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Numerical Modeling for Gravel Beach Deformation Using 2-Way Method

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Fluid motions of waves interact with bed materials mainly through the bottom shear stress caused by water particle motion near the bottom, which leads to topographical changes. The altered bottom profile, in turn, affects the wave fields, and changes in these fields can lead to sequential bottom profile change. Most of the studies on the sediment problems, however, have not considered the effects of the altered bottom profile on wave fields. To predict topographical changes more accurately, the changed bottom profile should be reflected in calculation of wave fields over time, i.e., the 2-way method is required. In this study, a numerical model considering dynamic interactions between wave fields and topography change caused by on-offshore sediment transports is proposed to estimate the topographic change of gravel beaches. The new feature of the present model is the integration of the wave and sediment model. Comparison between numerical and existing experimental results showed that the present model is useful to simulate wave fields and the beach topographical change of gravel beaches. In particular, the newly developed model based on the 2-way method, in which the dynamic interaction between fluid motion and sediments can be considered through the feedback process, greatly improves prediction of the gravel beach profiles.

INTRODUCTION

Beach erosion caused by broken coastal balance is one of the seriously important problems in coastal engineering and thus the subject of of large interest. So far, various attempts have been made to assess beach deformations. However, it is difficult to simulate beach morphodynamics directly because of the complexity of the underlying mechanisms involved in sediment transport. Therefore, most numerical models for predicting beach evolutions are based on the quantitative relationships for sediment transport and fluid motion, mainly established by laboratory experimental data. As a consequence, various empirical and semi-empirical formulations have been proposed (e.g., Engelund and Fredsøe, 1976; Madsen and Grant, 1976; Watanabe et al., 1980; Mimura et al., 1986; Sato and Kabiling, 1994) and used to predict sediment transport rate in most numerical investigations. For instance, Madsen and Grant (1976) established a relationship between an averaged sediment transport rate and the Shields parameter under unidirectional flow. Watanabe et al. (1980) and Mimura et al. (1986) proposed the semi-empirical equation for sediment transport, considering the effect of return flow, and developed the 3D beach deformation model under wave-current coexistence fields. Shibayama and Horikawa (1982) performed laboratory and field investigations to formulate a predictive model of 2D beach profile change, and proposed a sediment formula based on the observed transport patterns. Sato and Kabiling (1994) found the sediment transport equation capable of calculating the instantaneous local sediment transport rate with time development according to the bed load and suspended load of sediment transport, and succeeded in predicting sediment transport in the swash zone. Pedrozo-Acuña et al. (2006) applied the sediment transport equation considering the effect of slope corrections and friction angle by revising the formula for sediment transport rate proposed by Meyer-Peter and Mûller (1948) to gravel beaches. Also, from a sensitivity analysis, they showed that the topographic changes could be reproduced to some degree although there wasn't enough quantitative agreement between experimental and calculation profiles.

In general, since the estimation of the sediment transport depends entirely on the description of bottom shear stresses, the application of the appropriate hydrodynamic model is important for the determination of the sediment transport. However, most numerical models have applied the shallow water equations to determine the external force of sediment, which could not give sufficient information about the fluid fields. Furthermore, they are mainly based on a 1-way method, in which topographical change is updated based on the information of already computed fluid motions, i.e., in these approaches, the effects of the altered bottom profile on fluid fields or vice versa are completely neglected. Alternatively, the 2-way method, in which the dynamic interaction between fluid motion and sediments can be considered through the feedback process between 2 phenomena, is a more appropriate approach. Fluid motions of waves interact with sediments mainly by means of the bottom shear stress caused by water particle motion near the bottom, which leads to topographical changes. The altered bottom profile, in turn, affects the flow fields, and changes in these fields will lead to further alterations of the bottom profile. Therefore, to provide a better prediction of the gravel beach deformation, the changed bottom profile should be reflected when calculating fluid fields over time.

To date, only a limited number of numerical investigations has considered the fluid-sediment interactions in a morphodynamic model to predict the evolution of the bed. Liang and Cheng (2005) proposed the 2-way-based numerical model for assessing local

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