AN ANALYSIS OF THE RESPONSE OF SINES' TERMINAL XXI BASIN TO LONG WAVES' ACTION

R. Capitão[1], M.G. Neves[1], L. Pinheiro[1] and C.J. Fortes[1]

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1. Introduction

This paper describes measurements and subsequent analysis procedures at the Terminal XXI of the Port of Sines, the operational problems at this location reported by ship authorities, and the numerical analyses carried out for the identified resonant situations during the period under scrutiny. The identified situations are studied extensively to determine whether the reported problems are effectively due to resonance phenomena or to another nonrelated circumstance. A thorough characterization of the resonance characteristics of this harbor basin in its current configuration layout is made both using a simple approach of comparing data measured by tide gauge and buoy data, by relating characteristics of short waves and long waves within the basin, and a more complete study using wavelets to investigate the time evolution of the energy spectrum. Resonant oscillation periods of the basin are also computed with DREAMS numerical model.

2. The Terminal XXI of port of Sines

The port of Sines is located in the south-west coast of Portugal. The basin of the Container Ships' Terminal, known as "Terminal XXI", is located in the southernmost area of the harbor and is sheltered by a 1100 m long rubble-mound breakwater (see Figure 1). At the breakwater's head depths vary between 18 and 20 m while inside the basin depths are between 1 and 21 m, approximately. The berthing quay of Terminal XXI is 380 m long. Since February 2011, an expansion plan of Terminal XXI has been under way, the eastern breakwater and quay have been modified in order to enlarge its current capabilities. Undergoing works are to extend the berth from 380 m to 730 m and the breakwater from 1100 m to 1500 m. That harbor basin has experienced wave resonance episodes, due to long waves, with occurrence of excessive wave heights inside the basin and significant horizontal movements of moored ships, before and during the works. This type of phenomenon caused operational problems, particularly related to the disruption of port operations and to the rupture of mooring lines.

Figure 1. Port of Sines. Terminal XXI configuration.

3. Analysis of the resonance phenomena at the Terminal XXI basin

To study the response of this basin to the action of long waves and to improve the local knowledge of the resonant phenomena, field data obtained inside the basin for a representative set of resonant episodes were analyzed, and the determination of resonant oscillation periods of the basin itself, using the numerical model DREAMS, was computed, Fortes *et al.* (2012).

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[1] LNEC – National Laboratory for Civil Engineering, Av. do Brasil, 101, 1700-066 Lisbon, Portugal. rcapitao@lnec.pt, gneves@lnec.pt, lpinheiro@lnec.pt, jfortes@lnec.pt

Tide levels and surface elevations were obtained by a tide gauge of the Hydrographic Institute (HI) at a point inside the harbor basin, between December 22nd, 2011 and June 20th, 2012. Also wave data of a waverider buoy located outside the harbor in the same period of time was used to identify resonant episodes. These wave buoy data were preprocessed by HI by separating raw data into the following components: a) sea wave component (wave periods up to 32 s); b) long wave component (periods from 32 to 8192 s) and tide component (waves longer than 8192 s). In the above period (from 22 of December 2011 to 20 of June 2012), PSA identified three problem occurrences on ships moored at Terminal XXI. On the other hand, between November 2011 and June 2012, at Sines offshore buoy, the following storms (wave records with Hs > 5 m) were identified: i) on 24 and 27 October 2011; ii) on 3, 4 and 22 November 2011. These conditions would be, according to the PSA technicians, the most serious ones for ship maneuvering when docking at Terminal XXI. It should be noted that there were no occurrences of problems between January and June 2012.

A preliminary global analysis is made on data measured by tide gauge and buoy data, taking into account existing relationships between those two sources of data, by studying characteristics of short waves and long waves within the basin. A second, deeper, analysis is also made using wavelets, to analyze the time evolution of the energy spectrum, although existing data are too scarce for this type of analysis. However, interesting insights might be drawn from this analysis. Finally, one looked for a relationship between short waves, as measured by the buoy or predicted by numerical models, and the long waves measured inside the Terminal XXI basin, based on equation (Hernández, 2005):

$$Hs\_ol = K\ Hs\_oc^{\alpha}\ Tp\_oc^{\beta} \qquad (1)$$

where Hs_ol and Hs_oc are respectively the long and short wave significant wave heights , Tp_oc is the short wave peak period and K, α and β are fitting coefficients. To get this relationship, simultaneous values of Hs_ol, Hs_oc and Tp_oc were considered to obtain a surface fitting function with coefficients K, α and β computed by finding the lowest sum of squared absolute error between experimental data and the surface model function.

For the situations identified as resonance occurrences, DREAMS numerical model was then applied and its results were compared with the measured data, to evaluate the model’s ability to reproduce those situations. The model was also applied to predict the wave states inside the basin for planned future configurations of the basin resulting from the expansion plan underway.

4. Discussion

Final paper discusses the characteristics of the long period waves inside the harbor basin, as measured by a tide gauge, and the characteristics of the offshore waves, as measured by the offshore directional wave buoy of Sines, for selected wave conditions associated with identified resonant phenomena. Results of DREAMS model for the identified situations are studied extensively to determine whether the reported problems are effectively due to resonance phenomena or to another nonrelated circumstance. The methodology used and the long wave period numerical modeling will be analyzed in order to improve the methods and models used to attain a better understanding of the resonance phenomenon of Terminal XXI basin.

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