THE FUNCTIONALITY OF BREAKWATERS SYSTEMS FOR MAMAIA BAY

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ABSTRACT

Year by year, the coastal zones are constantly changing due to the action of waves, tides and human impact. Several factors and events have an impact in changing the shoreline from small time intervals, for a few seconds to several centuries. The shoreline has been particularly influences by the human impact over the years, especially by the location of hydro-technical construction to prevent erosion or floods. Thus, the problem of coastal erosion appears as an effect of sediment transport, modifying shore morphology. Sediments transport occurs after the action of waves and currents transversely and longitudinally along the shore. In this paper, we intend to study the hydrodynamic of the Romanian Coastal zone and the wave regime alteration due to the protection systems.

Keywords: *coastal protection systems, Mamaia Bay, wave impact, sediment transport*

1. INTRODUCTION

The technological evolution, the material and financial resources involved hydrodynamic research in making substantial progress in the recent years. However, the knowledge of coastal processes is still at a modest level, requiring intensification of theoretical and experimental research.

Coastal management specialists monitor the coastal line in two directions (longitudinal and transversal). The currents in the coastal zone are constantly changing, putting their footprint on shore protection structures. It is necessary to know the hydrodynamic peculiarities of the Romanian coastal zone in order to identify correctly the processes that occur in the coastal zone. Modelling is used to show the waveform transformations that take place, mostly numerical models and less physical models being used.

To determine the wave field in the near-coastal area, we have used the water-environment expert Mike by DHI software with the MIKE PMS extension, which deals with 2D coastline and sea modeling.

2. ROMANIAN COASTAL ZONE CONDITIONS

The Romanian coastal area is characterized by a climate specific to the temperate continental zone. This area, located in the western part of the Black Sea, has a length of 243 km, geomorphologically divided into two large units, namely the Northern Unit and the Southern Unit. The Romanian coast represents about 6 percent of the total length of the Black Sea coast. The two areas (Northern Unit and Southern Unit as we can see in figure 1) have a different sedimentary equilibrium and respond differently to the action of various environmental factors.

As the Coastal Masterplan developed in 2011, the Northern Unit measuring approximately 160 km of coastline is formed by the Danube Delta, which extends along the Romanian-Ukrainian border to Cape Midia, including the Razim lagoon complex (Razelm)-Sinoe. This area is characterized by low beaches in the Danube Delta and lagoons with a smooth underwater slope.

The southern unit, which is about 80 km long, extends to Cape Midia up to the border with Bulgaria (Vama Veche). The area is characterized in certain areas (especially in the south) by a high shoreline, while in the northern part (Năvodari-Mamaia) the beaches are straight and slightly tall. The phenomenon of coastal erosion has increased significantly in the recent decades, reaching an erosion rate of over 2 meters/year. Most hydro technical defense structures are located in this area.

Figure 1 – Units of Romanian Coastal zone [2]

In the Romanian coastal area, the annual wind speeds are relatively high (between 4.2 and 6.95 m/s), with the north and northwest directions. [1]

One of the significant effects of strong winds are marine storms, whose margins exceed 10 m/s. The duration of the storms in the NEs reaches an average of 107 hours, of which about 47 hours with speeds at a peak of over 28 m/s. [1]

Also in the coastal zone the breeze phenomenon, which is formed due to temperature differences between the sea and the sea, is also identified. The phenomenon manifests itself predominantly in the winter months, when there are differences in the high temperatures between sea water and the atmosphere. As a result of this phenomenon, a windy sediment transport on the beaches is generated, and the dunes are much drier and easier to train in wind transport. High wind speeds recorded during this period lead to significant erosion in the coastal area.

However, besides the wind erosion caused, the wind is the origin of the waves, being one of the main factors. The transport of sediments along the shore is influenced by waves, and any increase in sea level originates in the dynamic movement of winds and waves.

Dynamics of waves with characteristic parameters (height, length and period) is determined by the wind regime, the bathymetric structure of the area and the configuration and orientation of the shoreline.

The rosettes of the widespread waves on the Romanian seaside is presented in Figure 2.

Wind-blowing are those with speeds greater than 3 m/s, with a duration of about 82% per year. The predominant direction on the Romanian shore is in the north, and the weakest is the wind in the southeast direction. [3]

Two types of waves are generated: hula waves and locally generated wind waves. The average height of offshore waves increases from north (0.85m) to the south (0.95m) along the shore (see Figure 2). [5]

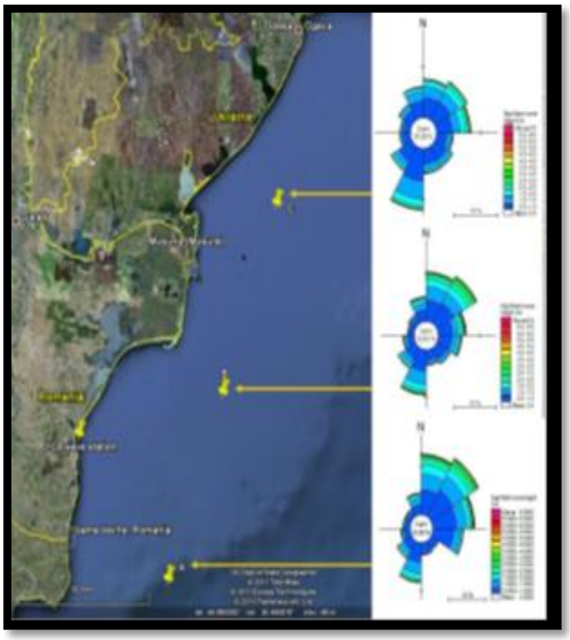

Figure 2 Rosettes of the widespread waves on the Romanian seaside [1]

It is known that on the Romanian Black Sea coast the wind and wave directions vary depending on the seasons. In terms of wave height, the period of the lowest heights is the summer period (April to October), and the period when the wave heights are significantly higher is represented by the winter months from November to March. The maximum wave height is recorded in the southern area during the winter season. [3]

3. PROTECTION SYSTEM IN MAMAIA BAY

Mamaia Bay (figure 3) is the first part of South Unit, from Cape Midia to Cape Singol. Here we found a zone characterized by occurrence of the first promontories with active, high cliffs separated by the large zones with accumulative beaches. The beaches are in certain places backed by littoral lakes. The sand bar from this area has 250 - 350m wide. [4]

This part of coast is affected by erosion and important beaches are lost due to anthropic constructions. Erosion processes are more intense during winter, when the storms are stronger. [4]

To protect the zone, more than half part of the beach is protected by “hard systems protection”, consisting in 5 immerse breakwaters and 2 jetties.

The breakwaters are designed to take the energy of the waves so that the area behind them is a calm water, built especially for the harbors. By placing these types of structures in the beach area, they will change the profile of the beach behind them. For example, if the sand accumulates in a parallel area, another area will undergo an erosion process.

Sometimes detached breakwaters are meant to provide shelter for landing on the beach on small fishing boats or swimming water.

Figure 3 Mamaia Bay zone [Google Earth]

4. METHODOLOGIES

In our study we perform a simulation of the morphological evolution behind several detached breakwaters that are exposed to the significant wave action from two direction.

The zone of study is the southern part of Mamaia Bay, Constanta, where we find several types of “hard protection systems”.

For the simulation we use Mike 21 PMS – Parabolic Mild Slope Wave Module software edited by DHI Water and Environment.

According to manual of MIKE 21 PMS, the module uses a linear refraction diffraction pattern based on a parabola approximation to the slight slope elliptical equation, which is solved using Crank-Nicholson finite difference scheme. The effects of refraction and shock due to variation in depth, diffraction along the perpendicular to the predominant wave direction and energy dissipation due to bottom rubbing and wave breakage are analyzed. The model will also take the analysis and effect of frequency and directional spread using linear overlapping. [5]

The output data are integral waveforms (e.g. root height, the peak wavelength, and the average wavelength).

Mike 21 PMS is used for waves disturbance projects in open coastal areas and for the calculation of interaction between wave fields and coastal structures (e.g. grooves, detached dikes) when negligible backward dispersion (reflection in the received waves) and the diffraction is predominantly perpendicular to the main direction of the waves.

The aim of the study was to model the morphological evolution behind several detached breakwaters exposed to wave action through a simulation.

As input data, first, we specified the bathymetry map, figure 4, which contains depths of water for the model area.

A grid spacing of 10 m is chosen in the x- and y-directions. This gives a resolution of 10 grid points per wave length at a water depth of 1 m. The conditions of the two boundaries that are perpendicular to the shoreline (in our case north/south) are unknown beforehand for the wave conditions, so we choose symmetrical conditions (depth contours parallel to the y-axis).

The bottom friction is specified by a constant Nikuradse roughness parameter with 1.5 mm, and the parameters in the Battjes & Janssen (1978) wave breaking formulation are specified as: α = 1.0, γ_1 = 1.0, γ_2 = 0.8 (which are the default wave breaking option and values).

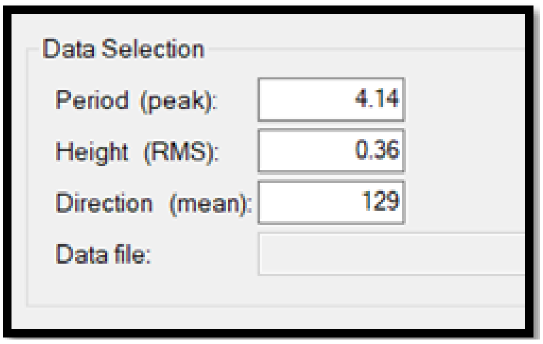

Figure 5 Input Data in MIKE 21 PMS

The wave conditions at the offshore boundary is specified as root mean square wave height H_{RMS} = 0.36 m, peak wave period Tp = 4.14 s, as we can see in Figure 3, with different wave crests. For the zone of study incoming waves of 129^o and 90^o were selected.

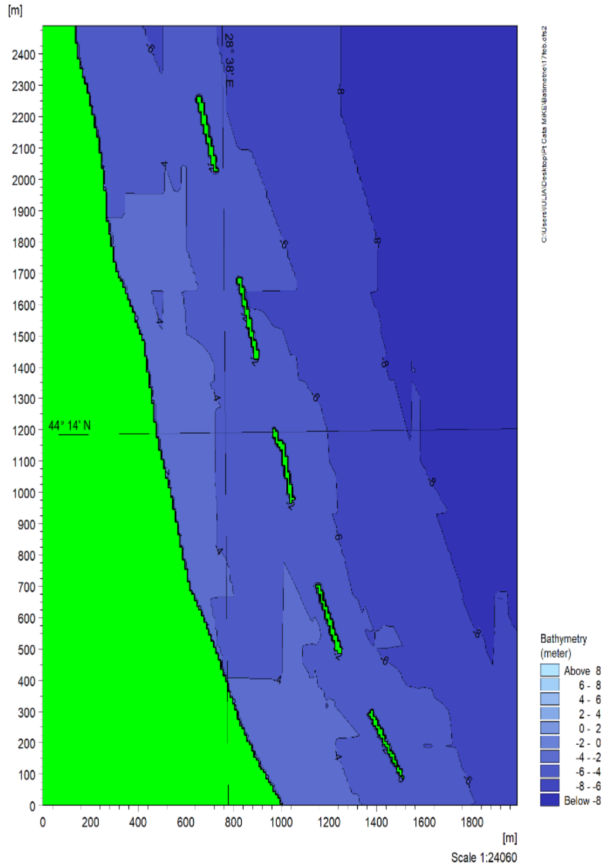

Figure 4 Bathymetry map of the Southern part of Mamaia Bay

5. RESULTS AND DISCUSSION

The result of this model is the effect of shoaling, refraction, diffraction, bottom dissipation and wave breaking. [4]

The model results are presented as contours of root mean square wave heights, H_{RMS} and wave direction vectors scaled by the wave height. The influence of wave breaking close to the shore is clearly evident, as well as the reduction of the heights behind the breakwater due to wave diffraction. [4]

From these 2 cases, we can see that the detached breakwaters have a significant effect on wave energy dissipation which can form saline or tombolo accumulation, depending on the distance between structure and shoreline.

In the first case, if there was a single structure parallel to the coast, this was not very efficient when the waves with 129^0 direction are fairly oblique to the shoreline (figure 6), as the effective length of the structure perpendicular to the wave direction is relatively small in this case (figure 8). The single breakwaters cannot be recommended because of the sand filet accumulation coasts which is very short.

More so than it can be seen in the South of the study area in Figure 6 the wave heights are relatively high (with red color) because the next adjacent zone is not protected by a breakwater or other coastal structure.

Segmented systems of breakwater schemes with relatively short gaps can also be used as a combined shoreline and coastal protection measure for all types of coasts, because for the formation of pocket beaches the gaps do not depend very much on the wave direction when the gaps are small. This type of protection can be found in the Southern Unit, especially in Eforie, Venus, Saturn etc.

For the case of Mamaia, even if the gaps between breakwaters are relatively short, the distance from the shore is higher than in the other cases and instead of the pocket beaches, "salient" accumulation is formed. figure 7.

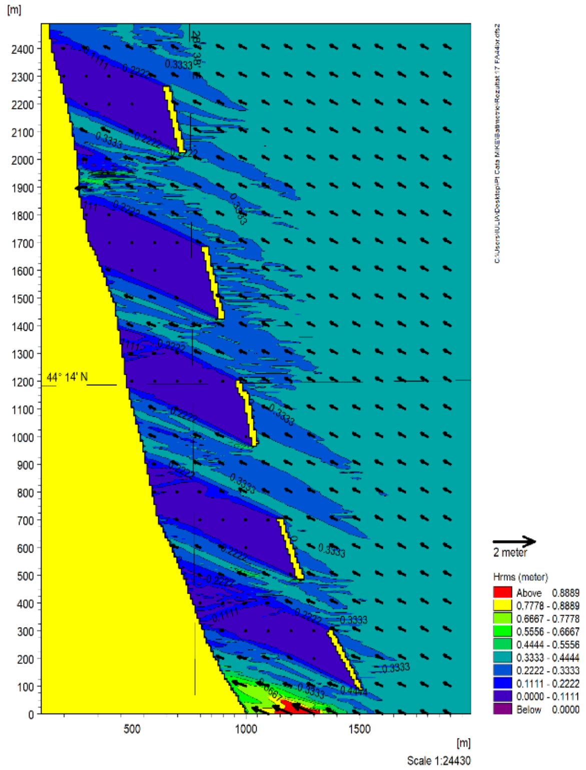

Figure 6 Mamaia Bay with 129^0 incoming waves

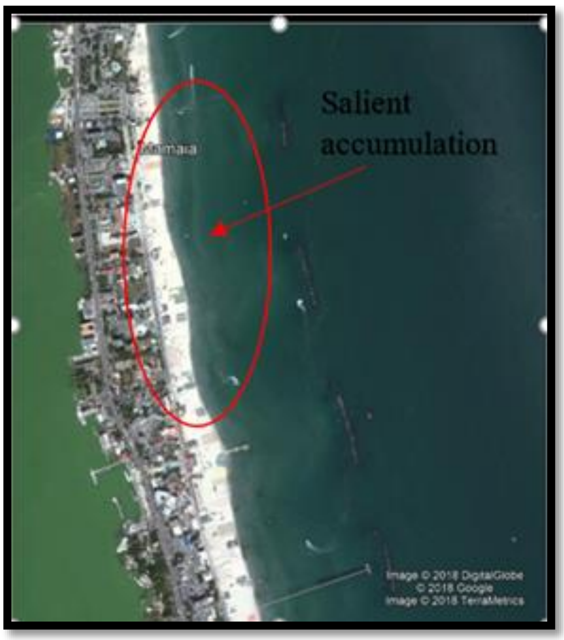

Figure 7 Salient accumulation in Mamaia Bay

The location of the dikes in a particular system has the role of protecting the beach from strong waves, but at the same time, it captures algae and floating debris in the sea. The location of the breakwaters system can create an advantage or disadvantage in the beach area, requiring a thorough study of the waves and current dynamics in the area concerned. It is known that sheltered areas are found behind the breakwaters, as has been shown in the above-mentioned modeling, while the areas where erosion is manifested are the areas in front of the dyke and the beach areas not protected by the breakwaters.

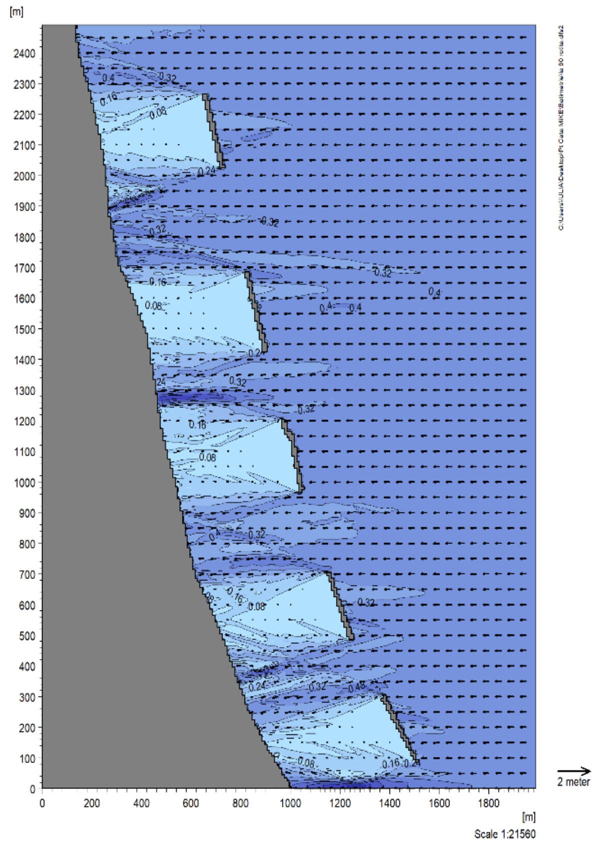

Figure 8 Wave height - Mamaia Bay with perpendicular incoming waves

As mentioned earlier, the special accumulation describing the study area as a result of the dykes is a function of the distance between the dykes and the coast, referring to the direction of the wave-breakwaters interaction and the angle that the breakwater makes with the coast line. This angle is particularly important because it is a component part of the formation of the bulk type, see figure 9. Depending on the angle at which the breakwaters were built, it influences and determines a new wave direction that will also attract the direction where the sediments will accumulate over time.

The phenomena of refraction and diffraction can be observed in the next figures, 10 and 11.

Measurement of diffraction waves is of particular importance. Both natural and human structures influence the diffraction characteristics to some extent and have an effect on height distribution in a port or sheltered place. Knowing the diffraction process is important in planning installations that provide protection against incident waves. The location of these installations and their design are essential to reduce shear and resonance phenomena, and in this case it is necessary to know the effects of diffraction. Similarly, the prediction of the wave height is influenced by the diffraction caused by hydrographic changes.

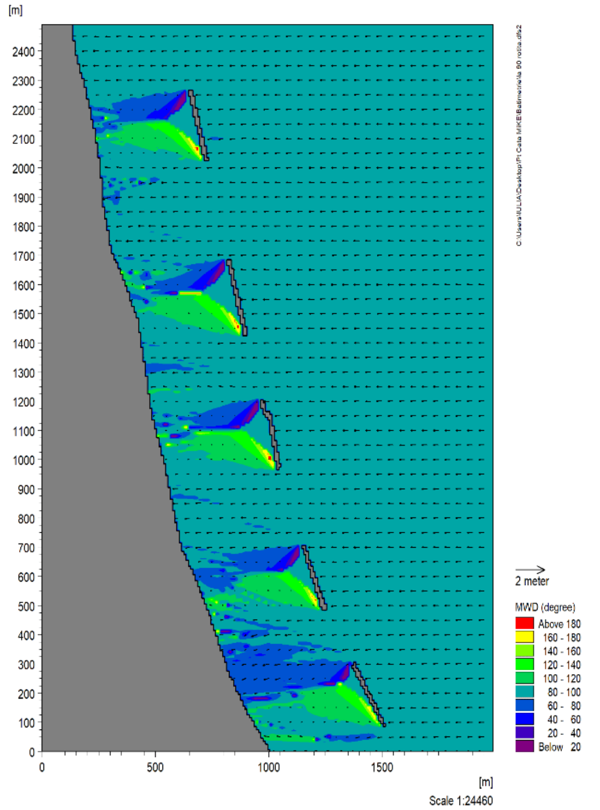

Figure 9 Direction of waves - Mamaia Bay with perpendicular incoming waves

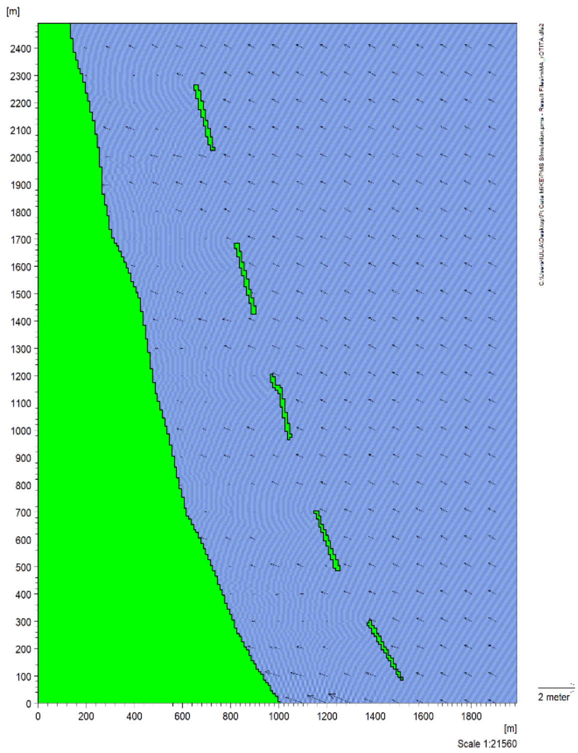

Figure 10 Refraction and diffraction of the Mamaia Bay with 129^0 incoming waves

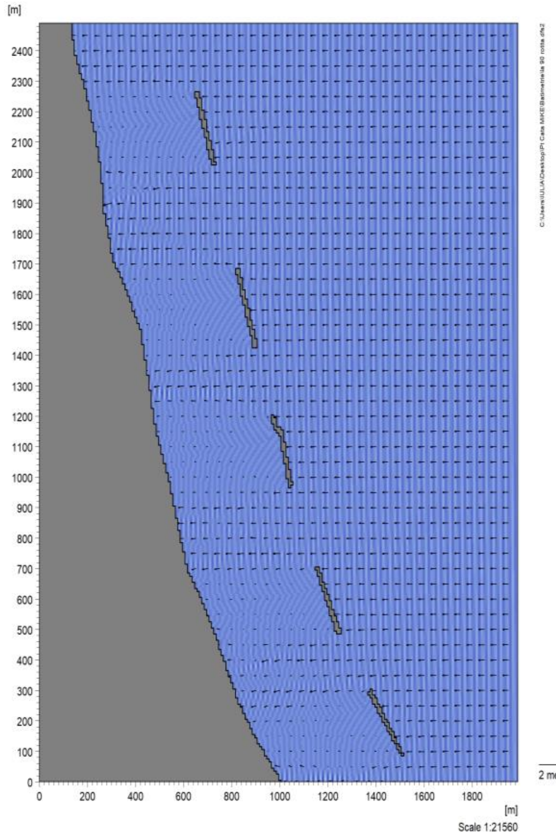

Figure 11 Refraction and diffraction of the Mamaia Bay with 129^0 incoming waves

The phenomenon by which energy is transferred laterally along wave surges is called water wave diffraction. This phenomenon controls the shore response to detached breakwaters. Water wave diffraction is particularly noticeable if a wave field is interrupted by a dike or a small island. If this phenomenon does not exist, behind the natural or artificial barrier located in the sea there would be a region of perfect calmness. The line separating the two regions would produce a discontinuity. However, through the wave diffraction phenomenon, the area behind the dikes is disturbed by the area in front of them.

6. CONCLUSION

Behind the detached dike, the waves decrease in height and there will be a significant sediment accumulation depending on the distance between the breakwaters and the shoreline. The two types of accumulation can be of the “salient” when the distance is larger and the “tombolo” type when the distance is smaller. The sand captured in this area will be from the adjacent beaches, which implies an erosion upstream and downstream. These types of accumulations are influenced by the position of the dykes, the height and direction of the waves; this phenomenon can be seen in Figure 4, the case of Mamaia Bay, where there are several detached cracks, and hydrodynamic conditions coincide with those described above.

It can be seen how the wave heights are changed at the time of a collision with a detached breakwater and how the phenomenon of diffraction appears as a result of this phenomenon.

A condition of no longshore transport is that the initial shoreline should be parallel with the incident breaking wave crests, and the wave diffracted into the shelter zone of breakwater which will transport sediment from the edges of this region into the shadow zone. In addition, this process will continue until the shoreline will be parallel to the diffracted wave crests.

From the above, it has been observed that a thorough study of the area is required before choosing coastal protection options: non-intervention option, coastline option, stop-controlled option and shoreline progression. After selecting the right option, there are various engineering solutions and techniques to implement the required project. Most types of solutions are based on "heavy" and "light" works that lead to loss of attractiveness and natural aesthetics.

From the models presented in the previous sections it follows that the construction of the breakwaters is dependent on the characteristics of the waves and the shores. These structures cannot fully accommodate the area as the diffraction phenomenon occurs, but the longer the breakwater is, the better the area is.

From this research, the wave's regime alteration due to the protection system is clarified and alternatives will be valuable in deciding the most efficient systems according to the natural conditions.

7. REFERENCES

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