A COMPOSITE MODELLING APPROACH FOR THE RETROFITTING AND REHABILITATION OF AN HISTORICAL COASTAL ASSET

Corrado Altomare, Xavi Gironella & Joaquim Sospedra, Universitat Politècnica de Catalunya - BarcelonaTech, corrado.altomare@upc.edu, xavi.gironella@upc.edu, joaquim.sospedra@upc.edu
Alejandro J.C Crespo & José M. Domínguez, Universidade de Vigo, alexbexe@uvigo.es, jmdominguez@uvigo.es

INTRODUCTION

The Pont del Petroli pier is a coastal structure located in the coastal town of Badalona, north of Barcelona, in Spain. The pier was built in the 60s to allow mooring of petroleum tankers, but fallen in disuse in 1990. Restored between 2003 and 2009, the pier is now regarded as a historical and social asset of the Catalan coast. In January 2020 the storm Gloria (Amores et al., 2020), characterized by extreme wave conditions (recorded offshore significant wave heights in excess of 8.5 m) and lasting for nearly two days, caused flooding events, casualties and severe damages to several structures in Spain. The pier head platform was damaged, four supporting piles failed and part of footbridge beam was washed away. There is no recorded wave climate that hit the pier so strong during its 50-year life. To reproduce the conditions that led to the failure of the pier a composite-modelling has been carried out at Universitat Politènica de Catalunya (UPC). The outcomes of the work provide further insight and information on the interaction between waves and the key pier elements (platform, footbridge, piles, pile caps) and aided the design for the structural retrofitting, including the study of four different alternatives for the pier head platform and the footbridge attached to it.

METHODS & RESULTS

A composite-modelling approach, comprising experimental and numerical modelling, is proposed herein to reproduce the specific conditions that led to the failure of the pier. For numerical modelling, the DualSPHysics code (Domínguez et al., 2021) has been employed. DualSPHysics is one of the most advanced among CFD models based on the meshless Smoothed Particle Hydrodynamics method (Violeau, 2012), and is conceived and developed for real engineering applications. The influence of different bathymetric profiles and local water depths on the impact loads has been analyzed. Data from bathymetric surveys carried out before and after the storm were used. The surveys showed a radical change in the bottom bathymetry at the toe of the structure, with sand accretion and reduction of water depth from 10.00m to 8.00m, approximately. Although employing a fixed bottom, the numerical model allowed understanding the influence of different bathymetries and local water depths on the wave breaking patterns and consequent loading. At this stage, a 2D modelling was performed. Results from DualSPHysics have been employed for the design of the experimental campaign (Fig. 1, left), carried out in the large-scale wave flume facility CIEM at UPC. Model scale was 1:10. Focused wave groups (Whittaker et al., 2017) were employed instead of random sea states, leading to benefits such as: increased repeatability, the possibility of enhanced measurement, no need of active wave absorption at the wavemaker. Focused wave group time series are created using the NewWave theory as described in Whittaker et al. (2017). The experiments have provided new insights on the horizontal and uplift forces acting on the pier during storm Gloria. Existing formulas for wave loads on exposed jetties (e.g. Cuomo et al., 2007) could not be applied, being derived for jetties on the horizontal bottom, while waves are breaking before/at the toe of the pier platform for the local varying bathymetry.

Figure 1 – Impact of focused wave group on the Pont del Petroli scaled model: experimental (left) and numerical modelling (right).

The vertical uplifting forces acting on the pier platform, as function of the focus location, focus phase and wave height at the toe are depicted in Figure 2. The focused location is measured from the position of the wavemaker at rest, being this x=0.00m. The toe of the platform was located at x=54.01m. Four different phases have been tested (0°, 90°, 180° and 270°). The wave height is measured at x=53.55m.

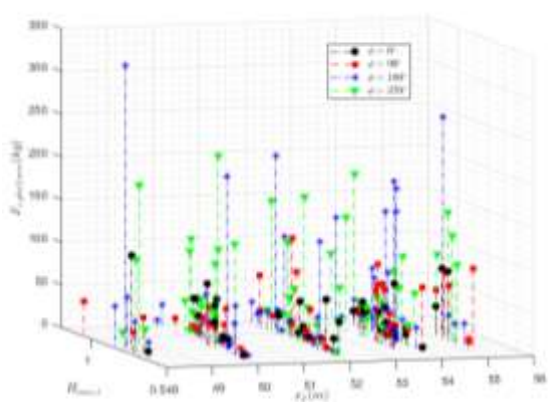

Figure 2 – Vertical uplifting forces on the pier platform, as function of the focus location (x_f), phase (Φ) and wave height at the toe of the structure ($H_{max,t}$).

Larger vertical forces were exerted by trough-focused waves, rather than crest-focused or otherwise. Wave asymmetry played a major role on the magnitude of the forces, being this especially true for horizontal forces. All experimental model results will be presented at the conference.

In a further phase, DualSPHysics model, has been validated against the experimental model results (Figure 1, right) and employed to analyze the structural response of different remodeling solutions, one of which will is being tested experimentally to be finally built and to replace the pier damaged elements.

CONCLUSIONS

Composite modelling, consisting in experimental modelling in a wave flume and numerical modelling by means the meshless code DualSPHysics, was designed and performed to analyze the interaction between sea waves and the Pont del Petroli pier, in Badalona (Spain). With the proposed approach it was possible to resemble the hydrodynamic conditions occurred during the storm Gloria, in January 2020, which caused heavy damages to the seaward part of the pier, including the pier platform and footbridge. Existing semi-empirical methods could not have been applied since they are derived for piers or jetties on horizontal bottom. The results of both experimental and numerical modelling have been used for the retrofitting of the damaged structure, where an alternative solution to replace the head platform has been analyzed.

ACKNOWLEDGEMENT

Dr. Corrado Altomare acknowledges funding from Spanish government and the European Social Found (ESF) under the programme 'Ramón y Cajal 2020' (RYC2020-030197-I / AEI / 10.13039/501100011033).

REFERENCES

Amores, Marcos, Carrió, Gómez-Pujol (2020): Coastal impacts of storm Gloria (January 2020) over the north-western Mediterranean, Nat. Hazards Earth Syst. Sci., 20, 1955–1968.

Domínguez, Fourtakas, Altomare et al. (2021): DualSPHysics: from fluid dynamics to multiphysics problems, Computational Particle Mechanics, Springer.

Cuomo, Tirindelli, Allsop (2007): Wave-in-deck loads on exposed jetties, Coastal Engineering, 54, 657-679.

Violeau (2012): Fluid Mechanics and the SPH Method: Theory and Applications Oxford University Press.

Whittaker, Fitzgerald, Raby, Taylor, Orszaghova, Borthwick (2017): Optimisation of focused wave group runup on a plane beach, Coastal Engineering, 2017.