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BREAKWATER GEOMETRIC MODEL BASE ON MANGROVE ROOTS STRUCTURE

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

BREAKWATER GEOMETRIC MODEL BASE ON MANGROVE ROOTS STRUCTURE

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May 2015

Chair: Associate Professor Nuraini Bt Abdul Aziz, PhD
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In year 2013, the Department of Irrigation and Drainage Malaysia indicates that 29% or 1,394 km out of 4,809 km of the country's coastline are facing erosion. The coastal erosion had caused 1% of mangrove forest area to continue decline each year. Although mangroves were affected by the erosion but the erosion rate was reduces in the area which mangroves inhabited. Hence, researchers had conducted studies on wave dissipation process in mangrove forest structure that concentrated at west coast of the Malaysia peninsular. Contrarily, this study had taken different approach by investigating on a sole mangrove trees structures at east coast of Malaysia peninsular. The study were focused in the geometrical properties of the mangrove roots and the water flow structure within the mangrove roots area of the *Avicennia marina* (*A. marina*) and *Rhizophora apiculata* (*R. apiculata*) mangrove species. The roots properties were investigated by conducting a field work at Pantai Marina, Kemaman where the geometrical coordinate of each roots of *A. marina* and *R. apiculata* species were collected using grids. Henceforth, a 2D model of the mangrove roots was constructed using meshing software. The simulations were conducted in Computational Fluid Dynamic software using unsteady Spalart-Allmaras turbulence model, water liquid material and by setting the velocity inlet in boundary condition to 6 m/s. From the investigation, it was found that the mangrove roots tend to grow around the mangrove primary trunk which facing the direction of the water traveled. It had been observed that there was large density of mangrove roots within the distance 100 cm to 150 cm from the primary trunk. The simulation result shows that mangrove roots were capable to decrease the initial velocity 6 m/s of water flow to almost 2 m/s. The breakwater model also shows that the geometrical coordinate and the distance between structures were related to the velocity deficit rate. Each structure was arranged in zigzag pattern and the distance of the structure was placed within the maximum range of three times of the structures cross section diameter to create optimum velocity dissipation rate. Thus, the study had found that both

mangrove roots and the breakwater models were capable reducing the velocity to 60 %. The velocity deficit also was related to the roots density, structure and coordination. Henceforth, the finding could contribute to the future construction of breakwater along the coastline in order to overcome the current coastal erosion problem or in the near future.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MODEL GEOMETRI PEMECAH OMBAK BERASASKAN STRUKTUR AKAR POKOK BAKAU

Oleh

MOHAMAD ZAMIN BIN MOHAMAD JUSOH

Mei 2015

Pengerusi: Profesor Madya Nuraini Bt Abdul Aziz, PhD
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Pada tahun 2013, Jabatan Pengairan dan Saliran telah mendapati bahawa 29% atau pun 1,394 km daripada 4,809 km persisian pantai di negara ini menghadapi masalah hakisan diperingkat bahaya. Masalah hakisan ini telah mengakibatkan kemusnahan hutan bakau yang berterusan dimana hampir 1% daripada hutan bakau akan mengecil setiap tahun. Walaupun hutan bakau terkesan dengan masalah hakisan pantai, akan tetapi hakisan yang dialami hutan bakau dapat dikurangkan kerana kelebihan pokok bakau untuk memecah ombak. Oleh itu, penyelidik telah menjalankan kajian mengenai proses pelesapan ombak dalam struktur hutan bakau yang tertumpu di pantai barat Semenanjung Malaysia. Sebaliknya, kajian ini telah mengambil pendekatan yang berbeza dengan mengkaji struktur pokok bakau di pantai timur Semenanjung Malaysia. Kajian ini bertujuan untuk menganalisi proses mitigasi pokok bakau dengan mengkaji ciri akar pokok bakau dan struktur aliran air dalam kawasan akar pokok bakau dari spesies *Avicennia marina* (*A. marina*) dan *Rhizophora apiculata* (*R. apiculata*). Kajian telah dijalankan di Pantai Marina, Kemaman dengan melakar grid di sekeliling pokok *A. marina* dan *R. apiculata* bagi mendapatkan data akar pokok bakau tersebut. Seterusnya, model akar pokok bakau telah dilukis dalam bentuk 2D dengan menggunakan perisian pemodelan. Manakala simulasi pemecahan ombak dan struktur aliran air di dalam kawasan akar pokok bakau telah dijalankan dengan menggunakan model Spalart-Allmaras, model cecair dan halaju dalam sempadan 6 m/s. Daripada kajian yang dijalankan, didapati akar pokok bakau cenderung untuk tumbuh disekeliling batang pokok utama dan menghadap laluan air. Hasil kajian menunjukkan akar pokok bakau tumbuh dengan lebih padat pada jarak 100 cm hingga 150 cm dari batang utama pokok bakau tersebut. Keputusan simulasi ke atas akar pokok bakau pula mendapati bahawa pokok bakau secara individu mampu untuk mengurangkan kelajuan aliran air daripada 6 m/s kepada 2 m/s. Keputusan simulasi ke atas model pemecah ombak menunjukkan kadar pengurangan kelajuan aliran adalah

bergantung kepada koordinat dan jarak diantara struktur model pemecah ombak. Kelajuan air dapat di kurangkan secara optima dengan mengaturkan struktur model dalam bentuk bersilang-seli dan dengan menjarakkan struktur model dalam linkungan jarak maksima tiga kali nilai keratan rentas struktur model tersebut. Oleh itu, kajian ini mendapati bahawa kedua-dua model akar bakau dan pemecah ombak mampu mengurangkan halaju hingga 60%. Defisit halaju juga berkaitan dengan ketumpatan, struktur dan koordinat akar pokok bakau. .Dengan adanya penemuan ini, ia dapat menyumbang kepada pembinaan struktur pemecah ombak yang lebih efisien untuk menangani maslah hakisan pantai yang sedang dialami sekarang atau pun dimasa akan datang.

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I certify that a Thesis Examination Committee has met on 26 May 2015 to conduct the final examination of Mohamad Zamin bin Mohamad Jusoh on his thesis entitled "Breakwater Geometrical model Base on Mangrove Roots Structure" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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Signature: ______________________________
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LIST OF ABBREVIATIONS

°C	Celcius
2D	Two Dimensional
3D	Three Dimensional
AEP	Atlantic East Pacific
A.marina	*vicennia marina*
ArMs	Artificial Mangrove Roots System
cm	*Centimeter*
C_{b2}	Moleculor viscosity
C_L	Energy dissipation coefficient
C_R	Reflection coefficient
C_T	Transmission coefficient
C_{rn}	Reflection coefficients
C_{tn}	Wave transmission coefficients
CFD	Computational Fluid Dynamic
CSD	Cross Section Diameter
d	Water depth
d_s	Structure height
D	Diameter
FTCS	Forward in Time Central in Space
f	Angular frequency
Ft	Feet
g	Gravitational acceleration
G_v	Production of turbulence viscosity
h	Height
IWP	Indo West Pacific
Km	Kilometer
L	Distance travel
m	Meter
M	Mach number
N	Number of time step

NCES	National Coastal Erosion Study
NSWE	Non-Linear Shallow Water Equation
r	Radius
R_e	Reynolds number
R.apiculata	*Rhizophora apiculata*
R.mangle	*Rhizophora mangle*
R. stlylosa	*Rhizophora stlylosa*
R.mucronata	*Rhizophora mucronata*
s	*Second*
$S_{\tilde{v}}$	User define source term
SCB	Semicircular Breakwater
SCB9	Semicircular Breakwater with 9% Front Wall Porosity
SCB9-FS	Semicircular Breakwater 9% with Front wave Screen
SCB9-RS	Semicircular Breakwater 9% with Rear wave Screen
SCB9-DS	Semicircular Breakwater 9% with Double wave Screen
SCB9-DS25S	Semicircular Breakwater 9% with Double wave Screen 25% Porosity
t	Time
u	Velocity of flow travel
μ	Dynamic viscosity
V_e	Volume of Empty Space
V_t	Total Model Volume
ν	Kinematic viscosity of the sea water
$\tilde{\nu}$	Turbulence kinematic viscosity
ν I	Velocity of wave
ν_{sound}	Velocity of sound
W	Width
Y_v	Destruction of turbulence viscosity

Δt	Time step
ζ_n	Porosity
ρ	Density
$\sigma_{\tilde{v}}$	Constants

CHAPTER 1

INTRODUCTION

1.1 Background

The most common mangrove species that can be found in Malaysia are *Rhizophora, Avicennia, Bruguiera, Sonneratia, Xylocarpus* and Nypaspecies. Those mangroves species are tend to colonize at five geomorphologic environments which are river-dominated deltas, tide-dominated deltas, wave–dominated barrier lagoon, drowned bedrock valley and combination-river and wave dominated lagoon (Jan de Vos, 2004; RRC.AP, 2011). Mangrove trees have special adaptation called aerial roots that facilitate the ventilation of the root systems and allow mangroves to fix themselves on muddy soil (Mitsch and Gosselink, 2000). The main types of aerial roots are Stilt Roots (*Rhizophora*), *Pneumatophores* (*Avicennia*, *Sonneratia*), Root Knees (*Bruguiera*) and Plank Roots (*Xylocarpus*) (Jan de Vos, 2004). Stems or roots of mangroves play a major role in protecting the coast by dissipate incoming wave energy and reduce the rate of coastal erosion, hence making the trees as a natural breakwater.

1.2 Problem statement

The development which occurred along the coastlines has led to the problems such as coastal erosion, siltation, loss of coastal resource and the destruction of the marine habitat. This had led the Malaysia Government to carry out National Coastal Erosion Study (NCES) to study the erosion rate in Malaysia. Based on the study, Malaysia shoreline erosion were cause by natural threat and man activities such as high tide due to major storm and port or harbor activities. The result shows that 29% or 1,380 km from of 4,809 km out of the country’s coastline are facing erosion (Department of Irrigation and Drainage Malaysia, 2011). Although mangroves were affected by the erosion but the erosion rate was reduces in the area which mangroves inhabited (Thampanya *et al*., 2006).

Furthermore, the tragedy of Andaman tsunami occurred on December 26, 2004 had cause enormous casualties around the Asia region including Malaysia. But the damage received by Malaysia is small compared to other countries because of the Malaysia Straits of Malacca is protected by Sumatra island and the mangrove forest that grow in the shallow water along the west coast of Peninsular Malaysia. In this tsunami incident, the role of mangroves in reducing the tsunami waves has been credited and these indirectly raise awareness about the role of mangroves forest as a natural breakwater on the beach (Teh *et al*., 2008)

1.3 Recent research

Furukawa *et al.* 1996 in their study stated that an individual mangrove tree was also capable of mitigating the incoming wave within it roots area by creating friction and obstacles to the flow. The study which was conducted using VORTEX models manage to estimate the wave flow structures in the roots area where the obstacles created by the roots generated jet flow and complex current with eddies behind the individual roots. Thus, the complex circulation created a flow that was friction-dominated and each region behind the *Rhizophora* roots generated low velocity stagnation areas (Furukawa *et al.*, 1996).

Consequently, tsunami runup simulation study was carried out by researchers from Malaysia and overseas in Penang beaches using non-linear equations of shallow water (NSWE) in order to analyze the breakwater properties of the mangrove species. Teh, *et al*. 2008 had conducted simulation of tsunami wave mitigation over the shallow coastline of mangrove forests by using TUNA-RP model. The model had similar simulation data of wave height and velocity with TUNA-M2 model that were used by Koh *et al*. 2008. From the research it was concluded that the ratio of wave height and velocity reduction may vary depending on factors such as wave height, wave period and wavelength and the features including the width of the mangrove forest and the density (Teh, Koh *et al*., 2008).

In another study, researchers investigate the vulnerability of mangroves by using an integrated approach that includes analysis of satellite imagery, field surveys, and numerical model of coastal Pakarang Cape, Thailand. The study objective was to identify the damaged mangrove areas and to measure the rate of damage from tsunami. Based on the estimated probability of damage from the numerical model, show that the mangrove *Rhizophora* sp. with a density of 0.2 trees m-2 and stem diameter of 15 cm in the 400 m wide can reduce 30% of tsunami flooding depth (Yanagisawa *et al*., 2008).

Hence, from the above study it can be observe that most researches had been conducted at west coast of the peninsular. The studies also were more focusing on the dissipation process of the wave in mangrove forest structure rather investigating on the mangrove trees in individually and most simulation processes were conducted using numerical models. Thus, this study had taken different approach by investigating on the mangrove trees structures at east coast of Malaysia peninsular. The study had focused o the roots structured of each mangrove species sample which then converted into data that appropriate for Computational Fluid Dynamic simulation process.

1.4 Research objective

The aim of the study is to investigate the geometrical properties of the mangrove roots and flow structure within the mangrove roots area of the *Avicennia marina* and *Rhizophora apiculata* species for breakwater modeling. Thus, to achieve aim of the study, several objectives had been put forward which were:

1. To identify the mangrove roots geometrical properties of the *Avicennia marina* and *Rhizophora apiculata* mangrove species.

2. To analyze the flow structure of *Avicennia pneumatophores* and *Rhizophora* stilt roots.

3. To construct a breakwater model that applied similar mitigation mechanism as the mangrove roots.

1.5 Scope and limitation

1.5.1 Research scope and limitation

The research had limited the scope of the study within two mangrove species which are *Avicennia marina* and *Rhizophora apiculata*. These species are commonly inhabited at Malaysia coastline especially in the mangrove forest at the study area location. Since the study was focusing on investigating the flow structure around a mangrove tree, the study had selected a sample of tree from each species. The sample was sufficient as similar study was conducted by Furukawa *et al*. at Middle Creek, Crains, Australia. Furukawa *et al.* in his study on vegetation-induced current also used a single model to produce the fine scale flow pattern around *Rhizophora* roots. He had observed that the roots had created two-dimensional currents, with jets, eddies and stagnation region. He also had created a VORTEX model which had produced similar flow features to the observation result. Hence, the study decided to take only a tree sample from each species since it was sufficient in observation of water flow pattern in mangrove roots area.

Henceforth, the study had only investigated the mangrove roots geometrical properties which are the geometrical coordinate and the cross section diameters of the roots in 3x3 m wide area. An area of 3x3 m was chosen by referring to the previous study conducted by Furukawa *et al.* for *Rhizophora* species. Furukawa *et al*. in his study had used an area with 2.5x2.5 m wide to observe the flow pattern around mangrove roots and the result of the study was as stated above. Thus, the study had created an area of 3x3 m around the mangrove trees due it was sufficient to cover all the roots around the selected mangrove trees.

Simulation process was conducted using Sparlart-Allmaras turbulence model with water liquid material provided in Fluent data base. Since the study was only focusing in computational simulation of water flow in the mangrove roots area, the data validation was conducted by comparing the simulation results with previous studies that were done by other researchers.

1.5.2 Software limitation

1.5.2.1 Gambit

Gambit is software which is use to design mesh model whether in 2 Dimensional (2D) or 3 Dimensional (3D). It can generate various types of mesh such as structured, unstructured and hybrid mesh. Hybrid mesh is generally as a combination of unstructured mesh and boundary layers. A hybrid mesh was proved to produce more accurate calculation for a very complex mesh model (Gambit 2.2 Tutorial Guide, 2004; Fluent 6.3 Tutorial Guide, 2006; ANSYS Fluent User Guide, 2001). Thus, in this study a 2D hybrid mesh model had been created since the complex structure of the *Avicennia marina Rhizophora apiculata* roots geometrical coordinate.

1.5.2.2 Fluent

ANSYS Fluent software is use in various fields to simulate the heat transfer, air flow over an aircraft wing, bubble columns and the blood flow. The software is capable to simulate model flow in both laminar or turbulence with whether in 2D and 3D models. Fluent database contains large number of material properties from gases to liquid or even solid. The study had conducted simulations using turbulence flow as the value of Reynolds number exceeds 500k. Water liquid properties from fluent data base had been used since the study will only simulate the water flow around the mangrove roots area.

1.6 Outline of the thesis

The introductory briefly review the habitat of mangrove species in Malaysia and the coastal erosion problem which are occurred along Malaysia coastline.

Meanwhile, the literature review chapter had discussed the mangrove habitat and mangrove species distribution especially for *Avicennia marina* and *Rhizophora apiculata* species. This chapter also discusses the previous study on mangrove trees water wave velocity dissipation properties and the research of breakwater structures.

Chapter 3 describes the method used to collect the geometrical coordinate of each mangrove roots and the roots simulation procedure in dissipating water flow velocity.

Chapter 4 and 5 discussed the result of the study during the field work and on the simulation results of the *A. marina* and *R. apiculata* species roots.

Chapter 6 will discusses the simulation results of breakwater models constructed based on the roots.

Chapter 7 presents the conclusion of the study on field work study, mangrove roots simulations and breakwater simulations.

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