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A COMPARATIVE STUDY OF DEVELOPMENT STRUCTURAL BREAKWATERS PROPOSALS FOR AL-FAW PORT IN IRAQ

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ABSTRACT

This investigation carried to analyze the possible structural solutions for the break waters of new Al-Faw port in Iraq. This investigation deals with the description of the general characteristics of the break waters and with the typical structural solution adopted, attributed to the environmental conditions at Al-Faw port, its location and description the structural design criteria to be adopted in the Al-Faw break waters at the eastern and western side of Al-Faw port.

Keywords: Al-Faw port, rubble mound breakwaters, berm breakwaters, armour units, geotechnical characterization, and environmental conditions.

1. INTRODUCTION

Historically, the construction of breakwaters date back hundreds of years B.C. to the ancient Egyptian, Phoenician, Greek and Roman cultures. Ancient breakwaters were constructed of stone blocks and in the form of timber cribs filled with stones. The Greeks and the Romans constructed mainly rubble mound breakwaters along some parts of the Mediterranean coast.

Common types of breakwaters were used in different countries; ruble mound breakwaters, vertical breakwaters, pneumatic breakwaters…etc. Choosing the type of breakwater depends mainly on several factors such that soil characteristics of the zone, geotechnical characteristics of construction materials, seismic characteristics, composition of sea water and sea water height (Greban *et al* 2010).

2. TYPES OF BREAKWATERS

Generally, the marine defense structures in a harbor can be subdivided in to:

a) Structures protecting the internal water basins against the wave penetration, generally called breakwaters.
b) Structures protecting the embankments against both the erosive combined action of waves and currents and the wave over topping, generally called rock revetments. Two main different types of breakwaters are described below according to their structural features:

2.1 Rubble mound breakwaters

Rubble mounds arranged in trapezoidal prismatic shape with gentle slopes represent the most common method to protect the harbors from the destructive effects of waves on part operation.

A typical rubble mound is defined as a mound of randomly shaped and randomly placed stones protected from wave action by a cover layer of selected stones and \ or specially shaped concrete armour units, as shown in Figure-1.

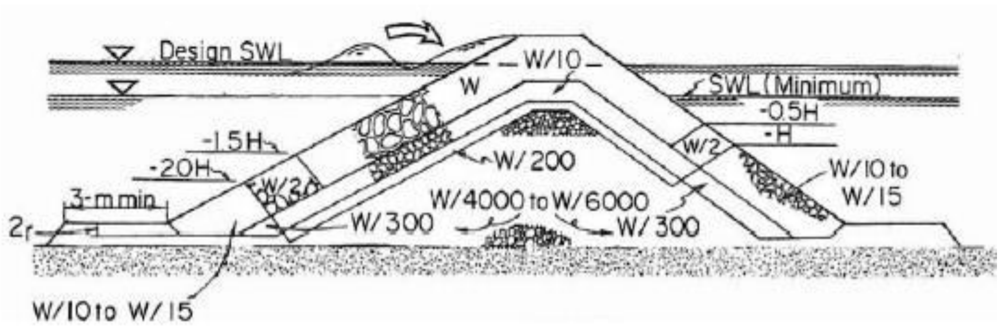

Figure-1. Typical cross section, layered rubble-mound breakwater.
(U.S. Army Corps of Engineers,1984)

The conventional type in which the rock materials is placed in layers. The selection of stone size depends on site environmental conditions. The breakwaters crest can be formed either by large rocks \ concrete units or by a parapet wall of miscellaneous construction as shown in Figure-1 (Gravesen and Sorensen 1977).

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2.2 Berm breakwaters

Structures with a horizontal section extending seaward and located close to the waterline Figure-2. In al-Faw port, this solution will not be analyzed because:

a) Even if it is possible to use smaller rocks, anyway the required size is not available from local quarries.
b) Breakwaters are subject to an oblique wave attack, which leads to a longitudinal drift of the armour stones (Sigurdarson *et al.,* 2006).

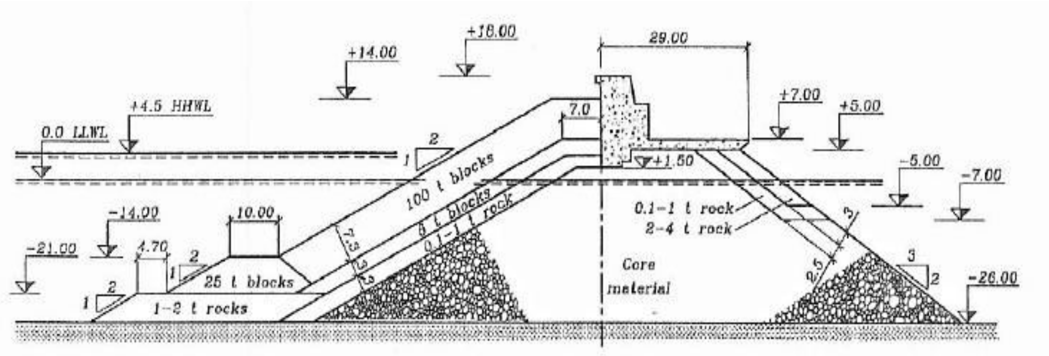

Figure-2. Typical cross section, rubble-mound breakwater with concrete parapet wall.

2.3 Vertical breakwaters

A conventional vertical breakwater is a monolithic type of breakwater consisting of stone bedding placed on the natural seafloor or an excavated trench and a gravity upright section as shown in Figure-3 (Juhul 1994).

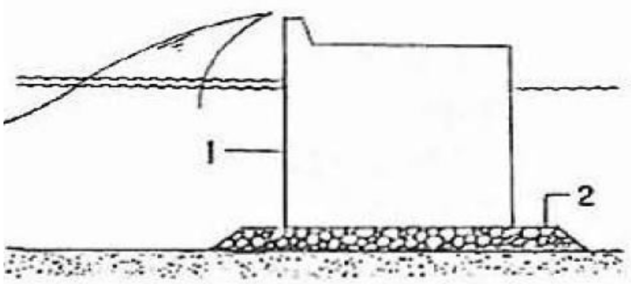

Figure-3. Conventional vertical breakwater.

3. UNCONVENTIONAL BREAKWATERS

The unconventional breakwater types are the following:

a) Floating breakwaters;
b) Pneumatic breakwaters.
c) Environmental Conditions at Al-Faw Port:

3.1 Tidal height

The tidal range varies considerably in the area of the port. The mean high high water level (MHHW) varies from about +3.0 m at the outer bar of Shat Al-Arab to over +4.9 m in the upper part of KhawrAbd Allah near Um Qasr Port.

In the Table-1, the available information concerning the tide level in relation to the lowest astronomical tide level and the mean sea level for Shat Al-Arab outer bar are resumed, see Figure-4.

Table-1. Tide level in relation to the chart datum and to the mean sea level in correspondence of Shat Al-Arab outer bar.

Height in meters in relation to chart datum			Height in meters in relation to mean sea level
+3.00	M.H.H.W	Mean higher high water level	+1.26
+2.40	M.L.H.W	Mean lower high water level	+0.66
+1.74	MSL	Mean sea level	+0.00
+1.30	M.H.L.W	Mean higher low water	-0.44
+0.40	M.L.L.W	Mean lower low water	-1.34

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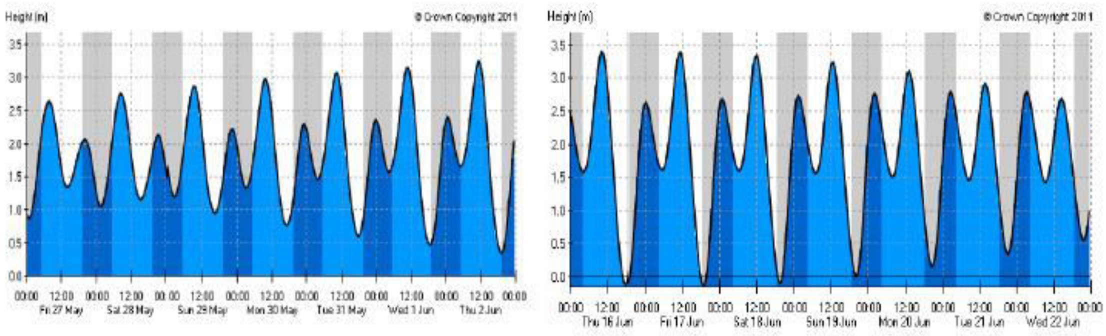

Figure-4. Typical neap (left) and spring (right) tides at Shaţţ Al ʻArab outer bar.

3.2 Wave and associated water level

The offshore winds in the Arabian Gulf are predominantly between west and north throughout the year. The predominantly N-W winds are known as Shamal. There are slight variation in the direction of the Shamal wind both according to season and position. The Shamal is most frequent in N Arabian Gulf and it blows more continuously in summer than in winter, when the Shamal is often interrupted by the passage of depressions. The absence of prolonged S-E winds is characteristics. The S-E wind, known as Kaus, commonly lasts for one of three days and is then, with an hour or so, replaced by Shamal. The results of statistical data are shown in Figure-5.

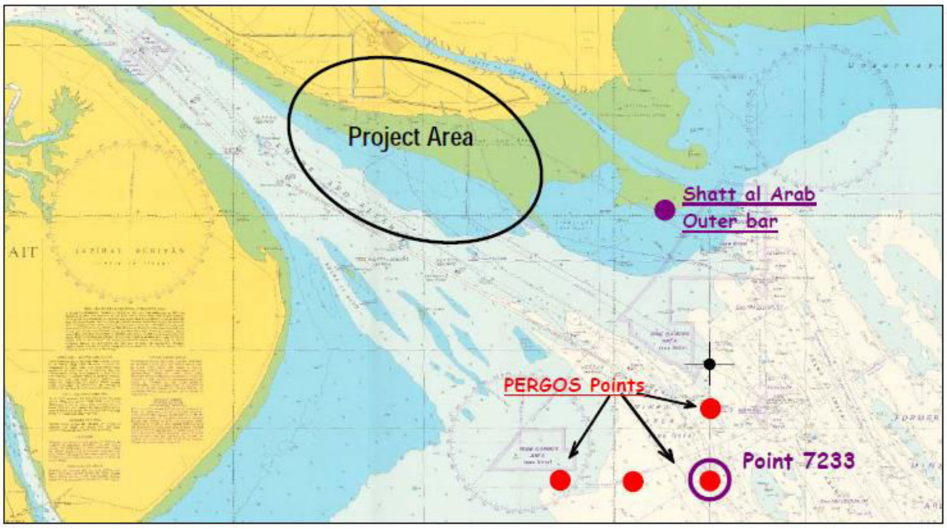

Figure-5. PERGOS grid points locations in the area surrounding target location.

4. GEOTECHNICAL CHARACTERIZATIONS

4.1 Geotechnical characterization of the natural soil

The collected data and information provided the necessary background for the geomorphologic of the area. In addition to this, data from several boreholes, CPTUs and trial pits were retrieved from subsequent soil investigations, which were carried out within Bubiyan Island, Khawr Abd Allah Channel, Al-Faw and Basrah that can be seen at Table-2, Table-3 and Figure-6.

Table-2. Preliminary soil characteristics.

Layer	γ kN/m3	Pl	Cu kPa	C' (kPa)	Ø' (°)	Cv (m²/s)	K (m/s)	E (MPa)	ν	k_o
A2-crust	19	10-25	50	15	28	1E-7	1E-8	5	0.3	0.8
A2-OC	18.5	10-25	15	5	30	1E-7	1E-8	1.5	0.4	0.6
A2	18	10-25	*	0	30	1E-7	1E-8	**	0.4	0.5
B	19	-	-	5	36	-	1E-7	15	0.3	0.6
C	20	-	-	10	40	-	1E-7	70	0.3	0.8

Table-3. Preliminary average soil stratigraphy within project area.

Layer	Elevations (m on CD)	Average thickness (m)	Description
A2	Ground level/seabed to -24/ -26 m on CD	20-25	NC consolidated clayey sandy silt, low to medium plasticity; it tends to slightly immerge in seaward direction. Off-shore, the thickness is between 25 and 20 m and the profile is normally consolidated. In the intertidal zone it has a total thickness of about 25 m and the shallower 1-2.5 m, above elevation 0 m on CD, is an OC layer called A2-OC. Inland, such layer is further overlain by a 1-2 m of OC crust, A2-crust.
B	From -24 / -26 to -26 / -28 m on CD	2	Interlayering of clayey silt and silty sand/sand, from stiff to very stiff. Its thickness is assumed to be constant 2 m.
C	Below -26 / -28 m on CD uo to at least -60 m on CD	>30	Poorly cemented deposit composed of metric layers of very dense sand spotly very hard clayey silt/clay/shale is encountered. Presence of gypsiferous cement and cemented particles.

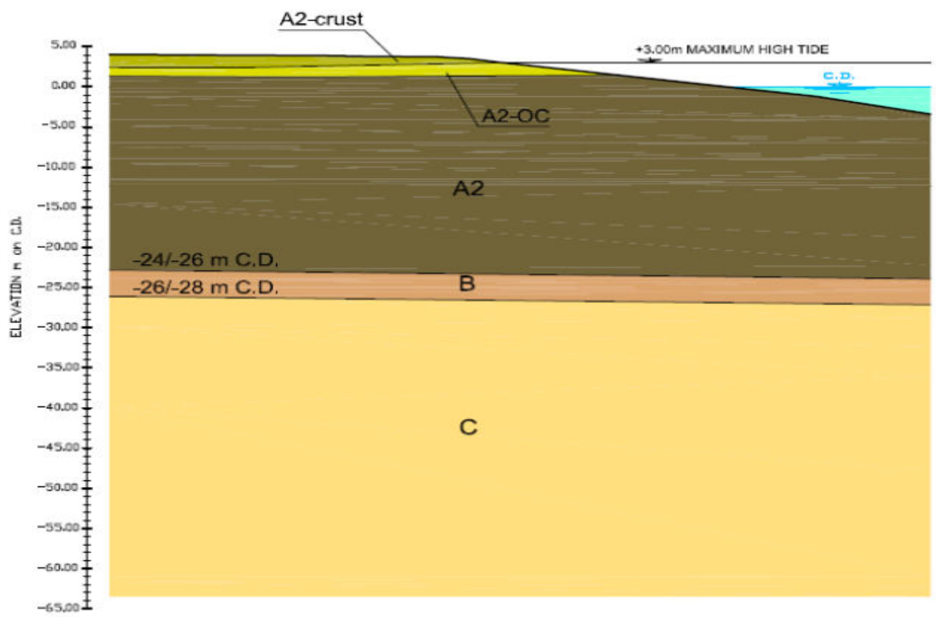

Figure-6. Typical stratigraphic profile.

4.2 Geotechnical characterization of construction materials

The breakwater is composed of a core body, external stabilizing berms and a superficial rock protection. The grain size distributions and the type of the construction materials basically depend on the seabed depth. Different typical cross sections have been designed in a way to ensure short- term and long-term stability in all the seabed conditions. The following Table-4 provides a preliminary geotechnical characterization of the out-sourced construction material to be used for the breakwater construction.

Table-4. Geotechnical characterization of construction materials material.

Material	γ(kN/m^3)	C' (kPa)	Ø' (°)	E (MPa)
1	18	0	40	10
2	18	5	45	15
3	18	0	40	5
4	17	5	42	10
5	18	5	42	15
6	19	20	30	20

5. SEISMICITY OF THE PROJECT AREA

From a tectonic standpoint, Iraq is placed on the Arabian Plate, which is limited by five tectonic features: in the N-NE, the plate collides with Persian and Turkey Plates and such collisions are marked by the Dead Sea Transform, the Zagros Thrust zone, the subduction zone beneath the Makran region of Pakistan and Iran and the Owen's Fracture Zone. On the West and South, the Arabian Platform is pushed eastwards from the African Plate, whereas the plate contact is marked by the spreading centers along the axis between Gulf of Aden and the Red Sea. Such tectonic features and borders are illustrated in Figure-7. The regional seismicity of the area Iraq-Iran-Kuwait tends to be governed by Zagros Fault, which shows a very high rate of occurrence. In this regional frame, the area of Basrah- Al-Faw is characterized by a fairly mild seismicity recorded earthquakes in the southern part of the country are limited to magnitude 4-5, connected with minor and shallow tectonic structures. For reference, the distribution of earthquake epicenter occurred within 20_{th} century across Iraq and Iraq-Iran border is depicted in Figure-8.

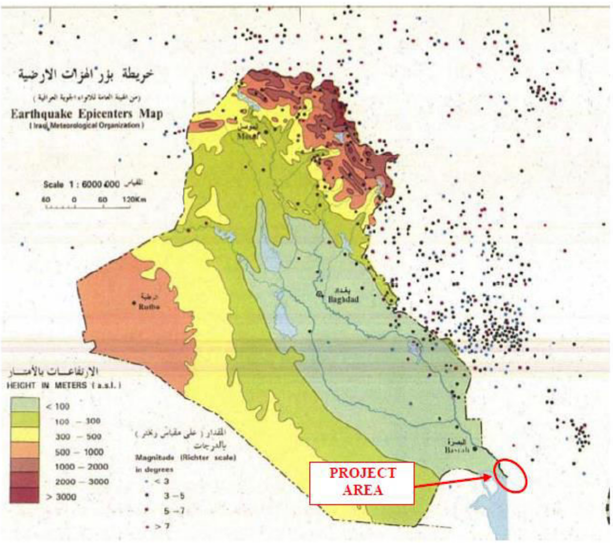

Figure-7. Tectonic setting from A.W. Sadek (2004).

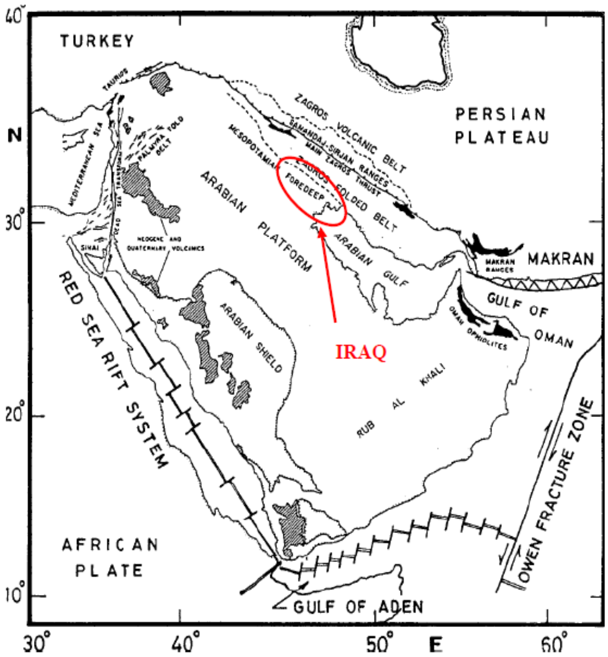

Figure-8. Earthquake epicenter map for recorded earthquakes within 20th century, sourced from "Geological Hazards Map of Iraq" GEOSURV 2005.

6 DESIGN CRITERIA

6.1 Maritime structures standards

The design of the maritime structures will be undertaken in accordance with the following publications and guidelines:

- BSI 6349: part 1 - 2000 - "Maritime structures - Part. 1 - General criteria", issued by the British Standard Institution;
- BSI 6349: part 2 - 1988 - "Maritime structures - Part. 2 -Design of quay walls, jetties and dolphins", issued by the British Standard Institution;
- BSI 6349: part 3 - 1988 - "Maritime structures - Part. 1 -Code of practice for general criteria", issued by the British Standard Institution;
- BSI 6349: part 7 - 1991 - "Maritime structures - Part. 7 - Guide to the design and construction of breakwaters", issued by the British Standard Institution;
- CIRIA, CUR, CETMEF - 2007 - "The Rock Manual. The use of rock in hydraulic engineering (2nd edition)", publication C683, issued by CIRIA, London;
- EAU 1996 - "Recommendations of the Committee for waterfront structures, Harbours and Waterways", issued by the Committee for Waterfront Structures of the Society for Harbour Engineering and the German Society for Soil Mechanics and Foundation Engineering;
- EurOtop Manual - 2007 - "Wave overtopping of sea defences and related structures: Assessment

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manual", issued by the Environmental Agency, UK

- PIANC - 2003 - "Breakwaters with vertical and inclined concrete walls", issued by the Permanent Association of navigation Congresses;
- PIANC - 1997 - "Dredged material management guide", issued by the Permanent Association of navigation Congresses;
- PIANC - 1997 - "Guidelines for the design of armoured slopes under open piled quay walls", issued by the Permanent Association of navigation Congresses;
- PIANC - 1987 - "Guidelines for the design and construction of flexible revetments incorporating geotextiles for inland waterways", issued by the Permanent Association of navigation Congresses;
- ROM 0.2-1990 - "Actions in the design of maritime and harbour works", Maritime works recommendations issued by Puertos del Estado, Spain;
- ROM 0.2-2000 - "General procedure and requirements in the design of harbour and maritime structures", Maritime works recommendations issued by Puertos del Estado, Spain;
- USACE - 2008 - ""Coastal Engineering Manual. EM 1110-2-1100", issued by THE United States Army Corps of Engineering;

6.2 Design working life

The design working life of a structure is the specified period for which the structure, undergoing a planned maintenance program, can be fully operational and used for its intended purpose. The evaluation of the design life of a structure takes into account the possibility and economic feasibility of repairs works; the probability and possibility of changes in the requirements and conditions of the structure utilization due to variation of port traffic and its operations; the variability of reinforcements and adaptations to the new service needs.

Taking into account the foreseeable use of the new Port at Al-Faw, that can be classified as General use infrastructure, and the safety Level 2 (works and installations of general interest. Moderate risk of human life or environmental damage in case of failure. (works in large ports outfalls of large cities, etc), which can be assumed for works and installations of general interest presenting a moderate risk of loss of human life or environmental damage in case of failure, the design life for the new structures should be taken equal to 50 year. It should be considered that:

6.3 Design wave return period

The frequency of recurrence of a wave event is here specified by its return period, TR, defined as the period which, on the average, will separate two occurrences. Among the possible procedures, design return period TR is here given by specifying a required lifetime of the structure.

7. MAINTENANCE AND DURABILITY

The concept of Design Working life and Design wave returnperiod of a breakwater is immediately associated with its durability. Given a certain DWL and the environment aggressiveness, a set of durability measures shall be consequently established together with a maintenance program that is supposed to be applied on the structures. Durability concept must therefore get along with maintenance durability planned for structures are a paramount driver for choosing project elements and materials. The structural elements have to be followed by a required level of maintenance to keep the efficiency of the system during its service life. The maintenance level required for the working life is usually inversely proportional to the initial investments made for the elements that ensure better durability determination of supplies and maintenance cost derived from them must be evaluated accordance with cost minimization and time working life as shown in Figure-9.

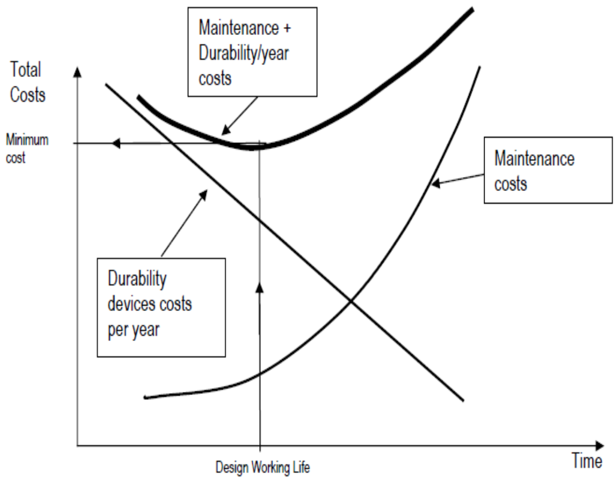

Figure-9. Graphic "Construction/maintenance costs".

8. STRUCTURAL PROPOSALS

In the new Al-Faw Grand Port two main breakwaters are envisaged the eastern breakwater and the western breakwater. A minor and internal breakwater is located at the shoreward head of the container quay, where a defence structure is required to retain the embankment for the storage of empty containers. Hereafter preliminary structural solutions for each breakwater are proposed. The layout depicted in Figure-10 shows the possible breakwater alternatives applicable to different portions of breakwaters. Based on the different wave conditions, water depths and on the different funds on requirements, the structural typologies for the different stretches of breakwaters are proposed, as indicated in Figure-10.

a) Rubble mound breakwater armoured with gabions.

b) Rubble mound breakwater armoured with natural rocks exposed to internal waters and backfilled by an embankment

c) Rubble mound breakwater armoured with natural rocks and exposed to open sea.

d) Rubble mound breakwater armoured with concrete unit's vertical breakwater with reinforced concrete caissons.

e) Vertical breakwater with double sheet pile wall.

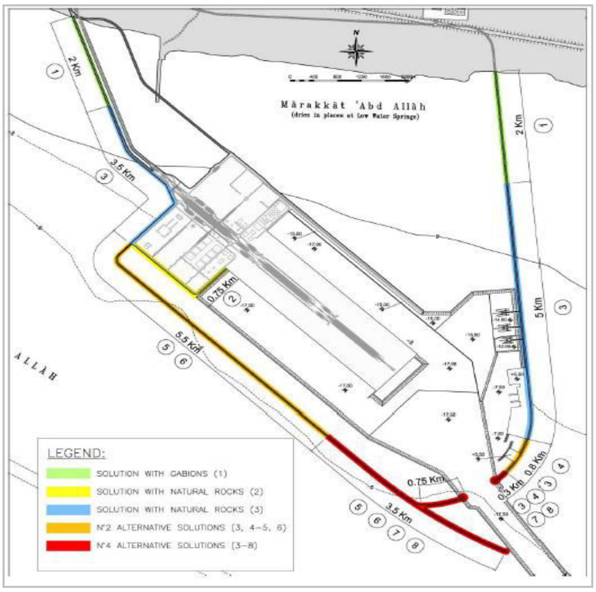

Figure-10. Al-Faw Grand Port - Layout of possible breakwaters typologies.

In the following, these alternatives are discussed with reference to the specific above noted.

8.1 Eastern breakwater

The Eastern Breakwater is approximately 8,000 m long and spans from +2m CD to around -5.0 m contour. It is envisaged that the breakwater will be built in two phases:

a) At a fist stage only that portion necessary to erect the staging pier will be constructed.

b) In the second phase the breakwater will be completed to protect the port basin, so it will be enlarged meet the functional requirements. In the final port layout it is also envisaged that the eastern breakwater will carry a pipeline above the breakwater crest, so the width shall be increased as appropriate. For most part of the eastern breakwater, the limited and varying water depth at the project site (mostly shallower than 4.0 m CD), as well as the poor conditions, makes the rubble mound breakwater the most feasible and cost effective solution, Figure-11.

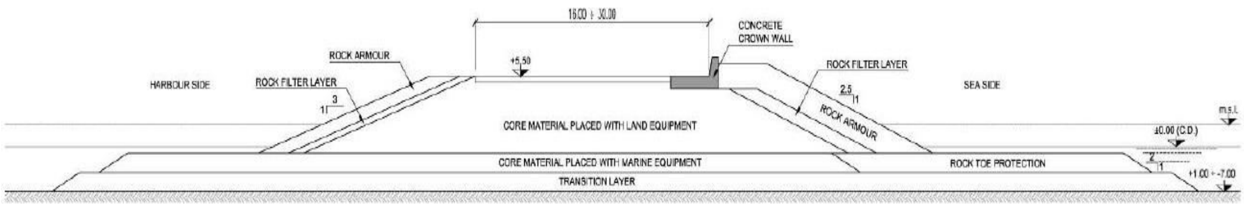

Figure-11. Rock armour solution- East breakwater.

8.2 Western breakwater

Most of the considerations made for the eastern breakwater are applicable to the Western breakwater as well, since they both lie on the same water depths and face similar environmental conditions. Therefore, the same structural alternatives as noted for the eastern breakwater can be proposed in corresponding conditions, Figure-12.

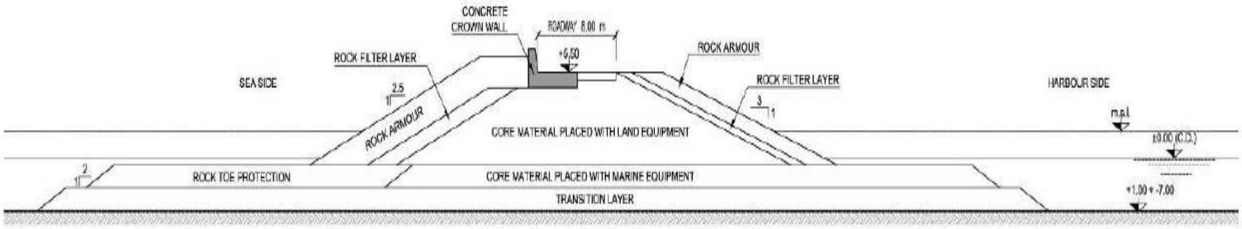

Figure-12. Rock armour solution- West breakwater.

8.3 Internal breakwaters

An internal breakwater is located at the North West end of the container quay basin, where an earth retaining structure is required to protect the embankment for the storage of empty containers. This retaining structure will be located in average water depths of 4.00 m CD, so the most important load will be exerted by the backfill. To define the optimal solution it is important to consider the behavior of the structures following the completion of the embankment. The earth pressure of the backfill can produce high loads in the subsoil, Figure-13.

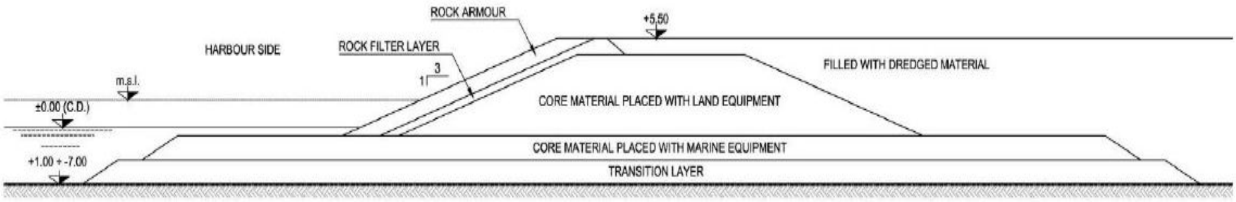

Figure-13. Rock armour solution- Internal breakwater.

9. CONCLUSIONS

As a results of above considerations for Al-Faw Port, below the most important conclusions that can be drawn from this investigation:

a) The main advantages of using concrete armoured rubble mound breakwater at the project site are: given the great distance of the construction site from quarries, rubble mound breakwaters with concrete armour units may represent a cost effective solution because they require a lower volume of stones for their construction than rock armoured structures.

b) The main disadvantages of using concrete armoured rubble mound breakwater at the project site are: the manufacture of armour blocks the availability of wide prefabrication yards which, however, can be located outside the project site; especially for concrete armour units require higher precision rock armour stones single layered armours.

c) The main advantages of using a rubble mound breakwater armoured with Gabions at the Al Faw Grand Port are: Gabion filling stones could be supplied by national quarries as they usually are of small so they may represent a cost effective solution in shallow waters where relatively calm wave conditions are expected; They are very flexible structures so they adapt well to settlements; They are easy and fast to install.

d) The main disadvantages of using a rubble mound breakwater armoured with Gabions at the Al Faw Grand Port are: They can be damaged and filling stones can be easily moved in case of direct wave action, so they cannot be used in a severe wave environment. The steel wire is exposed to corrosion, so specific protection (galvanization of the wire, protective plastic coating) should be provided.

e) The main advantages of using reinforced concrete caissons is possible to employ local labor other works going on at in a different construction system in order to minimize interferences with other works going on at the main site, construction activities are independent rate of the materials; the harbour side of the breakwater might be used as a temporary berth for small vessels or empty vessels waiting to be loaded.

f) The main disadvantages of adopting a reinforced concrete caisson breakwater in the Faw port are an extensive solution improvement treatment shall be undertaken to enhance the poor subsoil properties and to enable caissons to withstand cyclic loadings induced by tides and waves; its requires special equipment and specialized labor.

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g) The main advantage of adopting sheet pile wall structure system are provide a straight face suitable for marine projects and deep berths the Hz system.

h) The main disadvantages of adopting sheet pile wall structure system that it should only be installed by leading experience contractors equipped with heavy plant suitable for open water conditions where appropriated.

REFERENCES

Greben J. M, Gledhill L, Cooper A. K, Rosalie D. V. 2010. Characterization and Properties of Breakwater Structures modelled by aPhysics Engine. Seventh South African Conference on Computational and Applied Mechanics, Pretoria, South Africa, 10-13 January. pp. 254-265.

Gravesen, H. and Sorensen, T., 1977. Stability of Rubble Mound Breakwaters. 24th International Navigation Congress. Leningrad. U.S.S.R.

Sigurdarson Smarason, Voggosson and Bjordal. 2006. Sigurdur S., Omar B. S., Gisli V. and Sverre B. Wave height limits for the statically stable icelandic-type berm breakwater. ICCE.

Juhl J. 1994. Danish experience and recent research on vertical breakwaters. Proceeding of International Workshop on Wave Barriers in Deepwaters. PHRI, pp. 154-171.

BSI 6349: part 1.2000. Maritime structures Part 1.General criteria', issued by the British Standard Institution.

BSI 6349 part 2 1988 structures Part 2 Design of quay walls, jetties and dolphins. Issued by the British Standard Institution.

BSI 6349: part 3 1988. Maritime structures Part 1-code of practice for general criteria issued by the British Standard Institution.

BSI 6349; part 7. 1991 Maritime structures Part 7-Guide to the design and construction of breakwaters. Issued by the British Standard Institution.

CIRIA, CUR, CETMEF 2007 The Rock Manual, The use of rock in hydraulic engineering (2nd edition). Publication C683, issued by CIRIA, London.

EAU 1996 Recommendations of the Committee for waterfront structures, Harbours and Waterways, issued by the Committee for Waterfront Structures of the Society for Harbour Engineering and the German Society for Soil Mechanics and Foundation Engineering.

EurOtop Manual. 2007. Wave overtopping of sea defences and related structures Assessment manual issued by the Environmental Agency, UK.

PIANC. 2003. Breakwaters with vertical and inclined concrete walls. Issued by the Permanent Association of navigation Congresses.

PIANC. 1997. Dredged material management guide", issued by the Permanent Association of navigation Congresses.

PIANC. 1997. Guidelines for the design of armoured slopes under open piled quay walls. Issued by the Permanent Association of navigation Congresses.

PIANC. 1987. Guidelines for the design and construction of flexible revetments incorporating geotextiles for inland waterways issued by the Permanent Association of navigation Congresses.

ROM 0.2-1990 Actions in the design of maritime and harbour works. Maritime works recommendations issued by Puertos del Estado, Spain.

ROM 0.2-2000. General procedure and requirements in the design of harbour and maritime structures. Maritime works.

USACE 2008 Coastal Engineering Manual. EM 1110-2-1100, issued by The United State Army Corps of Engineering.