Numerical Investigation of Shoreface Nourishment Performance during a Storm

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ABSTRACT

In this study, a process-based numerical model is used to simulate the storm-induced evolution of a double-barred beach profile with different schemes of shoreface nourishment. Analysis was made with respect to the wave energy dissipation, bar morphology change, shoreline retreat, beach erosion, and so on. Results show that both outer bar and inner bar will migrate seaward under storm waves, with a decrease of bar crest elevation. The location of nourishment is more important than the height of nourishment. Inner bar nourishment performs better than the outer bar nourishment, but is less stable in morphology. The sediment grain size of nourishment significantly affects the bar stability.

KEY WORDS: Nourishment; bar; beach protection; numerical model.

INTRODUCTION

Shoreface nourishment has been recognized as an efficient and promising approach to protect the beach from storm impacts as well as to feed the berm via wave-induced onshore sediment transport (Stive, de Schipper, Luijendijk, Aarninkhof, van Gelder-Mass, van Thiel de Vries, de Vries, Henriquez, Marx and Ranasinghe, 2013; van Duin, Wiersma, Walstra, van Rijn and Stive, 2004). Normally, the shoreface nourishment is formed by filling sands adjacent to a natural sandbar. During storms, it serves as a submerged breakwater to dissipate wave energy by triggering wave breaking over the bar crest, reducing the storm wave energy and sediment transport capacity in the covered area. Many studies have been conducted to investigate the natural sandbar evolution subject to different wave and tide conditions (e.g., Nielsen and Shimamoto, 2015; Eichentopf, Cáceres and Alsina, 2018). They have found the dynamic relationships between bar morphology, migration direction and wave parameters and water levels. Unlike a natural sandbar, however, the nourished sandbar does not adapt to the local morphodynamics and will evolve more obviously from its original morphology, thus affecting its performance with time. Due to this reason, the morphological change and the underlying hydrodynamic mechanisms of a shoreface nourishment as well as its influence on the beach protection during a storm is still not completely understood.

In this study, we use a process-based numerical model to simulate the storm-induced evolution of a double-barred beach profile with different schemes of shoreface nourishment. The main contribution of this study is to increase our knowledge of bar nourishment performance with respect to the systematic influences of nourishment locations, heights and grain sizes.

NUMERICAL MODEL

The CROSPE model (Zheng, Zhang, Demirbilek and Lin, 2014) for cross-shore sediment transport and beach profile evolution is used in this study. The model consists of four modules briefly described below.

Wave Module

The phase-averaged energy-balance equations are used to simulate transformation of wave and surface roller (Stive and de Vriend, 1994):

\[ \frac{\partial (E_c c_g)}{\partial x} = -D_w - D_f \]  
\[ \frac{\partial (2E_c c_g)}{\partial x} = D_w - D_f \]

where \( E_w \) is wave energy density, \( E_c \) is roller energy, \( c_g \) is group velocity, \( c_p \) is phase velocity, \( x \) is horizontal coordinate (positive shoreward), \( D_w \) and \( D_f \) are energy dissipation due to wave breaking and bottom friction, respectively, \( D_r \) is roller dissipation. \( D_w \) is estimated with the breaking formulation proposed by Janssen and Battjes (2007). The wave setup \((\eta)\) is solved with the depth-integrated and time-averaged momentum equation:

\[ \frac{\partial S_w}{\partial x} + \frac{\partial R_w}{\partial x} + \rho g (h + \eta) \frac{\partial \eta}{\partial x} = 0 \]

where \( S_w \) is wave radiation stress, \( R_w \) is roller momentum flux, \( \rho \) is water density, \( g \) is gravity acceleration and \( h \) is still-water depth.