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Wave modelling in the vicinity of submerged breakwaters

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Abstract

This paper describes a simple method for modelling wave breaking over submerged structures, with the view of using such modelling approach in a coastal area morphodynamic modelling system.

A dominant mechanism for dissipating wave energy over a submerged breakwater is depth-limited wave breaking. Available models for energy dissipation due to wave breaking are developed for beaches (gentle slopes) and require further modifications to model wave breaking over submerged breakwaters.

In this paper, wave breaking is split into two parts, namely: 1) depth-limited breaking modelled using Battjes and Janssen's (1978) theory [Battjes, J.A. and Jannsen, J.P.F.M. (1978). Energy loss and setup due to breaking of random waves. Proceedings of the 16th Int. Conf. Coast. Eng., Hamburg, Germany, pp. 569-587.] and 2) steepness limited breaking modelled using an integrated form of the Hasselmann's whitecapping dissipation term, commonly used in fully spectral wind–wave models. The parameter γ_2, governing the maximum wave height at incipient breaking ($H_{\max}=\gamma_2 d$) is used as calibration factor to tune numerical model results to selected laboratory measurements. It is found that γ_2 varies mainly with the relative submergence depth (ratio of submergence depth at breakwater crest to significant wave height), and a simple relationship is proposed. It is shown that the transmission coefficients obtained using this approach compare favourably with those calculated using published empirical expressions.

Keywords: Submerged breakwaters; Wave modelling; Wave breaking; Wave transmission; Dimensional analysis

1. Introduction

Submerged breakwaters are used to reduce wave energy reaching the beach, and thus reduce sediment transport and the potential for coastal erosion in the lee of the breakwaters. One desirable feature of submerged breakwaters (and low crested structures, in general) is that they do not interrupt the clear view of the sea from the beach. This aesthetic feature is important for maintaining the tourist value of many beaches, and it is one of the considerations in using such structures for shoreline protection.

The role of submerged breakwaters in reducing incident wave conditions at the coast is well known, and several empirical equations (for example Briganti et al., 2003; Seabrook and Hall, 1998; D'Angremond et al., 1996) are available for calculating the transmission coefficients at such structures. These equations are valuable for estimating the transmitted wave heights in the lee of the structure, and thereby carry out an initial assessment of the level of protection provided by a submerged structure.

However, such empirical equations provide limited information on the spatial distribution of the rate of energy dissipation over the breakwater. The modeller can only compute the average rate of energy dissipation over the structure using the calculated transmission coefficient. This approach assumes that wave breaking occurs continuously over the entire structure. This is not correct, and leads to incorrect gradients in wave radiation stresses and corresponding wave-driven flow over the breakwater, especially close to the ends of the structures, where diffraction is also important.

This paper is part of an effort to improve coastal area modelling of waves, flow circulation, sediment transport and morphodynamics in the vicinity of submerged breakwaters. A first step towards this is a reasonably accurate prediction of the rate of energy dissipation over the submerged structure, as this is a key requirement for calculating the wave driving forces required for coastal area modelling of flow circulation and

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associated sediment transport and morphodynamics. This paper is an attempt to contribute to the modelling of wave energy decay and wave transmission over submerged structures, with the view of using such modelling approach in a coastal area morphodynamic modelling system.

Wave energy dissipation over submerged breakwaters is caused by several mechanisms, namely wave breaking, bottom friction and percolation through the porous structure. Of these mechanisms, wave breaking is the most dominant. However, existing models for energy dissipation due to wave breaking are developed for beaches (gentle slopes) and are not directly applicable to breaking over submerged breakwaters. The aim of this paper is to adapt an existing refraction/diffraction wave model to adequately simulate wave breaking (and hence transmission) over submerged breakwaters. The approach is based on Battjes and Janssen's (1978) (hereafter BJ78) theory. This breaking wave model is discussed and calibrated against laboratory measurements for submerged breakwaters. Furthermore, a relationship is developed between the calibrated parameters and wave/breakwater parameters that can be used in coastal process modelling in the vicinity of submerged breakwaters.

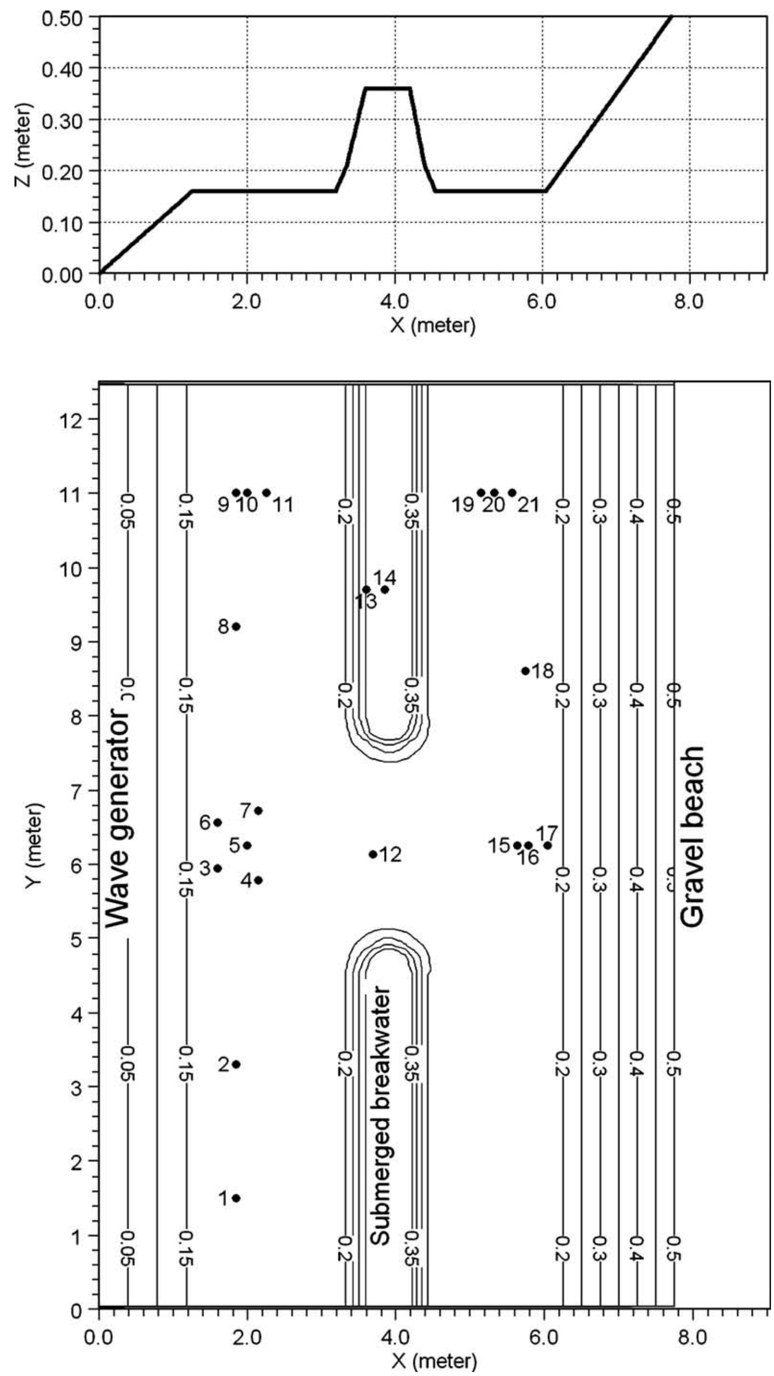

Fig. 1. Bathymetry layout for wide berm showing the locations of wave gauges. Top: bathymetry cross-section through the breakwater. Mean water level at 0.43 m for all the tests.