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Innovative Sand Groin Beach Nourishment with Environmental, Protective, and Recreational Purposes

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This paper presents a 3-D experimental investigation (scale: 1 to 50) carried out to reproduce the short-term evolution of beach nourishment with two equally sized (15,000 m^3) but differently shaped disposals: (1) two sandy groins, representing localized nourishments, and (2) a distributed nourishment. The aims are to investigate the short-term planform and profile evolution for the two cases, under the wave forcing of typical Adriatic Sea (Italy) storms and to compare the experimental results with a 2-D horizontal (2-DH) numerical model (XBeach). The "sand groins" nourishment, which is needed to mitigate erosion, evolved into a dune–lagoon system that makes the environment more attractive and is an appealing prospect for tourism.

INTRODUCTION

Dean (2002) considers plain nourishment as a preferential remedy for coastal erosion and flooding. Suitable sand is usually placed along a certain stretch of the coast, shifting the mean waterline seaward. In order to reduce placement costs, the same amount of sand may be dumped in concentrated areas, thus relying on the natural nearshore sediment transport processes to redistribute the nourishment along the adjoining sections of the coast.

A well-documented example of local nourishment is the Netherlands' "Sand Engine" project (Stive et al., 2013), in which a huge, highly concentrated volume of sand (17,000,000 m^3) was placed in the shape of a large peninsula (named, in fact, "Sand Engine peninsula") that protruded 1 km from shore. The objective was to provide safety against flooding and to create new spatial values.

Shoreline evolution after distributed or localized nourishment can be predicted by numerical models, such as XBeach, developed by Roelvink et al. (2009). The XBeach model has been shown to perform well in 2-D laboratory tests in cases of retreating beaches (Roelvink et al., 2009; Van Thiel de Vries, 2009). Simulations of 2-D wave run-ups and inundations (McCall et al., 2010) suggest that the model is capable of reproducing the 2-D morphological features common to overwash, such as foredune erosion, back barrier deposition, and wash-over fans. Additionally, an avalanching mechanism helps to predict dune undercutting (Van Gent et al., 2008) in saturated and dry sand.

XBeach compared successfully with a prototype observation of dune erosion (De Winter et al., 2015) and barrier-island breaching (Williams et al., 2015). For instance, Harter and Figlus (2017) used XBeach to model the impact of Hurricane Ike on the subaerial morphology of a stretch of coastline along the Gulf of Mexico, comparing those results with another numerical model, CSHORE (Kobayashi, 2016). They found that, despite being computationally less efficient, XBeach gave more accurate results when simulating the coastal response and could capture 2-D effects, such as the locations of large breaches.

However, the morphological processes related to short-term evolution of beach nourishment are very complex to study in real conditions, because of the inherent uncertainty of actual constraints and the complexity of the environment examined. Several experimental studies on short-term postnourishment regression and sediment transport rates are available for 2-D conditions, and an overview of work on beach nourishment in large wave flumes was given by Dette et al. (2002). More recently, Di Risio et al. (2010) carried out a wave flume experimental investigation in order to reproduce the cross-shore evolution of unprotected sandy beaches and coasts protected by submerged breakwaters. Grasso et al. (2011) studied the morphological response of nourishments placed either on the outer bar or directly on the beach face. Ruessink et al. (2016) used a large-scale laboratory to investigate cross-shore sediment transport under "erosive" storm waves and "accretive" swell waves. Scale effects were studied within the EU Sands Project in which three wave flumes with different geometrical scales were used to reproduce identical wave conditions (Grüne et al., 2008).

Experiments in 3-D conditions (i.e., carried out in wave basins) focus on the evolution of traditional distributed nourishments. For instance, Work and Rogers (1998) investigated in a wave basin the influence of several wave and beach parameters on the rate of diffusion from a nourished beach, involving two different nourishment planforms. Karasu et al. (2008) conducted a series of 3-D laboratory experiments on beach nourishment behavior in order to analyze the influences of berm height, beach-fill median grain size, wave height, and wave period. Martinelli et al. (2006) described beach evolution protected by submerged barriers. Ruol et al. (1997) and Tondello et al. (1998) investigated in wave basin the reshaping of beach nourishment realized in the form of a series (39) of sand groins, effectively remodeled by wave action.

In conclusion, the experimental studies available provide sufficient information to calibrate the numerical models for distributed nourishments, but further investigation is necessary for localized ones.

In view of possible applications along Northern Italy's Adriatic coast, experimental and numerical investigations were carried out in order to examine the evolution of two different types of small localized maintenance nourishment under the wave forcing of typical Italian storms.

This paper compares the traditional configuration of a rectangular nourishment with an innovative design called "sand groins."

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