DESIGN OF SUBMERGED BREAKWATER

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ABSTRACT

Pantai alexsandria yang berlokasi di Mesir merupakan pantai tujuan wisata yang terkena erosi gemburan gelombang. Untuk melindungi pantai dari erosi yang berlanjut dipilih struktur submerged breakwater dengan alasan lebih estetis dibandingkan dengan merged breakwater. Hal ini dikarenakan puncak struktur beradadi bawah muka air laut rata-rata sehingga para wisatawan masih dapat melihat pemandangan ke laut lepas tanpa adanya penghalang bagi pandangan mereka. Alasan lain, dengan perlindungan oleh submerged breakwater pengunjung dapat dengan aman berenang di pantai, tetapi dapat pula merasakan gelombang, dan arus. Untuk tujuan renang sub merged breakwater dibagi dalam segmen-segmen. Tinggi gelombang signifikan (Hs) harian digunakan untuk merencanakan struktur sub merged breakwater, tetapi untuk kekuatan breakwater digunakan Hs dengan kala ulang 100 tahun.

Keyword : *submerged breakwater*

General

The aim of this study is to design sub-merged breakwater so lee side area of breakwater will be suitable for swimming activity in Alexandria, Egypt. As a tourist destination, viewing to the sea may not blocked by crest of breakwater as one conditional requirement of the structure. Another reason, sub merged breakwater Is more pleasant aesthetically than mer-ged breakwater. There are permanent waves transmissions behind breakwater, so the wave high can be determine.
The tidal range is so small about 0.7 m then off shore breakwaters and submer-ged breakwaters can be applied in this area**.**

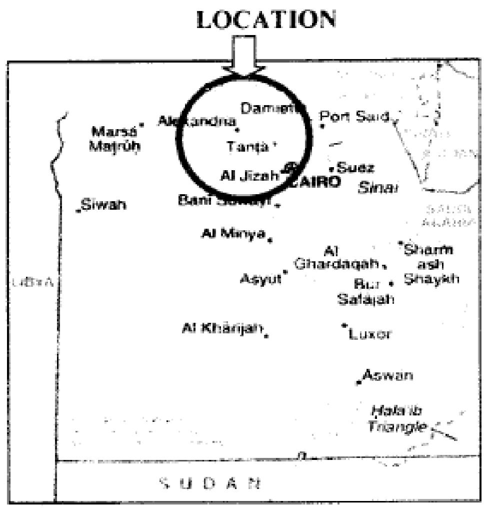

Figure 1. Map of Project Location

DATA

Wave Data

Wave data is found from www.wavec-limate.com. For this design, seasonality data is used as requirement value to

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decide position of sub-merged breakwater for coastline. Another reason, determining of crest levels with concern on wave transmission behind the submerged breakwater use this data with assumption as daily condition. The value 3.5 m is taken as significant wave height for daily condition. As a tourist destination needs daily wave condition, so it concerns on what wave high transmission behind the submerged breakwater.

Extreme significant wave height is used as input data for calculation strength of structure. Determine of return period depends on design lifetime of structure. The extreme significant wave height is Used to calculate dimension of structure Of submerged breakwater. Choice with 3 hours storm duration is based on history of incident storm. Another reason, return period of 3nhours exceedance has a bigger value of significant wave height than 6 hours and 12 hours. From this data, significant wave height in 100 years return period is taken 7.6 m.

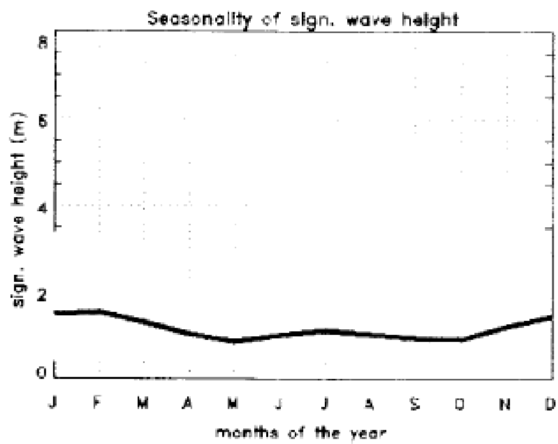

Figure 2. Seasonality of wave height

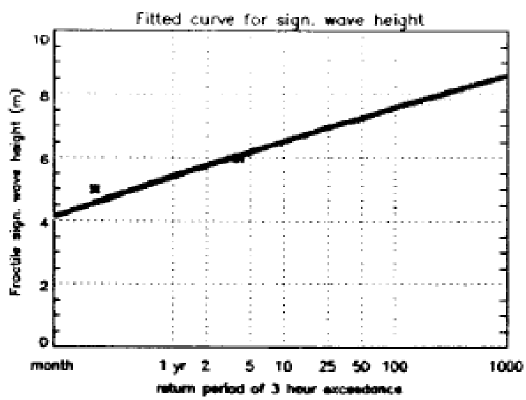

Figure 3. Fitted curve for significant wave height

Table 1. Significant wave height for extreme condition

Fractile sign. Wave height (m) versus return period of 3 hour exeedance			
return period	**sign. Wave height**	**lower limit**	**upper limit**
month	4.1	4.0	4.2
1 yr	5.4	5.3	5.6
2	5.8	5.6	6.0
5	6.2	6.0	6.4
10	6.5	6.3	6.7
25	7.0	6.7	7.2
50	7.3	7.0	7.5
100	7.6	7.3	7.8
1000	8.6	8.3	8.9

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Beside that website, data from Global Wave Statistics was looked as comparison. From these sources, the prevailing waves are from Borth Wave direction (α = 45°).

Table 2. Wave Height Data at project site (from Global Wave Statistic)

Hs	**Number observation**	**% of Occurence**
0 -1	349	34.90
1 - 2	373	37.30
2 - 3	171	17.10
3 - 4	65	6.50
4 - 5	24	2.40
5 - 6	10	1.00
6 - 7	4	0.40
7 - 8	2	0.20
8 - 9	1	0.10
9 - 10	1	0.10
	1000	100.00

Bathymentary Map and Situation Map

Map of depth contours is available. Depth contours are relatively parallel with shoreline and perpendicular with north direction, so the shoreline is in stable condition. From situation map, is known that the location is relatively close (not open sea). The northwest direction is big possibility of dominant incoming wave, so for calculation we take 45˚ as the angle of incoming wave.

WAVE CALCULATION

Time Period Calculation

Time period data is not available. To know about time period, below formula is used to predict it.

$$H_s = 0.24\frac{U_{10}^2}{g} \qquad T_s = 1.2T_m$$

$$\frac{U_{10}}{C_p} = 0.84 \qquad C_p = \frac{g}{2\pi}T_p$$

where :

H_s = Significant wave height (m)
U_{10} = wind velocity above 10 m from the land.
G = gravitate acceleration (9.81 m^2 /-sec)
Cp = Phase velocity of peak
Tp = Peak Time period (second)

For daily condition with significant wave high is 3.5 m, the time period is 7.6 seconds. Time period for extreme signifycant wave condition is 11.2 second.

Breaking Index Calculation

The location of breaking wave is important because it will be considered as location of submerged breakwater position.
Breaking depth, breaking index and breaking height can be obtained by trial and error process as follows :
Step 1 : Guess water depth “h”
Step 2 : Calculate h/ Lo, tan (kh) and Ks
Step 3 : Calculate α = $\sin^{-1}$(tanh(kh) * sin α_0)
Step 4 : Calculate Kr from $Kr = \sqrt{\frac{\cos\alpha_0}{\cos\alpha}}$
Step 5 : Calculate H = Ho *K_s *K_r
Step 6 : Plot the graph No. 1 between water depth “h” and wave height “H”.

And then based on Weggel (1972) Formula is used to find breaker index.

$$\frac{H_b}{d_b} = (C_2 - C_1\frac{H_b}{gT^2})$$

where

$$C_1 = 43.75(1 - e^{-19m})$$

$$C_2 = \frac{1.56}{(1 + e^{-19m})}$$

To find relationship between breaking depth (d_b) and breaking height (H_b), the graph No. 2 is plotted in the same axis on no. 1. At the intersection point of two graphs, the breaking height is representted. Also breaking index cab be calculated easily by dividing breaking height by breaking depth. The results of calculateon are presented in Table 1 and 2.

Table 3. The calculation of breaking depth and breaking height for normal wave condition (1/1 year)

Water depth (h)	h/Lo	tanh (kh)	K_s	$\alpha = \sin^{-1}(\tanh(kh)*\sin \alpha_0)$	K_r	H (m)	Hb (m)
7.0	0.05	0.5446	1.013	22.6493	0.8753	3.10	5.98
6.5	0.05	0.5261	1.026	21.8395	0.8728	3.13	5.61
6.0	0.05	0.5066	1.042	20.9909	0.8702	3.17	5.22
5.5	0.04	0.4854	1.059	20.0737	0.8676	3.22	4.83
5.0	0.04	0.4631	1.080	19.1147	0.8650	3.27	4.44
4.5	0.03	0.4454	1.098	18.3575	0.8631	3.32	4.03
4.0	0.03	0.4205	1.125	17.2978	0.8605	3.39	3.62
3.5	0.03	0.3929	1.159	16.1302	0.8579	3.48	3.20
3.0	0.02	0.3626	1.202	14.8563	0.8553	3.60	2.77
2.5	0.02	0.329	1.258	13.4524	0.8526	3.75	2.33

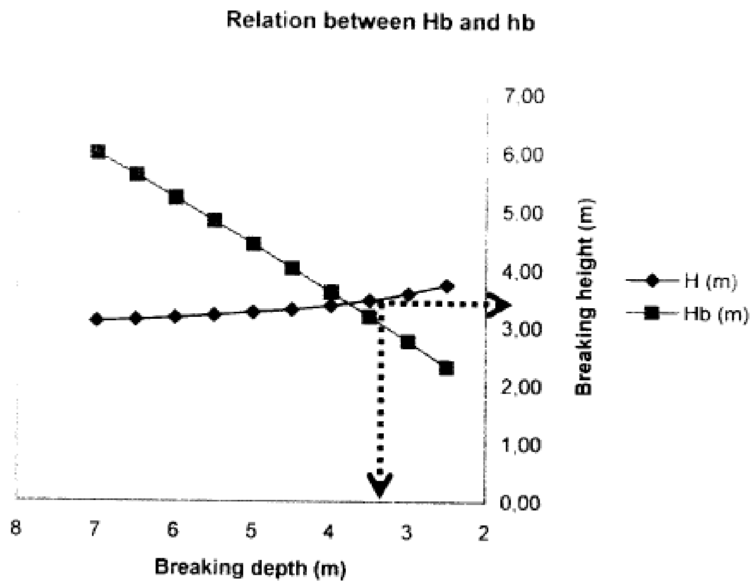

Figure 4. Relation between H_b and h_b of 1/1 year wave condition

Cress program can be used to check above result. It looks similar result between Cress Program and manual calculation.

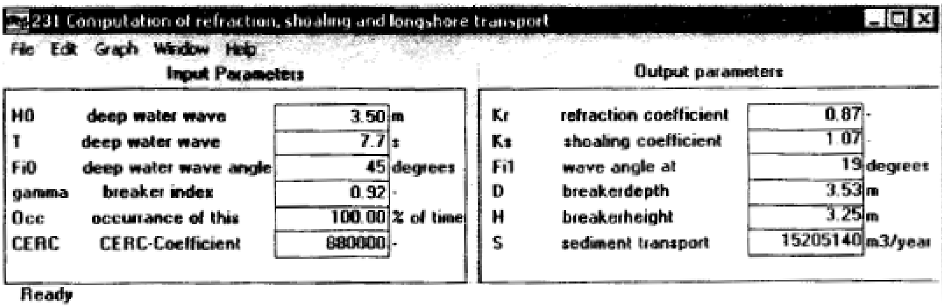

Figure 5. Result of Cress Calculation for Daily wave height condition

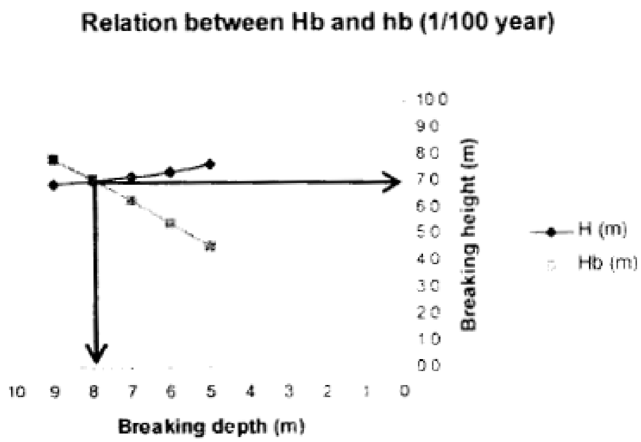

Figure 6. Relation between H_b and h_b of 1/100 year wave condition

To check aboveresult, calculation using Cress program is done too.

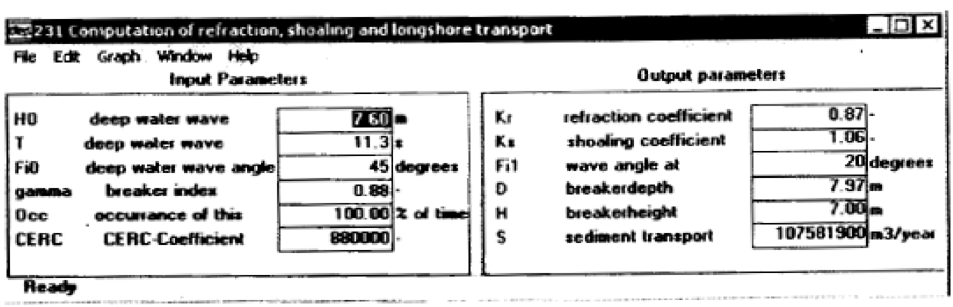

Figure 7. Cress program calculation for extreme wave condition

Summary of breaking conditions, from above calculation, it can be concluded :

Daitaly wave height condition

Wave condition	: normal (1/1 year)
Ho	: 3.5 m
Tp	: 9.2 seconds
Tm	: Tp/1,2 = 9.2/1.2 = 7.66 seconds
α_0	: 45^0
γ	: 3.45/3.75 = 0.92
Breaker depth	: 3.75 m
Breaker height	: 3.45 m

Extreme wave height condition

Wave condition	: normal (1/100 year)
Ho	: 7.6 m
Tp	: 13.5 seconds
Tm	: Tp/1,2 = 13.5/1.2 = 11.2 seconds
α_0	: 45^0
γ	: 7.0/8.0 = 0.875
Breaker depth	: 8.0 m
Breaker height	: 7.0 m

BOUNDARY CONDITION

Bottom slope

Bottom slope can be measured directly from the given contour map on the 3 lo-Cations (0.0265, 0.02885, 0.027). Average of bottom slope from three sample Locations is 1 : 37 (0.027)

Water level

Data of water level are :

Mean high water spring	= + 0.70 m CD
Mean sea level	= + 0.35 m CD
Mean low water spring	= 0.00 m CD

The tidal range is small (only 0.7 m), so mean sea level can be used as the design water level for shake of convenient.

Sea bed material and design water depth

The sea bed material at the project site is medium to fine sand. Then assume that sand particle size is 0.2 mm and density is 2650 kg/m^3.
Assume density of seawater is 1025 kg/m^3. The breakwater is located in the contour depth of – 3.50 below MSL then the design water depth is 3.50 m.

Maximum transmitted wave height

In order to make suitable area for swimming activity and others water tourism activities, it is proposed to allow maximum wave height at the lee side of the breakwatera of 1.0 m. The design wave height is not dangerous for swimmers. If lee side is protected completely from wave, this condition will not liked by swimmers or others tourism water acti vities.

Wave conditions

Usually, the design life structure of breakwater is about 50 – 100 years. In this project, the design life of 50 years is proposed to use. It means that extreme wave condition 1/100 year has to be considered as a design wave conditions.

Ho = 7.6 m
Tp = 11.25 sec
Tm = 1.2 T_m = 13.5 s
α_0 = 45^0

For the design water depth of 3.50 m, the extreme deep-water wave height 7.6 m will be broken with the breaking index 0.875. In this condition, the breaking depth is 8.0 m, and the breaking height 7.0 m. Then, the design wave height can be calculated as below formula :

Breaking index * water depth = 0.875 * 3.50 ≈ 3.0 m

Wave length can be determined with Formula L = L_o tanah (kh)

L_{om}	= 1.56 * 11.25²	= 197.4 m
L_{op}	= 1.56 * 13.2²	= 284.3 m
Tanah (kh)		= 0.2694
L_m		= 0.2696 * 197.4
		= 53.22 m
L_p		= 0.2696 * 284.3
		= 76.64 m

DETERMINE OF BREAKWATER POSITION AND DIMENSION

The main fuction of submerged breakwater is to protect water zone near the beach (behind the submerged breakwater) so suitable for tourist swimming activity. It is daily condition, so determination of submerged breakwater position is based on daily wave height condition. To avoid some destroy on rock material of submerged breakwater that caused by wave attack, the submerged breakwater should be placed inside the breaker line in order to let the waves break before approaching the breakwaters. The position of submerged breakwaters in the region of breaking waves and on the surf zone will give higher scour impact if the wave height is higher. The location of surmeged breakwaters on the seaward side of the breaking line will cause higher erosion if their crest is lower. The breaker depth of normal wave condition is 3.75 m. Based on this value; it is proposed to place the breakwater at the water depth of 3.50 m

The estimation of distance between the coastlines to the water depth 3.50 m can be done by directly measurement from the available map. The distance is about 160 m be able to observed.

For this design, the concept of Uda et al (1988) is used to determine how many lengths of breakwaters and the distance between two breakwaters. This formula coincides about flow patterns arround by wave. For swimming activity, the fourth patterns have to be selected. The relations of length (L_B), gab width (G_B), and distance (X_B) from shore of the breakwater are shown as follos :

L_B/X_B = 1 to 3

$L_B/G_B > 4$

The value of X_B 160 m has already calculated from the previous step. Then L_B and G_B will be determined using formula as below :

$L_B / X_B = 2$
L_B = 1.5 * 160 = 240 m ≈ 250 m
$L_B / G_B = 5$
G_B = 240/5 = 48 m ≈ 50 m

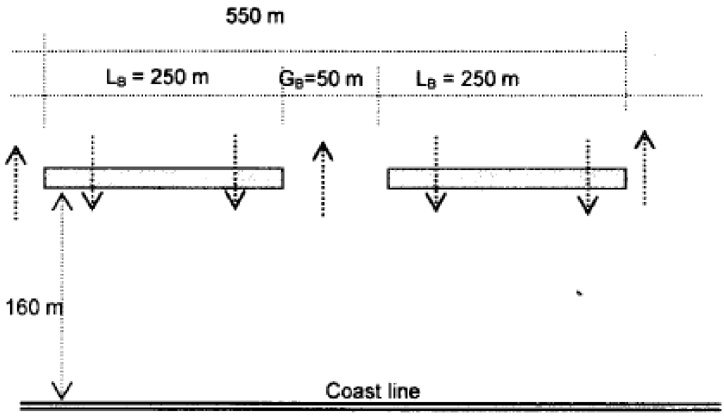

Figure 8. Layout of submerged breakwaters

It is proposed to protect the beach in the distance of 580 m along the coastline. So, the numbers of sumerged detached breakwaters are 2 segments.

Crest Width

Crest width is desgned base on condition :

- Maximum wave transmission is 1 meter.
- Crest level is designed 0.5 m below sea water level.

Strucure such as breakwaters with low crest levels construction will transmit wave energy into the sea behind the breakwater. The transmission performance of low-crested breakwaters is dependent on the structure geometry, principally the crest freeboard, crest height, crest windth, water depth, permeability, and on the wave conditions mainly the wave height and period.

The next graph is the relationship between crest width and transmission coefficient, which is proposed by Tanaka (1976). Based on breaking index analysis, wave height at sumerged breakwater location is 0.875 * 3.75 = 3.3 m. The incoming wave is 3.3 m so the value of Ht/Hi is 0.3. Value of hc/Ho is -0.15, so from Tanaka graph, we find B/Lo ≈ 0.2. Finally, we find width of crest sub merged breakwater is 10 m.

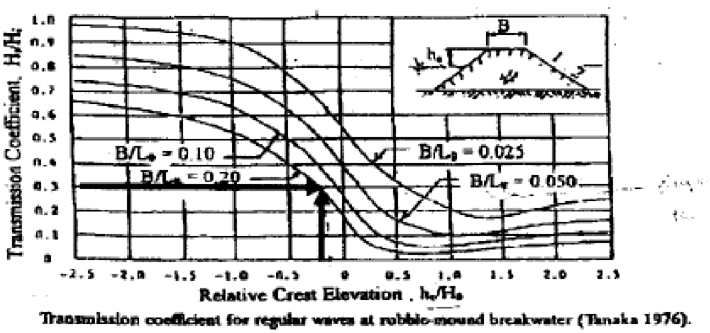

Figure 9. Transmission coefficient for regular wave at rubble mound breakwater (Tanakan 1976)

CROSS SECTION DESIGN

Armour Layer Weight

In shallow water conditions the distribution of the wave heights deviate from Rayleight distribution (truncation of the Curve due to wave breaking). Based on the model test by Van de Meer, the stability of the armour layer in depth limited situation is better described by a higher characteristic value of the wave height distribution $H_{2\%}$ than by H_s. The ratio of $H_{2\%}$ / H_s is 1.4

$$\xi_m = \frac{\tan\alpha}{\sqrt{2\pi H_s / gT_m^2}}$$

For plunging waves (in shallow water):

$$\frac{H_{2\%}}{\Delta D_{n50}} = 8.7.P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2} \xi_m^{-0.5}$$

For surging waves (in shallow water):

$$\frac{H_{2\%}}{\Delta D_{n50}} = 1.4.P^{0.18}\left(\frac{S}{\sqrt{N}}\right)^{0.2} \sqrt{\tan\alpha\xi_m^p}$$

For this project, we can calculate :

$$\xi_m = \frac{0.027}{\sqrt{2\pi.7.6 / (9.81).(11.25^2)}} = 0.138(\text{plunging type})$$

S is level of damage. For this design, it is taken S = 2 (start to damage). The materials of sructures are rocks, so permeability factor P is 0,4.

$$\Delta = \frac{2650}{1025} - 1 = 1.585$$

N is the amount of wave attack on structure.

$$N = \frac{\textit{storm}\,\text{duration}}{\text{wave period}} = \frac{3*60*60}{11.25} = 960\ \textit{times}$$

To determine rock diameter for plunging breaking wave type, this formula can be used:

$$\frac{1.4*7.6}{1.585*D_{n50}} = 8.7.P^{0.18}\left(\frac{2}{\sqrt{960}}\right)^{0.2} 0.138^{-0.5}$$

So, it is found D_{n50} = 0.585 m with weight ≈ 530 kg

During construction time, D_{n50} for armour layer between 0.585 m (0.5 Ton) – 0.72 m (1 Ton)

Armour layer thickness

The thickness of the armour layer can be determined by using this following equation (SPM, 1984):

$t_a = n\ k_t\ D_{n50}$

Where :

- t_a = thickness of Armour layer
- k_t = layer thickness coefficient
- D_{n50} = nominal diameter (0.72 m)
- N = number of layers

In this design, it is based on 2 armour layers then layer thickness coefficient of rough rock for 2 layerss is 1. Therefore, yield :

t_a = 2 * 1 * 0.72 = 1.44 m (say 1.50)

The core

Rubble mount structures in coastal and shoreline protection are normally constructed with an armour layer and one or more underlayers. But for the submerged breakwaters, it is obvious that the underlayer is not necessary. The armour layer can be simply placed upon the core of structure. The SPM (1984) recommend for the stone size of the core under the armour a range of 1/10 to 1/15 M_{50} of armour layer.

Then yield :

M_{50c} = 1/10 M_{50a}

= 1/10 * 9500 to 1000) = 50 to 100 kg

For this weight, the rock size is $\left[\frac{50to100}{2650}\right]^{\frac{1}{3}} = 0.27\ m \text{ to } 0.33m$ (say 0.3m)

Side slope

The side slope of the submerged break-water is vary from 1 : 1.5 to 1 : 3 . In this structure, it is proposed to use side slope at the sea side of 1 : 2 in order to have the smooth breaking. At the lee si-de, the steeper slope can be considered so it is proposed to use lee side slope same as with sea side (1: 2).

RECOMMENDATION

Submerged breakwater is very expensi-ve structure. The failure of structure will be able to loss a lot of money. There are different phenomena for each location where the submerged breakwater will be built. So, it is strong recommendation to make model test, which can describe and record others phenomina around the model. Unpredicted phenomena from model test can be revised in design before construction time.

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Cross section :