



Ain Shams University - Faculty of Engineering

**EFFECT OF USING MULTIPLE ROW-PILE BREAKWATERS AS
WAVE ENERGY DISSIPATER IN COASTAL AREAS**

A Thesis Submitted in the Partial Fulfillment of the
Doctor of Philosophy

Civil Engineering - Irrigation & Hydraulics

BY

CHRISTINA FRANCIS GAD ABD ELMALAK

B.Sc. (2008) Civil Engineering, El Shourok Academy

M.Sc. (2012) Civil Engineering, Ain Shams University.

Supervised by

Prof.Dr.Sonia El-Serafy
Prof. of Coastal Engineering
Ain Shams University

Prof.Dr.Yasser Elsayed Mostafa

Professor of Harbor Engineering & Marine
Structures
Ain Shams University

Dr.Yasser Mohamed. EL Saie

Associate Professor
Irrigation & Hydraulics Dept.
Ain Shams University

Cairo

2017

**EFFECT OF USING MULTIPLE ROW-PILE BREAKWATERS AS
WAVE ENERGY DISSIPATER IN COASTAL AREAS**

By

Eng. CHRISTINA FRANCIS GAD ABD ELMALAK

A Thesis Submitted in the Partial Fulfillment of the

Doctor of Philosophy

Civil Engineering - Irrigation and Hydraulics

Examiners Committee

Name	Signature
Prof. Dr. ABD EL MOHSEN EL MONGY	Professor of Coastal and Harbor Engineering, Ain Shams University
Prof. Dr. Abdelazim Mohamed Ail	Professor of national water research center, hydraulics research institute
Prof.Dr.Sonia El-Serafy	Professor of Coastal Engineering, Ain Shams University
Prof. Dr.Yasser Elsayed Mostafa	Professor of Harbor Engineering & Marine Structures Ain Shams University

TITLE SHEET

Name : Christena Fransis Gad Abd Elmalak

Degree : Doctor of Philosophy

Department : Irrigation & Hydraulics

Faculty : Engineering

University : Ain Shams

Graduation Year : 2008

Degree Granting Year : 2017

THE AUTHOR

Name: Christena Fransis Gad Abd Elmalak

Date of birth: November-03-1985

Place of birth: Cairo, Egypt.

Scientific Degrees B.Sc. Civil Engineering June-2008

M.Sc. Civil Engineering - Irrigation and
Hydraulics, Ain shams 2012

Present position: Assistant Lecturer, Civil
Engineering, El Shourok Academy

STATEMENT

This thesis is submitted to the Irrigation and Hydraulics
Department, Faculty of Engineering, Ain Shams University
in the partial fulfilment of the requirements for the Degree
of Doctor of Philosophy in Civil Engineering.

The work in this thesis was carried out in the Civil
Engineering, El Shourok Academy from 2014 to 2016

No part of this thesis has been submitted for a degree or a
qualification at any other university or institution

Date:

Signature:

Name: Christena Fransis gad

ACKNOWLEDGMENT

First and foremost, praise and thanks For God.

Deepest gratitude and appreciation are to be conveyed to **Prof. Dr. Sonia El-Serafy**, Professor of Coastal Engineering, Ain Shams University, for the kind supervision, support, guidance, help, encouragement and useful suggestions all through this work.

Indebted to **Dr. YASSER EL SAYED MOSTAFA**, Professor of Harbor Engineering & Marine Structures, Ain Shams University, for constant supervision, planning, generous support, helpful advice and constructive thoughts throughout this work.

Thanks are extended to **Dr. YASSER SADEK EL-SAIE**, Associate Professor in Irrigation and Hydraulics Department, Ain Shams University, for his constant supervision, planning, generous support and help during the course of this work.

Finally, appreciations are due to my parents and family for their support.

ABSTRACT

In terms of the importance of safeguarding the coastal zone in Egypt, this thesis was initiated with the motivation of proposing an innovative coastal protection measure and investigating its capability of energy dissipation, experimentally. Primarily, literature was reviewed, analysed, categorized and comprehended. models to solid piles breakwater were designed and constructed. Experimental flume was set up to test these models, where measuring devices were arranged. Contributing parameters (i.e. wave height, period, steepness, piles arrangements, diameters.....etc.) were varied. Measurements were undertaken ;analysed; presented on graphs and discussed. Based on the discussions and within the experimented range of parameters, it was clear that solid piles so as the staggered possess an enormous capability of dissipating the wave energy by a percentage that ranged between 20 to 75%, which is considered to be a reasonable amount from the coastal engineering point of view. In terms of the importance of coastal zones, some previous research tried to reduce wave energy attacking the shoreline. This thesis 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. It can also be applied to the equation (C_t) on the solid piles. Moreover, the pile breakwater was investigated to assess it, in terms of the

environmental impact (i.e. shoreline changes) and economic (i.e. cost estimate), but found piles breakwater better than rubble mound breakwater.

Key words:

Pile breakwater ---Wave transmission -- Wave reflection—Energy dissipation

ACKNOWLEDGMENT	i
ABSTRACT	ii
LIST OF FIGURES	v
NOTATION... ..	vi
ACKNOWLEDGMENT	6
ABSTRACT	7
List of tables	8
NOTATION.....	9
CHAPTER (1) INTRODUCTION.....	13
1.1. PROBLEM DEFINITION	14
1.2. STUDY OBJECTIVES.....	14
1.3. RESEARCH METHODOLOGY	15
1.4. THESIS LAYOUT	15
CHAPTER (2): REVIEW OF LITERATURE	18
2.1. COASTAL DISCIPLINES AND PROJECTS PLANNING	18
2.2 WAVES AND WINDS	19
2.3. WAVE TRANSFORMATION MECHANISMS.....	19
2.3.1. WAVE REFLECTION	19
2.3.2. WAVE TRANSMISSION	20
2.3.3. WAVE BREAKING.....	21
2.4. WAVE ENERGY DISSIPATION	11
2.5. WAVE STRUCTURE INTERACTION	12
2.6. INVESTIGATIONS OF PILE BREAKWATERS	15
2.6.a. INVESTIGATIONS IN THE FIELD OF PILES	15
2.6.b. INVESTIGATIONS ON PERFORATED PILE BREAKWATERS.....	21
2.7. INVESTIGATIONS ON PILE BREAKWATERS	22
2.8.APPLICATIONS AND CASE STUDIES	24
CHAPTER (3) EXPERIMENTAL WORK.....	36
3.1. HYDRAULIC MODELING	36
3.2. CHOOSING THE SCALE OF THE MODEL.....	38
3.3. MODELING OF THE INVESTIGATED PARAMETERS	42
3.3.1. MODELING OF THE FLUID FLOW PROPERTIES.....	42
3.3.2. MODELING OF THE PILE BREAKWATER GEOMETRY.....	44
3.4. EXPERIMENTAL WORK.....	44
3.4.1. USED EXPERIMENTAL DEVICES.....	44
3.4.2. EXPERIMENTED WAVE VARIABLES	46
3.4.3. WAVE ABSORBERS	48
3.5. EXPERIMENTAL PROGRAM.....	10
3.6. MODEL CALIBRATION	12
3.7. EXPERIMENTAL PROCEDURE.....	12
CHAPTER 4 DIMENSIONAL ANALYSIS	14
4.1. CONSIDERED VARIABLES	14
4.2. DIMENSIONAL ANALYSIS.....	15
CHAPTER 5 RESULTS ANALYSIS AND DISCUSSION	18
5.1 PHYSICAL QUANTITIES	18
5.1.1 WAVE PARAMETERS	18
5.1.2 COMPUTED QUANTITIES	19
5.2 RESULTS OF DIMENSIONLESS COEFFICIENTS (C_t , C_r , and C_d)	19
5.2.1 COEFFICIENT OF TRANSMISSION (C_t).....	19
5.2.2 FOR CONFIGURATION (1).....	20
5.2.2.1 RELATION BETWEEN (C_t) AND (H_i/L)	20

5.2.3 COEFFICIENT OF REFLECTION (C_r)	28
5.2.3.3 RELATION BETWEEN (C_r) AND (S/D)	34
5.2.3.4 RELATION BETWEEN (C_r) AND ($T\sqrt{g/d}$)	35
5.2.3.5 RELATION BETWEEN (C_r) AND (D/L)	35
5.2.4 COEFFICIENT OF DISSIPATION (C_d)	36
5.2.4.1 RELATION BETWEEN (C_d) AND (H_i/L)	36
5.3 COMPARISON WITH OTHER RESEARCH	40
5.4 COMPARISON OF SOLID PILE RESULTS	40
5.5. COMPARISON Of PERFORATED PILE RESULTS	40
5.5.1 RESULTS OF DIMENSIONLESS COEFFICIENTS (C_t , C_r AND C_d)	41
5.5.1 .1 COEFFICIENT OF TRANSMISSION (C_t), $\varepsilon = 14\%$, $D = 5$ Cm	41
5.5.2.2 COEFFICIENT OF TRANSMISSION (C_t), $\varepsilon = 20\%$	42
5.5.2 .3 COEFFICIENT OF TRANSMISSION (C_t), $\varepsilon = 14\%$, $D = 7.5$ Cm	42
5.5.2.4 COEFFICIENT OF REFLECTION (C_r), $\varepsilon = 14\%$, $D = 7.5$ Cm	43
5.5.2 .5 COEFFICIENT OF DISSIPATION (C_d), $\varepsilon = 14\%$, $D = 7.5$ Cm	45
5.6. EFFECT OF ENERGY DISSIPATION (RELATION BETWEEN (E_i) & (D))	46
5.7. ESTABLISHED EQUATIONS	47
5.7.1. REGRESSION STEP-BY-STEP USING MICROSOFT EXCEL	47
5.7.2. ESTABLISHED EQUATIONS	50
6.1 ASSESSING THE ENVIRONMENTAL IMPACT OF BREAKWATER	53
6.1.a. DESCRIPTION OF GENESIS	55
6.1.b. GENESIS APPLICATION	57
6.1.c. ENVIRONMENTAL IMPACT OF THE PILE BREAKWATER ON THE SHORELINE	58
6.a.2 COST ESTIMATE of PILE BREAKWATER	62
.....	62
6.2.b COST ESTIMATE OF STEEL PILES	63
6.2.c. COST ESTIMATE OF CONCRETE PILES	63
6.3 COST ESTIMATE OF RUBBLE MOUND BREAKWATER	63
6.3.a COST ESTIMATE TO RUBBLE MOUND BREAKWATER AT $H_p = 3.75$ m	64
6.4 COST ESTIMATE COMPARISON	65
CHAPTER (7): CONCLUSIONS AND RECOMMENDATIONS	70
7.1 CONCLUSIONS	70
7.2 RECOMMENDATIONS	72
REFERENCES	73
ملخص الرسالة	124

List of figures	page
Figure (2-1) Spilling breaking wave	22
Figure (2-2) plunging breaking wave	23
Figure (2-3) Surging breaking wave	23
Figure (2-4) Collapsing breaking wave	22
Figure (2-5): Definition sketch of piled breakwater (from Suh, 2011)	26
Figure (2-6) Pile Arrays	29
Figure (2-7) Definition sketch of the multiple-row pile breakwater model	33
Figure (2-8) Test Model in the flume and Porosities (Norzana et al, (2010)	35
Figure (2.9) Elevation of the piles at low tide, showing relative close spacing (Reedijk&Allsop, 2003)	38
Figure (2.10) Image during construction of Blairgowrie wave screen, showing piles and impermeable panel to the right of the image (Atkins &Mocke, 2009)	38
Figures (2.11) shows the 50% porosity model wave screens and Wave staffs attached to CCM wave screen(after Thomas 2010)	39
Figure (3.1) Plan and Elevation of the Experimental Flume	44
Figure (3-2) General View of the experimental Wave Flume	45
Figure (3-3) Plan and elevation of the model	45
Figure (3.4) General View of the Wave period device	45
Figure (3.5) General View of the Wave height device	46
Figure (3.6) Wave Absorbers	46
Figure (3.7) Measured wave parameters	48
Figure (4-1) The considered geometrical and wave parameters	51
Figure(5-1) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 90° , $D= 6$ cm for configuration (1) and configuration (2) staggered solid piles	57

Figure (5-2) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 90° , $D= 5$ cm for solid piles and solid staggered pile	57
Figure (5-3) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 30° , $D= 5$ cm for solid piles and solid staggered piles	59
Figure (5-4) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 45° , $D= 5$ cm for solid piles and solid staggered piles	60
Figure (5-5) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 90° , $D= 6$ cm for solid piles and solid staggered piles	61
Figure (5-6) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 30° , $D= 6$ cm for solid piles and solid staggered piles	63
Figure (5-7) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 45° , $D= 6$ cm for solid piles and solid staggered piles	64
Figure (5-8) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 90° , $D= 7.5$ cm for solid piles and solid staggered piles	65
Figure (5-9) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 30° , $D= 7.5$ cm for solid piles and solid staggered piles	66
Figure (5-10) The relation between Transmission Coefficient (C_t) and Wave Steepness (H_i/L) for angle 45° , $D= 7.5$ cm for solid piles and solid staggered piles	67
Figure (5-11) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 90° , $D= 5$ cm for solid piles and solid staggered piles	69
Figure (5-12) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 30° , $D= 5$ cm for solid piles and solid staggered piles	70
Figure (5-13) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 45° , $D= 5$ cm for solid piles and solid staggered piles	71
Figure (5-14) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 90° , $D= 6$ cm for solid piles and solid staggered piles	72
Figure (5-15) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 30° , $D= 6$ cm for solid piles and solid staggered piles	73
Figure (5-16) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 45° , $D= 6$ cm for solid piles and solid staggered piles	74
Figure (5-17) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 90° , $D= 7.5$ cm for solid piles and solid staggered piles	75
Figure (5-18) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 30° , $D= 7.5$ cm for solid piles and solid staggered piles	76

Figure (5-19) The relation between reflection Coefficient (C_r) and Wave Steepness (H_i/L) for angle 45° , $D=7.5$ cm for solid piles and solid staggered piles	77
Figure (5-20) The relation between (d/L) and Reflection Coefficient (C_r) for angle 90° , 30° , and 45° For solid pile	78
Figure (5-21) The relation between (d/L) and Reflection Coefficient (C_r) for angle 90° , 30° , and 45° For solid staggered pile	79
Figure (5-22) The relation between (S/D) and Reflection Coefficient (C_r) for different angle for constant values of $h=27.5$ cm For solid pile and solid staggered pile	80
Figure (5-23) The relation between ($T\sqrt{g/d}$) and transmission Coefficient (C_t) for different (D) for constant values of $T=1.10$ sec , angle 90° For solid pile	81
Figure (5-24) The relation between (d/L) and transmission Coefficient (C_t) for different (D) , angle 90° for solid piles and solid staggered piles	82
Figure (5-25) The relation between (d/L) and transmission Coefficient (C_t) for different (D) , $T=1.1$ sec ,angle 30° for solid piles and solid staggered piles	83
Figure (5-26) The relation between (d/L) and transmission Coefficient (C_t) for different (D) , $T=1.1$ sec ,angle 45° for solid piles and solid staggered piles	84
Figure (5-27) The relation between (H_i/L) and (C_d) for different (T) ,angle 90° $D=5$ cm ,for solid piles and solid staggered piles	85
Figure (5-28) The relation between (H_i/L) and (C_d) for different (T) ,angle 30° $D=5$ cm for solid piles and solid staggered piles	86
Figure (5-29) The relation between (H_i/L) and (C_d) for different (T) ,angle 45° $D=5$ cm for solid piles and solid staggered piles	87
Figure (5-30) The relation between (H_i/L) and (C_d) for different (T) ,angle 90° $D=6$ cm for solid piles and solid staggered piles	88
Figure (5-31) The relation between (H_i/L) and (C_d) for different (T) ,angle 30° $D=6$ cm for solid piles and solid staggered piles	89
Figure (5-32) The relation between (H_i/L) and (C_d) for different (T) ,angle 45° $D=6$ cm for solid piles and solid staggered piles	90
Figure (5-33) The relation between (H_i/L) and (C_d) for different (T) ,angle 90° $D=7.5$ cm for solid piles and solid staggered piles	91
Figure (5-34) The relation between (H_i/L) and (C_d) for different (T) ,angle 30° $D=7.5$ cm for solid piles and solid staggered piles	92
Figure (5-35) The relation between (H_i/L) and (C_d) for different (T) ,angle 45° $D=7.5$ cm For solid piles and solid staggered piles	93

Figure (5-36) The relation between (d/L) and transmission Coefficient (C_t)	94
Figure (5-37) The relation between (H_i/L) and transmission Coefficient (C_t)	95
Figure (5-38) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 90° , $D = 5$ cm for perforated piles and perforated staggered piles	96
Figure (5-39) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 30° , $D = 5$ cm for perforated piles and perforated staggered piles	97
Figure (5-40) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 45° , $D = 5$ cm for perforated piles and perforated staggered piles	98
Figure (5-41) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 20\%$,angle 90° , $D = 5$ cm for solid piles and solid staggered piles	99
Figure (5-42) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 20\%$,angle 30° , $D = 5$ cm for perforated piles and perforated staggered piles	100
Figure (5-43) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 90° , $D = 7.5$ cm for perforated piles and perforated staggered piles	101
Figure (5-44) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 30° , $D = 7.5$ cm for perforated piles and perforated staggered piles	102
Figure (5-45) The relation between (H_i/L) and (C_t) for different (T) , $\varepsilon = 14\%$,angle 45° , $D = 7.5$ cm for perforated piles and perforated staggered piles	103
Figure (5-46) The relation between (H_i/L) and (C_r) for different (T) , $\varepsilon = 14\%$,angle 90° , $D = 7.5$ cm for perforated piles and perforated staggered piles	104
Figure (5-47) The relation between (H_i/L) and (C_r) for different (T) , $\varepsilon = 14\%$,angle 30° , $D = 7.5$ cm for perforated piles and perforated staggered piles	105
Figure (5-48) The relation between (H_i/L) and (C_r) for different (T) , $\varepsilon = 14\%$,angle 45° , $D = 7.5$ cm for perforated piles and perforated staggered piles	106
Figure (5-49) The relation between (H_i/L) and (C_d) for different (T) , $\varepsilon = 14\%$,angle 90° , $D = 7.5$ cm for perforated piles and perforated staggered piles	107
Figure (5-50) The relation between (H_i/L) and (C_d) for different (T) , $\varepsilon = 14\%$,angle 30° , $D = 7.5$ cm for perforated piles and perforated staggered pile	108
Figure (5-51) The relation between (H_i/L) and (C_d) for different (T) , $\varepsilon = 14\%$,angle 45° , $D = 7.5$ cm for perforated piles and perforated staggered piles	109
Figure (5-52) The relation between (d) and (E_t) at ($T = 1.6$ s) ,angle 90° , $D = 7.5$ cm for solid piles and perforated piles	109
Figure (5-53) The relation between (d) and (E_t) at ($T = 1.1$ s) ,angle 90° , $D = 5$ cm for solid piles and perforated piles	110

Figure (5.54) The relation between (d) and (E_t) at $(T=1.6 \text{ s})$, $\alpha= 45^\circ$, $D= 5 \text{ cm}$ for solid piles and perforated piles	110
Figure (5.55) The Excel Sheet	111
Figure (5.56) Analysis tools	113
Figure (5.57) Input range	114
Figure (5.58) Output range	114
Figure (5.59) The relation is comparison between (C_t) at case study (New Gersey)and (C_t) at equation for solid piles	116
Figure (6.1) Isometric view to the shoreline change	122
Figure (6.2) Definition for shoreline calculation	122
Figure (6.3) Shoreline changes without breakwater system	124
Figure (6.4) Shoreline change with protection	125
Figure (6.5) Prototype pile shape of the experimental investigation	127
Figure (6.6) Prototype of the Rubble Mound Breakwater	129
Figure (6.7) Reflection coefficient (C_r) in case of piles and rubble mound breakwaters at different wave steepness (H_i/L)	133
Figure (6.8) Transmission coefficient (C_t) in case of piles and rubble mound breakwaters at different wave steepness (H_i/L)	133