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Determination of bar parameters caused by cross-shore sediment movement

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Abstract

Waves, topographic features and material properties are known as the most important factors affecting the sediment movement and coastal profiles. In this study, considering wave height ($H = 6.5$, 17, 16, 20, 23, 26 and 30 cm) and period ($T = 1.46$ and 2.03 s), bed slope ($m = 1/10$, 1/15 and 1/25) and sediment diameter ($d_{50} = 0.18$, 0.26, 0.33 and 0.40 mm), cross-shore sediment movement was investigated using a physical model and various offshore bar geometric parameters were determined by the resultant erosion profile. The offshore bar geometric characteristics are the distance between the bar crest and the shoreline, the depth from bar crest to the still-water level, the distance between the equilibrium point and the shoreline, the distance between the closure point and the shoreline, and the bar volume. Dimensional and non-dimensional equations were obtained by using non-linear regression methods through the experimental data and compared with those of previously developed equations. The results have indicated that the proposed equations fit to experimental data better than previously developed equations.

Keywords: Cross-shore transport; Coastal profiles; Storm-built profiles; Bar characteristics; Experimental study

1. Introduction

The beach profile and sediment transport are highly important factors in design of coastal structure and the latter is mainly affected by a number of parameters such as wave height and period, beach slope, and the properties of the bed and this result in effects on bed profiles.

The beach profiles in which the wave energy is mostly dumped may lead to different characteristics of erosion and deposition under various wave conditions in time. Since most problems of coastal engineering are dependent on a number of parameters, the solution to these problems is usually obtained by physical modeling. The previously carried out works have shown that the results obtained by physical modeling produce better results with respect to those by the prototype model. On the other hand numerical modeling is not satisfactorily fitting due to complexity of coastal hydrodynamics and there is still ongoing research on its reliability (Dean, 1985; Kamphuis, 1985; Güler, 1985; Lakhan and Trenhaile, 1989). It is emphasized that the results obtained from the physical modeling should be non-dimensional due to being easily applicable to field problems and minimizing experimental errors originated from laboratory conditions (Hallermeier, 1985; Wang et al., 1994).

In this work, cross-shore sediment transport is widely studied by taking into account for the wave conditions, the beach slope, and bed material properties by means of a physical model and the bar parameters in erosion profile are aimed to determine during this transport. The studies carried out previously in this subject are summarized as follows.

Dally and Dean (1984) proposed a formula for cross-shore sediment transport by taking an account for sediment transport in suspension only.

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Watanabe et al. (1986) developed a three-dimensional numerical model to estimate cross-shore sediment transport. The results of the model show a good agreement with those obtained by the formulae for sediment transport caused by waves and currents.

Horikawa (1987) proposed a parameter to the beach profile by taking account for the mean beach slope (m) and material diameter (d_{50}), and defined deposition and erosion using this parameter.

Later Hanson and Kraus (1989) proposed a model to express the changing of shoreline and the results of this model were compared with those from field measurements, hence this concludes that the model can be used for preliminary works.

Meanwhile Larson and Kraus (1989) studied erosion and deposition profiles and proposed a formula for bar parameters using experimental data as well as for erosion and deposition criteria. The proposed formulae for bar parameters are given in Table 1.

The current deposition and erosion criteria about cross-shore sediment transport were studied by Kraus et al. (1991) and the relationship between the current deposition and erosion criteria was examined and it is proven that these criteria are insufficient to use in this study.

Table 1
Currently used equations for determination of bar parameters

Sources	Equation	Eq. no.
Larson and Kraus (1989)	$h_{\mathrm{bc}} = 0.66\,H_{\mathrm{b}}$	(1)
	$V_{\mathrm{bv}} = 0.088\,H_0^{2.26}\,w^{-1.36}\,T^{0.55}$	(2)
Silvester and Hsu (1997)	$X_{\mathrm{be}}/L_0 = 0.96(H_0/L_0)/\tan\beta$	(3)
	$X_{\mathrm{bc}}/L_0 = 0.022 + 1.508(H_0/L_0)/\tan\beta + 0.140[(H_0/L_0)/\tan\beta]^2$	(4)
	$h_{\mathrm{bc}}/L_0 \tan\beta = 0.0269 + 0.391\,X_{\mathrm{bc}}/L_0$	(5)
	$V_{\mathrm{bv}}/(H_0L_0) = 160(H_0/L_0)\tan\beta + 11.560[(H_0/L_0)\tan\beta]^2$	(6)
Hsu (1998)	$X_{\mathrm{be}}/L_0 = 1.9\xi_0^{-1.42}$	(7)
	$X_{\mathrm{bc}}/L_0 = 0.40\,\xi_0^{-1.12}$	(8)
Günaydın and Kabdaşlı (2005)	$X_{\mathrm{be}} = 113.98(\tan\beta\sqrt{H_{\mathrm{s}}/L_0})^{1.9762}L_0$	(9)
	$X_{\mathrm{bc}} = 64.966\left(\tan\beta\sqrt{H_{\mathrm{s}}/L_0}\right)^{1.6754}L_0$	(10)
	$h_{\mathrm{bc}} = 3.2041\left(\tan\beta\sqrt{H_{\mathrm{s}}/L_0}\right)^{1.413}L_0$	(11)
	$h_{\mathrm{bd}} = 102.33\left(\tan\beta\sqrt{H_{\mathrm{s}}/L_0}\right)^{1.1813}L_0$	(12)
Hallermeier (1978)	$h_{\mathrm{bd}} = 2.28\,H_0 - 685\,(H_0^2/gT^2)$	(13)

Quick et al. (1991) experimentally studied the discharge of long-shore sediment transport along the beach profile and as a result of this work, it is highlighted that the bed slope and the mean particle diameter have an effect on sediment discharge and its variation along the beach profile.

Hedegaard et al. (1991) studied various wave and current parameters by considering cross-shore sediment transport and defined a bar structure by developing a model for cross-shore sediment transport. The compared results of this model with those from several experiments carried out under regular waves.

Schoonees and Theron (1995) compared 10 models agreed to use for cross-shore sediment transport with each other and the models were divided into three categories, namely fine, average and poor.

In studies of Zheng and Dean (1996), a model was proposed for non-linear cross-shore sediment transport and this model was compared with linear and other currently developed models using experimental data from laboratory conditions and a field having been subjected to two storms.

Leont'yev (1996) studied the discharge of cross-shore sediment transport due to waves by the total transport as a sum of sediment transport and wave run-up, and proposed a model for variation of beach profile by the discharge of sediment transport and shown that the model exhibits good agreements with laboratory and other previously developed models results. On the other hand, without considering the particle diameter indicates one of major lacks of the model in various applications.

Larson (1996) developed a numerical model to compute cross-shore sediment transport and the beach profile under effects of regular waves and in this modeling, three cases of variation of profiles were studied. With this model, it is aimed to investigate bar-forming erosion in equilibrium, berm erosion and effects of broken waves on offshore bar; whereas this model is well fitted in erosion conditions but deposition conditions.

Silvester and Hsu (1997) determined beach profile parameters by non-linear regression techniques using various experimental data obtained from previous works. In this study, equations for bar parameters are also given in Table 1.

Hsu (1998) carried out experimental and theoretical works to determine the geometry of offshore bar. In his experiments, effects of cross-shore waves traveling with variable angles in three-dimensional wave basin. He concludes that cross-shore waves traveling with variable angles make the beach profile be in equilibrium. Eqs. (7) and (8) obtained for bar parameters are also given in Table 1.

Ruessink et al. (2002) made an attempt to determine long-time variation of bar crest near beach profile using the remote sensing method.

Rozynski (2003) assessed observation results in South East Baltic coast and experimental orthogonal function