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Dry Dock with Anchored Bottom

Cale sèche à radier ancré

Trockendock mit verankerter Bodenplatte

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SUMMARY
In order to obtain a dry dock of great dimensions in Romania, for the foundation slab a solution for anchoring into the foundation rock has been applied by using an original tie-bar allowing a favourable distribution of forces into the bulb, thus reducing the tension members by comparison with classical solutions

RÉSUMÉ
Pour la réalisation d'une cale sèche de grande dimension en Roumanie, on a choisi la solution d'ancrage dans la roche de fondation, utilisant un type original de tirant qui permet une distribution favorable des efforts dans le bulbe, réduisant ainsi la valeur des contraintes par comparaison aux solutions classiques.

ZUSAMMENFASSUNG
Für den Bau eines grossen Trockendocks in Rumänien wurde die Lösung gewählt, die Grundplatte in den darunter liegenden Felsen zu verankern. Dazu dienen besondere Zugstangen mit verbreiteter Fussverpresszone, die eine günstige Krafteinleitung erlaubt. Dadurch sinkt das Zugspannungsniveau gegenüber einer herkömmlichen Lösung.

1. GENERAL

Within Mangalia shipyard located on the Romanian shore of the Black Sea, a dry dock has been built for ship repair up to 250000 dwt (fig.1)
The foundation ground is rocky, being very heterogenous the rock being compacts resistent, with different densities from soft and friable with pseudohorizontal and with variable and less permeability on the vertical.At a depth about 22.0 m we may find a layer with reduced permeability, 2 m thick.

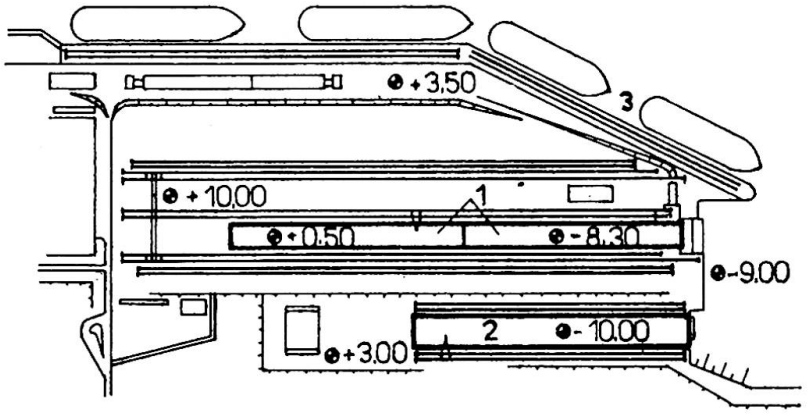

Fig.1 Dry dock in Mangalia shipyard-Romania
1,2-existing dry dock; 3-new repair dry dock

2. THE CONSTRUCTIVE SOLUTION OF THE DRY DOCK

In cross section, the dock is made up of an anchored bottom plate 1.80 m thick and of two lock walls 2.75 m thick and 13 m heigh with a cantilever towards the filling for the ballance of the bending moments into the bottom plate (fig.2).

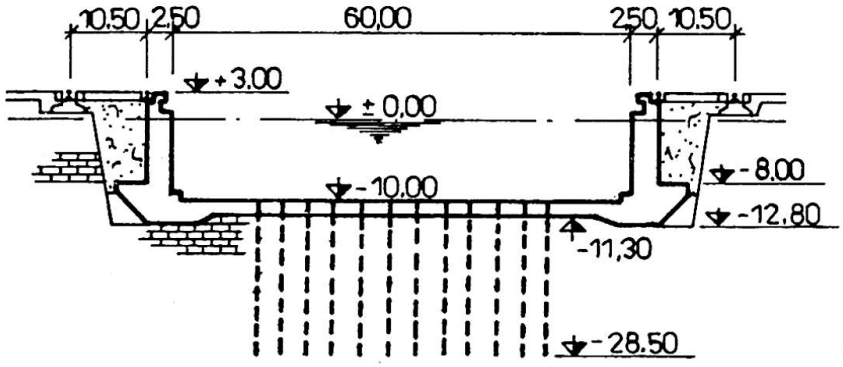

Fig.2 Repair dry dock

To adopt a classical solution a gravity one would have led to a slab thickness of 7.80 m in order to undertake the water pressure. By excavating the enclosure up to -18.0 m the rock bottom plate would have had a lesser thickness above the half-permeable layer existing the peril to loose its stability under the effect of underpressures.That would have led to considerable increase of in flows into the enclosure with an imprevisible evolution by moving the material from the rock holes. In order to avoid that

situation we must make a screen in order to waterproof at -30.0 m, which costs very much.In the end was adopted the solution of interlocking with the foundation rock, using pretensioned tie-bars.

The rock between the bottom plate and the anchoring of tie-bars constitutes a ballest in order to undertake the underpressure of water, this, the foundation platform thickness has been reduced to 1.80 m.

3.TIE-BARS MAKING UP

The tie-bars have been made up of 48 wires Ø 7 mm used for prestressed concrete, with a resistance of 16,000 daN/sq cm disposed in an optimum network with a side of 3.50 m, this resulting 1224 pieces.

The calculation charge for a tie-bar is of 1450 KN, determined by the condition that the joint between the bottom plate and the rock should be mentained as compressed in all calculation hypotheses.

The tie-bar is 17.30 m long and comprises an anchoring bulb of 6.0 m the free lenght being of 11.30 m (LI) (fig.3).The anticorosive protection has been obtained by means of wires into the cement concrete on the bulb area and in a haft fluid solution an the free lenght everything being introduced into a sheath made up of polyetilene Ø 110 mm, the wall being 1 mm thick-closing the bunch.The space between the rock and the sheath has been filled with mortar and cement.

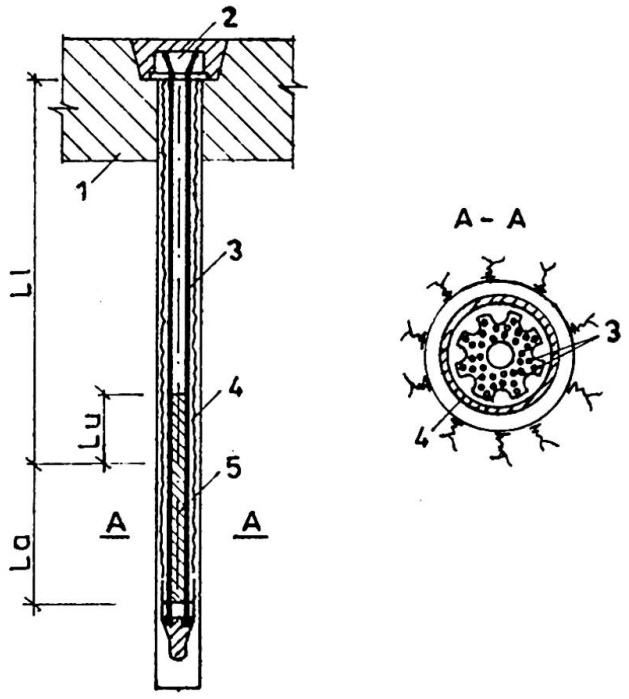

Fig.3 Anchoring cross-bar for the dry dock bottom
1.the dry dock bottom;2.blocking system; 3. Ø 7 mm wires; 4.striated casing; 5.cement mortar ; Lu-prebulb lenght; La-bulb lenght

From experiences from similar works the bulb has presented cracks upwards due to the excessive efforts produced by the wire tensioning. In order to eliminish that, the tie-bar has been executed in an original way, using a prebulb 2.80 m lenght (Lu), upwards of the bulb, having as a characteristic the lock of adherence to the wire.By this constructive measure the prebulb acts like a washer, this contributing to the reduction of the tensioning efforts in the bulb (fig.4).

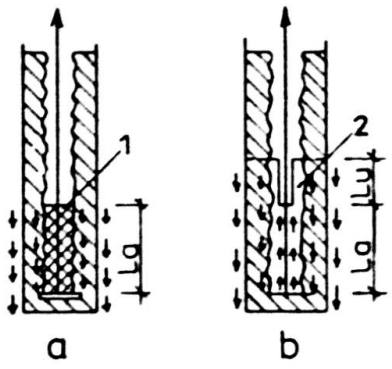

Fig 4. Eficiency of tie-bar with prebulb
a.tie-bar without prebulb ; b.tie-bar with prebulb
1.area with cracks ;2.prebulb with a washer effect

4.THEORETIC STUDIES CONCERNING THE EFFORTS IN TIE-BARS AND IN THE ROCK

In order to make in evidence the pre-bulb effect,theoretical studies have been made using programme SAP IV, discretising the tie bar into elements with axial rigidity and respectively symetrically axial calculating the values of efforts in different hypotesses.It has been noticed that in the section immediately downwords to the contact area prebulb-bulb, the maximum tensional vertical effort and the sliding one decreases by about 50% in the variant with pre-bulb (fig.5)

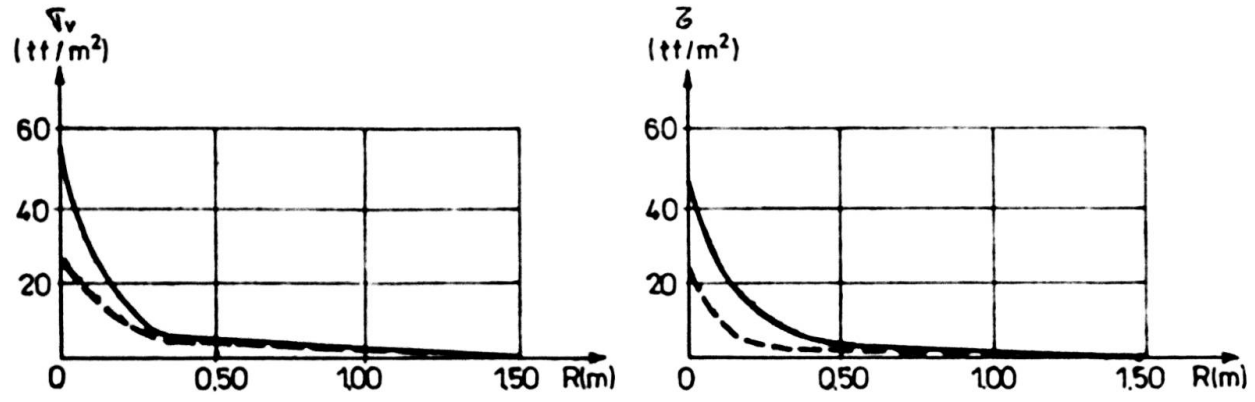

Fig.5 Diagramme of normal and tangential unitary efforts at the level of the contact area between bulb and prebulb
------ tie-bar with prebulb
——— tie-bar without prebulb

In the rock the efforts decrease rapidly that decrease undertaking to a great quota to the loading transmitted to the anchorage (fig.6).

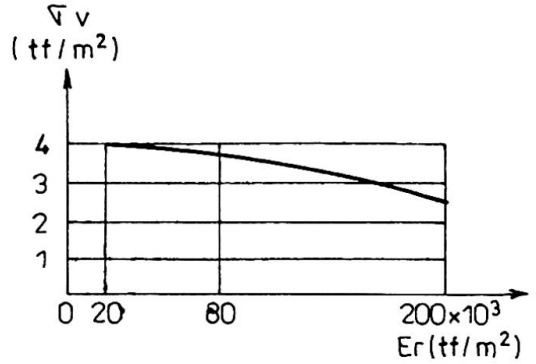

Fig.6-Variation of normal unitary effort σ_v at the contact between rock and tie bar, at the upper side of the bulb, according to the size of the elasticity modulus of the rock Er

5.THE TIE BARS TENSIONING

In order to obtain a good connection between the tie-bars and the rock, the cimenting must be carried out in a relatively dry hole.So, the holes Ø 150 mm were filled with cement mortar under pressure.
The process of redrilling was carried out at maximum one day before introducing the tie bar.
The tie-bars were introduced into the holes when the concrete resistance to compression of the bulb reached 250 daN/sq.cm. After reaching a resistance of 280 daN/sq.cm. of the cement mortar of the outer sheath,the tie-bar were pretensioned by means of a hydraulic press of 2,500 KN.Considering the loss of tension into the wires, the blocking force (Fb) of 1840 KN and the operation charge (Fe) of 1450 KN that is Fb=1.27 Fe.Tensioning was carried out up to the checking charge (Fv) of 2010 KN (Fv=1,1 Fb) wich was maintained 10 min and if slipping was greater of 2 mm everything was let clown in steps up to 1150 KN, then tensioning was relaken up to the blocking charge (fig.7)

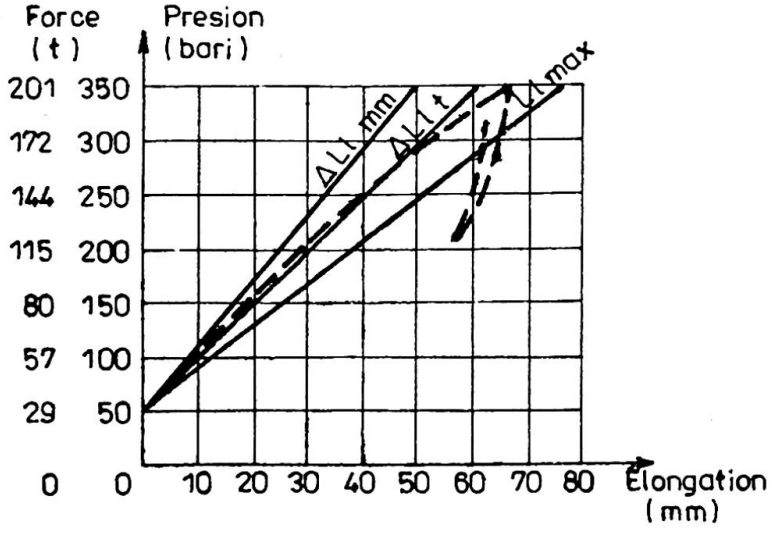

Fig.7 Diagramme of the tie-bar tensioning

If slipping surpassed 2 mm the duration of recharging was prolonged with 20 min and if lenghening was stationary, the tie bar was considered as good.If not, pressure was lessened to zero and everything was recharged at a checking charge 10% lesser and was blocked at a charge also 10% lesser.For about 10% of the tie bars the effort checking was made by blocking detachment.At the detachment moment the reading on a manometer was not less then 3% that the blockage value, admited.
As compared to the total number of 1224 tie-bars,the charge after the blocking was of 1140 pieces (93%) between 1840 KN (blocking charge) and 1660 KN (blocking charge reduced by 10%). From the rest of 7% to 50 pieces (4.1%) the charge after blocking was between 1660 KN and 1450 KN (operating charge).From the 34 tie bars with remaining charge after a blocking less than 1450 KN, 23 pcs (1.9%) were receptioned after some checkings of the real operation charge considering the interlocking with the neighbouring tie-bars and the surface of the foundation platform and 11 tie-bars (0.9%) were remade in the neighbourough.

6.CHECKING IN TIME OF TIE BARS BEHAVIOUR

In order to check in time the efforts inside the tie-bars, some of them were provided with tensiometrical, electroaccustical doses, making periodical measurements.
In the first 5 years, the initial effort decreased by 1-1.5% wich is admited by the project (fig.8)

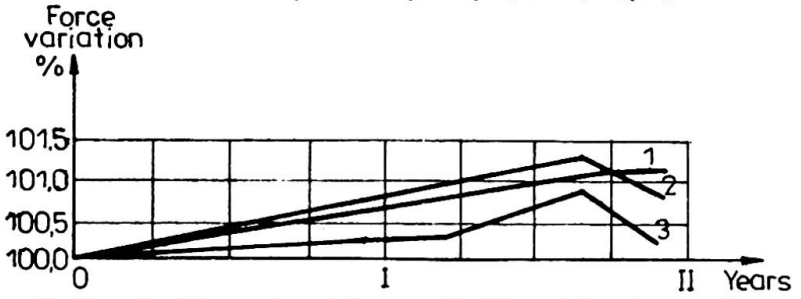

Fig.8 Variation in time of the tie-bar force
1,2,3 -the tie-bars

There have also been made checkings for environment corrosion an the tie-bars wires.
It could be noticed that the protection materials do not present aging phenomena.

7. CONCLUSIONS

By applying the solution of interlocking the concrete structure pwith the rock by means of tie-bars important advantages were obtained.
The use of tie-bars with a pre-bulb has the advantage of reducing tensions in the bulb which contributes to a greater lasting and to a good behaviour of the work.