PLANNED RESEARCH ON THE HYDRAULIC STABILITY OF

GEOTEXTILE SAND CONTAINERS

by

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ABSTRACT

Geotextile Sand Containers (GSC) is a low cost, soft and reversible solution for the shore protection structures and for the reinforcement of existing threatened coastal barriers and structures. The findings from the recently conducted research works have remarkably increased the potential use of GSC in many coastal applications. However, there are still several critical issues, which require further research, in order to enhance the application and performance of GSC-structures. From the extensive analysis conducted on the available knowledge, the important engineering properties of GSC, which were not yet fully understood, were identified. This paper describes the necessity of the knowledge of those properties in understanding the hydraulic stability of GSC-structures. From this study, it was concluded that the influence of different engineering properties of GSCs on hydraulic stability of GSC-structures can be studied by means of specifically designed scaled experiments and numerical simulations. After having more insight into the hydraulic stability of GSC-structures and the influencing parameters of GSCs, it is believed that, more simplified and still reliable stability formulae for the stability of GSC-structures can be developed.

1. INTRODUCTION

There is an urgent need for cost effective, environmentally friendly solutions to mitigate the risk of disasters related to climate change in coastal settlements. More versatile materials and innovative solutions are required for the design of new, cost effective shore protection structures as well as for the reinforcement of existing threatened coastal barriers and structures (Oumeraci and Recio, 2009). Geotextile Sand Containers (GSC) is an ideal solution for the above problem and it has a history of more than 50 years in hydraulic and marine applications. A range of successful coastal protection structures using GSCs have been constructed in many parts of the world, especially in Australia and Germany (Heerten 2000, Saathof et al 2007).

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2. MOTIVATION AND RESEARCH OBJECTIVES

The hydraulic processes affecting the stability of GSC-structures were extensively investigated by Oumeraci et al (2003, 2007), Recio (2007) and Recio & Oumeraci (2008a, 2008b). Nevertheless, the GSC is still an emerging technology and there are no proper design guidelines available for the design of GSC-structures on a sound scientific base. The formulae developed by Recio (2007) are the only process-based hydraulic stability formulae for GSCs. However, these formulae still need to be improved incorporating some more important parameters and also need to be simplified and refined in order to make them more user friendly. In addition, Recio (2007) has adopted and improved a numerical modelling system for GSC-structure, consisting a computational fluid dynamic model (CFD) and two computational structural dynamic models (CSD). Further advancement of this modelling tool will lead to a development of an operational design tool based on CFD and CSD models.

Therefore, the current research will focus on the sand fill ratio and its effect on hydraulic GSC-structures, the use of other fill materials for GSCs and their effect on stability of GSC-structures and the friction between GSCs and its effect on hydraulic stability of GSC-structures. Then, an operational design tool based on RANS-flow model and CSD will be developed. Also, the Recio's formulae will be refined and simplified to make them more user friendly. Finally, a computational model for the stability of GSC-Structures by combining both the semi-empirical formulae and numerical modelling will be developed.

3. METHODOLOGY

A range of different types of laboratory experiments will be designed, which will allow to have an insight into the influence of the properties of GSCs on the stability of GSC-structures and also to obtain the required parameters for numerical modelling of GSC-structures (see figure 1).

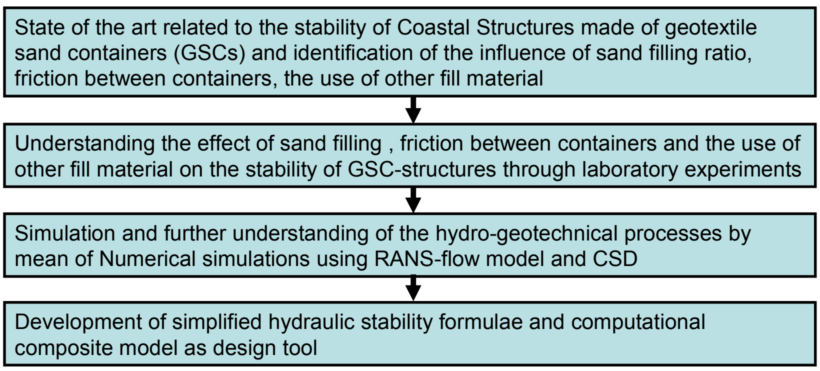

Figure1: Methodology of the planed research

Then, the most appropriate numerical model system will be selected to simulate the hydraulic stability of GSC-structures initially starting with the partially coupled RANS-VOF model and FEM-DEM models as used by Recio (2007). The hydraulic stability of GSC-structures will be modelled using the selected modelling system incorporating the results obtain from physical models tests. Based on this knowledge, finally more simplified hydraulics stability formulae will be developed

4. PRESENT STATE OF THE KNOWLEDGE-DISCUSSION OF FIRST KEY RESULTS

4.1 Properties of Geotextile Sand Containers

The most important engineering properties of GSCs are identified as the properties of geotextile material, the sand fill ratio, the type of the fill material, the interface friction of GSCs, deformability of GSCs and the movement of sand inside the container. More importantly these properties are interrelated (see Figure 2) and their influence on hydraulic stability of GSC-structure is not yet properly explained. Table 1 summarises the conclusions drawn from the state of the art review on properties of GSCs and identified unsolved area to be investigated.

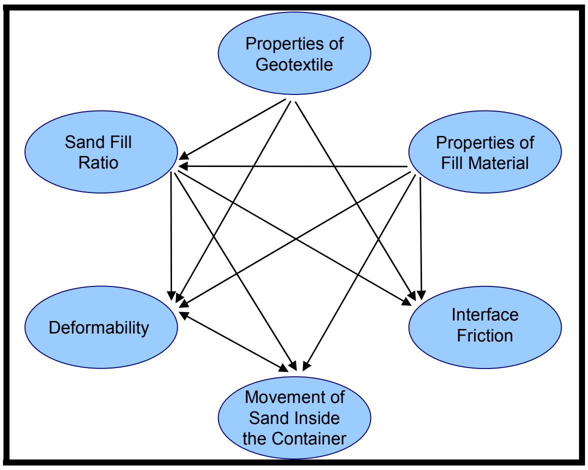

Figure 2: Interrelationship of properties of GSCs

The Sand fill ratio of geotextile containers has been identified as an important property for the stability of GSC-structures by many authors (Oumeraci et al 2007, Recio 2007, Recio & Oumeraci 2008b, Oumeraci & Recio 2009 etc). Nevertheless, none of the exiting formulae for the designing of GSC-structures accounts for the sand fill ratio. Moreover, a clear definition for sand fill ratio is still lacking. Also, the use of other fill materials than sand (Eg. Dredged sediments consist of more fine particles) is also a vital topic to investigate. However, GSCs are more exposed to cyclical wave loading and wetting and drying processes. Therefore, there is a higher risk of loosing fine particles from the GSCs and established filter criterion will not be applicable. Furthermore, Recio (2007) found out that the interface friction between GSCs considerably affects the hydraulic stability of GSC-Structures. However, the effect of interface friction properties is still not fully explained or experimentally verified.

4.2 Processes Affecting Hydraulic Stability of GSC

Considerable amount of process-oriented investigations have been recently performed on the stability of GSC-structures. However, most of the research studies were limited to 1:1 seaward slope and 80% fill ratio. Therefore, more detailed investigation is required to broaden the knowledge on hydraulic stability of GSC-structures with different geometries. Formulae developed by Recio (2007) considered only the stability of the GSCs against two failure modes, sliding and overturning. Therefore, formulae which are not limited to specific geometrical conditions and a sand fill ratio are still to be developed. The overall permeability of the GSC-structure is governed by the size of the gaps between containers (Recio 2007).

Nevertheless, the different fill ratio might results different gap sizes and consequently will have different permeability. A smaller fill ratio more likely to result in smaller gaps. Apart from that, different fill material and different types of geotextiles might also influence the permeability of GSC. Five different applications of GSC have been identified by Recio (2007). The effect of deformation of GSCs on the hydraulic stability for each these applications were however, treated equally. The deformation of GSCs depends on many parameters and more importantly, properties of fill material, fill ratio and properties of geotextile material. Therefore, a new series of experiments should be performed to identify the deformation of GSC during each of the applications and the significance of the influencing factors on deformation for each application.

Table 1: Conclusions drawn from the review of state of the art knowledge on properties of GSCs and identified unsolved area to be investigated.

Property of GSCs	Conclusions Drawn	Areas to be investigated
Properties of Geotextile	Elongation properties of geotextile influence the deformability of GSCs causing lower sand fill ratio and high AOS. However, due to 3D structure of thick nonwoven geotextiles, this effect is relatively lower. Also, friction properties of geotextile influence the interface friction of GSCs.	• Influence of elongation properties of geotextile on deformation of GSC • Fine retention criteria of GSCs and its relation to properties of geotextile (Eg. AOS) Contribution of friction properties of geotextile to interface friction of GSCs
Properties of Fill Material	Properties of fill material decide the migration of sand, the sand fill ratio, deformability of container, movement of sand in side the container, and interface friction of GSCs	• Influence of properties of fill material on deformability and internal movement of sand of GSC • Influence of properties of fill material on migration of fine particles of a GSC subjected to wave attack • Influence of fill material on stability of GSC-structures
Sand Fill Ratio	Identified as an important factor contributes to hydraulic stability. The sand fill ratio decides the deformability of container, internal movement of sand, and interface friction.	• Definition of fill ratio • Influence of the sand fill ratio on stability of GSC-structures • Optimum fill ratio for different GSC applications
Deformability of GSCs	Deformability of GCS depends on elongation characteristics of geotextile material, the sand fill ratio, properties of the fill material, internal movement of sand and stresses acting on GSCs	• Influence of these properties on deformation of GSCs and ultimately on stability of GSC-structures
Interface Friction	Interface friction has high sensitivity towards the stability of GSCs. Interface friction depends on the type of geotextile material, type of the fill material, overlapping length and the sand fill ratio (shape of the GSCs).	• Influence of interface friction of GSCs on the hydraulic stability of GSC-structure • Relationship between direct shear test results of geotextile material and friction properties of GSCs
Movement of Sand inside the Container	Movement of the sand influences the deformation. Movement of sand depends on properties of the fill material, the sand fill ratio and deformability of containers	• Influence of properties of the fill material and the sand fill ratio on movement of particle inside the container and on the hydraulic stability of GSC-structure

4.3 Failure Mechanisms of GSC-Structures

Due to the flexibility and lower specific gravity of GSCs as compared than the rock material or concrete armour units, they behave differently and established design guidelines for rock or concrete units are not applicable. Furthermore, the stability of GSC is more complex and GSC-structures show a number of particular failure modes. A good Knowledge of potential failure modes of GSC-structure is required for the development of computational model for the stability of GSC-structures.

5. SUMMARY

The most important engineering properties of GSCs were identified as the type of geotextile material, the sand fill ratio, the type of the fill material, the interface friction of GSCs, deformability of GSCs and the movement of sand inside the container. More importantly these properties are interrelated and most of them are not yet systematically investigated. Therefore, a series of experimental and numerical modelling will be conducted, in order to understand their influence on the hydraulic stability and to develop a modelling system and simple formulae for the hydraulic stability GSC-structures.

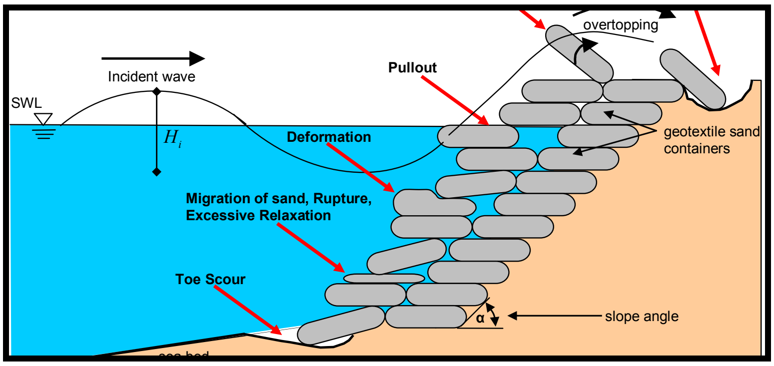

Figure 3: Potential Failure Modes of a GSC-Revetment (After Recio 2007)

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