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EFFECT OF USING SUBMERGED RECTANGULAR STEPPED BREAKWATER FOR THE DEFENCE OF THE SHORE LINE

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ABSTRACT

Rectangular breakwater is a barrier with its crest at, over or below the still water level. For economical solution submerged breakwaters have been effectively used but for more protection a clear rectangular breakwaters prefer to use. So in this paper experiments were done to study these cases in the wave flume in the laboratory of Hydraulics, Department of Civil Engineering, Shorouk Academy, Higher Institute of Engineering.

A rectangular breakwater with constant width (W) = 50 cm as the total width of the experimental flume and different heights (Y) worked one by one or acting as a group (stepped)with different water levels (d_w), different height of water above crest level (d_s) and different wave heights (H_i), Compared the efficiency and percentage of energy reduction calculated between these types of breakwaters, also measuring incident, reflection and transmission wave heights for three kinds working as single or as a group as shown in figure (1).

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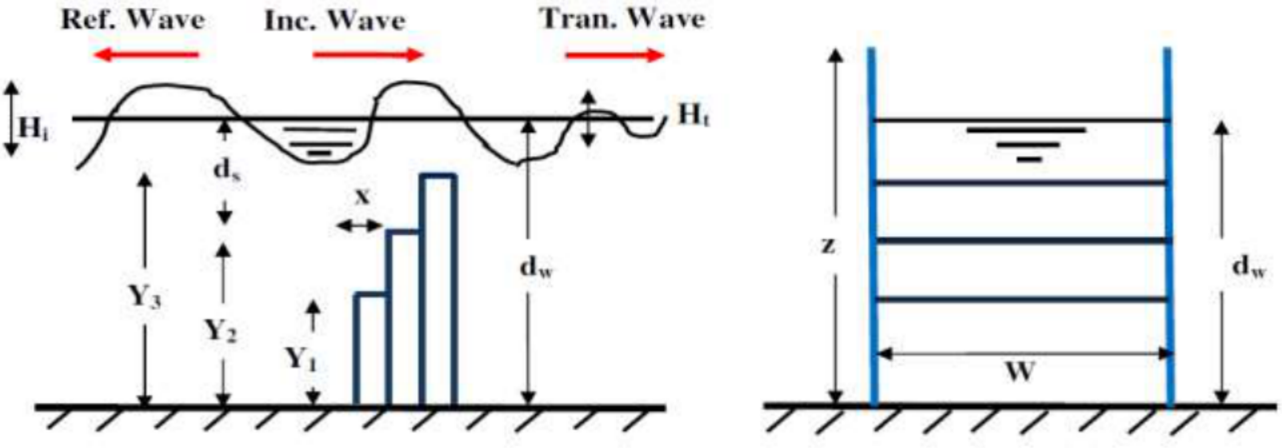

Elevation **Side View**

Figure (1): Definition sketch of the rectangular breakwater with different heights

1. INTRODUCTION

Submerged breakwaters are becoming more popular as a potential alternative to coastal protection measures where a moderate degree of energy transmission is acceptable. Such situations include areas where vegetative shore protection is existing or proposed or in the event that an existing shore protection structure has become damaged or under designed and a method is needed to reduce the incident wave energy. Physical model studies were performed at the wave flume in the laboratory of Hydraulics, Department of Civil Engineering, Shorouk Academy, Higher Institute of Engineering as shown in figure (2), to assess the performance of submerged rectangular vertical breakwaters.

Many parameters affect the design; several researches studied the wave reflection and transmission from similar perforated breakwaters, this type of breakwaters is considered as a good and cost-effective substitute for the conventional type of breakwaters, especially for coastal works where the tranquility requirements are low. This type occupies small zone so that, not affecting the seabed creatures. The submerged types of this kind permit to exchange the water masses along the beaches which minimize the pollution aspects. In addition, the land side of the emerged types of this breakwater kind can be used for berthing purposes.

Figure (2): Modelling Wave Flume

2. LITERATURE REVIEW

Dick and Goda, Y., Takeda, and Moriya (1967) tested vertical, smooth impermeable structures for wave transmission by overtopping. The breakwater crest width was varied; wave reflection coefficients were measured to determine the incident wave height acting on the structure. Mei and Black (1968) studied experimentally and theoretically surface piercing and bottom standing thick vertical barriers and used various formulations as the basis for numerical computations of the reflection and the transmission coefficients and obtained accuracy within one percent for the numerical results.

Seeling (1980) obtained the most information about wave transmission, reflection, and energy dissipation from hydraulic model tests. The measurements in the model tests were generally limited to the free surface oscillations on the landward and seaward sides of submerged breakwater.

Abdul Khader and Rai (1981) investigated experimentally the damping action of impermeable submerged breakwaters of various shapes (thin, rectangular, trapezoidal and triangular). The effectiveness of the breakwater in damping the incident wave energy is measured in terms of coefficient of transmission.

Kobayashi and Wurjanto (1989) modified the numerical model for predicting the up rush and down rush of normally incident monochromatic waves on rough or smooth impermeable slopes.

Mootaz Khaled (1992) study wave energy dissipation by using submerged rubble mound breakwater. Abul-Azm (1993) analyzed the linear wave potential near submerged thin barriers using the Eigen Function Expansion to determine the breakwater efficiency.

Isaacson et al. (1996) carried out an experimental investigation on the reflection of obliquely incident waves from a model rubble-mound breakwater of single slice. Heikal (1997) examined the efficiency of an impermeable, vertical thin submerged breakwater sited on sloping impermeable bed experimentally and numerically by using the Eigen Function Expansion method.

Koraim (2002) investigated experimentally and theoretically the wave interaction with impermeable, submerged thin and thick breakwaters, rectangular and trapezoidal, on horizontal and sloping beaches. Stamos et al. (2003) conducted a parametric experimental study to compare the reflection and transmission characteristics of submerged hemi-cylindrical and rectangular rigid and water-filled flexible breakwater models.

Jeng et al. (2005) investigated experimentally the mechanism of dynamic interaction among water waves, a submerged breakwater, a vertical wall, and a sandy seabed.

Shirlal et al. (2007) experimentally investigated the armor stone stability of the submerged reef and the influence of its varying distances from shore and crest width on ocean wave transmission.

Musfique Ahmed and Rifat Anwar (2011) studied the efficiency of the submerged breakwater as shore protection structures. A set of experiments are conducted at a still water depth of 50 cm with a fixed rectangular submerged breakwater of three different heights (30 cm, 35 cm and 40 cm), for five different wave periods (1.5 sec, 1.6 sec, 1.7 sec, 1.8 sec, and 2.0 sec) in the wave flume mentioned before. It is clearly seen from this experiment that a submerged breakwater is very effective in reducing the transmitted waves.

El-Saie Yasser Mohamed (2013) examined number of row-piles with different heights in experimental study, for the defense of the shore line.

3. EXPERIMENTAL SETUP

Physical modeling is performed in the wave flume in the laboratory of Hydraulics, Department of Civil Engineering, Shorouk Academy, Higher Institute of Engineering.

The flume was 12 m long, (W) = 0.5 m wide and (Z) = 0.6 m deep. It is equipped with a wave generator at one end, a wave absorbing in the other end and wave gauges for measuring wave height.

The water depth in the flume (d_w) ranged as (25, 27.5, 30, 32.5 and 35 cm), the wave generator makes five eccentricities (leads to five wave period) to produce minimum and maximum wave heights, breakwater height = (Y_1= 15 cm, Y_2= 20 cm and Y_3= 25 cm), different height of water above crest level (d_s) ranged between (10, 12.5, 15, 17.5 and 20).

Thickness of any single submerged Breakwater (x) = 5.0 cm. The layout of the experimental wave flume and the measurement sections (elevation and plan) as shown in figure (3).

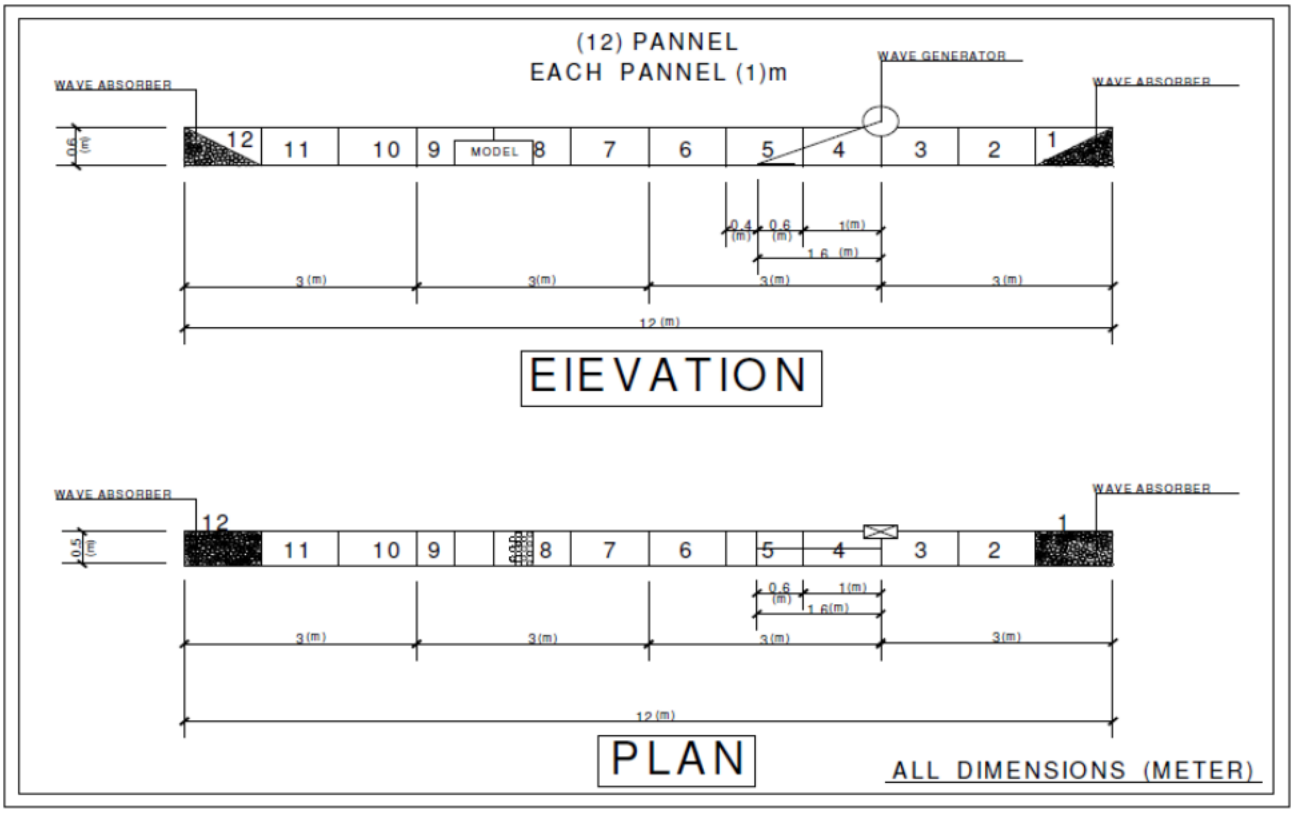

Figure (3): experimental Wave Flume

Undistorted models are usually not used for wave studying, for instance there is no theory which satisfactorily describes the wave breaking. Also wave effects from generator as shown in figure (4) are reproduced by means of mechanical devices and this prevents the distortion of modeled waves.

Figure (4): Photo of the wave generator

The main forces affecting waves are gravity forces and all other forces such as fluid friction and surface tension can be neglected. Therefore in this study Froude Number F_n are considered in modeling and similarity.

F_n for model = F_n for prototype

$$F_n = \frac{v}{\sqrt{gL}}$$

Where:
F_n = Froude's Number
V = velocity
g = acceleration due to gravity
L = characteristic length of flow

$$n_v = \frac{v_m}{v_p} \qquad \ldots(1)$$

$$\left[\frac{v}{\sqrt{gL}}\right]_P = \left[\frac{v}{\sqrt{gL}}\right]_m \qquad \ldots(2)$$

$$n_L = \frac{L_m}{L_p} \qquad \ldots(3)$$

$$n_T = \frac{T_m}{T_p} \qquad \ldots(4)$$

$$n_T = \sqrt{n_L} \qquad \ldots(5)$$

$$n_v = \frac{\sqrt{L_m}}{\sqrt{L_p}} \qquad \ldots(6)$$

$$C = \frac{\lambda}{T} \qquad ...(7)$$

$$n_\lambda = \frac{\lambda_m}{\lambda_p} \qquad \ldots(8)$$

$$n_c = \frac{C_m}{C_p} \qquad \ldots(9)$$

$$n_\lambda = (n_T)^2 \qquad \ldots(10)$$

Where:
n = scale (ratio)
C = celerity, λ = wave length and T = wave period

The efficiency of the system is evaluated through the transmission coefficient C_t where it is equal to (H_t/H_i), additional information of the system response under the wave action is obtained through the evaluation of the reflection and dissipation coefficient, $C_r = (H_r/H_i)$.
Finally $(C_d)^2 = (1 - C_t^2 - C_r^2)$, evaluated indirectly through energy conservation concept.
Where:
H_i = incident wave height,
H_r = reflected wave height and H_t = transmitted wave height.
Also, $H_i = (H_{max}+H_{min})/2$ and $H_r = (H_{max}- H_{min})/2$

From the previous analysis, the best linear scale was found to be 1:25 and for the study of wave transmission, reflected and dissipation the wave period of 2.0 seconds as maximum is more sufficient.

Therefore, four parameters are to be modeled; these are fluid properties, generated waves, pile geometry and depth of water.
The experimental program is as follows:

W = crest width = 50 cm, constant.
X = width of breakwater (5, 10 and 15 cm).
Y = height of Breakwater (step by step, their heights will be 15, 20, 25 cm)
d_w = water depth (25, 27.5, 30, 32.5 and 35 cm)
N = number of breakwaters as single, double or triple (back to back).
G.W. = generated wave heights (5 eccentricities from wave generator, leads to 5 wave period, T_o = 1, 1.25, 1.5, 1.75 and 2 seconds).

Run the experiments for all parameters so wave generator produces different waves in such a way that they covered the possible range found in nature. The wave then traveled pass the vertical rectangular breakwater and was absorbed almost entirely at the other end of the wave flume. Wave heights were measured in front of and behind the system of breakwaters. Starting with single rectangular vertical breakwater with different height Y (15, 20 and 25 cm), as shown in figure (5).


Single Y = 15 cm Single Y = 20 cm Single Y = 25 cm

Figure (5): photos of different single rectangular vertical breakwater

Repeating these experiments by using different double vertical rectangular breakwater with different heights back to back as shown in figure (6)

Double (Y = 15, 20 cm) Double (Y = 15, 25 cm) Double (Y = 20, 25 cm)

Figure (6): photos of different double rectangular vertical breakwater, different heights

Ending these experiments by using the three types together back to back (Y = 15, 20 and 25 cm), as shown in figure (7).

Figure (7): photo of three rectangular vertical submerged breakwaters with different heights back to back

4. EXPERIMENTAL RESULTS

Some of these experiments results were plotted in group of curves figures (8, 9, and 10) with different depths of water (25, 30 and 35 cm) indication for minimum, average and maximum water depth and x = (5, 10 and 15 cm) to give relations between wave steepness and coefficient of transmission to realize the effect of using single, double and triple vertical rectangular breakwater with different heights as wave energy dissipation.

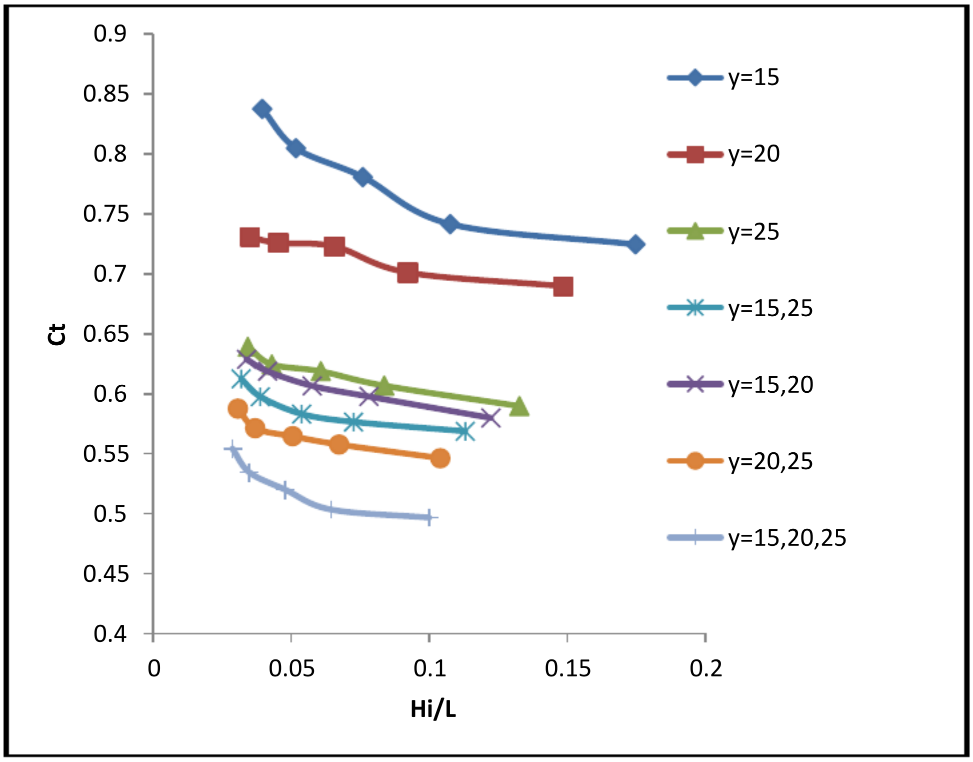

Figure (8): H_i/L versus C_t, with different (T_o) and constant water depth 25 cm

The difference between using different heights Y = 15, 20 and 25 cm was very clear, so the coefficient of transmission and energy reduction varied as shown in table (1) for minimum depth = 25 cm, Computing the total wave energy in front of and behind the system of piles using:
$E = 0.125\ (\rho.g.h^2)$, where:
E is the total average wave energy per unit surface area.
ρ is the water density, G is the gravity acceleration and h is the wave height.

Height (Y) cm	15	20	25	15,20	15,25	20,25	15,20,25
d_s/d_w	0.4	0.2	0	0.2	0	0	0
X (cm)	5	5	5	10	10	10	15
Average (Ct)	0.777	0.714	0.615	0.606	0.587	0.565	0.521
% of Energy reduce	38.39	47.92	55.08	57.51	62.47	66.88	71.25

Table (1): Variable C_t and energy reduction for different heights of breakwaters at minimum depth = 25 cm

Also, for using average depth of water = 30 cm, as shown in figure (9) and the same variables and conditions.

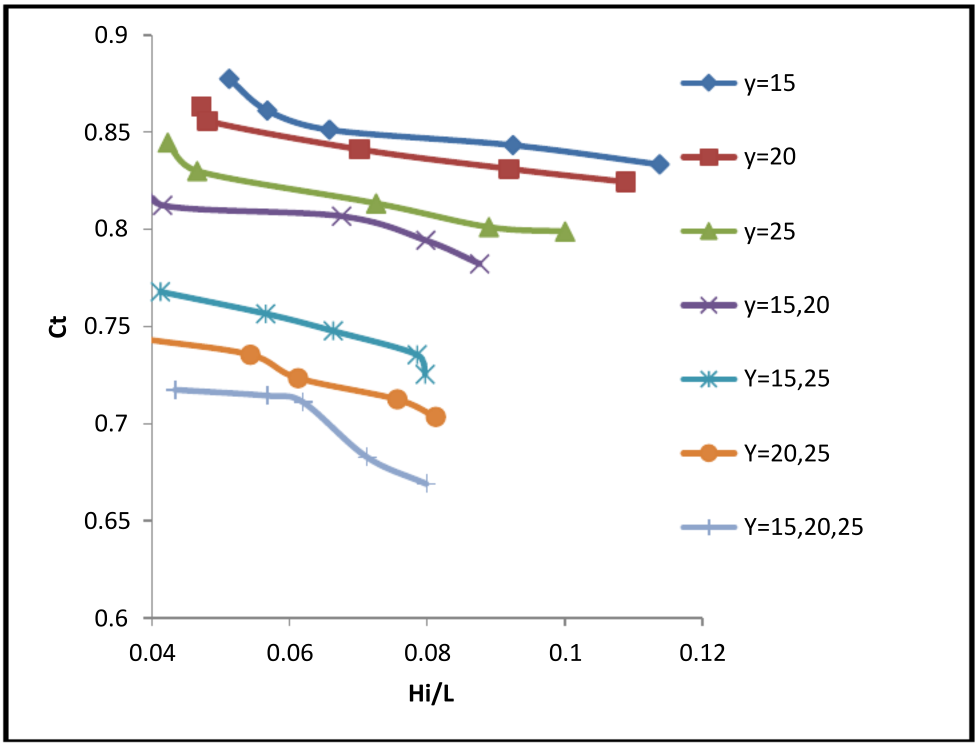

Figure (9): H_i/L versus C_t, with different (T_o) and average water depth 30 cm

Also, the coefficient of transmission and energy reduction varied as shown in table (2) for average depth = 30 cm as it below.

Height (Y) cm	15	20	25	15,20	15,25	20,25	15,20,25
d_s/d_w	0.5	0.333	0.166	0.333	0.166	0.166	0.166
X (cm)	5	5	5	10	10	10	15
Average (Ct)	0.853	0.843	0.817	0.804	0.746	0.723	0.698
% of Energy reduce	24.07	27.88	37.22	40.09	47.30	47.85	51.78

Table (2): Variable C_t and energy reduction for different heights of breakwaters at average depth = 30 cm

Finally for maximum depth = 35 cm and with the same variables and conditions, figure (10) shows also the relation between Hi/L and Ct for different heights, thickness and wave period.

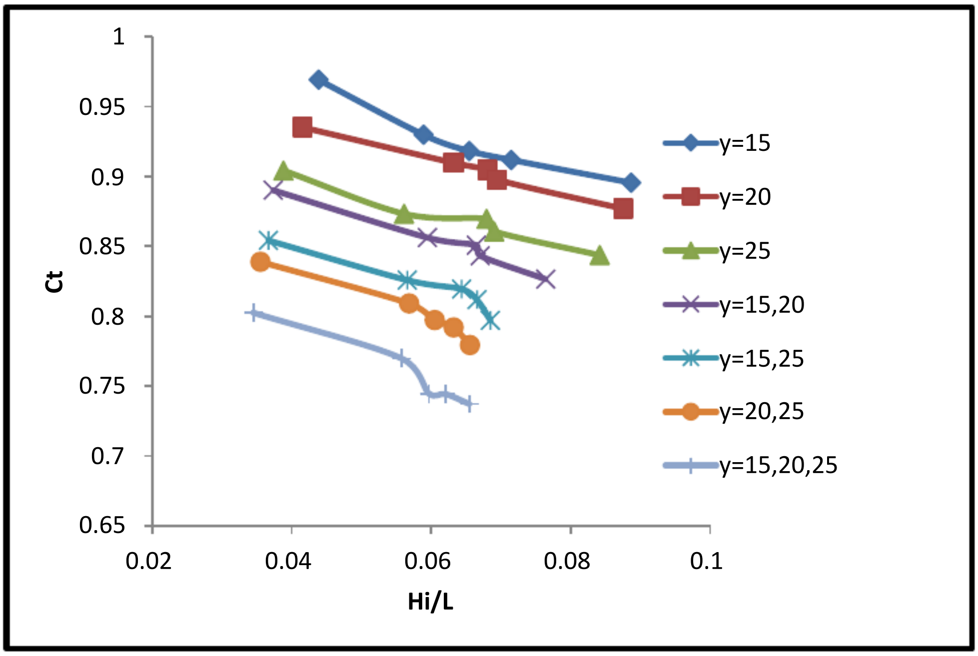

Figure (10): H_i/L versus C_t, with different wave period (T_o) and maximum water depth 35 cm

Table (3) shows also the coefficient of transmission and energy reduction for maximum depth of water = 35 cm.

Height (Y) cm	15	20	25	15,20	15,25	20,25	15,20,25
d_s/d_w	0.571	0.428	0.285	0.428	00.285	0.285	0.285
X (cm)	5	5	5	10	10	10	15
Average (Ct)	0.924	0.904	0.870	0.853	0.821	0.803	0.759
% of Energy reduce	11.26	15.04	21.42	23.97	30.73	33.63	39.70

Table (3): coefficient of transmission and energy reduction at maximum depth = 35 cm

The efficiency of the vertical rectangular submerged breakwater increases with increasing of its height and thickness, so using three rows of submerged breakwater with different heights was more effective in reduction of energy, but the percentage of reduction varied from tables (1, 2 and 3) so we can use any of these vertical rectangular submerged breakwater in order to any energy that we can allow behind these submerged breakwater. Wave steepness is directly proportional with the reduction of wave energy, so increasing of wave steepness leading to increases of wave energy reduction.

Comparing with these seven kinds the average energy reduction were (24.57, 30.28, 37.9, 40.52, 46.83, 49.45 and 54.24 %).

5. COMPARISON WITH (EL-SAIE AND MOOTAZ)

Comparing the results by (El-Saie), effect on using of a multiple – row pile breakwater with different heights in experimental study, the heights were (15, 20 and 25 cm) with diameter = 7.0 cm, constant spacing (3.5 cm), five depths of water (20, 22.5, 25, 27.5 and 30 cm) and five eccentricities of wave generator.

And also by Mootaz Khaled , wave energy dissipation by using submerged rubble mound breakwater natural stones with constant height = 25 cm, crest width 20, 30 and 40 cm and five depths of water (22.5, 25, 27.5, 30, 32.5 and 35 cm), five eccentricities of wave generator and (S) slope = 2.

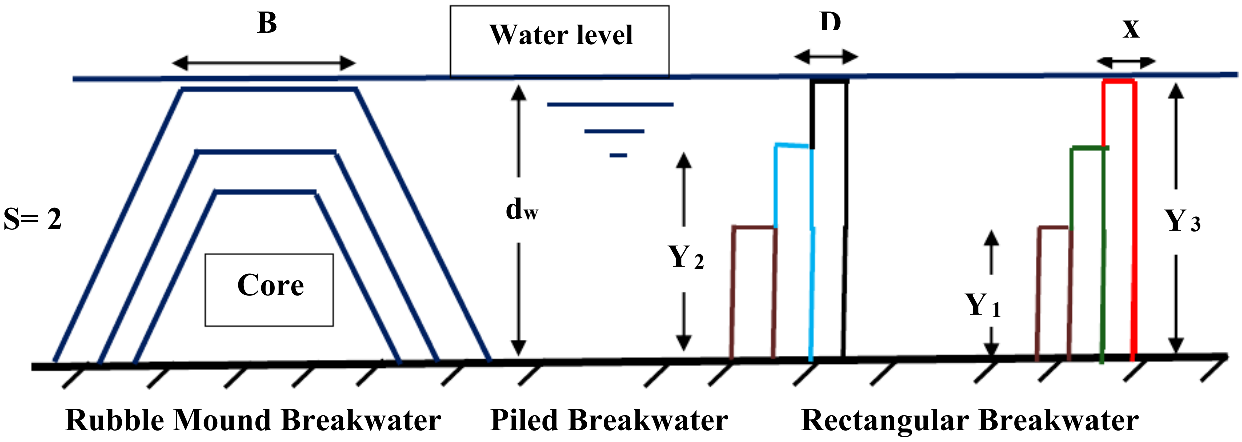

Figure (11): Comparison profiles between the three Breakwaters

To be able to compare between three kinds the same depth d_w = 25.0 cm, Y_1 = 15, Y_2 = 20 and Y_3 = 25 cm, D = diameter of pile = 7.0 cm, spacing between piles in the same row = D/2 = 3.5 cm, B = top width of rubble mound breakwater = 20 cm, (S) = 2.0 and finallythickness of each rectangular vertical breakwater (X) = 5.0 cm, to verify an exact comparison.

Figure (12) shows a relation between wave steepness (H_i/L) and coefficient of transmission (C_t) between the three kinds of breakwaters.

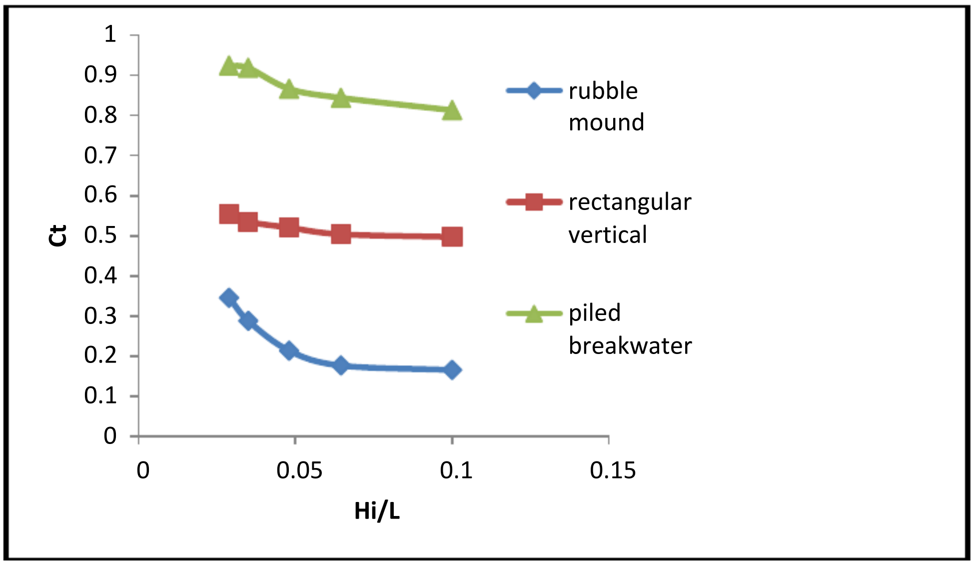

Figure (12): Comparison between H_i/L versus C_t for the three different kinds of breakwaters

To compare between these three kinds acting as energy reduction as shown in figure (13).

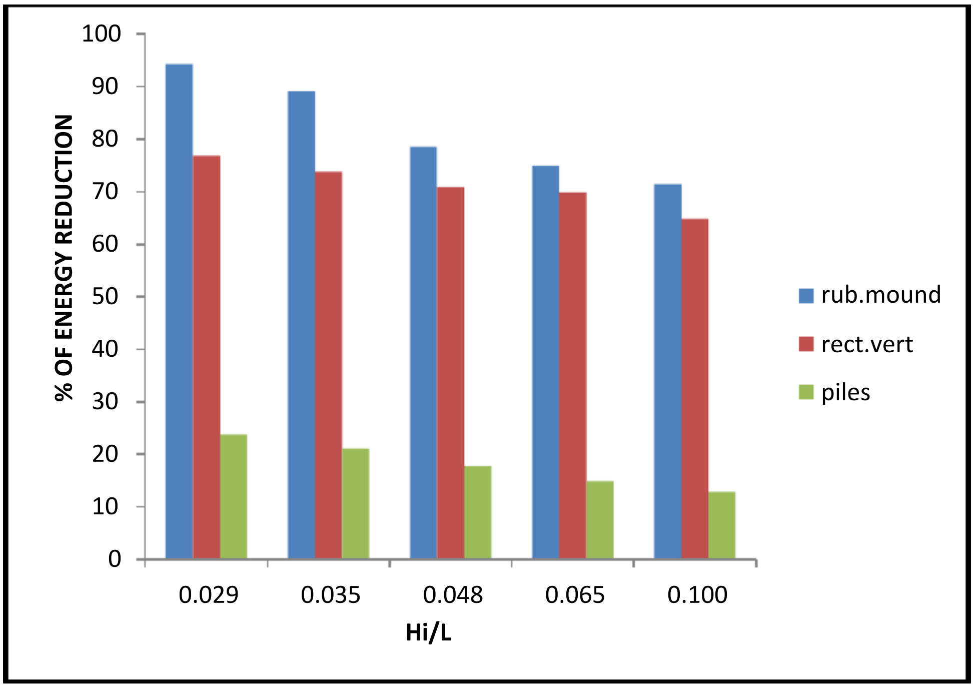

Figure (13): H_i/L versus % of energy reduction for the three kinds

6. CONCLUSION

- From the physical model results, we found that, the effect of using rectangular vertical submerged breakwater with different heights reduce energy by (24.57, 30.28, 37.9, 40.52, 46.83, 49.45 and 54.24 %), in average wave generator conditions and average water depth in experiments.
- Minimum energy reduction in case of single rectangular vertical submerged breakwater about (11.26 %), but in case of maximum energy reduction by using the three rectangular vertical submerged breakwatersit's about (71.25 %).
- Using rectangular vertical submerged breakwater, coefficient of transmission decreases with the increasing of wave steepness while decreasingof wave period. Using three rows with different heights is better than using two rows than single row.
- Comparing the system of three rectangular vertical submerged breakwater with rubble mound and three rows of piles with spacing (D/2), the percentage of energy reduction were about (71.25, 92.6 and 23.34 %) respectively in case of minimum water depth.
- The increasing of ratio (d_s/d_w) leads to decreasing of percentage of energy reduction, and increase of thickness of rectangular breakwater leads to maximum energy reduction from x = 5.0 cm to 15.0 cm as working in group.

7. RECOMMENDATION

- More wave steepness with different depths of water must be tested.
- For more economical of the rectangular vertical submerged breakwater, I suggest to make it pours by making some holes with relative percentage of permeability and compute energy reduction in this case.-Study the movement of soil in front of the system of breakwater and its effect on it.

REFERENCES

[1] Abdul Khader, M.H. and Rai, S.P. (1981) “A Study of submerged breakwaters” J.of Hydraulic Research Vol. 18, No. 2.

[2] Abul-Azm A.G. (1993) “Wave diffraction through submerged breakwaters” Waterway, Port, Coastal and Ocean Eng., Vol. 119, No. 6.

[3] Dick, T.M. and Brebner, A. (1968) “Solid and permeable submerged breakwaters”Proc. 11th. Conf. On Coastal Engineering, ASCE, New York, N.Y., II, 1141-1158.

[4] El- Saie Yasser Moh, (2013), Performance analysis of a multiple-pile row breakwater in experimental study, Vol. (35) N0 (5), Civil Engineering Research Magazine, Al Azhar University, Faculty of Engineering.

[5] Heikal, E. M. and Attar, A. A. (1997) “Effect of beach slope on the efficiency of submerged breakwaters” 2nd Int. Conf., Mansoura Univ., Mansoura, Egypt.

[6] Isaacson, M., Papps, D., Mansard, E. (1996) “Oblique reflection characteristics of rubble-mound structures” J. Waterways, Port, Coastal, Ocean Eng., ASCE, Vol. 122, No. 1.

[7] Jeng, D. S., Schacht, C., and Lemkert, C. (2005) “Experimental study on oceanwaves propagating over a submerged breakwater in front of a vertical seawall”J. Ocean Engineering Vol. 32, Iss. 17-18.

[8] Kobayashi, N., and Wurjanto, A. (1989) “Wave transmission over submerged breakwaters.” J. Waterway, Port, Coastal and Ocean Eng., Vol. 115, No. 5.

[9] Koraim, A. S. (2002) “Effect of beach characteristics on submerged breakwaters efficiency” A Thesis Submitted for Partial Fulfillment of Master Degree in Civil Eng., Zagazig University, Zagazig, Egypt.

[10] Mei, C. C. and Black, J. L. (1969) “Scattering of surface waves by rectangular obstacles in water of finite depth” J. of Hydraulic Research, IAHR, Vol. 38.

[11] Mootaz, Khaled (1992), “Wave energy dissipation by using submerged rubble mound breakwater” A Thesis Submitted for Partial Fulfillment of Master Degree in Civil Eng., Ain Shams University, Cairo, Egypt.

[12] Musfique Ahmed and Rifat Anwar, (2011) “Experimental study on the performance of submerged breakwater as shore protection structure”, International Conference on Environment and Bioscience IPCBEE vol.21.

[13] Seelig, W. N. (1980). “Two-dimensional tests of wave transmission and reflection characteristics of laboratory breakwaters”, Tech. Report No. 80-1, U. S. Army Coastal Engineering Research Center, Fort Belvoir, Va.

[14] Shirlal, K. G., Rao, S., and Manu (2007) “Ocean wave transmission by submerged reef - a physical model study” J. Ocean Engineering Vol. 34, Iss. 14-15.

[15] Stamos, D. G., Hajj, M. R., and Demetri, P. (2003) “Performance of hemi cylindrical and rectangular submerged breakwaters” J. Ocean Engineering Vol. 30, Iss. 6.

[16] Priyamvada Singh, J.N. Tripathi and Sushil Kumar, “Quality Factor of Seismic Coda Waves in Garhwal Himalayas”, International Journal of Civil Engineering & Technology (IJCIET), Volume 3, Issue 2, 2012, pp. 279 - 291, ISSN Print: 0976 – 6308, ISSN Online: 0976 – 6316.