Morphological responses of the sand engines to a flood process

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ABSTRACT

Sand engines are first used as sandy headlands and nourishing source in Qinhuangdao, China. To investigate the morphological responses of the submerged and emerged sand engines to a flood process, a numerical model is established for simulations. The results indicate that the flood-induced vortex can alter the littoral currents, and generate a high sediment concentration zone by the upstream input, flood-induced bed scour and wave-induced coastal erosion. The sand engines can hinder the littoral currents, and decrease the maximum concentration along the coast by 80%. Moreover, the maximum erosion depth in the engineering cover area decrease by at least 50%.

KEY WORDS: Sand engine; submerged sandy headland; flood; morphological evolution; coastal protection.

INTRODUCTION

In the past decades, sea level rise led to a great risk of coastal erosion (Luijendijk et al., 2018). To protect the coasts, both hard structures and soft structures were constructed for defense. However, soft structures were superior to hard structures in terms of the maintenance of natural coastlines (Celli et al., 2019; Zhang, 2014). In general, the core technology of soft structures is sand nourishment. Such an approach was first adopted in 1923 for the public beach and boardwalk improvement (Dornhelm, 2003), and then it was spread and developed gradually in the following century (Elko et al., 2021). In 2010s, a sand engine was first applied to provide littoral sand nourishment for the coast under erosion in Netherlands (Stive, 2013), then this pattern was utilized in Mexico, and achieved great effects on local protection (Escudero, 2020). Simultaneously, with the accumulation of experiences in practice, Beidaihe pattern was generated, as an advanced pattern of sand nourishment, which consists of nourished beach, submerged sandbars and artificial reefs (Cai et al., 2019). Based on Beidaihe pattern, shoreward multi-protection systems were widely established, and turned out to be effective on wave attenuation in particular (Kuang et al., 2019).

Moreover, hard structures, such as headlands, were also utilized to improve the system by the compensation for the littoral protection (Kuang et al., 2019).

Nowadays, climate changes lead to the increase of precipitation in North China, and bring about the risks of flood. For example, Hebei Water Resource Bulletin (2021) shows that there were 15 rivers recorded as the peak flood discharge over 1000 m³/s in Hebei Province in 2021. Generally, previous researchers focused more on the interaction between flood and hard structures, like artificial islands and bridges (Sheng et al., 2016; Sheng, 2016; Zhang, 2014). With the progress of ecological restoration, massive soft structures were constructed. Therefore, it is necessary to concern the flood impact on the nourished beaches near estuaries.

Recently, a multi-protection system was utilized for the ecological restoration from Dapu River Estuary to Jinsha Bay, covering vegetated dunes, nourished beach, submerged sand engines, submerged sandbars (Maritime and Fishery Bureau of Qinhuangdao, 2020). Such a system could act as a distributed soft structure based on the combined actions of its components. In this study, we focus on the morphological responses of the sand engines to a typical flood process. MIKE21 is utilized to simulate the hydrodynamics and sand transport at Dapu River Estuary and its adjacent coast. To investigate the littoral protection of the sand engine, three scenarios are set for comparisons, including the bare shore, the restored shore with the submerged sand engines and the restored shore with the emerged sand engines. The distributions of suspended sediment concentration and the bed thickness changes in a flood process are analysed. The findings will provide a reference for the arrangements of sand engines.

METHODOLOGY

Numerical Model

The target shore is located near Dapu River Estuary, in Qinhuangdao.