Horizontal Coherence of Wave Forces on Vertical Wall Breakwaters

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HORIZONTAL COHERENCE OF WAVE FORCES ON VERTICAL WALL BREAKWATERS

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1. INTRODUCTION

Evaluation of spatial coherence of breaking waves is of great importance and of recent interest Grønbech (1997); indeed the stability of a caisson depends on the resulting pressure force acting on it, where the horizontal dimension of breakers, judged on the basis of vertical water jets produced and documented in photographs, seems to be shorter than the length of the caisson, thus producing a lower force than derived from the application of the maximum force to the full length of the caisson. Non-breaking waves of long period are generally rather correlated in space, so that for the majority of the structures the applied force never accounts for the directional spreading.

It is anyway evident from pictures of important storms that the spatial correlation of forces produced by breaking waves is rather limited.

Usually the probability of breaking against the vertical wall is so seldom that its occurrence does not affect significantly the design force.

Nevertheless, either for analysis of badly designed structures or for probability based designs it is of some interest the knowledge of the spatial correlation of these highest waves.

Spatial coherence of wave forces in non-breaking wave conditions was analytically studied by Batties (1982). In the following paper the horizontal coherence of wave forces on vertical wall breakwaters is investigated. The main objective of the work is to provide a piece of information needed to evaluate the risk that a caisson may fail.

The main objectives of the work are:

- to define the dynamic behaviour of the structure;
- to provide an objective method for classification of breakers, on the basis of elevation and force applied to a vertical structure;
- to provide statistics of the breaker characteristics and of their impact on the wall (duration, impulse) needed for a probabilistic analysis of a failure due to the effect of breaking waves;
- to provide horizontal dimension of the breaker and of the spatial coherence of the horizontal forces.

2. TEST DESCRIPTION

Model tests were carried out at the Large Scale Facility of Hydraulic Research (Wallingford, UK). In a 1:100 scale a 1.7 m long breakwater model represented the vertical wall caissons of Genoa Voltri (Martinelli, 1998) main breakwater in Italy.

The model was exposed to multidimensional seas containing both non-breaking and breaking waves. The structure was placed 18.7 m from the wave generator and occupied only a small fraction of the basin total width, 36 m; the structure symmetry axis was 2 m out of the basin axis, in order to allow bigger spreading for wave field with inclined mean direction.

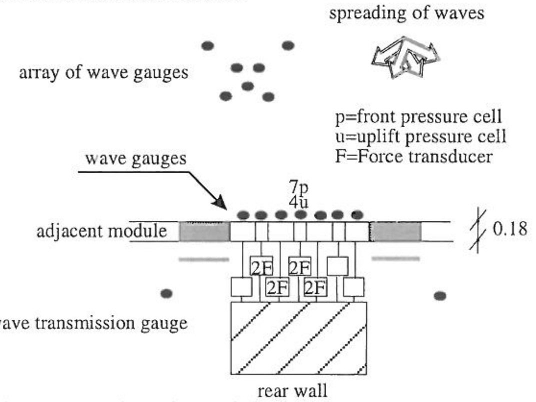

Figure 1 – Plan view of the instrumented structure.

The model breakwater was formed by aluminium modules 10 or 20 cm wide, 1 mm distant one another being separated by disks of teflon. Modules were instrumented with one or two force cells and with uplift and front pressure transducers.

Tests with different wave conditions and measuring device set up were performed. Detailed information on test program and experimental set up are give in Sauer et al. (1999).

3. DRY TESTS: ANALYSIS ON STRUCTURE STIFFNESS

A preliminary analysis , dry tests, aimed at defining the system behaviour (eigenfrequencies and eigenmodes of the system, and the dynamic system response) was performed

The small and big caissons can be considered to give a static response up to 36 Hz and 26 Hz respectively when the caissons are immersed in water.

The horizontal projection of measured force along the bars is just slightly smaller than the applied horizontal force. It was noted that all the caissons respond statically at least below 26 Hz, (e.g. up to 2.6 Hz in prototype, the model scale being 1:100). This is indeed an essential point for the model testing, since it is essential that the system is proportionally (slightly) stiffer than typical prototype conditions.

The measured force, filtered by the model through a system very similar to a breakwater, has all the necessary information to describe the prototype dynamic behaviour, since it filters out only the high frequency (above 2.6 Hz in 1:100 scale) that are anyway filtered out also by a typical prototype (1.4 Hz for Genoa Voltri main breakwater).

In conclusion, the measured forces are totally representative of the force field applied to a vertical breakwater.

4. BREAKING CRITERION

The waves were classified in the following homogeneous groups believed to produce different spatial coherence characteristics:

- Non breaking waves;
- Wave breaking directly on the structure;
- Waves that arrive at the structure already broken.
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The classification of waves is indeed based on the deviation of the force signal from the proportionality to the surface elevation signal.

Figure 2 presents the non dimensional force VS elevation for theoretical distinguish of wave types.

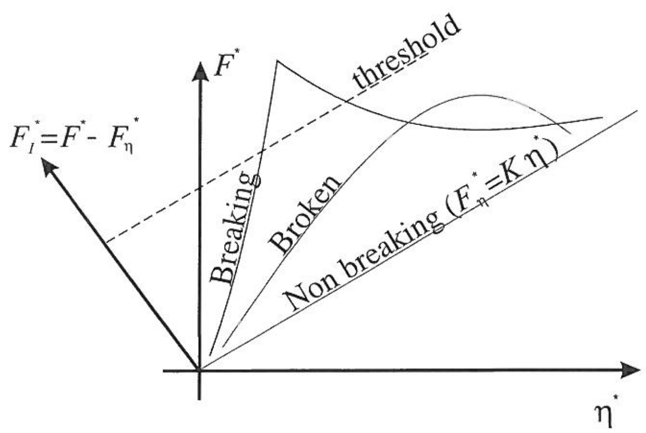

Figure 2 – Time history of a breaking and broken wave in the co-ordinate system F*, η*. For the theoretical non breaking wave the force is proportional to the elevation.

5. ANALYSIS ON HORIZONTAL CORRELATION OF FORCES

Aim of the analysis is to define the reduction of the maximum force per unit length with the increase of the integration length i.e. to apply such filter to the force time history, in order to evaluate directly the effective force.

First step of the analysis is the separation of the signal in breaking and non breaking components: the wave force is divided in a fundamental part proportional and in phase with the elevation and in the remaining impulsive part.

Two approaches are used:

- direct statistical description of the maximum force per unit length identified on the sum of adjacent modules.
- spatial correlation between forces referenced to the distance between the modules centres. On the basis of the correlation coefficient it is possible to find the reduction of the maximum force per unit length with the increase of the integration length.

6. CONCLUSIONS

A useful method for the identification of breaking waves is presented.

Horizontal coherence of the force applied to vertical breakwater by waves in multidirectional sea is investigated using two methods: comparing the statistics of the force signal applied to breakwaters of different length and evaluating the spatial correlation between force signals recorded at different positions.

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