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Experimental Optimization of Perforated Structures in Presence of Ship-generated Waves

A. Panizzo and P. De Girolamo
D.I.S.A.T., L'Aquila University, L'Aquila, Italy

R. Piscopia
D.I.T.S., University of Rome–La Sapienza, Rome, Italy

ABSTRACT

Due to waves generated by ferries and motorboats in Venice's canals, the navigation of small vessels, such as typical gondolas, has recently become more and more difficult. With the goal of reducing ferry- and motorboat-generated waves, 2 types of perforated breakwaters have been considered. After a preliminary sizing by using a mathematical model, the structures have been tested with experiments on physical models. Transient wave trains, similar to the ship waves observed in Venetian canals, have been considered incident loads. A wavelet transform-based method has been used to evaluate breakwaters' reflection coefficients. This paper looks at presenting an optimization-design procedure for perforated breakwaters subject to ship-generated transient waves. Since the breakwaters are going to be in Venice, an area of great architectural and environmental interest, their visual impact was one of the most important issues in our analysis.

INTRODUCTION

Due to waves generated by ferries and motorboats in Venice's canals, the navigation of small vessels, such as typical gondolas, has recently become more and more difficult. In order to reduce the wave heights generated by shipping, the Consorzio Venezia Nuova S.p.A. has funded a research program aimed at designing perforated breakwaters for placement in the city's canals.

The research program was planned in 4 steps. First, ship wave characteristics (wave height H and the associated period T) were defined by wave monitoring in the canals. Then, 2 different types of perforated structures were chosen, bearing in mind the preservation of Venice's architectural context. The third step was the breakwaters' preliminary sizing, which was carried out using the mathematical model proposed by Fugazza and Natale (1992). Finally, the breakwaters' design optimization, aimed at minimizing the structures' reflection coefficient C_r in the presence of transient wave trains, was obtained by means of tests on physical models. As a first step, the structures had been tested with normal incident waves generated in a wave flume; then, 3-dimensional tests in a wave tank were recently carried out in order to take into account the real incident angle of ship waves. The experiments were performed by Protecno s.r.l. in the laboratory of the Italian Ministry of Public Works, at Voltabarozzo.

This paper is mainly pointed at describing the experimental data analysis and the optimization results of breakwaters, and discussing the problem of the insertion of harbour structures in one of the most beautiful marine environments in the world. The text is organized as follows: First, background research results are summarized and the preliminary design of the perforated breakwaters is outlined. Then the laboratory facilities as well as the experimental program are presented. Next, the wavelet transform method proposed by Panizzo et al. (2002) for the estimation of the reflection coefficient is thoroughly described and applied to experimental time records. Finally, results along with ongoing studies are presented.

BACKGROUND RESEARCH

Ship-generated waves were defined considering the various canal dimensions and the wide variety of vessels that usually moves along them; a preliminary classification of wave characteristics (H and T) was made taking into account both the various speed limits and the ship displacements. Wave data were thus recorded in several Venetian canals over an approximate 2-year period. Waves generated by ships were characterized considering the maximum wave height $H_{\max}$ and the associated wave period $T_{H_{\max}}$ that occurred in each wave train.

It has been observed that, in canals with a speed limit equal to 6 knots, $H_{\max}$ falls in the interval of 0.15 m to 0.25 m, while $T_{H_{\max}}$ ranges between 1.0 s and 2.0 s. As one could expect, due to the imposed small velocities, the highest value of $H_{\max}$ is associated with the largest vessels, such as barges and ferries. On the other hand, where the speed limit is 12 knots, it has been observed that $H_{\max}$ varies between 0.25 m and 0.45 m, and $T_{H_{\max}}$ within 1.5 s

Wave	$H_{\max}$ [m]	$T_{H_{\max}}$ [s]
A	0.15	1.2
B	0.15	1.4
C	0.15	1.7
D	0.15	2.0
E	0.30	2.0
F	0.45	2.5

Table 1 Characteristics of wave trains defined according to ship-generated waves measured in Venice's canals

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