Topo-bathymetric behaviour of a beach controlled by a groyne field and a dune-seawall backshore

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Introduction

Due to shortage of sediment supply and anthropic pressure, the maritime front of Cova-Gala, in the central west coast of Portugal, is seriously threatened by erosion and wave overtopping. Despite being protected by a defence scheme with a groyne field, dunes and seawalls, the continuous anthropic actions, direct and indirect, such as the impact of climate changes, tend to aggravate these hazards (Andrade *et al*. 2007). A better understanding of the wave-structure-sediment interactions and their impact in the surrounding area is key for coastal protection planning.

The advances in morphodynamics numerical modelling and the free availability of such updated process based models have made XBeach (Roelvink *et al*. 2009; Roelvink *et al*., 2018) a powerful tool to predict the hydrodynamic and morphologic processes on sandy coasts. The ultimate objective of the present study is to understand, through XBeach applications, how the morphodynamics of the study site is affected by the local sea-structure-sediments interactions and how much these effects vary with the hydrodynamic driving factors, building upon the consolidated knowledge on modelling approaches of the nearshore and beach dynamics (Van der Hoeoven 2010; Van der Salm 2013; Van Rijn 2013).

Methods

A preliminary evaluation of the relative importance of the processes of diffraction, reflection and undertow currents in the surroundings of a single groyne was done. The two XBeach modes, Surfbeat (SB) and Non-hydrostatic (NH), were applied and compared. The morphological features encountered were analysed and related to the processes accounted in the respective mode. The XBeachX NH mode predicts higher bottom gradients in the surroundings of the single groyne than the SB mode. The NH mode bottom features, specifically the cross-shore submerged bars, more pronounced at the updrift side of the groyne, suggest the impact of the reflection (updrift) and diffraction (downdrift) phenomena induced by the groyne when exposed to high energy waves with a 45° angle of attack. The results of these

preliminary tests, tailored to conclude on the model mode to be applied in the study case, evidence the importance of considering the NH mode.

Due to the challenge of monitoring within the highly dynamic breaking zone, the frequent practical limitation when applying 2DH (area) numerical models is the calibration and validation process, particularly for models that allow several degrees of freedom (parameters estimated from field data), as is the case of XBeach. In the present study, the XBeach model was calibrated through a 1D (profile) modelling exercise and validated through a 2DH modelling test against measured morphological data (Oliveira, 2022). The best morphological performance of the NH mode was obtained with the parameters maxbrsteep=0.4, bedfriction=manning, bedfriccoef=0.02, facsl=1.4, bdslpeffdir=Talmon, dilatancy=1, gwflow=1, gw0=2.22 and the default values for the remaining calibration parameters.

Eight scenarios, with varying hydrodynamic conditions and systematic suppression of structures from the defence scheme (without seawall and without both, seawall and groyne field) were computed. The reference scenario is the existent defence scheme submitted to the Hercules storm (maximum Hs=9.42 m), which occurred in February/2014. The comparison of the morphology of the computed scenarios allowed to conclude on: i) the effect of the defence scheme elements in the morphodynamics during the storm, by comparison of the reference scenario with the scenarios without seawall and total absence of structures; ii) the effect of the wave obliquity; iii) the effect of the surf zone width relatively to the length of the groynes; and iv) the effect of the tidal range.

Results

Despite the seawall being essential in the defence scheme to protect against wave overtopping, this structure is responsible for the additional seabed lowering, verified when comparing with the morphological evolution of this cell (defining a cell as the coastal area between two consecutive groynes) considering dune at the backshore (instead of seawall).

If no restrictions of the sediment supply are imposed at the lateral boundaries, that is, if the incoming sediment fluxes are equal to the waves induced sediment transport potential, the existent defence scheme decreases the protection of the stretch towards south. This situation is caused by the groynes alone but the presence of the seawall aggravates this phenomenon.

The wave obliquity, in the high energy conditions of the study site, highlights the downdrift decrease in protection in the total stretch and within the cells of 250 m length (distance between groynes), independently of the different beach backshore typology, dune or seawall, despite the groynes only partially block the longshore transport.

Under high energy conditions (for waves with Hs higher than the local average wave) the sediment fluxes mitigate the scour at the toe of the groynes head, where the submerged alongshore bar is strengthened.

The phenomenon of erosion of the toe of the groynes head, verified for the case of the local average wave, is aggravated with the tidal range. That must be due to the higher sediment fluxes around the groynes head reached during the lowest sea levels.

The present work provides new knowledge on the implications of modelling morphological evolution in the presence of structures through the different XBeachX mode-versions available. It addresses the morphological impact of sea-structure-sediments interactions in the presence of a combined groyne field-dune-seawall defence scheme. The knowledge acquired can support the interpretation of the topo-bathymetric behaviour in similar coastal defence schemes worldwide, since besides the investigation on the effect of the defence scheme structural elements in the morphodynamics, also comparative tests have been performed to investigate on the effects of the hydrodynamic driving factors, namely the wave energy and obliquity and the tidal range.

The coastal stretch would benefit from sand nourishment of the foreshore-backshore zone in order to guaranty, at least, a minimum width to avoid direct wave action on the seawall and the consequent trigger of erosion.

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