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Reducing Wave Energy by Using of Perforated Piles Breakwaters

Sonia y. El.serafy[1], Yasser E. Mostafa[2] , Yasser M. EL Saie[3] and
Christena F. Gad[4]
[1]*Professor of Coastal and Harbor Engineering, Ain Shams University*
[2]*Professor of Harbor Engineering and Marine Structures, Ain Shams University*
[3]*Associate Prof., Irrigation and Hydraulics Dept., Ain Shams University*
[4]*Teaching Assistant, Dept. of Civil Engineering, El Shorouk Academy*

Abstract: *In terms of the importance of coastal zones, some previous research tried to reduce wave energy attacking the shoreline. This paper presents a special coastal protection measure which is perforated piles, evenly distributed and staggered, breakwaters and experimentally investigates piles breakwaters capability of energy dissipation. Physical models of perforated piles breakwater were designed and constructed. Experimental flume was arranged to test these models and measuring devices were arranged. Contributing parameters such as wave height, period, steepness, piles arrangements and pile diameter were varied. Based on the discussions and within the experimented range of parameters, it was clear that perforated piles possess an enormous capability of dissipating the wave energy by a percentage ranged between 15 to 55% which is considered to be significant amount from the coastal engineering point of view.*

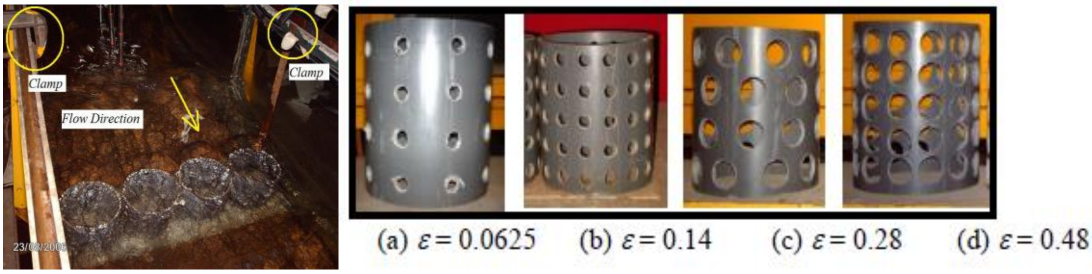
I. Introduction

The coastal zone (seashore) is a delicate and dynamic area in which the majority of a water body's kinetic energy is dissipated through wave pile breaking. The most significant result of these processes is the erosion and subsequent transport of the shore and beach materials. This paper introduces the problem that motivated the researchers to initiate this study, the study objectives together with the planned methodology to achieve the study goals, the experimental work and the results together with their discussions.

II. Literature Review

Norzana et al, (2012) investigated the transmission response of a two-row perforated double ring pile (DP) using experimental tests. The tests were conducted in unidirectional waves with different wave conditions and pile porosity that varied from 0.0625 to 0.48. From the experimental results, it was found that when the pile porosity increases, less wave energy was attenuated, resulting in higher wave transmission coefficient, K_t. Furthermore, K_t was found to be decreasing when the wave steepness increases for all porosity values. An empirical equation to predict transmission coefficient was also derived based on statistical analyses using independent wave parameters namely relative depth (h/L), wave steepness (H_i/L), relative model spacing (S/D) and model porosity (ε). A multiple linear regression analysis was used to model the relationship of these variables. Comparisons of transmitted wave performance by other researchers were also analyzed.

Norzana et al,(2010) conducted experimental work to compare the transmission characteristics of one-row and two-row submerged perforated pile breakwater models. The tests were conducted in unidirectional waves with different wave conditions and pile porosity that varied from 0.0625 to 0.48. The influences of water depth, incident wave steepness and porosities were studied. From the obtained experimental results, it was found that when the number of rows increased, more wave energy was dissipated. This resulted in the decrease in transmitted wave heights. When the pile porosity was increased, less wave energy was attenuated, resulting in higher wave transmission coefficient, K_t and the transmission coefficient, K_t decreases as the wave steepness increases for all porosity values. Four different porosities were tested, ε = 6.5, 14, 28 and 48% with pile diameter (D) being 200 mm as shown in Figure (1).



(a) $\varepsilon = 0.0625$ (b) $\varepsilon = 0.14$ (c) $\varepsilon = 0.28$ (d) $\varepsilon = 0.48$

Figure (1) Test Model in the flume and Porosities (Norzana et al,(2010) Thomson (2000) studied previous literature and set up tests to derive comparative values from previous work, as well as some equations. No theory or numerical work was undertaken to form new equations from ground principles; however, of high value was an overview of previous literature on the topic. A very high level overview of papers by Wiegel (1961), Hayashi (1966, 1968) were quoted with simplistic empirical equations. For example, the transmission coefficient component solely depended on the porosity of the breakwater, and not to incoming wave parameters. The author of this thesis found the derived empirical equations put forward by Thomson highly valuable. The equations were derived from measured data and are therefore useful to compare to data from testing in this study.

Rao et al. (1999) studied the performance of two rows perforated hollow piles with a porosity of 6.5%. They found that the perforated pile attenuated more wave energy than non-perforated piles. He concluded that the influence of porosity remained uncertain. Therefore, he recommended that further investigations be carried out to study the influence of the porosity of submerged pile breakwater on wave transmission coefficient by using porosity value greater than 6.5%.

III. Study Objectives And Planned Methodology

Due to the importance of the protection of the Egyptian coastal areas, this research was initiated with the objective of proposing a suitable measure to be implemented to the Egyptian coast. The consequential objectives were to investigate the hydrodynamic performance of the suggested pile breakwater system when used as a wave energy dissipater and calculate coefficients of transmission and reflection. Also, to study different factors affecting the waves such as wave height, wave period, angle and spacing between piles.

IV. Experimental Work

Many researchers conducted numerical studies on piles as wave dissipater devices, but there was obvious discrepancies in investigating piles, experimentally. This argument motivated the researchers to complement the ongoing research by executing experimental work. The experimental work was carried out in the Research Laboratory in Shorourk Academy Higher Institute of Engineering, Egypt.

4.a. Experimental Flume And Modelled Breakwater

The wave flume is 12.0 m long, 50 cm wide and 60 cm deep. The side walls are glass panels. The flume is provided with a wave generator. The layout and the details of the flume and model are presented on figures (2) to (3). The investigated parameters were wave period, wave length , wave height and porosity.

Figure (2) General View of the experimental Wave Flume

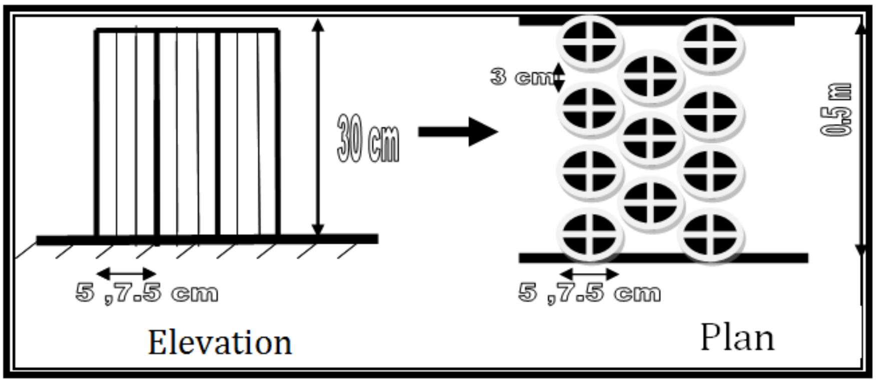


Figure (3.a) Plan and elevation of the model

Figure (3b) Piles breakwater models

Figure (3c) Piles breakwater models

4.b. Wave Absorbers

In order to perform accurate and efficient wave tests in the flume, it is necessary to prevent reflection of waves. Therefore; absorbers were installed at the ends of the flume to prevent the reflected waves from inducing standing waves throughout the flume length.

4.c. Experimental Program

A summary of variables used in the experimental program is shown in Table (1). The experiments comprised of 380 runs on perforated piles. The following parameters were varied according to the following ranges:

Table (1) Summary variables used in the experimental program

Perforated piles (380)	**Wave height (cm)**	**Diameter (cm)**	**Depth of water (cm)**	**Angle**	**Spacing between piles(cm)**	**Porosity (ε)**
	(2-5-6-7)	**(5-7.5)**	**(17- 23-27-34)**	**(45°-60°-90°)**	**(3 -7.5)**	**14% , 20%**
	(2-5-6-7)	**(5-7.5)**	**(17- 23-27-34)**	**(45°-60°-90°)**	**(3 -7.5)**	
	(2-5-6-7)	**(5-7.5)**	**(17- 23-27-34)**	**(45°-60°-90°)**	**(3 -7.5)**	
	(2-5-6-7)	**(5-7.5)**	**(17- 23-27-34)**	**(45°-60°-90°)**	**(3 -7.5)**	

4.d. Experimental Procedure

A parametric study of laboratory at two cases (solid pile and perforated pile), but this paper indicated (perforated pile). The investigated breakwater models were installed near the middle of the flume and the testing steps proceeded, as follows:

1. The water was filled to the required depth.
2. The wave generator was operated with the required wave height.
3. The wave period was measured.
4. The maximum wave height (H_{max}) was measured and the minimum wave height (H_{min}) was also measured to determine the incident and reflected wave heights.
5. The transmitted wave height (H_t) was measured. The water level was changed to the next level and the same steps were followed. Also, the dimensions of the pile breakwater were changed and the same procedure was replicated.
6. The contributing parameters (i.e. wave height, period, steepness, piles arrangements, diameters…..etc.) were varied and measurements were taken, for each case.

4.e .Numerical Modeling

In this paper, the software program Microsoft office Excel was used to calculate the equations wave characteristics (wave transmitted, wave reflection and wave incident) by using to obtained laboratory results.

V. Results Analysis And Discussions

The measurements were analyzed. The incident and reflected waves were calculated, for every tested case, as follows:

$$H_i = (H_{max} + H_{min}) / 2 \qquad (1)$$

$$H_r = (H_{max} - H_{min}) / 2 \qquad (2)$$

where:

H_i : incident wave height

H_r : reflected wave height

The dissipated energy was calculated based on the following relation
, Neelamani and Vedagiri (2002):

$$E_i = E_r + E_t + E_d \qquad (3)$$

where,

E_i = Incident wave energy
E_r = Reflected wave energy
E_t = Transmitted wave energy
E_d = Dissipated wave energy, and

$$(\rho g H^2)_i/8 = (\rho g H^2)_r/8 + (\rho g H^2)_t/8 + (\rho g H^2)_d/8 \qquad (4)$$

$$\Delta E = E_i - E_t \qquad (5)$$

$$E_d = \Delta E / E_i \qquad (6)$$

Furthermore, the variables were paired into dimensionless parameters and the different relations were presented on graphs; a sample of which is provided on figures (4) to (14).

Additionally, a comparison study was executed to compare the present results with the previous results. Figures (15) and (16) are provided for comparison purposes.

Based on the taken measurements results shown in figures (6) to (14), it was clear that:

- For all the tested cases, the coefficient of transmission "C_t" decreased as the dimensionless incident wave height "H_i/L" increased.
- For all the tested cases, the coefficient of reflection "C_r" increased as the dimensionless incident wave height "H_i/L" increased.
- For all the tested cases, the coefficient of dissipated energy "C_d" increased as the dimensionless incident wave height "H_i/L" increased.
- For all the tested cases, the coefficient of transmission "C_t" decreased as diameter "D" increased.
- For all the tested cases, the coefficient of transmission "C_t" decreased as wave angle "α" increased.

Figures (15) and (16), that the present study show the same trend and compares very well with the results from studies conducted by others

Based on the calculations, the following was found:

- In case of the 90^o wave incident angle, perforated piles D=5 cm , ε = 14% , wave energy was dissipated by 15 to 60 %.
- In case of the 60^o wave incident angle, perforated piles D=5 cm , ε = 14% , wave energy was dissipated by 20 to 60 %.
- In case of the 45^o perforated piles D=5 cm , ε = 14% , wave energy was dissipated by 15 to 55 %.
- In case of the 90^o perforated piles D=7.5 cm, ε = 14% , wave energy was dissipated by 20 to 75 %.
- In case of the 60^o perforated piles D=7.5 cm , ε = 14% ,wave energy was dissipated by 20 to 60 %.
- In case of the 45^o perforated piles D=7.5 cm , ε = 14% ,wave energy was dissipated by 20 to 69 %.

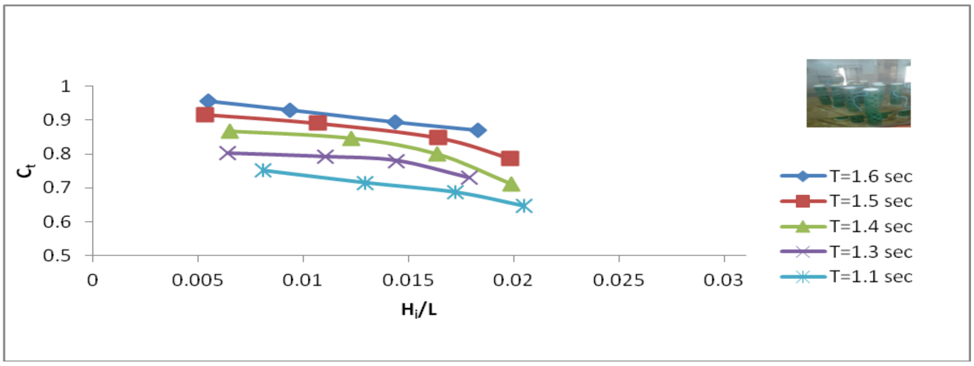


Figure (4). Relation between C_t and H_i/L
For perforated piles (D=5 cm , ε = 14% , angle=90˚)

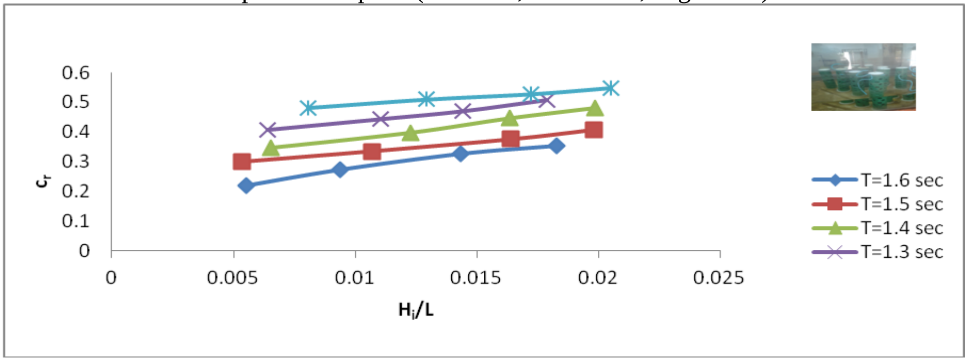


Figure (5). Relation between C_r and H_i/L
For perforated piles (D=5 cm, ε = 14% , angle=90˚)

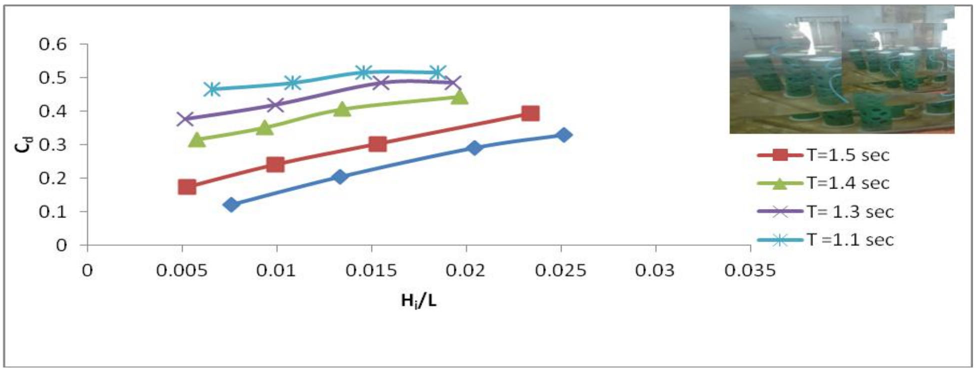


Figure (6). Relation between C_d and H_i/L
For perforated piles (D=5 cm, , ε = 14% , angle=90^o)

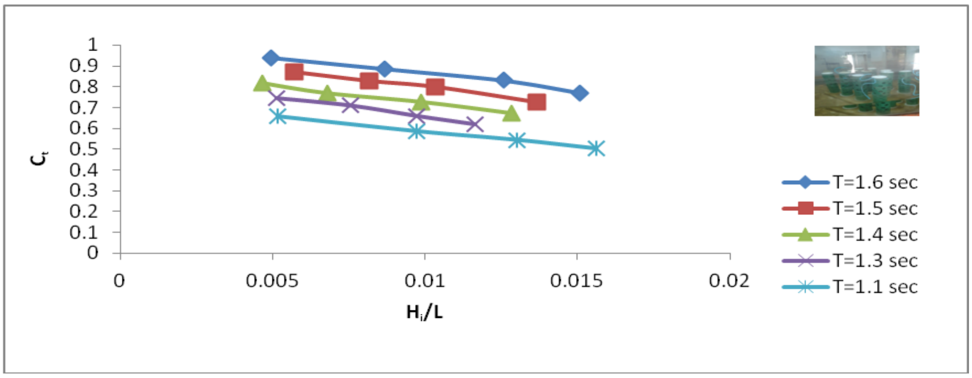


Figure (7). Relation between C_t and H_i/L
For perforated staggered piles (D=5 cm , ε = 14% , angle=90^o)

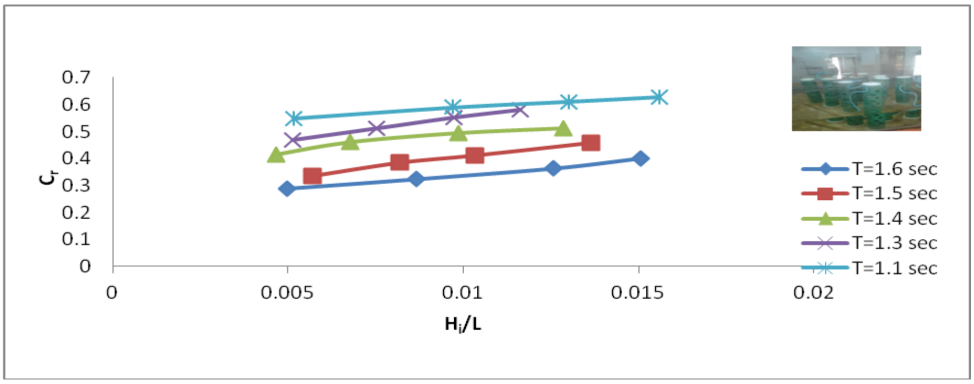


Figure (8). Relation between C_r and H_i/L
For perforated staggered piles (D=5 cm , ε = 14% , angle=90^o)

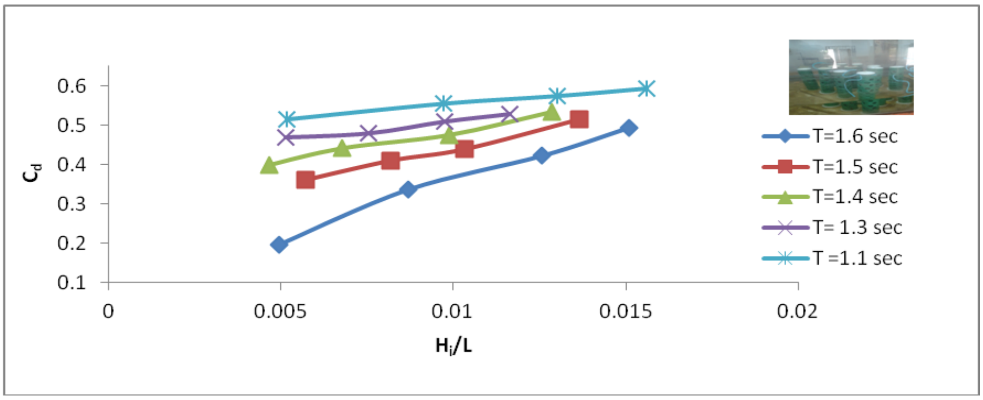


Figure (9). Relation between C_d and H_i/L
For perforated staggered piles (D=5 cm , ε = 14% , angle=90^o)

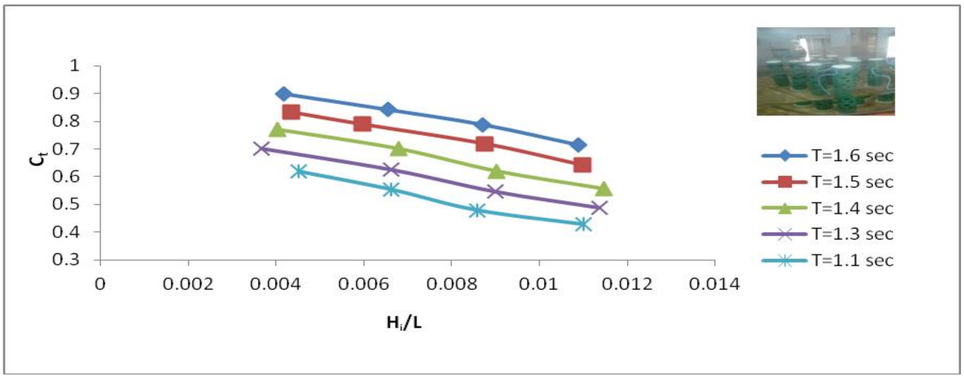


Figure (10). Relation between C_t and H_i/L
For perforated piles(D=5 cm , ε = 20% , angle=90°)

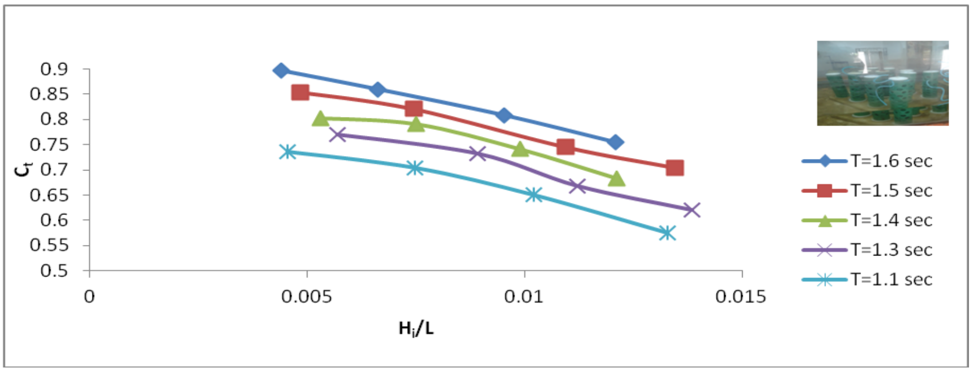


Figure (11). Relation between C_t and H_i/L
For perforated piles (D=5 cm , ε = 20% , angle=60°)

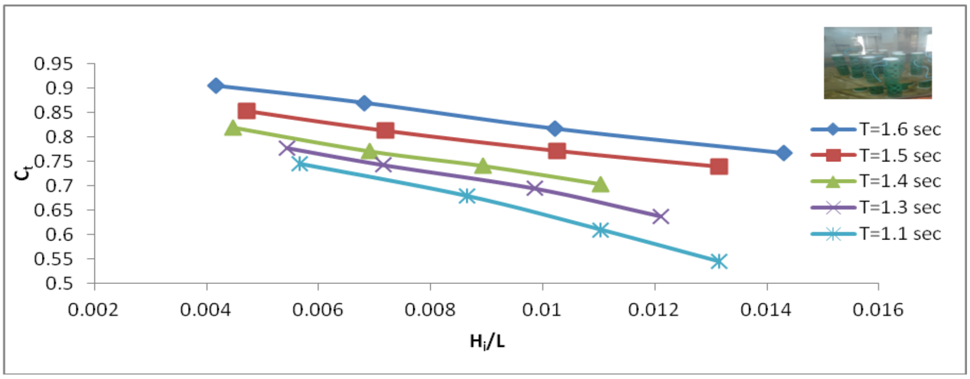


Figure (12). Relation between C_t and H_i/L
For perforated piles (D=5 cm , ε = 20% **,** angle=45°)

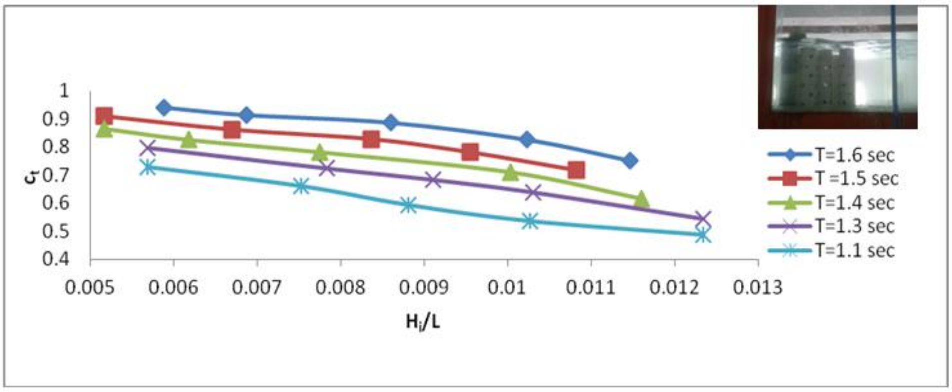


Figure (13). Relation between C_t and H_i/L
For perforated piles (D=7.5 cm , ε = 14% , angle=90°)

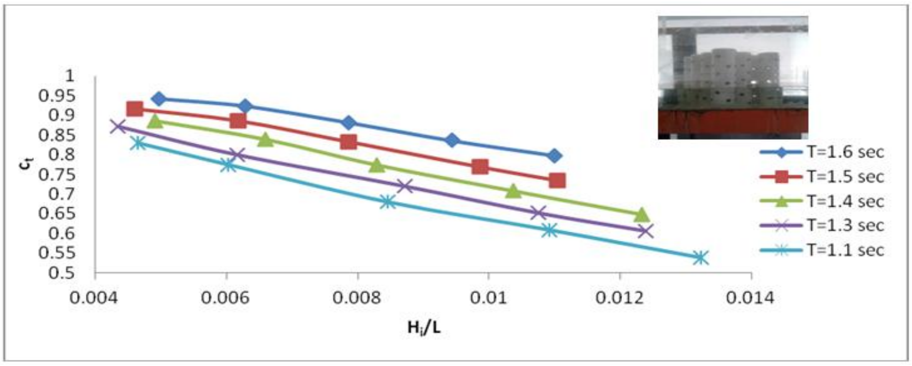


Figure (14). Relation between C_t and H_i/L
For perforated piles (D=7.5 cm , ε = 14% **,** angle=60^o)

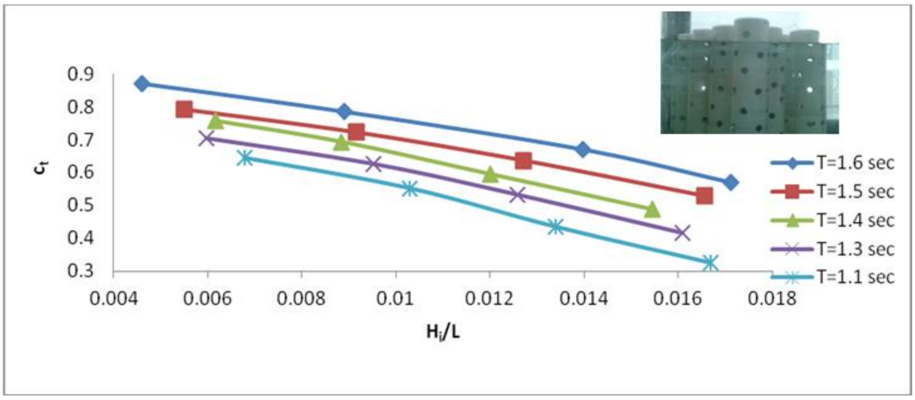


Figure (15). Relation between C_t and H_i/L
For perforated piles (D=7.5 cm , ε = 14% **,** angle=45^o)

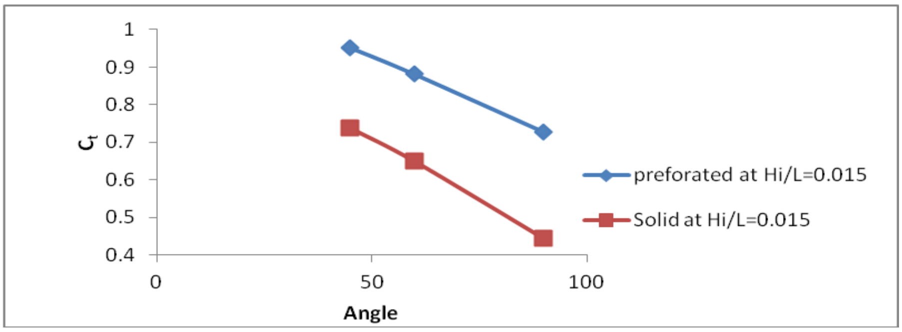


Figure (16). Relation between C_t and different angle at constant H_i/L =0.015
For perforated piles (D=5 cm , ε = 14% **,** T =1.6 sec)

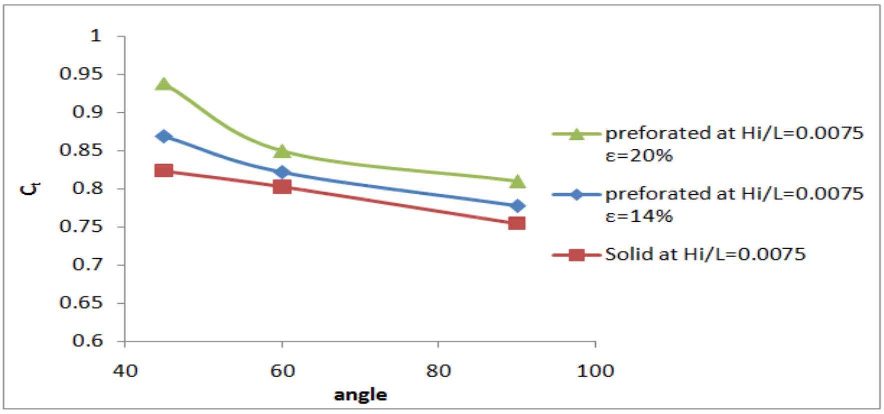


Figure (17). Relation between C_t and different angle at constant H_i/L =0.0075
For perforated piles (D=5 cm , ε =   0, 14 , 20 % , T =1.6 sec)

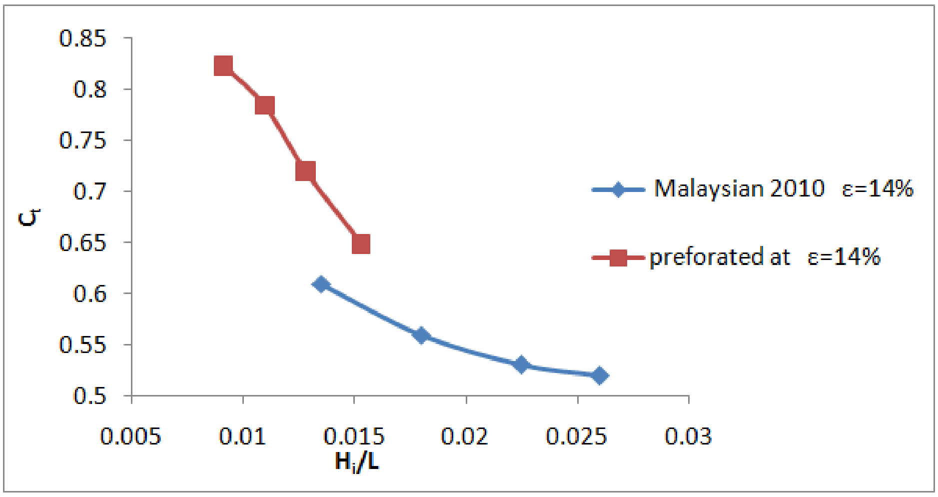


Figure (18). Relation between C_t and H_i/L at constant h =0.23m, ε =14%
For perforated piles (D=5 cm)

VI. Analytical Functions

Microsoft offices Excel has been used to speed up analytical and equation derivation process. The statistical analysis was performed to develop the simplest and most viable equation to aid in the evaluation. Multiple linear regression analysis was used to model the relationship of the independent non-dimensional variable with the dependent variables C_t , C_r. eq .(7),(8)

Perforated pile:

$$c_t = -0.0147 Ln\left(\frac{Ht}{L}\right) - 0.0269 Ln\left(\frac{Hi}{L}\right) + 178.275\left(\frac{A}{L^2}\right) + 0.1365\left(\frac{gT^2}{L}\right) - 6.40\left(\frac{D}{L}\right) + 1.61\left(\frac{d}{L}\right) - 5.32\left(\frac{S}{L}\right) \quad \text{eq(7)}$$

$$c_r = -0.02756 Ln\left(\frac{Hr}{L}\right) + 0.1154 Ln\left(\frac{Hi}{L}\right) - 209.224\left(\frac{A}{L^2}\right) + 0.2076\left(\frac{gT^2}{L}\right) + 8.17\left(\frac{D}{L}\right) + 0.6795\left(\frac{d}{L}\right) + 7.87\left(\frac{S}{L}\right) \quad \text{eq (8)}$$

Where
d/L, H_i/L, A/L^2, gT^2/L, D/L, H_t/L, H_r/L , and S/L are the independent non-dimensional variables.

VII. Conclusions And Recommendations

The experimental work for piles breakwaters was presented. The following conclusions can be drawn:

- The smallest pile diameter provided the best performance as piles breakwater
- For the diameter (5 cm), wave transmission is inversely proportional to wave steepness; and the energy transmitted ranged between about 20 to 50 % of the total energy.
- For the diameter (5 cm), wave reflection is directly proportional to wave steepness and the energy reflected ranged between about 15 to 45 % of the total energy.
- For the diameter (5 cm), dissipated energy is directly proportional to wave steepness and the energy dissipation ranged between about 15 to 55 % of the total energy.

Within the studied range of parameters, it was clear that solid piles and the staggered possess an enormous capability of dissipating wave energy by a percentage that ranged between 20 to 65% Based on the above conclusions, it is recommended to implement a pilot project to investigate the efficiency of the proposed piles breakwaters configurations using a prototype scale.

References

[1]. Rao, N. B. S., Sathyanarayana, V. S. (1999). Laboratory Investigation on Wave Transmission through Two Rows of Perforated Hollow Piles. *Ocean Eng. vol* **26**, pp. 675-699.
[2]. Thomson, G. G. (2000) Wave Transmission through Multi-layered Wave Screens. Master Dissertation, Dept. of Civil Eng., Queen's University, Kingston, Ontario, Canada.
[3]. Neelamani, S., and Rajendran, R. (2002) "Wave interaction with T-type
[4]. breakwaters" Ocean Engineering, Vol. 29, Iss.(2).
[5]. Norzana ,A and Faridah ,S.(2010) the use of perforated pile breakwaters to attenuate waves, Malaysian Journal of Civil Engineering, Vol 22 Iss (1), pp.152-170.
[6]. Norzana ,A and Faridah ,S.(2012) wave characteristics around perforated piles in a two rows arrangement, Malaysian Journal of Civil Engineering, Vol 24 Iss (1), pp.48-66.

List Of Symbols

C_t:Transmission coefficient
C_i:incident coefficient
C_d: coefficient of dissipated energy
S:Spacing between piles (cm)
D:Pile diameter (cm)
d:Water depth (m)
L: wave length (m)
H_i:Incident wave height (m)
H_t:Transmitted wave height (m)
H_r:reflected wave height (m)
T:Wave period (sec)
g:gravity (m/s^2)
ε: Porosity (%)