes, Failure, Field Observations

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1 Introduction

The shoreline and coastal islands of the Atlantic coast are face with dramatic development and the continuance of a natural erosion process that makes these shoreline dynamic. The author was asked to review the design of a 'soft' erosion control system that would slow the loss of sands from the shoreline of a small private island off of North Carolina. Significant erosion was occurring on an annual basis as the result of Northeaster storms that are common in the winter months. Additionally, hurricane Diane had swept near the island and depleted the shoreline and impacted the primary dune system, see Figure 1. The owners of the island had been through several cycles of expensive beach renourishment, only to see the newly placed sand eroded the next winter.

North Carolina has enacted a Coastal Area Management Act (CAMA) that established a Coastal Commission empowered to limit construction along the States coastline. Early in their history, the Coastal Commission banned the use of hardened structures to limit shoreline erosion. Hardened structures are those constructed of timber, concrete, or steel and include jetties, groins, etc. However, the Coastal Commission did rule that the use of sand bags was acceptable. Such 'soft' elements are composed primarily of sand and can quickly be removed without leaving significant debris that can hurt swimmers or damage boats. Additionally, the Commission had not established a limit on the size of the sand bags.

The initial 'soft' system had been developed by a landscape architect who had been involved in the development of the island, a local geotechnical engineer, and a local manufacturer of nonwoven geotextiles. The author was asked to review this design and the impact that restrictions imposed by CAMA would have on its serviceability.

2 Soft Shoreline Erosion Control System

A section drawing of the proposed soft shoreline erosion control system is shown on Figure 2. Each erosion control tube was to be constructed of a 16 ounce per square yard polyester nonwoven geotextile. The tubes were to be sewn together using two lines of stitching forming a prayer seam. The AOS of the geotextile was selected to provide maximum retention of the sand filling while still allowing rapid drainage of water. Individual tube lengths exceeded 400 feet and the overall length of shoreline to be stabilized was approximately 2000 feet, see Figure 3. It was assumed that the tubes would be filled by inserting the discharge pipe from a small cutter head dredge reclaiming sand from offshore sandbars.

The geotextile tubes were intended to limit erosion by shielding the sand located behind the tubes from the force of the surf. As the sea removed sand from the toe of the system, the lead tube would drop and prevent the sea from undercutting the tube grouping as shown on Figure 4. Past studies had shown that the sand was commonly removed to a depth slightly below the -3 feet mean seal level (MSL) level. The design called for placement of the first (and lowest) erosion control tube at an elevation close to this elevation. This would limit the potential depth that the tube would have to drop to seal off further sand loss. It was anticipated that the sand loss would occur during a winter Northeaster or during a fall hurricane. That following spring, it was common for the sand from off-shore sandbars to be redeposited on the shoreline. This natural replenishment had previously been insufficient to restore the beach but would be sufficient to bury the erosion tube system before the summer season.

Early in the design process, there was concern that the high ultraviolet light at the beach would cause a quick degradation of the nonwoven. However, samples left on the beach for up to six months indicated that the UV degradation was limited to a surface crust. This crust was formed from sand embedded in the nonwoven and by the degraded surface fibers. While no attempt was made to study the role of fiber denier, needling pressure, etc. It was observed that the 16 osy nonwoven to be used stabilized at a strength associated with 11-12 osy materials.

3 Regulatory Interference

While the Coastal Commission approved a trial use of the large erosion tubes, they were concerned about their impact on the nesting habits of sea turtles common to the Carolinas. The owners of the island had a local marine biologist evaluate the potential for us of the island by sea turtles. Both island records and the work of the biologist clearly indicated that this island had not previously been a breeding ground for sea turtles. However, the Coastal Commission ruled that the erosion tube system must not interfere with the potential laying of sea turtle eggs. To protect the sea turtles, the Commission ruled that the tube system could not be installed below +3 feet mean sea level (MSL) as shown on Figure 5. This raised the total system approximately 6 feet and meant that a layer of dredge fill would have to be placed beneath the lowest tube. The preferred design placed the lowest tube on the existing beach elevation, which was the lowest recorded in recent history.

4 To Much Money, To Little Sense

At this point the author was asked to review the design of the shoreline erosion control system to evaluate the impact of the CAMA ruling. The raising the system of erosion control tubes meant that more than 6 feet of sand could be removed from the toe of the system. This would result in significant stretching of the lead tube as in deformed to limit soil loss from beneath the tube system. This distortion could cause failure of the lead tube either by bursting of the tube or by the tube simply rolling into the sea. It was clear that the nonwoven geotextile would not have sufficient strength to remain intact after significant movement. At this point, the author recommended abandonment of the project.

The owners of the island had, however spent considerable effort in obtaining CAMA approval for the project and insisted that it go forward. They reasoned that the erosion tubes once place would eventually settle to the desired design elevation. They also feared facing the next season of Northeasters with their primary dunes heavily damaged.

5 Construction of Soft Erosion Control System

The system of erosion tubes was installed on the beach during the summer of 1988. Each tube was filled with sand by placing the discharge pipe of an 8 inch cutterhead dredge through one of the fill ports provided every 100 feet in each tube. Figure 6 shows a tube being filled with sand in this manner. Note the dramatic discharge of dredge water through the tube. As the sand approached the fill port, the pipe was withdrawn and inserted into the next fill port. Movement of the pipe required a tracked backhoe, but the marine contractor soon became very adept at filling the bags. Approximately 1 bag could be filled each 8-hour day. Once the full system of tubes was placed, the marine contractor placed additional dredged sand behind the tube system. Figure 7 shows the final system in place and awaiting the fall Northeasters. Actual placement of the tubes when essentially as planned.

6 Micro-Degradation of the System

After approximately two months of service, the erosion control tubes began showing signs of localized failure of the geotextile. These failures were due to damage of the tubes by fisherman stabbing pole holders through the bags and other points of weakness in the nonwoven geotextile Figure 8, and at the locations of the dredge pipe fill ports, Figure 9. The fill port failure was particularly surprising and occurred when a Lyster gun had been used to thermally seam a flap of geotextile inside the tube. These breaches in the tubes were simply repaired by sewing patches over the holes and signs were placed on the beach to remind beach users to use care around the tubes. Fortunately, since the island is private, all beach users had a financial stake in the tubes and the frequency of damage reduced.

7 Macro-Degradation of the System

The patched up tube system survived through the summer months and through a series of small late fall Northeasters. These had removed sufficient sand from the beach that the face of the lead tube had dropped approximately 3 feet. The system appeared to be stable in this condition.

Early in winter, a large Northeaster struck the North Carolina coast and precipitated dramatic erosion seaward of the tubes. This erosion caused the lead tubes to drop dramatically; in some locations the drop exceeded 10 feet. The lead bags initially stretched and managed to maintain the erosion seal. This gave the impression of a curtain of geotextile forming a low retaining wall, Figure 10. Within days, several of the tubes had rolled from the system into the sea and gave the appearance of dead whales floundering on the shore, Figure 11.

At this time, the author was asked to evaluate the safety of the remaining system. Arriving early one morning, the sight of dozens of people walking on and beneath the damaged system greeted the author. It quickly became obvious that many of the tubes were not stable and that the vertical faces were in danger of collapse. Fearing the curious could be seriously injured in such a collapse, the author made the decision to cut the tubes open that evening as the tide came in. The tubes were quickly drained of their sand by the ocean surf and the following morning found a stable, though unsightly, shoreline of sand and geotextile tube remnants.

Within a month, the remains of the geotextile tubes disappeared in the seas.

8 Lessons Learned

- The macro failure of the shoreline erosion control tubes followed the author's prediction. The key factor in the failure being placement of the system so high on the shoreline that the lead tube could not seal the toe of the system without experiencing excessive distortion. The original proposed design would have limited such distortions.

- The micro failures had shown that the nonwoven geotextile was not strong enough for this application. The geotextile should be strong enough to withstand the weight of the wet sand it contained,

- the geotextile should be woven or knit in a manner that prevents enlargement of puncture holes, and

- no lyster gun seams should be used when the geotextile will be exposed to an abrasive environment.

No attempt was made to rebuild the shoreline erosion control system and the natural build up of sand along this shore in subsequent years has eliminated the urgency for the home owners. The next hurricane or season of significant Northeasters will rekindle interest in such projects.

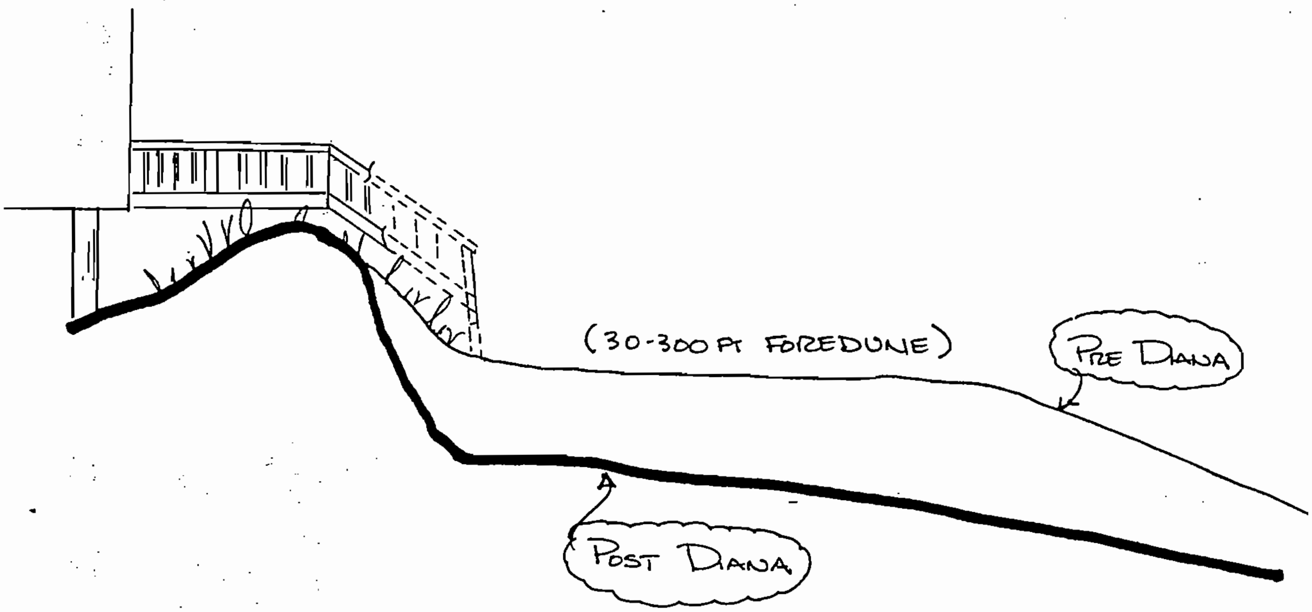

Figure 1 Shoreline Depletion from Hurricane Diane

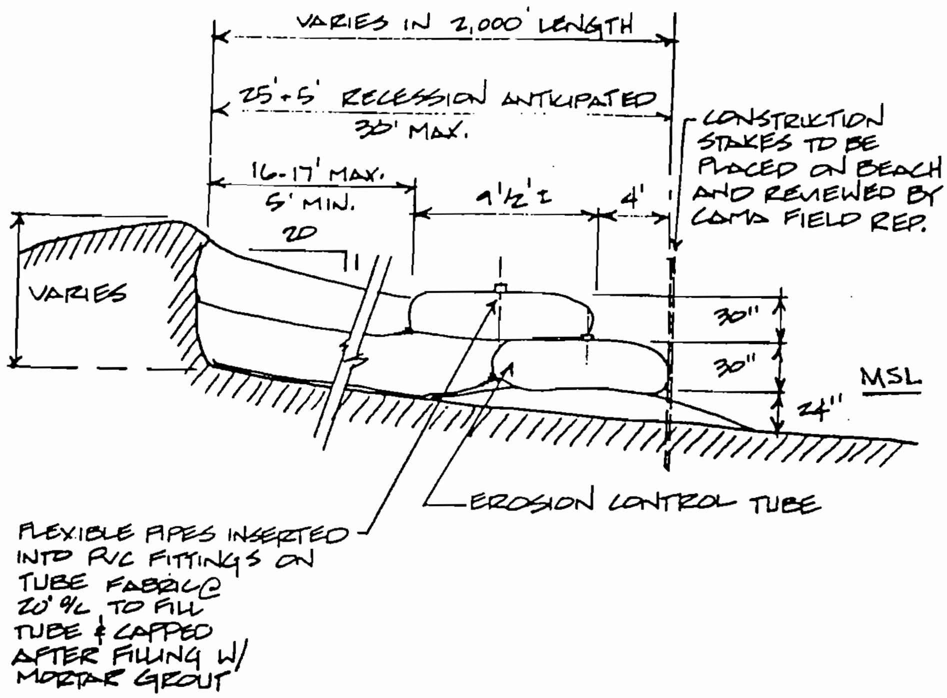

Figure 2 Section of proposed Shoreline Erosion Control System

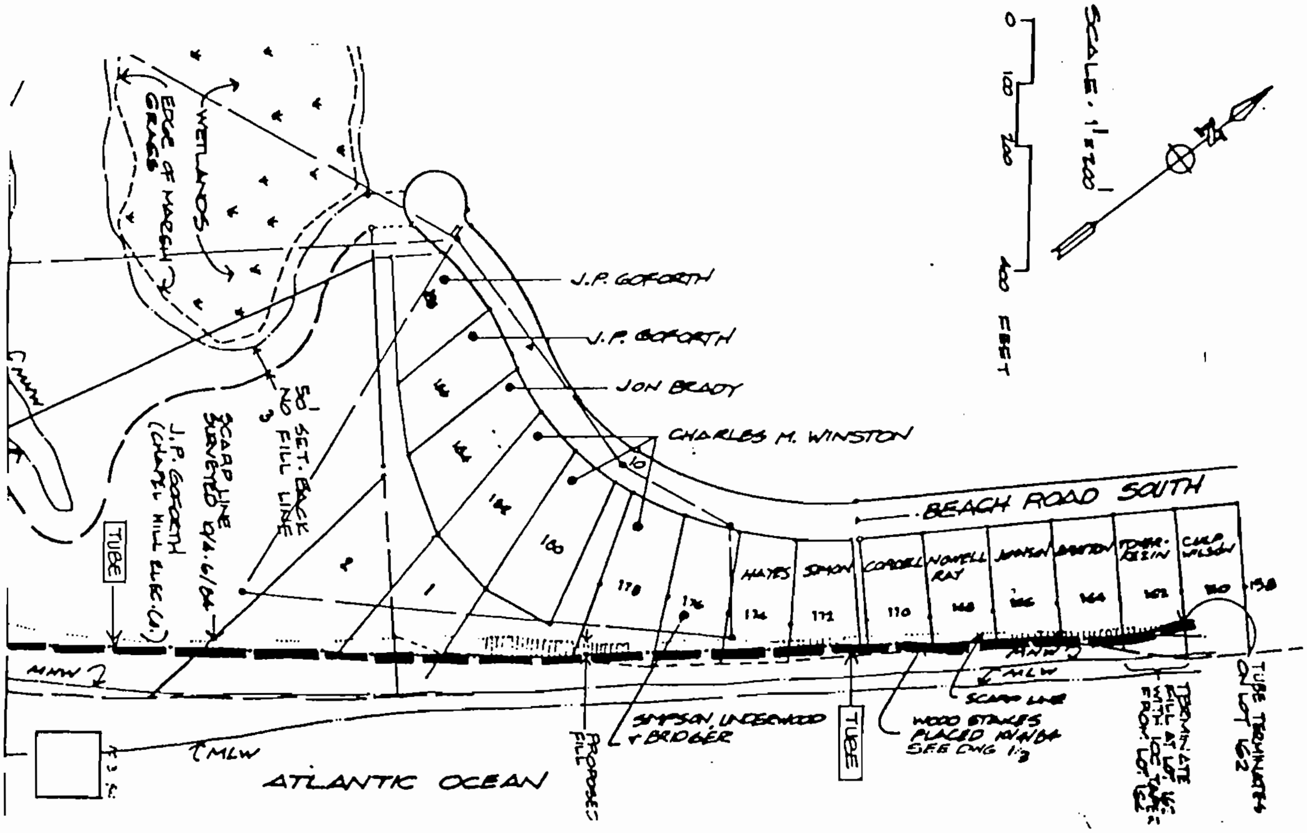

Figure 3 Plan View of Proposed Erosion Control System

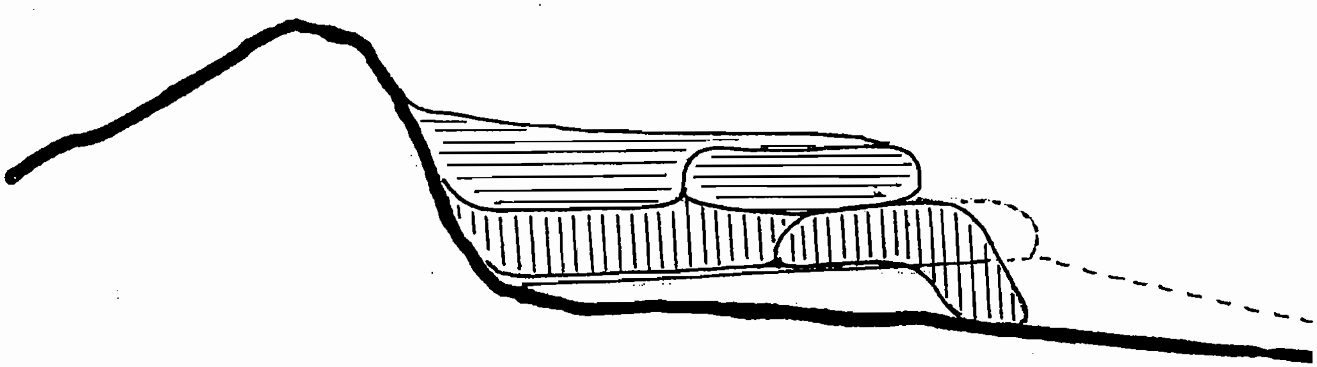

Figure 4 Sealing Role of Lead Tube

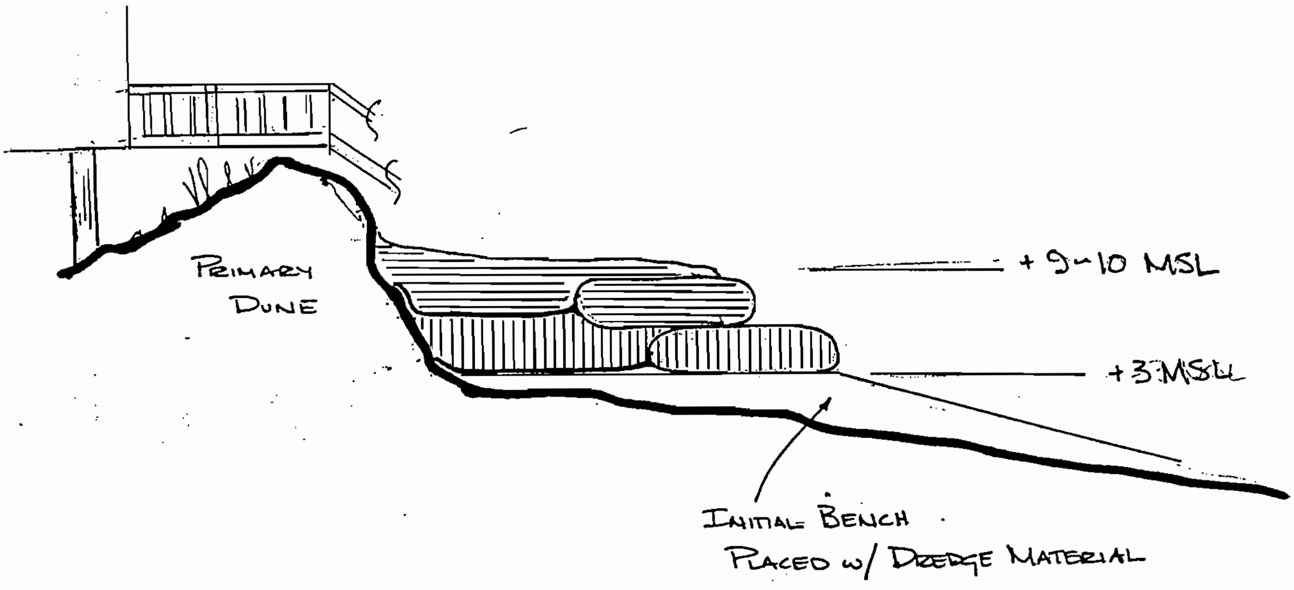

Figure 5 Section of CAMA Approved Erosion Control System

Figure 6 Filling Tubes from Dredge Discharge Pipe

Figure 7 Completed Shoreline Erosion Control Tube System

Figure 8 Micro-Degradation of Tubes - Weak Points in Geotextile

Figure 9 Micro-Degradation of Tubes - Dredge Pipe Fill Ports

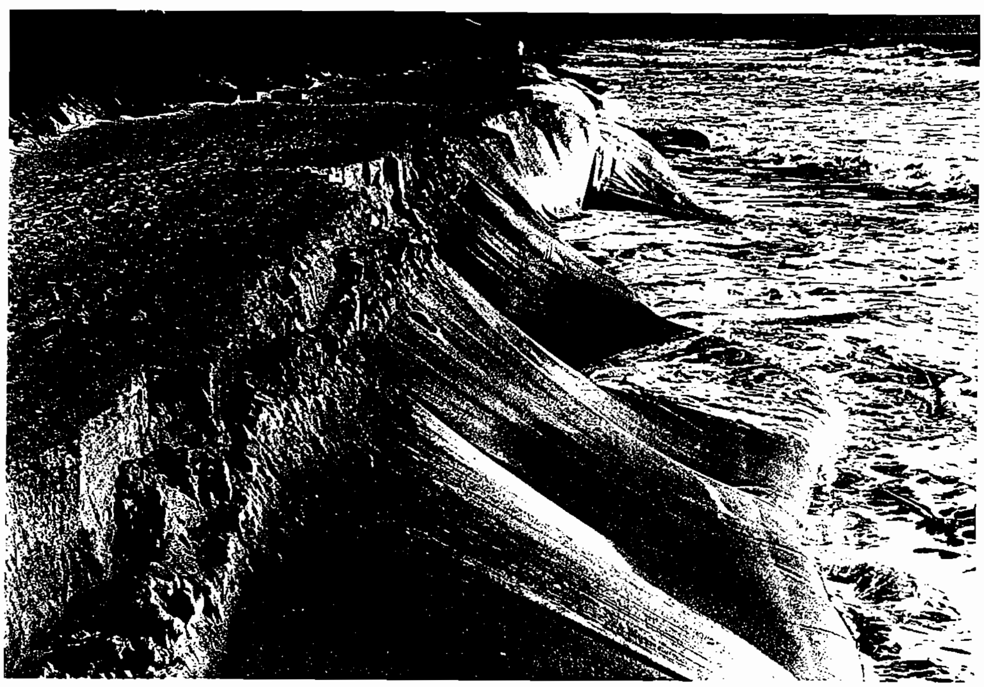

Figure 10 Macro-Failure - Excessive Drop of Lead Tube