CHAPTER 79

COMPUTERISED METHODOLOGY TO MEASURE RUBBLE MOUND BREAKWATER DAMAGE

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Abstract

The damage of rubble mound breakwater is a basic interest in the field of design and realisation of coastal works. The individuation of formulations to associate this element with the geometrical characteristics of structures and wave climate conditions is carried out using physical model tests. It is therefore necessary to implement an objective damage valuation method able to point out armour units movements on the layer from the settlement phase to the collapse.

A methodology able to permit an exact measurement of the external layer armour units movements and its damage has been carried out by ESTRAMED S.p.A.; it consists on a computerised analysis of armour units movements in order to give an objective valuation of the damage.

Such methodology is based on photographic images analysis of the armour taken from a fixed point. The procedure permits to determine the position of each armour unit on the images relative to the subsequential damage stages and the movement of each armour unit.

Introduction

The experiences relevant to the Port of Sines Main Breakwater, the improvement of computers capabilities, the wider use and the development of the physical modelling and the studies carried out in the last years improved the analysis of the rubble mound breakwater damage. Relations between rubble mound breakwater stability and incident waves and section characteristics were deduced.

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The breakwater stability is usually referred to the eroded volume or to the percentage of units moved more than a fixed threshold.(A.I.P.C.N. 1992, British Standard, 1991).

The measurements of these parameters are extremely important to carry out investigations on the rubble mound breakwater damages and to grow research in this field.

The use of objective methodology to describe the phenomenon from the first movement up to the collapse is essentially.

Methodology purposes

At ESTRAMED S.p.A. a methodology that allows to measure the external layer armour units movements by a computerised procedure, was developed.

Aims of the methodology were the following:
- to get information on the small armour units movements;
- to obtain objective measurements of the layer damages;
- to analyse armour units movements in a time comparable with the stability test duration.

It is necessary to obtain information on the small armour units movements as the experience on the physical models to test the rubble mound breakwater stability indicates. Small armour units movements are very important because they allow the description of layer damages under the action of ordinary wave motions and to evaluate the entity of the first settlement of the breakwater and therefore, on experiments in which comparative or repetitive tests are required, to make a correct comparison of breakwaters behaviour under the action of extreme waves.

A precise knowledge of small and large movements of the units make possible to draw graphs of the damage on the basis of the incident waves characteristics. These graphs are useful tools for the designer in order to choose the best solution considering the entire structure behaviour, not only in severe damage conditions. Small armour units movements analysis is of interest for the comparison of different solutions even when no severe damage level is reachable, for example, during tests on structures where the wave attack is limited by bottom effects.

The use of a standard laboratory method to measure rouble mound breakwater damage guarantees the repetitivity of test results and permits to compare results obtained from a large number of experiences carried out by different laboratories, increasing in this way the base of available experimental data for further formulations.

To obtain analysis results of armour units movements in a time comparable with the tests duration allows to make strategy choices on the next tests to be carried out. This permits the optimization of the tests programme and therefore, a large number of damages stages can be easily examined obtaining more information compared to the methodologies often used to measure rubble mound breakwater stability.

Methodology description

The methodology consists of five subsequent activities:
- set up of rubble mound breakwater armour units;
- acquisition of breakwater images in the subsequent conditions of damage and their importation into the computer;
- images processing;
- check and eventual corrections of images processed;
- print out of the analysis results.

Armour units in nine different colours are employed to built the external layer of the armour so that two units of different colours are located between two units of the same colour and the individuation of the position of each armour unit on each images is facilitated.

The colour selection for armour units painting is very important in this methodology. Each colour must be detected as different from the others by the computer analysis. The achievement of this objective depends on armour units colouring, lighting sources, breakwater contour characteristics, photographic equipment and images filtration; a useful set of colours was selected by Estramed carrying out several tests.

Once placed the units , it is necessary to draw a white point on the sight view of each of them as shown in figure 1 where in the white window are highlighted the units with the same colour. The movement of this point on the sequential images will show the armour unit movement.

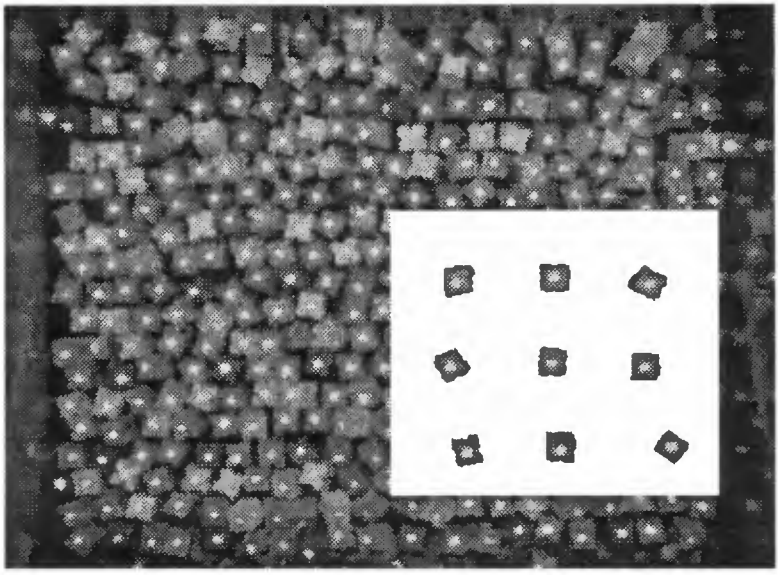

Figure 1 - Set up of rubble mound breakwater armour units

In order to permit the comparison of the different images, at the beginning of the experiments it is necessary to put three marks in the model so that the software can be able to compensate eventual shot point movements and to adopt one single coordinates system to locate each armour unit on each image.

The methodology permits to acquire rubble mound breakwater images in different damage stages and to import them into the computer. The camera station must be fixed and located in such a way that the shooting plane is parallel to the breakwater armour. Images have to be acquired without water in order to avoid reflection and refraction phenomena. The procedure uses a still video camera and a digitiser card with a resolution of 768x576 pixel to acquire and to import the images into a personal computer. Images must be taken at the end of the section construction and after each wave attack.

Once imported into the computer the images are analysed by a software that was set-up by Estramed. Such analysis individuates for each armour unit its colour and the coordinates of the white point located on it as pointed out in figure 2.

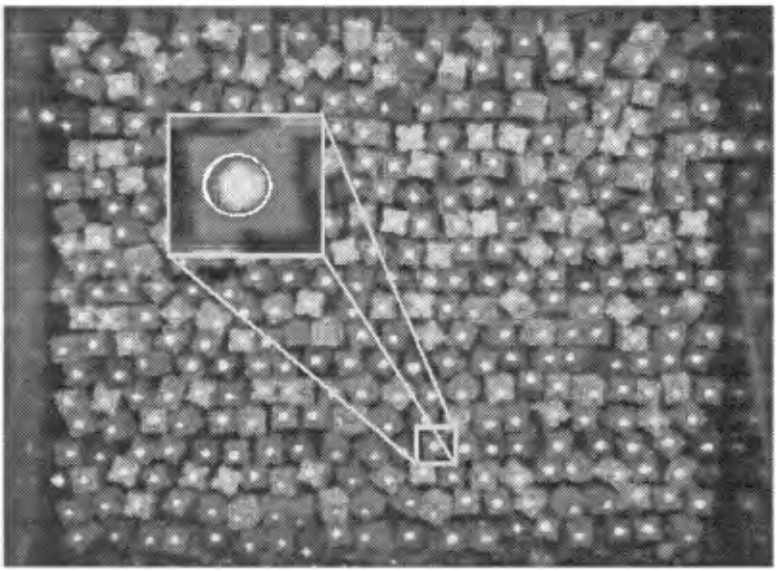

Figure 2 - Example of the analysis result

At the end of this phase, a further analysis is carried out on the files containing, for each image, the coordinates and the colours of the units in order to verify the number of armour units of each colour among all the images. If any inconsistencies arises (for example the number of armour units can be lower compared to the previous one in the case where one or more units rotate on themselves without originate unit barycentric movements, hiding the white evidence point) the operator, who disposes of an edit menu, points out and solves them.

Scope of the second analysis phase is to individuate the position of the same armour unit among all the different images. The procedure perfoms an analysis examining two files relevant to subsequent images: the file relevant to the less damaged condition is considered as reference for the computation of the units movements. The analysis is carried out taking into account separately armour units of the same colour. As first step, each armour unit of the first image is coupled with the nearest unit of the second image having the same colour in a range less than 0.5 times the characteristic length of the unit. Successively, the analysis is carried out on the not yet associated units increasing the range up to two and half times the characteristic length of the unit as shown in figure 3.

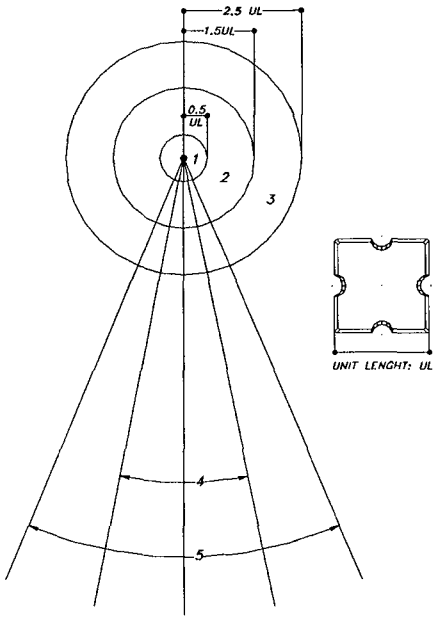

Figure 3 - Scheme of criteria to identify same unit in two successive images

The successive step on the not yet associated units is the coupling of the units present inside circular sectors (see figure 3) which centres are located on the units of the first image, which axis of symmetry is a vertical line and which angle is initially equal to 10° and is successively increased by step of 10° up to 180°. If two possible associations are individuated in the sector, the procedure chooses the one with the minimum angular value compared to the vertical.

Once the coupling of the units has been carried out, the results of the analysis are submitted to the operator for check and for eventual corrections.

The software shows a screen with four windows as shown in figure 4. An image is shown in the upper left window while the successive one appears in the upper right one. The lower right window shows the armour units movements and the lower left one displays an edit menu and the following information:

- number of units for each colour individuated in the two images;
- total number of units individuated in each image;

- number of reference marks individuated in each image.

If any inconsistencies arise the operator can correct the results using the edit menu in a proper way.

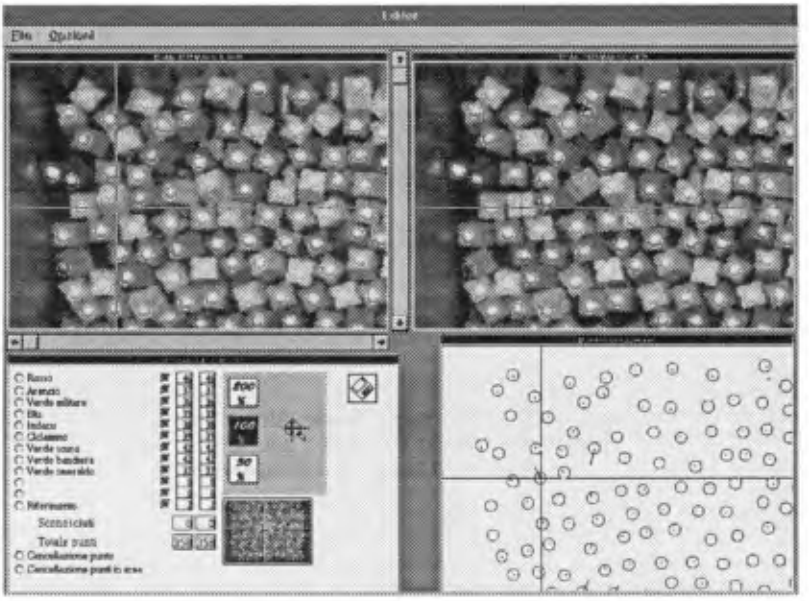

Figure 4 - An example of the results of the units movements analysis

A sequence of the results of the units movement analysis relevant to a test series with increasing waves is shown in figure 5.

The first image (upper left) of figure 5 was taken after the construction of the model and before the start of the tests. The second image (upper right) shows the units movements measured after a test with a very low significant wave height while the last image (lower right) shows the damage of the breakwater after a test characterised by a significant wave height higher than the design one.

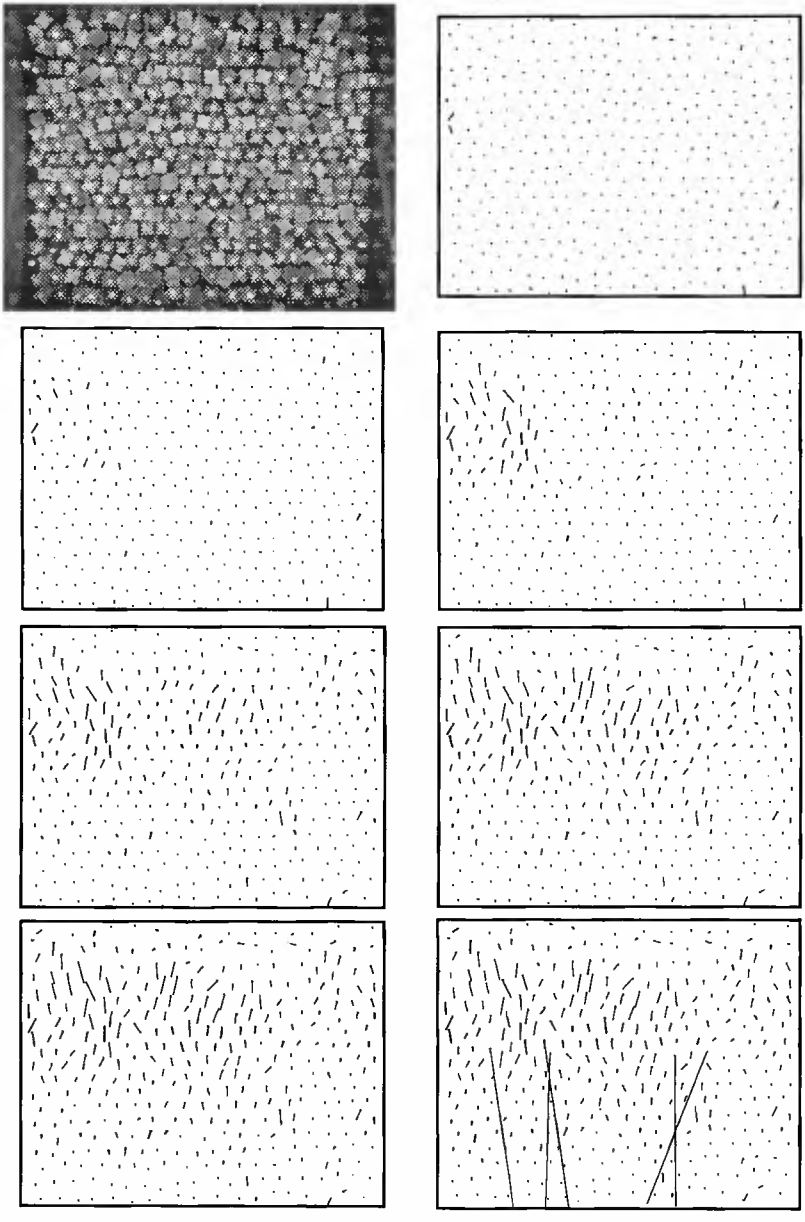

Figure 5 - A sequence of the results of the units movements analysis

The methodology allows to obtain a wide range of information about the units movements. Many information on the small movements of the units can be obtained, too.

A standard plot of the results of the analysis indicates for each test or wave height the percentage of armour units which movements were less than fixed values that are generally part of the characteristic unit length (B). In figure 6 a plot of the results relevant to the analysis of figure 5 is shown.

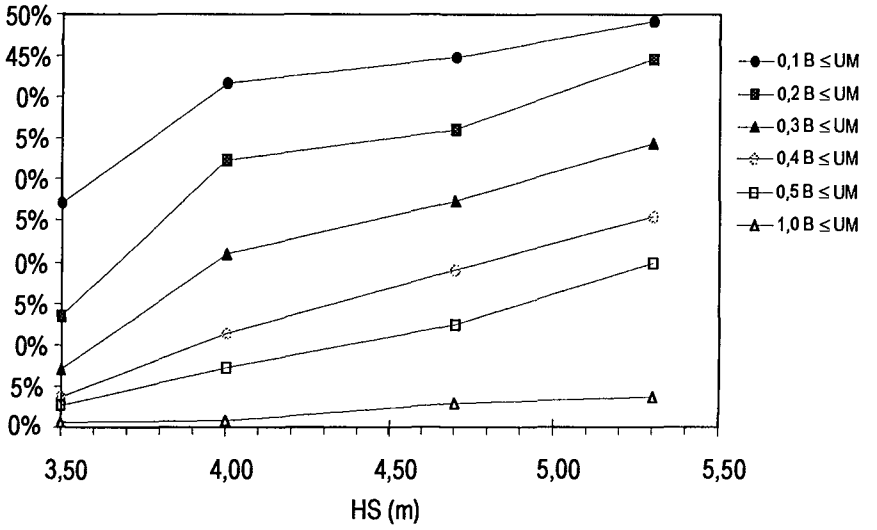

Figure 6 - Units movements versus significant wave height

The methodology has been tested comparing its results with those obtained using a traditional approach. The agreement was very good, at any rate, it must be noted that both methods find difficulties when an unexpected collapse of the whole breakwater happens (with more than 30% of armour units dislocated). This is not a real limit to the method application because, in such conditions the single armour unit movements doesn't give any essential indication on breakwater stability.

Fields of application of the methodology

The methodology has several fields of application in laboratory testing.

A first field is relevant to the two dimensional physical modelling. The methodology allows to carry out objective measurements which are essential for repetitive or comparative tests; to describe accurately the damage behaviour of the breakwater armour and to obtain results in a very short time. In the Estramed S.p.A. Laboratory the methodology has been employed in two dimensional tests to individuate also the movements of toe protection blocks and submerged crest blocks.

A second field is relevant to the three-dimensional physical modelling. Treating these models as plane images, the methodology cannot describe the armour units absolute movements but the parameters to asses a roundhead stability are various and not limited to the armour units movement. Therefore the computerised analysis gives a useful contribute that can be surpassed only using a very sophisticated three dimensional survey system.

Two-dimensional and three-dimensional applications of the methodology are currently used at Estramed S.p.A. Laboratory.

Conclusion

The computerised methodology allows a reliable and objective measurement of rubble mound breakwaters damage.

The analysis of a stability test is obtained at the end of each run in a shorter time than the test duration.

The use of this methodology permits the standardisation of test modalities and damage levels measurements.

The application in reality of this methodology, with some modifications could bring a remarkable increasing to rubble mound breakwaters know-how.

Acknowledgements

A special thank goes to Mr. Spartaco Coletta, to Mr. Pompeo Forte and to Mr. Danilo Marinucci for their contribution and cooperation.

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