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Laboratory Study on the Effect of an Artificial Sandbar on Nourished Beach Profile Evolution

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In this study, a physical experiment is conducted in a wave flume to investigate the evolution process of a beach profile confronted by an artificial sandbar. Random waves with the JONSWAP spectrum are chosen to represent the storm wave condition. The time series of free surface elevation along the wave flume and equilibrium beach profile are acquired. The spatial variation of wave hydrodynamics, bar behavior, and morphological characteristics during the nourished beach profile evolution toward the equilibrium state is investigated. The effect of installation position, submerged depth, and median grain size of the artificial sandbar on beach erosion is discussed.

INTRODUCTION

Many sandy coastal systems dominated by waves in the world have at least one longshore sandbar (Ruggiero et al., 2016; Aleman et al., 2017; Eichentopf et al., 2018), a ridge of sand generally located in water depths less than 10 m. The longshore sandbar is an important geomorphological unit in the coastal zone. Nearshore sandbars protect the coast by causing incoming waves to break further offshore and reducing the potentially harmful wave energy acts on the beach as a result (Pape, 2010; Dubarbier et al., 2015); this mechanism is named the "lee" effect (van Duin et al., 2004). During major storms, nearshore sandbars substantially reduce the intensity of swash zone processes and potential extreme wave run-up, which is a critical component to inundation as well as dune and cliff erosion (Sallenger et al., 1985). In addition, field observations show that artificial sandbars migrate toward the shore under certain conditions and contribute to the accretion of material on the beach face (e.g., Marinho et al., 2020)—in other words, the "feeder" effect takes place (van Duin et al., 2004). Building artificial sandbars has been adopted worldwide as a soft strategy to recover and protect beaches from erosion (e.g., Browder and Dean, 2000; Pan et al., 2017; Marinho et al., 2020; and Kuang et al., 2021).

A sudden placement of a sandbar underwater sharply changes the coastal hydrodynamics and in turn influences the sediment transport and morphological evolution (Kuang et al., 2021). Because of this important feedback between the morphology and hydrodynamics, the study of beach profile evolution in response to artificial sandbars with various configurations (e.g., geometry dimension and grain size) is of significant interest. However, an accurate prediction and widely acceptable design methodologies for artificial sandbars are still not well developed. Before being used in fields, physical experiments and numerical simulations are commonly used approaches for studying the effect of an artificial sandbar on beach nourishment.

Zwamborn et al. (1970) conducted several physical tests to determine the optimal dimensions of the bar for the protection of Durban's beaches. They concluded that the change of the beach can be reproduced if the similarity of the ratio of the shear to settling velocities between an experimental and field condition is satisfied. Hwung et al. (2010) carried out a series of experiments to study the motion of artificial sandbars with various initial geometries on various inclined bottom slopes under regular wave conditions. They proposed a new parameter, the cumulative transport rate, and related it to the sediment transport and sandbar stability. In this study, the sandbar was constructed on a fixed bed, and the evolution of background sandy beach was thus neglected. Grasso et al. (2011) experimentally investigated the effect of the installation position of an artificial sandbar on the wave hydrodynamics and associated sediment transport along cross-shore beach profiles at the timescale of storms. Their study shows that the bar acts as a wave filter and reduces shore erosion (lee effect) if positioned in deep water, whereas nourishment adjacent to the shore leads mostly to shore feeding and reconstruction (feeder effect). Atkinson and Baldock (2020) experimentally investigated different nourishment options, one of them being the building of an artificial sandbar, to mitigate sea-level-rise-induced erosion. Li et al. (2021) carried out two experiments on the beach profile equilibrium of shoreface nourishment under mild wave conditions. It was observed that the artificial sandbar increases local wave height and strengthens wave nonlinearity. Refer also to Ma et al. (2018) and Kuang et al. (2020) for other recent laboratory studies considering beach profile evolution under shoreface nourishment.

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KEY WORDS: Physical experiment, beach profile, artificial sandbar, sediment transport, wave hydrodynamics.