Research on the Beach of Grand Hotel Varna

Gencho Panicharov*, Aneta Georgieva*, Marta Seebauer**
*Varna Free University "Chernorizets Hrabar", Varna, Bulgaria
**Óbuda University Alba Regia Technical Faculty, Székesfehérvár, Hungary
dr_panicharov@abv.bg, angr@abv.bg, seebauer.marta@amk.uni-obuda.hu

Abstract — **The shoreline erosion is a central problem on the Black Sea costal in the north part of Bulgaria. The aim of this paper is to describe a common project "Marina" carried out by the students of Hydraulic Engineering Department of Delft University of Technology and Varna Free University "Chernorizets Hrabar" focused on the coastal protection research on the beach of Grand Hotel Varna. The main topics of the project was the problem definition, the data collection about the real state, the selection and implementation of methodology by mathematical modeling of expected wave height, and also elaboration of an economical optimal action plan for coastal protection using mainly the available building materials.**

I. INTRODUCTION

Bulgaria is a country located along the Western Black Sea Coast in South-East Europe. Varna, the third greatest city in Bulgaria is an important economical and touristic center. This large coastal city deals with port activities, industry, beaches and tourism but the landscape is rich in natural endowments. There is a lot of information and discussions regarding the natural features and development of the Bulgarian Black Sea Coast, however the information about these projects are not organized in a systematical way. Intensive coastal and landslide protection program has taken place in the 80-ties of the last century.

II.THE SHORELINE EROSION AND THE COASTAL PROTECTION

The landscape on north Bulgarian Black Sea Coast is varied on mountains and plains, rich in surface and ground water quells. This fact and the every more intensive storms due to global heating, also the reckless human encroachments are standing changing the natural landscape. (Fig.1.)

Figure 1. The coast defended from waves by sand dune at winter time

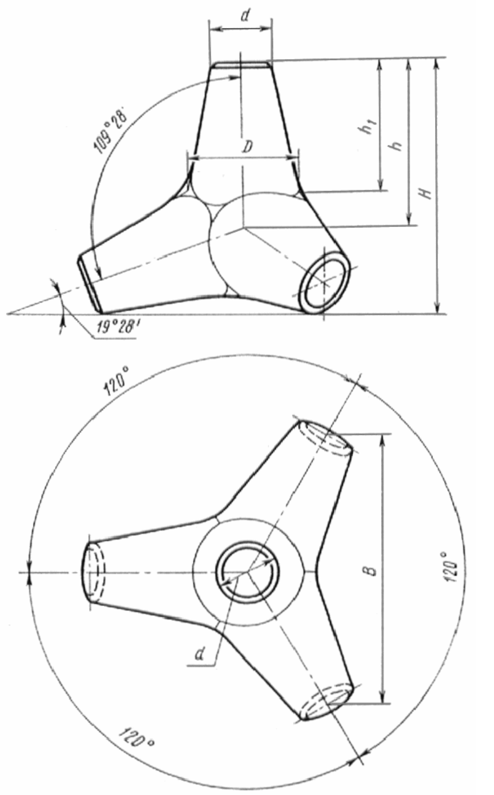

Figure 2. Tetrapod unit

At that time large number of groins and a few "marinas" were constructed. With the political and economic changes started in 1989, the state investments in coastal protection and development projects have been radical reduced. Presently, hotel owners construct small harbors and coastal protection structures attempting to maintain the beaches surrounding their property. These activities are extremely hazardous for the coastal dynamics and their effects are only partly or not at all predictable [1].

The role of coastal engineering is to maintain the shoreline, to keep it safety. Breakwaters are artificial structures built on the coasts in the reason of protect the shoreline from the effects of waves and storms. In shoreline structures as breakwaters armour units can be used several barrier materials, for example, natural shot rocks, ripraps, special concrete units.

Tetrapods are armour units in tetrahedral from used as breakwaters. A tetrapod's due to their special shape dissipate the incoming waves by allowing to flow the water around and distribute it of tetrapods to interlock as it is shown in Fig.3.

Figure 3. Breakwaters using tetrapods

Tetrapods were originally developed by Laboratoire Dauphinois d'Hydraulique (now ARTELIA) in Grenoble, France in 1950. After the patents expiration date they are produced by many contractors and widely used all over the world.

III. The Project of the Beach Grand Hotel Varna

Since 2003 a cooperation was established between the Hydraulic Engineering Department of Delft University of Technology and Varna Free University "Chernorizets Hrabar". The cooperation focuses on exchange of good practices and realization of common development projects on the coasts around Varna. Dutch and Bulgarian students get the possibility to gain experience in data collecting, processing and interpreting. Repeating this fieldwork every year in the same area will provide an overview of the coastal development in the Varna area.

The students act as consultants for local hotel owners at the Varna coast. Their work consists of measuring hydraulic aspects in the project Marina. Data collection covered the inventory of the materials near site, beach measurements, wave measurements, profile measurements, quarry analysis and a bathymetric survey. The rehabilitation plan contains the development of sub-areas in the St. Elias Marina (Fig. 4) like the peninsula, north beach, south beach and the breakwaters.

A. The problem definition

In the North of Varna, the first beach resort is established at the Bulgarian Black Sea Coast. This place is very attractive for Bulgarians and tourists.

Figure 4. Sub-areas in the St. Elias Marina

Therefore, it is economically important for the whole area. Part of this resort is the, the Grand Hotel Varna Resort. It has a small marina partly constructed in the early 90-s.

Although some temporary protection work was made but by the time the defects of the port structures became visible. The one of reasons was the experimental design that was not real tested in practice. The other one was the poorly carried out work.

Attempts were made to protect the existing constructions by laying rocks in front of the existing breakwater which was constructed of 'H' shaped concrete blocks. During a big storm in 1993 this protection proved itself unstable. In result of them tons of rock - that should protect the marina - were picked up by overtopping waves and deposited in the protected area of the port.

Later on due to the neglect of this problem the damage was progressed and by now the main breakwater was totally destroyed. In 2015, a sad, abandoned and devastated port lies at the shore of Grand Hotel Varna. There is huge contrast between the beautiful coastal area, good touristic infrastructure and collapsing marine structures.

Nowadays the owner of the beach resort lacks a fully functioning port in front of his lovely resort. The circumstances now are stated that the port is severely damaged and a high probable danger to human safety [2].

Moreover, the fact that the designated area of the port is not the best place for it in the first place because there is not calm water all year around. However, these high waves and significant amount of overtopping takes place in the winter whereas the port only is operational in summer time. This means that the structure must withstand the severity of wave attacks. Furthermore, during winter time waves form the port.

B. Data collection on the beachGrand Hotel Varna

For the data collection about the materials the area was divided on 6 different sub-areas. Fig. 5 shows the different areas. The data was qualitatively and quantitatively selected, so the amount of material was estimated as well as the quality of the material.

This estimation of the quality is necessary for the reusability of the materials. Due to the bad weather and the slipperiness, the marina (area 5 and 6) was not accessible from mainland. The approach from the boat was also very hard through the danger to come nearby due to steel wire sticking out of the water. Therefore, area 6 is not discussed in this report and assumed that is has the same qualitative condition as area 5.

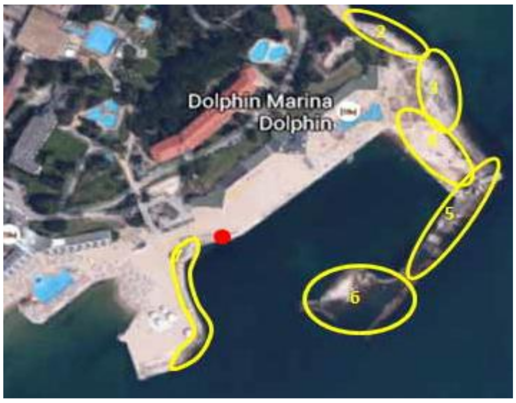

Figure 5. Different area's in the scope

Figure 6. Broken tetrapod units

Shores are influenced by the topography of the surrounding landscape, as well as by water induced erosion, such as waves. The geological composition of rock and soil dictates the type of shore which is created.

C. *Methodology*

The inventory and the quality check of the materials in the different areas were based on the visual inspection.

Within the total area we observed different sizes of tetrapod's, pyramid blocks, caisson slabs, rocks and a quay wall. (Fig.6) To check whether these materials are still usable at their current location or check if they're reusable at another location, it's important to know how many elements there're and how many are still intact. After this, for the areas directly influenced by the sea, calculations are made to estimate the wave heights that occurred in the last decades and predict the maximum wave height.

The broken parts and cracks were indicators for reusability of materials. A big part of units could be simple counted. When the observation was impossible due to no accessibility of the area or through the amount of units, an estimation was made [3].

The size of the units was defined by using a simple measuring tape. In case of tetrapod's, the rest of the dimensions was calculated with general formulas for tetrapod's. The size of the rocks was categorized in 4 different classes: small, medium, large and extra-large corresponding to their diameter.

For the calculation of the $D_{n,50}$, an estimation was made based on the distribution of the rock sizes. The different diameters are shown in Table 1:

TABLE I.
SIZE OF THE DIFFERENT BOXES FOR CLASSIFICATION OF THE DIFFERENT SIZES OF ROCKS.

	Diameter [m]
Small	<0,5
Medium	0,5-1,0
Large	1,0-1,5
Extra-large	>1,5

Calculations for the maximum wave heights are done with the Hudson and Van der Meer formulas. Hereby the maximum significant wave height is limited by the water depth in front of the wave protection.

We can use the dimensions of the elements on the locations to calculate which design wave height the protective structure has. We can also check which wave height certainly has occurred as some of the tetrapods are broken. For these calculations, two different formulas can be used: Van der Meer's formula and Hudson's formulas. The Hudson's formula (1) can rough estimate the needed rock weight.

$$W = \frac{\gamma_R H^3}{K_D \Delta^3 ctg\theta} \qquad (1)$$

where

W - the weight of required riprap armour [N]
γ_R - specific weight of the armour blocks [N/m^3],
H - the estimated wave height [m],
K_D - stability coefficient, experimental defined,
K_D ~ 3 for natural rocks
K_D ~ 10 for artificial blocks
Δ - relative density of rocks,
θ - angle with the horizontal.

This formula doesn't take wave period, damage level, permeability of structure and storm duration like the Van der Meer's formula does. The Hudson formula thereby can be only used in a preliminary design and for regular waves [4].

The Hudson formula in more simple form is

$$\frac{H}{\Delta D_{n,50}} = (K_D ctg\theta)^{\frac{1}{3}} \quad (2)$$

in them

$$D_{n,50} = \left(\frac{M_{50}}{\rho_t}\right) \qquad (3)$$

where

$D_{n,50}$ -nominal diameter of rocks [m]
M_{50} - median mass of rock grading given by 50% on the mass distribution curve [N],
ρ_t - mass density of the rocks [N/m].

In this case both formulas will be used, but due to lack of specific data for the Van der Meer formula (4), the standard case situation is considered [6]. The Van der Meer formula for surging waves

$$\frac{H}{\Delta D_{n,50}} = 1.0\, P^{-0.13} \left(\frac{S}{\sqrt{N}}\right)^{0.2} \sqrt{ctg\theta}\, \xi_m^P \quad (4)$$

where

P - notional permeability factor
S - damage level,
N - number of waves (storm duration)
ξ_m - transition from plunging to surging waves.

Because not all the areas are directly influenced by the waves on the sea, only location 1, 2 and 3 are considered. Locations 4, 5, 6 are not considered due to the concrete caissons are laying here.

The maximum wave height occurring at the toe of these protective structures is limited by the depth in front of these structures. The water depth at the front of the structures is around 6 meters. Also wind induced setup of 0.5 meters is assumed.

TABLE II.
THE DIMENSIONS OF TETRAPOD'S

	C [m]	H [m]	V [m³]	M [kg]
Small Tetrapod	0.80	1.68	1.32	3045.44
Large Tetrapod	1.08	2.26	3.25	7492.91

The maximum significant wave height is then given by:

$$H_{max} = (1 + \propto * H_o) H_{const} \quad (5)$$

where

H_{max} - the maximum wave height [m],
H_o - the minimum wave height [m],
H_{const} - average wave height [m]
α - corrections coefficient

D. Results

In the total area of the Grand Hotel Varna many tetrapods are present. Most of these can be re-used for reinforcing the coast. There are two different sizes of tetrapod's available on the coast.

The dimensions of these tetrapods are determined by measuring one rib with a measuring tape. The rest of the dimensions can be determined by parameters on Fig.2 in which "h" is the height of the total tetrapod and "d" is the length of a rib.

Fig.7 shows the severely tetrapods on location 3. A lot of tetrapods on the different locations have cracks on them or have pieces that are broken off. Still most of the elements, as indicated in Table 2, are reusable. Although with moving these elements there is a danger that the tetrapod's will be damaged. Thereby a few elements at location 3 are poured in concrete and per definition cannot be moved (Fig. 7.)

Figure 7. Tetrapod's on location 3

IV. CONCLUSIONS

The first conclusion that can be made from the inventory is the lack of structure in the design of the break water and other protective structure. A lot of different materials are used and it seems that a lot of them are randomly dumped at their current location. Due to this great amount of (broken) units it will be very expensive to remove these elements. Probably the easiest and cheapest way is to demolish the elements and use them as core or fill materials for the new design of the breakwater or other structures. The tetrapods are in good shape can be used, together with new produced elements as the armour layer.

The rocks in the different locations comes in all shape and sizes. Therefore, there're a lot of possibilities reusing of these rocks. The smaller rocks are also easier to place on a different location, so there're versatile to reuse.

According to the calculations of the maximum significant wave height the break waters and other protective structures can withstand; the values are under the maximum significant wave height that can occur. This means that especially for location 1, 2 and 3 the present design is not sufficient to the wave conditions that can occur. This is confirmed by the fact that some of the tetrapods are displaced and/or broken.

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