Geosynthetic Reinforced Dunes and Bluffs: No Longer Just an Emergency Solution for Shoreline Protection and Improving Resiliency?

Brian Maggi, P.E., M.ASCE,1 Christopher D.P. Baxter, Ph.D. P.E., M.ASCE,2 Aaron Bradshaw, Ph.D., P.E., A.M.ASCE,3 Annette Grilli, Ph.D.,4 and Naser Al Naser5

1University of Rhode Island, Civil and Environmental Engineering, Kingston, RI 02881; email: brianmaggi@my.uri.edu
2University of Rhode Island, Ocean/Civil and Environmental Engineering, Narragansett, RI 02882; email: cbaxter@uri.edu
3University of Rhode Island, Civil and Environmental Engineering, Kingston, RI 02881; email: abrads@uri.edu
4University of Rhode Island, Ocean Engineering, Narragansett, RI 02882; email: annette_grill@uri.edu
5University of Rhode Island, Ocean Engineering, Narragansett, RI 02882; email: naser_alnaser@my.uri.edu

ABSTRACT

“Soft” coastal protection systems, such as Geotextile Sand Containers (GSCs) and Geo-tubes, have been used in emergency or temporary applications for decades to stabilize erosion hot spots and protect homes from extreme storm events. These systems have the potential to protect coastlines, particularly when buried as a core of a dune from larger storm events (e.g. 25 or 50-year storms) while providing flexibility to account for uncertainty in rates of sea level rise and storm frequency. The objective of this paper is to present results of an on-going field study to assess the performance of GSC reinforced dunes in Montauk, NY. Performance of a geo-tube reinforced bluff in Nantucket, MA is also discussed. While laboratory experiments and numerical models have been developed to predict the hydraulic stability of coastal revetments made of GSCs, there is limited performance data of these systems, especially when they are used to reinforce the core of a natural dune system.

INTRODUCTION

The devastating effects of recent hurricanes and nor’easters highlight the need to improve the resilience of coastal communities. There is a trend towards implementing "soft" engineering solutions such as dunes reinforced with Geotextile Sand Containers (GSC) or coastal bluffs stabilized with geo-tubes to improve resiliency rather than traditional hardened structures like stone revetments. These have the potential to protect communities from some storm events (e.g. 25 or 50-year storms) while at the same time providing flexibility in design considering the uncertainty regarding rates of sea level rise and storm frequency. However, there are currently no accepted design standards for these geosystems and general permit requirements vary state to state. While numerous lab experiments and numerical models have been developed to predict the hydraulic stability of coastal revetments made of GSCs and geo-tubes, there has been limited in
situ validation of GSC systems, especially when they are used to reinforce a natural system (Dassanayake and Oumeraci, 2012).

The construction of a GSC-reinforced dune in Montauk, NY in 2016 and a coastal bluff stabilized with geo-tubes in Nantucket, MA in 2014 present excellent opportunities to assess the resilience, stability, and impact of storms on these systems along with the maintenance requirements necessary to ensure longevity of the geotextiles and minimize the container impacts on adjacent natural environments. The Montauk monitoring program being conducted by the authors includes the use of interferometric sonar for nearshore bathymetry, Real-Time Kinematic (RTK) DGPS, ship-mounted LiDAR, and unmanned aerial vehicles (UAV) with “Structure from Motion” (SfM) photogrammetry to develop cross-shore profiles and digital elevation models (DEMs) before and after storm events for the site. The Nantucket monitoring program is run by the Siasconset Beach Preservation Fund (SBPF) and project updates are regularly posted on their website, www.sconsetbeach.org. Observations from the Montauk site are being used to calibrate erosion modelling of a reinforced dune/beach cross section using the wave propagation and sediment transport model XBeach and to validate the performance and stability of the GSCs. The Nantucket site provides additional background when assessing the level of monitoring and maintenance required for a reinforced natural system in a State where coastal protection systems are heavily regulated.

BACKGROUND

In many locations throughout the world, GSCs and geo-tubes have proven to be effective stabilization solutions for temporary reinforcement and protection of vulnerable sections of coastlines in higher wave energy environments. Here in the U.S., most GSC or geotube applications have been in emergency or temporary applications where the level of design, monitoring, and maintenance seems to have a direct correlation to the in-situ performance of these systems (Figure 1). A history of temporary erosion control structures presentation provided by Mike Lopanski of the North Carolina (NC) Department of Environmental Quality summarizes the extensive use of GSCs in NC since 1994 to protect imminently threatened structures (Lopanski 2016). Throughout the timeline presented by Lopanski, the NC Coastal Resources Commission (CRC) made multiple revisions to GSC permit requirements and even explored the use of degradable materials. As of the 2015 legislation, key regulations include the following: permits are valid for eight years for all GSC structures, upon completion of a beach nourishment project exposed GSCs above grade must be removed, and upon expiration of the eight-year permit GSCs exposed above grade must be removed (Lopanski 2016). This summary is an example of the numerous revisions made to the GSC permit requirements in North Carolina over the past 20+ years and it illustrates the evolution of regulations as the assessed performance of these systems continues to evolve. The current conditions of the permits also support the effectiveness of GSCs to protect imminently threatened structures and that they can be incorporated into beach nourishment projects without possibly degrading the performance of the placed sand.
Detailed field monitoring programs are ongoing at two sites in Montauk, New York and Nantucket, Massachusetts where a GSC-reinforced dune and a geo-tube reinforced coastal bluff have been constructed. In New York, the U.S. Army Corps of Engineers has been working with State and Long Island coastal communities since the 1960s to study the coastal processes along the southern shore of Long Island as part of the Fire Island to Montauk Point (FIMP) Study. Due to the severe erosion resulting from Hurricane Sandy in 2012 in the Downtown Montauk beach area, one of the recommendations from the reformulation study following the hurricane was to implement a one-time, stand-alone stabilization project with an estimated 15-yr project life to protect the extremely vulnerable shorefront commercial buildings while a long-term plan was developed (USACE-NAN 2014). Waves are the dominant forcing mechanism for most coastal processes in the Downtown Montauk area and offshore significant wave heights during extreme storm events may exceed 5.5 m (USACE-NAN 2014). The alternatives considered for the stabilization project included (1) beach restoration, (2) beach restoration and a buried seawall, (3) a feeder beach, (4) dune reinforcement, and (5) dune reinforcement and a feeder beach. Since alternatives 1, 2, 3, and 5 assumed a periodic nourishment would be required every 4 years, this increased the annualized cost estimates for these alternatives and violated the stipulation that this project be a one-time, stand-alone project in advance of whatever long-term FIMP solution that may be implemented (USACE-NAN 2014). As a result, a GSC reinforced dune was considered the only viable alternative.

This was the first federally-funded GSC reinforced dune in the U.S. (Figure 2), and there were numerous protests and concerns voiced by a variety groups and individuals. The primary concern was whether the GSC revetment, if exposed, would act as a seawall, narrowing the beach until it disappeared (Young 2017). The Stabilization Project site is over 1 km and consisted of over 11,000 GSCs to reinforce the dunes, which were then reconstructed along with placement of a protective berm. The height and configuration of the GSCs were designed to conform to the existing dune height, tie into the existing undisturbed dunes to mitigate the transfer of erosion to adjacent areas, and are estimated to be stable up to a 50-year storm event. The initial cost of the project was approximately $7M and the final cost was close to $10M due to change orders caused by severe winter storms which eroded project sand and resulted in project delays. Construction was completed in March 2016 and a post-construction site visit was conducted to compare the reconstructed site to the conditions following Hurricane Sandy (Figure 3).
On the east coast of Nantucket, MA the Siasconset Beach community has experienced significant erosion of coastal bluffs leaving historic homes, the Sankaty Head lighthouse, and local roads extremely vulnerable. Surveys of the site began in 1994 prior to the installation of an upgrade to an existing dewatering system designed to redirect water flow and reduce erosion rates (Buck and Hamilton 2017). Since that time over 70 surveys have been completed to monitor the impact of the dewatering system upgrade (completed in December 2001) and subsequent mitigation measures. In 2013-2014, 260 m of geo-tubes (Figure 4) were installed to replace the dewatering system and reduce erosion. This effort was coordinated and funded by SBPF. Due to expressed concerns from the Nantucket Conservation Commission and general public about the transfer of erosion to the flanking areas and steepening of the beach profile in front of the geo-tubes, a rigorous monitoring and maintenance program was established with clear failure criteria. Additionally, funds have been escrowed to remove the geo-tubes and restore the site if the tubes were found to be ineffective or destructive to the adjacent natural environment.
FIELD MONITORING & PERFORMANCE

Various offshore Tropical Storms and nor’easters have impacted the Montauk and Nantucket areas resulting in erosion and exposure of the GSCs and geo-tubes. The Montauk site has been monitored since Tropical Storm Hermine (September 2016) as part of a grant from the National Science Foundation’s RAPID program for collecting perishable data (CMMI #1719671). Numerous post-storm surveys of the beach and dune system have been conducted and various cross-shore profiles and DEM change analyses have been developed. Examples of post-storm photos from a January 2017 nor’easter and collection of cross shore profiles for the most critical section of the project site are shown in Figure 5. The January 2017 storm has been the most severe storm to impact the site when considering peak wave characteristics and water levels. While the severity of various storms has not had a direct correlation to observed erosion due to various factors including mean wave direction during storm events, the January 2017 storm along with Tropical Storm Hermine and the March 2018 nor’easter have provided notable datasets to support additional erosion modeling research.

Surveys were performed using Real-Time Kinematic GPS, Structure-from-Motion photogrammetry using an unmanned aerial vehicle, and boat-mounted Lidar and interferometric sonar (Maggi et al. 2018). Peak wave characteristics and water levels were collected from NOAA’s Data Buoy Station #44017 23 NM SSW of Montauk Point, NY and Tide Station #8510560 in Montauk, NY. Each storm produced different levels of erosion and deposition at the site depending on the conditions. During calm periods between weather events, the beach profile recovers with the natural accretion of sand covering exposed GSCs. Since the severity of observed storms impacting the Downtown Montauk beach project site has not exceeded an estimated 5-year return period, the combined waves and surge from storm events has not produced a condition where waves are directly impacting the GSC revetment as modeled in wave tank experiments described previously (e.g. Dassanayake and Oumeraci 2012).

However, based on the regular monitoring of the Downtown Montauk project site and survey data provided through this research, the Town recently completed a renourishment project in May 2018 with a total cost of $986k to restore the beach for the 2018 summer season (Wright 2018). This has far exceeded initial estimates of annual maintenance for the project, and in 2017, Montauk Tide Station #8510560 set a new record for the number of high tide flood days per year and forecasts suggest 2018 may be worse (Sweet et al. 2018). If that is the case, it is likely periodic replenishment will continue to be needed in the future to maintain a beach profile suitable for
tourism and as required by the U.S. Army Corps of Engineers operations and maintenance agreement with the Town of East Hampton, NY to keep the GSCs covered.

Figure 5. (a) January 2017 nor’easter showing displacement of a single GSC (First Coastal Corp., January 2017), (b) January 2017 nor’easter showing movement of several GSCs towards the ocean (note the dashed line for reference) (First Coastal Corp., January 2017), and (c) Cross shore profiles for the most critical erosion area at the Downtown Montauk beach project site. For reference, the NAVD88 vertical datum is 0.1 m above Mean Sea Level (MSL) for this location.

In Nantucket, annual bluff monitoring, quarterly shoreline monitoring, annual beach invertebrate monitoring, and semi-annual underwater video monitoring has shown that the geo-tubes have performed very well with minimal negative impacts on the surrounding natural environment (Figure 6, Harnett 2017). During the series of nor’easters that struck in March 2018, the geo-tubes were able to keep the toe of the bluff stabilized while other sections of the bluff...
without the geotubes experienced erosion. While the geo-tubes may result in the loss of sand seaward of the tubes during significant weather events, SBPF’s proactive maintenance program restores the project site to acceptable thresholds during recovery. The success of this project, particularly in terms of its well-documented performance and maintenance has led to a follow up proposal, approved by the Nantucket Select Board and currently under review by the Nantucket Conservation Commission, to extend the geo-tubes an additional 900 m to reinforce additional sections of the vulnerable bluff (Sutters 2018).

Figure 6. (a) Shoreline monitoring at 46 transects along Siasconset Beach project area, and (b) Underwater monitoring to ensure cobble/bolder natural habitat is not being covered by the mitigation sand (Harnett 2017).

CONCLUSION

Geosynthetic Sand Containers and Geo-tubes have been used for decades in emergency or temporary applications to protect homes from storms and coastal erosion. More recently, however, there is an appreciation that these systems, particularly when covered or used as the core of a dune, may provide protection for longer periods (e.g 15 to 25 years). The objective of this paper is to provide details of two on-going field projects in Montauk, NY and Nantucket, MA. In Montauk, field monitoring is being used to inform town managers about annual beach replenishment requirements and performance of the GSC core during exposure. In Nantucket, demonstrated performance in protecting a portion of a coastal bluff has led to an application to extend the geo-tubes an additional 900 m to reinforce additional sections of bluff. Collection of such performance data helps to evaluate published design approaches, develop tools for predicting performance, and better inform coastal managers assessing coastal protection alternatives to make their coastlines more resilient.
ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. (CMMI #1719671). The support of Lynn Bocamazo, P.E., D.CE and her staff (U.S. Army Engineer District, New York), Kimberly Shaw and her staff (Town of East Hampton), Aram Terchunian and Benjamin Spratford (First Coastal Corporation), Sue Genther (Siasconset Beach Preservation Fund), and Chris Timpson (TenCate Geosynthetics) is acknowledged and greatly appreciated.

DISCLAIMER

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES


