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Prediction of Gravel Beach Storm Profiles under Bimodal Sea-states

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ABSTRACT

Presently our understanding of gravel beach response under wave attack is limited and approaches to predict gravel beach response rely on formulae and models based on a few physical modelling studies.
Field and laboratory studies (Hawkes, Coates, and Jones (1998)) indicate the importance of complex wave spectra (combining swell and wind sea) in the design of gravel beach recharge schemes.

The objective of the study was to develop a data-set and a new parametric model, Shingle-B, to analyse the generic profile response of shingle beaches under bimodal wave conditions in order to increase confidence in beach cross section design. A mobile bed flume study was therefore carried out at HR Wallingford.

This paper describes both the design and the results of the 2D physical model study.

KEY WORDS: Gravel beaches; shingle beaches; bimodal sea-state; cross-shore profile; physical modelling; wave spectra.

INTRODUCTION

Beaches consisting of gravel (2 to 64 mm), pebbles and cobbles (64 to 256 mm) are generally known as coarse beaches or shingle beaches along the English coastline and can be found in many mid / high-latitude regions (formerly glaciated) of the world (UK, Iceland, Canada, etc.). Gravel and barriers beaches around England and Wales are regarded as a highly effective coastal defence due to the efficiency of dissipating wave energy, and protection against coastal flooding.

Gravel beaches have received less attention than sandy beaches, resulting in a lack of data on storm response. Consequently current empirical models (Powell 1990; Bradbury 2000) remain the only sources for coastal managers to predict profile response.

A sea-state is composed of either wind-sea, swell-sea or a combination of the two (bimodal sea-state). Wind-seas are generated by local winds; their impacts at the coast in terms of overtopping, beach movement, etc., are relatively well understood for many simple configurations. Swell waves, produced as wind waves decay after a storm, have longer periods than locally generated storm waves (wind-sea), although usually lower wave heights.
The spectral shape of a sea-state will show where the principal proportion of the wave energy is and what the wave heights and wave periods are. The spectral parameters derived from wave spectra, principally wave height and period, are one of the most widely used descriptions for waves used in design and prediction methods in coastal/maritime environments. The distribution of the spectral energy may be more important than the wave period or the wave height, though conventional methods of analysis will generally only use these basic parameters.

Field and laboratory studies (Hawkes, Coates, and Jones (1998)) indicate the importance of complex wave spectra (combining swell and wind sea) in the design of gravel beach recharge schemes.
It is possible that extreme swell wave conditions (or a combination of wind-sea and swell) represent a worst case sea-state for some aspects of beach design (Bradbury, 2007). However, little is known about the effect of bimodal sea conditions on sea defences or beaches, and swell is rarely considered explicitly in the design or assessment of shoreline management operations.

Design of gravel beach recharge schemes in the UK over the past 30 years has relied heavily on a parametric beach profile model developed at HR Wallingford (Powell, 1990). Powell's model was developed from an extensive mobile bed wave flume study using waves defined by JONSWAP spectra; effects on wave height and period, water level, sediment size and underlying impermeable layers were all considered. A possible weakness in Powell's model, and in other beach or structure response models, is that they are based on simple wave sea-states, neglecting the possibility to have the complex wave conditions that combine wind sea and swell, forming a bimodal spectrum.

Plymouth University and Deltares, have recently (2014) developed a new numerical model, XBeach-G (a branch of the main XBeach development) which includes the gravel sediment transport processes to simulate the morphodynamics of gravel beaches during storms. However these transport processes are currently under further validation and the XBeach-G model was not fully validated for morphodynamic updating. Therefore, the user will be required to infer