AN IMPROVED AND INTEGRATED MONITORING METHODOLOGY FOR RUBBLE MOUND BREAKWATERS – APPLICATION TO THE ERICEIRA BREAKWATER

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Paper topic: Coastal and port structures

1. Introduction

Breakwaters have been constructed, repaired and have continuously deteriorated for decades with little attention to optimization of the lifecycle costs. Nowadays however, focus is placed on reducing these costs. The total lifecycle cost of a structure is estimated by adding the construction, monitoring, maintenance, repair, reconstruction and decommission/ reconversion costs. In most cases, where structures are designed conservatively using modern methods, construction cost represents the largest parcel of the lifecycle cost. Nevertheless, for structures designed many decades ago or underdesigned projects, the ensemble of monitoring, maintenance and repair/reconstruction costs constitutes the largest parcel of costs. Furthermore, for a breakwater located in an energetic environment and with a long lifespan, the latter costs can be larger than the related construction costs or at least of the same order of magnitude. Minimizing these lifecycle costs through monitoring and risk management is critically important. Thus, in the present paper, focus will be mostly placed on rubble mound breakwaters inspections, surveys and continuous monitoring as essential steps to the subsequent risk assessment and evolution.

With the present work, the state-of-the-art monitoring methodologies (Lemos and Santos, 2007, Oliver et al., 1998, USACE, 2002, CIRIA, CUR, CETMEF, 2007) are improved and integrated into a lifecycle framework and are used to assess the structure risk. Inspection techniques including 3D topographic scanning laser, multibeam sonar, SAR and visual inspection (walking, waterborne equipment and underwater) are related, combined and integrated into a larger asset management framework to assess the structure present risk and to manage the structure more efficiently. Significant improvements on inspection forms contents, analysis and data visualization were performed while developing this methodology. The complete method is applied to the Ericeira breakwater (Portugal) and the present condition and quantitative risk estimate summarized.

2. Monitoring methodology

Monitoring is defined as the set of all inspections, surveys and tools employed to assess the structure performance over its lifecycle. Traditionally, breakwaters are visually inspected using limited, qualitative and subjective forms (Lemos and Santos, 2007, Oliver et al., 1998) or when the importance of the structure justifies with traditional surveying techniques. When starting a new monitoring process several steps must be taken. Prior to monitoring, the breakwater must be analyzed and divided into homogeneous units called reaches (Oliver et al., 1998). Herein, these reaches are considered to have a length of 100 – 500 m and are subdivided into subreaches with a length of 10 – 50 m allowing the structure to be better assessed. For each reach/subreach/structural element triplet the most adequate inspection techniques are then selected based on the nature of the triplet and on the cost and periodicity. 3D laser and multibeam techniques are stressed since they allow the prototype structure geometry to be known with a detail that was only possible in laboratory models. The high-fidelity dense topographic/bathymetric point cloud allows a whole new group of analyses and data to use in numerical models. This level of detail and the magnitude of data imply a challenging new approach to the way data are stored, processed and presented. In

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most cases, data must be reduced using resampling and smoothing without loss of information.

Historically, several techniques have been used to assess a breakwater from different perspectives without combining the results directly. Nowadays, more reliable and useful information may be obtained by selecting the most adequate monitoring techniques and combining the obtained results. This integration is mandatory to overcome the inherent limitations of each monitoring technique per se and to achieve a sound risk assessment that stakeholders and/ or promoters may use to manage their facilities more efficiently. The qualitative and subjective nature of information obtained from visual inspections is overcome by clearly stating what the intervals of damage mean for a certain structure in a visual inspection manual. Furthermore, the detailed digital inspection forms are processed automatically using multicriteria methods to obtain the structural performance rating. This rating is presented as a multivariate plot and in other formats present in the literature to facilitate the early adoption of this method and the direct comparison with previous data (Lemos and Santos, 2007, Oliver et al., 1998). For other techniques, the information is quantitative and objective and may be processed using GIS tools to identify vulnerable areas. Results from these techniques are based on measuring volumes, areas, rotations, settlements and misplaced units complemented with indices from Melby and Kobayashi (1998) with 3D generalizations. These indicators are combined using multicriteria techniques and also at multi inspection technique levels.

3. Ericeira breakwater case study

The Ericeira rubble mound breakwater is exposed to the highly energetic north-westerly Atlantic Ocean waves. It was constructed during the 1970's and reconstructed and extended from June, 2008 to December, 2010. To assess and test the described methodology, each reach/subreach/element was inspected visually and using 3D laser scanning, SAR Interferometry (InSAR) and multibeam sonar techniques. Although severe degradation is not present, some pathologies were detected that should be closely monitored. After each future monitoring campaign, it is recommended that the structure rating and the present risk are reassessed.

In 2012/2013 winter several storms have occurred. Each of these is clearly described and its effect on the structure is discussed. With the continuous monitoring strategy, each of these storms was tracked allowing actions to be faster and more efficient. The quantitative risk estimation and evolution due to such severe storms will also be presented in the paper.

Acknowledgements

This research was funded by WW – Consultores de Hidráulica e Obras Marítimas, S.A. through the Doctoral Grant of the first author. Ana Paula Falcão is gratefully acknowledged for processing the InSAR data used to assess the settlement/ shoaling of the breakwater crest.

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