ANALYSIS AND MODELLING OF ISSUES RELATED TO WAVE AGITATION CAUSED BY LONG-PERIOD WAVES IN A TOURISTIC MARINA

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INTRODUCTION

The Marina of Ventimiglia (Liguria, Italy) holds a pivotal position as a tourist harbor due to its proximity to the Port of Monaco, with direct connections facilitated by a high-speed shuttle service. The marina, which features a distinctive shell-shaped design, shortly after its completion in 2020, faced significant wave agitation issues.

GOALS

This study, performed utilizing numerical modeling, is aimed at achieving a comprehensive understanding of the key factors influencing wave agitation and formulating effective mitigation strategies. The analysis was further enhanced through the installation of four high-frequency water level gauges, which served to validate and calibrate the modeling findings.

NUMERICAL MODEL APPROACH

Offshore wave data have been obtained from the forecast high-resolution wave model (developed by the MeteOcean Research Group of the University of Genoa - Mentaschi et al., 2013). Nearshore wave modelling and wave agitation modelling have been performed respectively by means of the MIKE21 SW (Spectral Wave) and MIKE21 BW (Boussinesq Wave) of DHI.

RECONSTRUCTING THE JANUARY 2021 STORM

On the night between January 22nd and 23rd, 2021, the Marina experienced significant issues concerning the safety of moored vessels and the comfort of moored boats. The reconstruction of the offshore wave conditions enabled to determine the following wave parameters at the peak of the storm (H_{m0}=3.3m; T_p=11.6s; MWD=202°N). The nearshore wave conditions were derived through spectral wave modelling and were used as input data for the BW Model, which confirmed a significant level of wave agitation (up to 0.9m) inside the marina. The MIKE21 BW results (Figures 1 and 2) split between the short-wave component (T<20s) and the long-wave component (T>20s), highlighted a significant influence of wave agitation, particularly along the marina internal perimeter, on the latter component.

These long-wave oscillations are also responsible for the intense currents that form within the narrow gaps of the Marina internal layout. These currents give rise to notable challenges for the moored small crafts in that area.

Additional spectral analysis conducted within the marina revealed an evident energy peak corresponding to a 50s wave period, whereas at a point outside the harbor, the energy peak was associated with a 11s wave period (Figure 3).

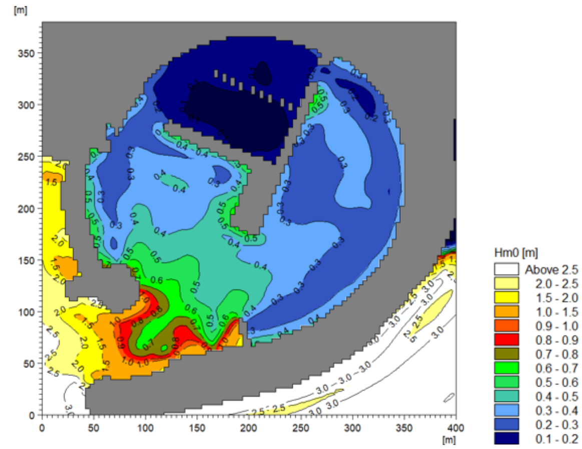

Figure 1 - Short wave component results - Jan'21 storm

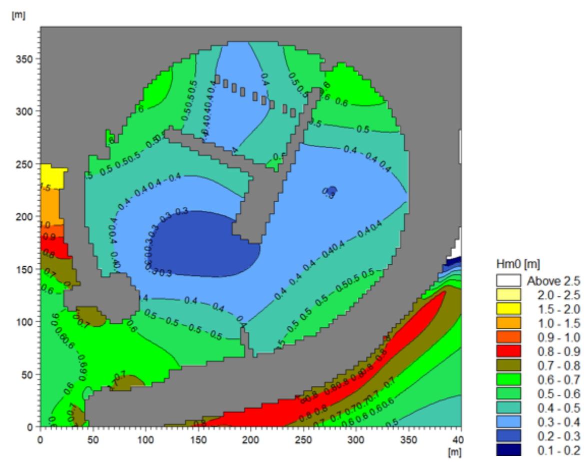

Figure 2 - Long wave component results - Jan '21 storm

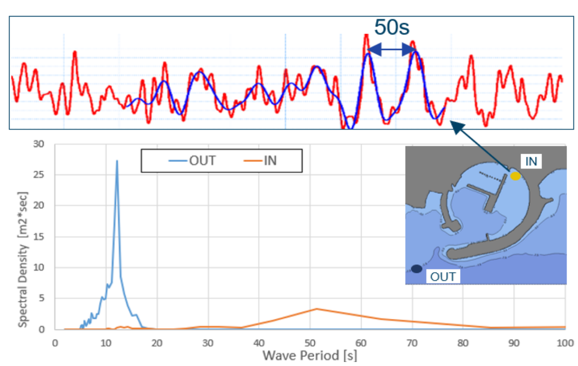

Figure 3 - Surface Elevation at an In-Marina Point (IN) and Spectral Analysis Comparison against a point outside the harbor entrance (OUT)

“WHITE NOISE SPECTRUM” SIMULATIONS

To investigate the natural oscillation frequencies of the harbor basin in its current configuration, DHI's MIKE 21 BW model was set up, using the input known as the "white noise spectrum" (Gierlevsen et al., 2001). The results of the white noise simulation (Figure 4), clearly reveal a peak in wave energy associated with a wave period of 50-60 seconds (confirming what was observed for the January 2021 storm), likely related to the shape of the harbor basin and therefore attributable to the natural oscillation frequency of the port.

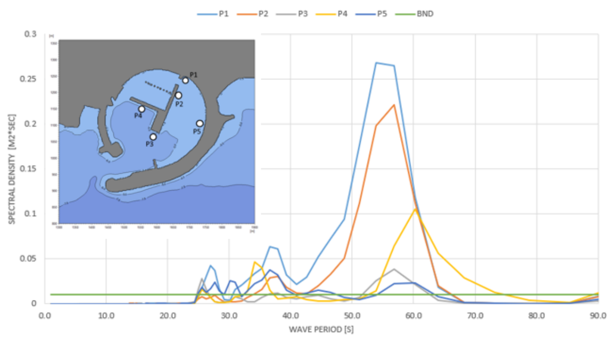

Figure 4 - Spectral analysis at five points within the harbor basin derived from white noise spectrum simulation

MEASUREMENT CAMPAIGN

In February 2021, DICCA (University of Genoa) installed four water level gauges within the harbor basin. Data was continuously recorded until the end of March (approximately 1.5 months) at a sampling frequency of 10 Hertz. The measurement stations are located immediately adjacent to the docks (Figure 5) and are therefore significantly affected, at least in terms of short waves, by wave reflection.

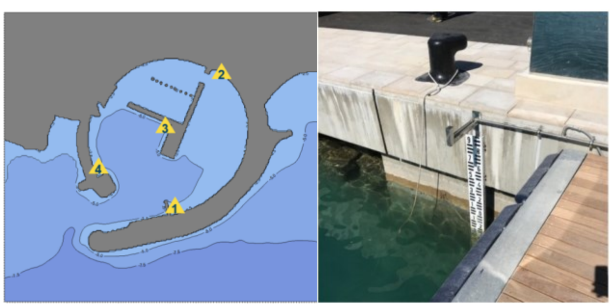

Figure 5 - Water level gauges installed by DICCA (University of Genoa)

RECONSTRUCTIION OF THE MARCH 2021 STORM AND MODEL CALIBRATION

During the measurement period, the marina experienced its most notable storm between March 13th and March 14th, 2021. During this event, the offshore wave conditions derived from the wave forecast model (operated by the MeteOcean Research Group of DICCA, University of Genoa) are as follows: H_{m0}=2.5m; T_p=7.4s; MWD=214°N. The MIKE21 BW results in terms of surface elevation at the four gauges locations have been processed by means of a spectral analysis and used as calibration sources. The measured spectra obtained are presented in Figure 6 alongside the modeled spectra (after the calibration process). The graphs show a good alignment between model and measures and again clearly reveal a peak in wave energy associated with a wave period of 50-60 s.

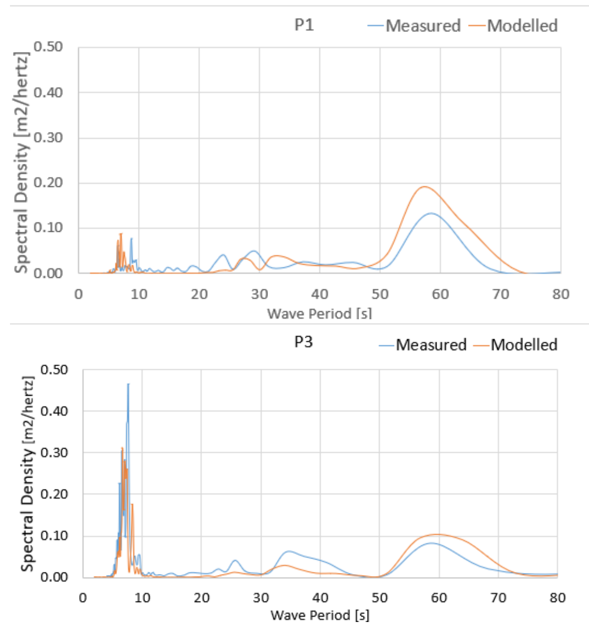

Figure 6 - Spectral Analysis Comparison between measures and model data for point P1 (top) and P3 (bottom)

SOLUTION

To solve the wave agitation issue, several solutions have been explored, including internal structures designed to mitigate long-period oscillations and external structures such as extending the main breakwater. In the end, the most cost-effective solution was determined to be the construction of a low-crested barrier strategically placed to protect the entrance (Figure 7) and preventing wave energy to enter the marina.

Figure 7 - Picture of the low-crested barrier realized to mitigate the wave agitation issue

REFERENCES

Gierlevsen, Hebsgaard & Kirkegaard (2001). Wave Disturbance Modelling in the Port of Sines, Portugal - with special emphasis on the long period oscillations. International Conference on Port and Maritime R&D and Technology. Singapore.

Mentaschi, Besio, Cassola & Mazzino (2013). Implementation and validation of a wave hindcast/forecast model for the West Mediterranean. In: Proc of 12th International Coastal Symposium, Plymouth, UK, 8-12 April.