DEVELOPMENT OF FRAGILITY CURVES FOR REINFORCED DUNES

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INTRODUCTION

The objective of this paper is to present the results of on-going field studies to assess the performance of geotextile sand-filled container (GSC) reinforced dunes and to develop probabilistic fragility curves for a range of damage states to these structures. While numerous lab experiments and numerical models have been developed to predict the hydraulic stability of coastal revetments made of GSCs, there has been limited in situ validation of these systems, especially when they are used to reinforce the core of a natural system (Dassanayake and Oumeraci, 2012). Furthermore, the formulas and nomograms developed to characterize GSC systems are not intuitive for coastal community stakeholders to assess the level of resiliency provided by a beach and GSC dune system. The development of fragility curves offers a solution to assess the performance and understand the tradeoffs of reinforced dunes for coastal protection systems.

IDENTIFICATION OF DAMAGE STATES

The development of fragility curves first requires the identification of appropriate damage states. The definition of "damage" depends entirely on the perspectives of the stakeholders of the dune/beach system. Key perspectives on which to assess resiliency of a reinforced dune include recreation and tourism, habitat, beach replenishment, and coastal protection. It is essential that the measures of damage are quantifiable and reflect all possible modes of failure. The proposed damage states for a reinforced dune include the as-built condition, different stages of sediment erosion leading to GSC exposure, normalized movement of GSCs, and instability of the GSC system for various failure modes.

DEVELOPMENT OF FRAGILITY CURVES

Clear and rational methodology is necessary to develop fragility curves that are an effective tool for coastal planners and decision makers. Storm surge, significant wave height, and return period are used to characterize the forcing hazard. Because of the low frequency of significant weather events at a given site, a large sample of data from the U.S. Army Corps of Engineers North Atlantic Coast Comprehensive Study and statistical cupola analysis proposed by Gruhn et al (2012) provides a joined pair of surge and significant wave height data corresponding to a given return period, e.g. the 100-yr storm. These subsets of selected storms, a hydrodynamic/erosion model, and geotechnical stability model lead to the development of fragility curves to predict the level of damage for a range of forcing hazards. Data from on-going field studies is then used to calibrate the model output.

FIELD MONITORING OF GSC-REINFORCED DUNES

In March 2016, the U.S. Army Corps of Engineers New York District completed one of the first federal projects to reconstruct dunes stabilized with GSCs in Montauk, NY as a short-term stabilization measure while long term alternatives are being analyzed. Since Tropical Storm Hermine in September 2016, the performance of the reinforced dune system has been monitored as part of a grant from the National Science Foundation's RAPID program for collecting perishable data (NSF CMMI #1719671). In addition to surveyed cross shore profiles, the monitoring program uses an unmanned aerial vehicle (UAV), close range aerial photography, and "structure from motion" photogrammetry to develop digital elevation models (DEMs). A georeferenced 3-D model, similar to the example shown in Figure 1, can also be developed from the photogrammetry dense point cloud to identify key features in a field study including damage states. A similar, privately funded project was constructed in Siasconset, MA in 2014 and another GSC reinforced dune is scheduled for construction in 2018/19 in Matunuck, RI. For the Matunuck project, the in situ conditions in and around the GSCs will be monitored with pressure sensor data loggers deployed in a configuration similar to the Recio and Oumeraci (2009) lab experiments.

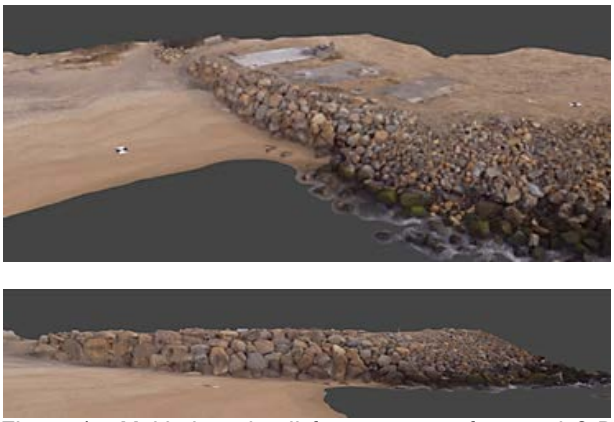

Figure 1 - Multi-view detail from a geo-referenced 3-D model of a revetment in Matunuck, RI

REFERENCES

Dassanayake and Oumeraci (2012): Hydraulic Stability of Coastal Structures Made of Geotextile Sand Containers (GSCS): Effect of Engineering Properties of GSCS, Coastal Engineering, 33.

Gruhn, Salecker, Fröhle, Schüttrumpf, and Thorenz (2012): Flood Protection Dunes - An Approach for Reliability Assessment by Means of Fragility Curves as Part of a Risk and Damage Analysis, Proceedings of 33rd International Conference on Coastal Engineering.

Recio and Oumeraci (2009): Processes Based Stability Formulae for Coastal Structures Made of Geotextile Sand Containers, Coastal Engineering, 56, pp. 632-658.