International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 30, No. 3, September 2020, pp. 349–356; https://doi.org/10.17736/ijope.2020.hc19

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Experimental Study on Spatiotemporal Profile Change in Gravel Beach

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To determine the mechanism of gravel profile evolution, the spatiotemporal beach profile change was investigated from hydraulic experiments. The temporal profile deformations were obtained by image sampling. Utilizing these results, the scenario experiments were conducted to produce ordinary morphological deformation, such as berm formation, collapse, movement, and growth, under the accretive-type regular wave. As a result, it was found that the incident wave complexly interacts with the downwash and morphological profile shape, and the deformation of the break-point step is affected by the amount of movable sediment. By controlling these factors, we successfully produce the berm collapse under the accretive-type wave.

INTRODUCTION

Gravel beaches are principally located in the rough wave environment. Frequently occurring storm waves directly affect beach erosion and rapidly generate beach deformation in a relatively short time. Littoral drift, infragravity waves, and tide are considered as essential factors affecting beach erosion (Katoh and Yanagishima, 1992; Mizuguchi and Seki, 2015), but the overall amount of energy is predominant in the wind waves and swells. Additionally, this fact becomes more apparent when the target beach is localized to the special environment where the beach has microtidal or low mesotidal conditions and consists of gravels (Short, 1991). As a result, the incident wave and the sediment transport in the cross-shore direction are subjected to the most influential factor causing dynamic changes in morphology, and determining the relationship between wave parameters and profile deformation was one of the main issues in previous studies (Dean, 1973; Sunamura and Horikawa, 1974; Hattori and Kawamata, 1980). These issues were discussed in U.S. Army Corps of Engineers (2008) and Goda et al. (2009).

Sunamura and Horikawa (1974) proposed the classification of beach profiles using wave height, wave period, slope of the initial profile, and size of sediment grain. The use of this discriminant equation facilitates the categorization of the beach profile as an erosive or accretive type for given wave and beach conditions. Hattori and Kawamata (1980) solved the problems for the application of grain size by using the fall velocity of sediment. Their solution is based on the balance of external forces acting on the sediment particle between the stirring power for suspending sand and the resisting power for the fall velocity. Dean (1973) also mentioned the importance of a dimensionless fall-time parameter consisting of the fall velocity, the wave height, and the wave period. However, it is necessary to determine whether these discriminant equations apply to the gravel beach.

Short (2006) classified Australia's various beach environments, including gravel beaches, to define general beach types. In the microtidal region, the wave-dominated beaches were classified into reflective, intermediate, and dissipative types (Short, 1999). From among these, the reflective beach often occurs on pure gravel beaches because of the steep slope and the large, heavy sediments. It can be distinguished by the surf-scaling parameter and fall-time parameter proposed by Guza and Inman (1975) and Wright and Short (1984), respectively.

For the pure gravel beach, it is important to understand the morphological changes for the berm and beach step evolution in the narrow swash zone and surf zone due to the steep beach slope and the characteristics of the gravel particle. However, classifying beach deformation by the relationship between wave information and fall velocity has an uncertainty in the gravel beach that is not affected by suspended sediment. Furthermore, the use of the equilibrium-state beach profile with the fragmentary wave information, fall velocity of bed material, and beach slope cannot explain the process of morphological changes occurring on the beach face on the foreshore. Examples of morphological change caused by unknown mechanisms appeared in the field observations of Shichiri-Mihama Ida Beach, Mie Prefecture, Japan (Watanabe et al., 2017). The berm deformation for the formation and collapse are very ordinary morphological changes occurring on the beach face, but these phenomena are not sufficiently elucidated by previous studies (Dean, 1973; Sunamura and Horikawa, 1974; Hattori and Kawamata, 1980; Short, 2006; Short and Jackson, 2013) as mentioned above, because the erosive deformation of the berm occurred under wave conditions of the accretive type.

To determine and understand this issue, a spatiotemporal beach profile change in a gravel beach is investigated in 1:25-scale hydraulic experiments. The properties of the gravel beach used in the experiments were based on real field information from Shichiri-Mihama Ida Beach. To determine the mechanism of beach profile change in the gravel beach, the process of profile evolution under regular wave conditions is analyzed spatiotemporally. Based on this, the scenario for the berm formation, collapse, movement, and growth under wave conditions of the accretive type is designed and experimentally reproduced.

METHODS

Experimental Setup

The experiments were conducted by using the two-dimensional wave flume, which has a length of 30.0 m, a width of 0.7 m, and

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Received March 5, 2019; updated and further revised manuscript received by the editors August 26, 2019. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-eighth International Ocean and Polar Engineering Conference (ISOPE-2018), Sapporo, Japan, June 10–15, 2018.
KEY WORDS: Gravel beach, break-point step, reflective-type beach, step-type beach, beach profile, berm collapse.