One Hundred Years Settlement of the Verna's Breakwater - Construction on Soft Clay Like a Typical Example from University Program of Port Construction in Bulgaria

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ONE HUNDRED YEARS SETTLEMENT OF THE VERNA'S BREAKWATER - CONSTRUCTION ON SOFT CLAY LIKE A TYPICAL EXAMPLE FROM UNIVERSITY PROGRAM OF PORT CONSTRUCTION IN BULGARIA

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ABSTRACT

The breakwater of the bigger Bulgarian Black See Port has erected in the first years of the XX-th century near Varna. Soon after the complained of its construction considerable settlements have appeared. Some times during the one hundred years superstructures and gravity increasing on the soil around the breakwater have made. The last restoration has made around 30 years ago and after that – 10 years later too when concrete tetrapodes have laid before the structure. Thereafter the settlements are continuing. The investigations and studies point out local no stability soil. It is delay to apply a send bed, known from the classical examples La Spetzia (Italy) and Kobe (Japan).

Now a new restoration and protection is executing. Many small caissons in chess order on the See bottom before the structure have to increase the grave and the weight, to break the waves like underwater breakwater, to decrease the bottom velocities and totally to protect the stability and to stop the settlements.

Schemas, profiles, history of the construction, decisions are shown in the report.

INTRODUCTION

Varna is located on the Black Sea coast, in East Bulgaria, approximately 35 sea miles south of the Bulgarian-Romanian border. Varna Port is situated on the West bank of Varna bay.

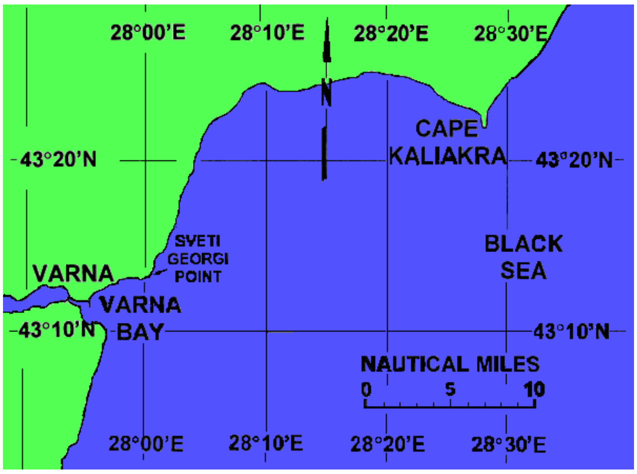


Fig.1. Varna bay

The surrounding relief is hilly, with several uplands reaching an altitude of up to 305 m. The East part of the Stara Planina mountain range with altitudes up to 914 m is located about 40 sea miles West of Varna.

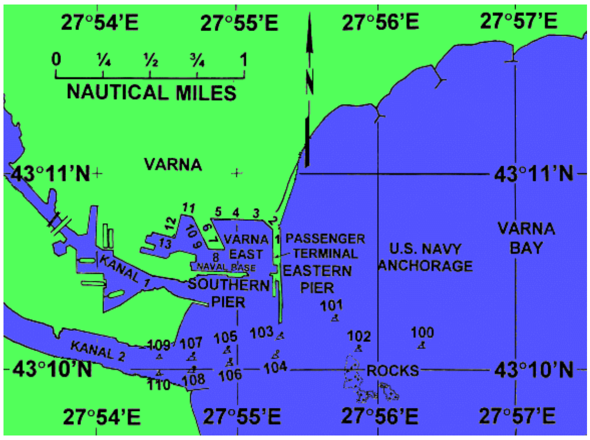
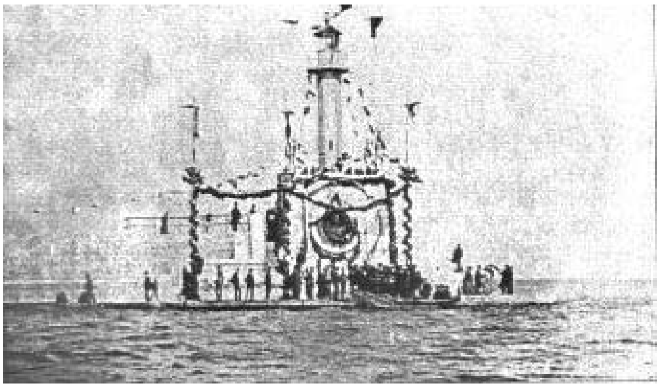


Fig.2. Varna East, two kanals, breakwater, aquatoria

Varna Port is divided in two parts: Varna-East and Varna-West. Varna-West is located several miles West of Varna-East, and encompasses two lakes, Beloslavsko lake and Varnensko lake. The ports are connected by means of two canals (Fig.1 and Fig.2).

I. DESCRIPTION OF THE BREAKWATER AND THE CASE OF SUBSIDENCE

The construction of the main breakwater started in September 1896 and finished in August 1901. However, it subsided



unexpectedly and had to be reinforced. One day, for several minutes only the breakwater sank nearly 4 meters along a front of about 100 meters. When restoring it, it became necessary to expand the base of non-sorted rock blocks in order to ensure better distribution of the strain in the earth base. The breakwater was constructed completely in 1903. It is long 1220 m.

Fig. 3. Inauguration of the lighthouse in 1906

Fig4. The breakwater and the lighthouse (Pharr)

An entrance lighthouse was constructed at the end of the breakwater. It has white light, stopping every three seconds. A second breakwater, perpendicular to the main one, was later constructed. It is long 110 meters. An entrance to the port, which is wide 200 m, is left between the two breakwaters.

II. HISTORICAL BACKGROUND

The first studies for construction of a new port were conducted in 1854. At that time measurements were taken of Varna bay and Varna lake since there was an idea to construct the port in the lake. In 1872 Pascal, the chief engineer of the Port of Marseille was assigned the task to conduct a study and to present a design. He sent his assistant Adolf Gerard, who took new geodesic measurements. Charles Hartley, a well known English engineer, also contributed to the final design by developing two different designs.

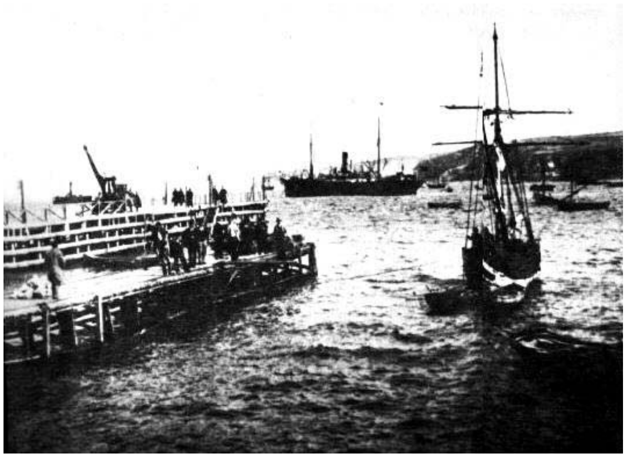


Fig. 5. Port Varna before 1895

The design envisaged the construction of a sea-shore breakwater in the direction North-South, a southern breakwater perpendicular to the first one, pier walls with embankments behind them and deepening of the port.

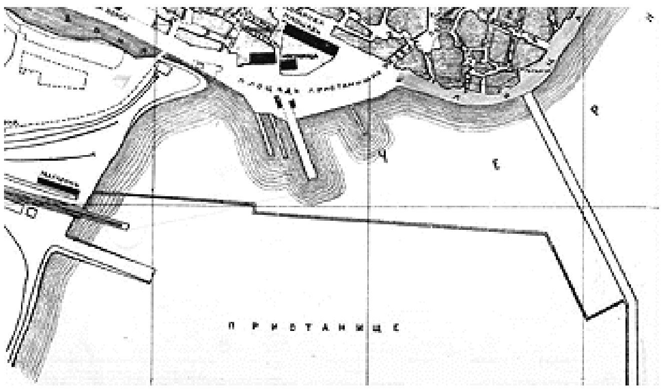


Fig. 6. Plan of the new Port Varna (1895)

The construction started in 1895 and, according to the contract, had to be completed in 1901 (*Fig.7*). Due to financial reasons the construction continued until 1906.

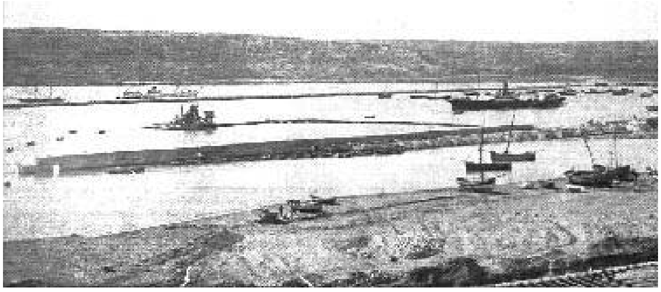


Fig7. Embankments on the New Port Varna (1896-1900)

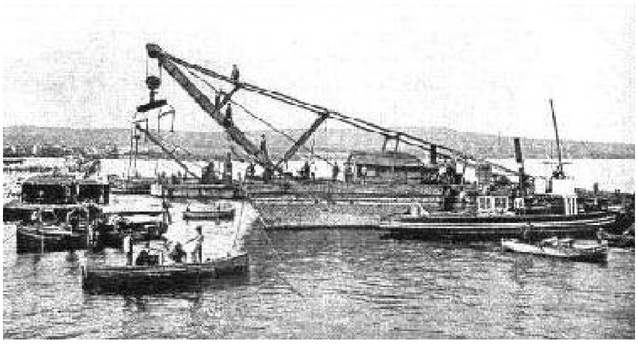


Fig8. Floating crane for the stone blocs (1896-1903)

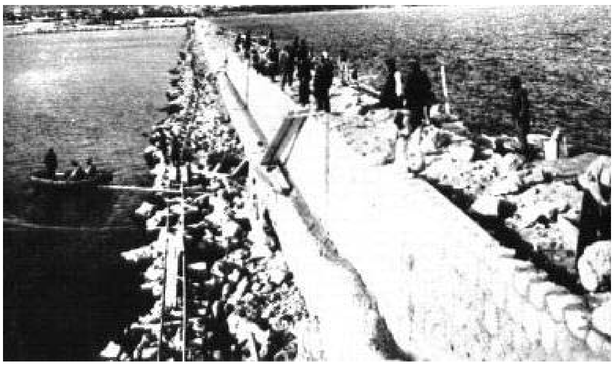


Fig. 9. Construction of the breakwater (1896-1903)

The breakwater was an important part of the port. It consisted of two parts with a kink between them - the first was long 330 meters and the main one, directed North-South, was long 890 meters (*Fig.9*). For the first time in Bulgaria, underwater divers, mostly French and Russians, took part in the construction of the ports in Varna and Burgas. They put two straight 8-meter rails along the outline of the main rocks. Afterwards they used a cross-rail to level the embankment surface.

The wall was constructed with the help of floating cranes (*Fig.8*).

III. PLACE OF THE CASE IN UNIVERSITY PROGRAMS

The example with the subsiding of the Varna breakwater during its construction is a classic example of founding in weak soils (mud), along with the examples of the ports Kobe (Japan) and Specia (Italy), where for the first time sand padding under the fencing equipment was successfully implemented. The case of Varna breakwater was included for the first time in the university programs of Sofia Polytechnics by Prof. Valerian Minkov about 50 years ago. It is described in his books on port construction and founding.

Fig10. Port Varna East today (2007)

The transverse profile of Varna breakwater is also described in the book and lectures of Prof. Valerian Minkov as an example of application of the experience of the Mediterranean sea port construction during the 19th century (Fig.11). In this type of profile the stone blocks of the wall are arranged step-like at the outer berm and batter, as indicated in Fig. … With such arrangement the high waves go up very high along the steps during their caving and, under the influence of the wind, overflow behind the wall and incur damages to the inner batter of the wall. It is explained that in order to avoid this disadvantage, special concrete extinguishing elements (tetrapods, tetrahedron, tribars, etc.) have to be placed on the steps of the outer batter.

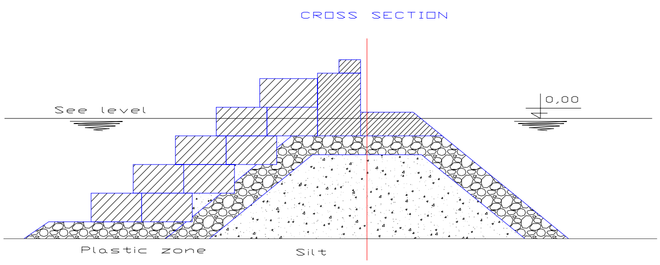


Fig.11. Cross section of the Varna's breakwater

Today the examples with Varna breakwater continue to be discussed in the programs of two more Bulgarian universities in Varna and Sofia, in the lectures on port construction, as well as on geotechnics.

Fig12. Protection by tetrapodes (2007)

IV. CONTEMPORARY SOLUTION

Currently the breakwater is undergoing a reconstruction. Since the construction of the breakwater, only one the body was made about 25-30 years ago when tetrapods (Fig.12) were arranged in the most critical sections of the outer batter.

The adopted contemporary solution for the reconstruction of the breakwater complies completely with the lessons learned from the two examples with the same equipment, discussed in the University. It is clear that the earth base is mud, which is a type of weak construction soil and during the construction a local loss of stability of the equipment occurred. The current reconstruction will reinforce and close the plastic zones in the soil in front of the breakwater by means of embankment of additional powerful berm of rock mass. The dynamic load of the energy of the crashed waves will also be dispersed over this berm by means of a “crest” of reinforced concrete thresholds in the form of chests filled with rock mass. The sequence of high underwater thresholds is designed to crash the waves before they reach the breakwater. Thus the waves would not reach the crown of the equipment and overflow through it.

A more detailed description of the reconstruction, as shown in *Fig.13* is as follows: the additional reinforcing berm will be constructed along the East side of the breakwater (from the side of the sea) from rock blocks with a mass of 500 to 1500 kg to a level of -7.00 m. Thresholds of reinforced-concrete chests filled with rock mass are laid on the berm. The distance between the chests is 5 m. Hexalegs (three-peak concrete elements) with a mass of 2.5 t are arranged around the head for additional protection.

The surface part of the breakwater will be completed with pier walls and hexalegs.

In its current state the breakwater will overflow in case of high sea of 4-5 balls, which happens often in the Black Sea. However, this overflow is inadmissible for the port aquatory.

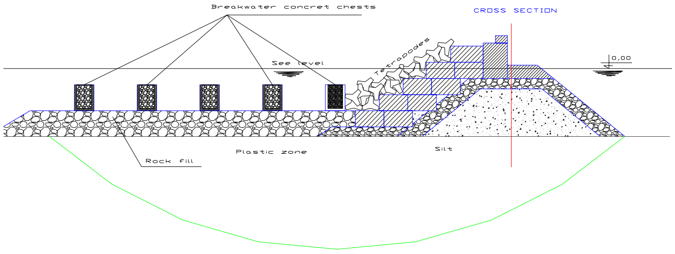


Fig.13. Profil of the reconstructed breakwater

V. CONCLUSIONS

1. The breakwater represents heavy sea equipment, which requires excellent knowledge of the earth base underneath and the character of the rough sea. That is why the case with the subsidence of part of Varna breakwater is very instructive, given that the weak soils are a very common phenomenon near the sea shore.
2. The adverse consequences of the imprecise evaluation of the earth base during the stage of designing are present during the whole period of operation of the equipment.
3. The case of Varna breakwater is very well studied by Bulgarian engineers and has served as a classic example to students for a long time.
4. One hundred years later the same breakwater is being reconstructed, taking into account the analysis and lessons learned from the failures during its construction.