Inside a Beach Drainage System: a tridimensional modeling

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ABSTRACT

The capabilities of Computational Fluid Dynamics (CFD) to investigate detailed aspects of a physical phenomenon are here used to study the drainage efficiency of a Beach Drainage System (BDS), namely a low-environmental impact tool for shoreline stabilization. Since its controversial performances, a specific and detailed analysis is needed to investigate the performances of BDS. In this regard, the CFD could be an ally to physical modeling with its flexibility. Furthermore, perhaps the most notable of the advantages is its capability to investigate aspects that otherwise it would have been more difficult to measure experimentally. In order to focus the attention on what happens during the percolation inside the drain, a simplified domain is taken into account in order to achieve the tridimensional modeling of filtering phenomenon inside a perforated pipe by means of the OpenFOAM® solver IHFOAM. It solves the volume-averaged Reynolds-averaged Navier–Stokes (VARANS) equations to simulate flow through fine porous media such as the one in a sandy beach. A parametric study has been carried out, with respect to the porous medium and the draining surface characteristics as well as the flow regime inside the BDS. Different solutions on the draining surface are considered, namely different arrangements of the holes within the water flows through. This work aims at investigating the influence on the drainage performances when an oscillating groundwater level (simulating the swash infiltration) is considered. A comparative analysis shows that the finer the sand (lower permeability), the less the draining pattern (i.e. the extent of the perforated surface over the whole surface of the pipe) counts. Results show a good efficiency of the drainage system, that can be addressed, for a given permeability, not only to the conveyed discharge, but also to the hydraulic regime inside the pipe, resulting in a more spread draining surface.

KEY WORDS: CFD; Beach Drainage System; porous medium flow; percolation; swash zone; groundwater; VARANS.

INTRODUCTION

The swash zone plays a crucial role in cross-shore sediment transport (e.g. Mas selink, 2006). It is characterized by phenomena that cover a wide range of variability among temporal scales (i.e. short waves, infragravity or bounded waves), flow regimes (i.e. sub or supercritical), swash-swash interactions, bed or suspended sediment loads, infiltration/evaporation and hence, interaction with the coastal groundwater system.

Less attention has been paid to the swash motion consequences on the groundwater response (Bakhtyar, 2009), rather than the tidal one, even though it was proved to play a role in the sediment transport mechanisms as well (Waddell, 1987). On the interaction between swash zone hydrodynamics and groundwater-dynamics, the idea of beach dewatering was developed. In this context, a research concerning the Beach Drainage System (BDS) performance has been carried out. BDS is a low-environmental impact tool, thought to stabilize the shoreline, at least coupled with other methods (i.e. beach nourishment, Di Risio et al., 2010) in order to increase their lifetime and to guarantee them better economical and efficient performances (Saponieri et al., 2018). It consists of a series of buried pipes, that gravitationally or by means of a pumping system, aim at keeping the groundwater level lower than the natural oscillating level, driven by both tides and waves.

In a porous medium, the water table is defined as the free surface where the pore pressure is atmospheric. Below the water table, in the frame of a continuum approach, it is usually assumed a two-phase phenomenon, where the void spaces between the solid matrix are filled by the fluid phase, i.e. the domain is considered as saturated. The role of the drainage is to interact with the saturated beach in order to enhance the infiltration of the thin oscillating layer in the swash motion, and, thus, to modify the normal mechanisms whereby the particles motion in the swash zone interact with the groundwater system. These mechanisms were found to be correlated to both the shear-stress and the seepage force effect on the immersed particles, other than the altering of the boundary layer due to the infiltration (Baldock and Nielsen, 2010), according to the grain size of the sediment particles (Briganti et al., 2015).

The correlation between the groundwater level and the sediment particles was already studied in past research works since the middle of the last century (Grant, 1948). Nonetheless, different and controversial results have been obtained from its application during the years around the world, hence progressively it has been leaving, even because the field-experience results showed site-dependent performances (i.e. Vicinanza et al., 2010; Bain, 2016). It is worth pointing out that, other to the lack of any guideline (that could help in the design stage of the tool), some aspects of the system have been neglected ever since, e.g. the hydraulic behavior of the pipes, their hydraulic efficiency and some technical aspects that are proper to the hydraulic constructions rather than the coastal field. To face these aspects, the use of a Computational Fluid Dynamics (CFD) tool has been employed, suitable to investigate a domain and phenomena that are fully-tridimensional and non-linear. In order to have an insight about some aspects of its functioning, e.g. the water motion and the flow characteristics inside the drain, in this work a CFD model is used.

The groundwater-swash interaction numerical modeling has been often achieved in the past by simplified process-based models (e.g. Vesterby, 2000; Mas selink and Li, 2001) or coupling two models that were capable to account for both the waves motion and the groundwater dynamics (e.g. Li et al., 2002, Karambas, 2003; Bakhtyar et al., 2011; Saponieri and Damiani, 2015). The model of Li et al. (2002) links beach groundwater and swash, simulating interacting wave mo-