BEACH RESPONSE DUE TO THE PRESSURE EQUALIZATION MODULES (PEM) SYSTEM

MOHD SHAHRIZAL BIN AB RAZAK

A project report submitted in fulfillment of the
requirements for the award of the degree of
Master of Engineering (Civil-Hydraulics and Hydrology)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JUNE 2009

Especially dedicated to my beloved family, fellow friends and to everyone who involves in my life, you will always be in my heart……………………..

ACKNOWLEDGEMENT

I would like to convey my sincerest thanks to my supervisor Professor Hadibah Binti Ismail for her dedicated guidance, valuable assistance and endless encouragement throughout the accomplishment of this project.

I am grateful to the staff of Department of Irrigation and Drainage Malaysia who had been very helpful in providing assistance throughout the work. Special thanks are also extended to Director of Department of Irrigation and Drainage, Malaysia for his permission to allow the accessibility of data for this project. My thanks are also extended to other lecturers for their advice whether directly or indirectly in improving my Master Project. Also not forgetting my friends especially Mr. Bahman Esfandiar Jahromi, Miss Hasmida Hamza, and Mr. Abdul Haslim Shukor Lim for their guidance in helping me to clarify any problems related to this study.

I am indebted to my employer Universiti Putra Malaysia and Ministry of Higher Education for providing me the opportunity and the financial means to pursue this study. Last but not least, my deepest and eternal gratitude to all those who had helped directly or indirectly in my project.

ABSTRACT

Coastal erosion is a significant problem with dramatic effects on the coastline. There is an urgent need to introduce new and cost-effective measures that can mitigate the impacts on the shoreline. This study has been initiated to investigate the response of the beach at Teluk Cempedak due to the beach nourishment and Pressure Equalization Modules (PEM) system. The objectives of this study are the determination of closure depth and effectiveness of the system in treating the erosion process. The depth of closure was examined using both data from a series of beach profile surveys and from empirical formulae. The widely accepted Fixed Depth Change (FDC) method was explored and the h_c before and after the installation of PEM system was investigated. The research found that multiple closure points can occur along the profile lines. The closure depth after the installation of PEM system was found to be deeper and the closure point is further seaward at the southern part of the beach. The Hellemeier's equation over predict h_c by 76 %, however it reveals that the equation is still robust in determining an upper limit of h_c. The simplified equation was developed at Teluk Cempedak beach in predicting closure depth and can be equated to 0.98 times $H_{0.137}$. From the survey data, it is found that after three years, the total sand volume and beach elevation are significantly higher in PEM areas. Generally, the result presented indicates the decreasing value of rate of erosion. Thus it revealed that PEM system is able to stimulate accretion of sand and yet slow down the erosion process. However, based on the sand volume distribution pattern, after three years, it is obviously seen that the accretion of sand occurring at the northern part while erosion process is taking place in the southern part of the beach. Based on the distribution pattern of bed elevation over the chainage, overall, the upper part of the beach is convex unlike earlier *i.e* before the installation of PEM system, where the beach was low and concave. This phenomena indicates that the system contribute to a significant accretion of sand and thus created a higher beach level at about 10 m to 55 m towards the sea. However, this trend only can be seen at a certain chainage. The PEM efficiency in terms of increment in bed elevation can only be observed at CH 400 till CH 800 while at CH 900 towards the south, the efficiency is decreasing. This shows that the accretion of sand is only occurring at the northern part and the beach is eroding at the southern part. Therefore, based on the available four years record of data, there is a certain part of the beach benefiting from the PEM system. However, some parts are still experiencing the erosion process.

ABSTRAK

Hakisan pantai merupakan masalah ketara yang memberi kesan kepada perairan pantai. Oleh itu, terdapat tindakan segera untuk memperkenalkan kaedah baru dan lebih menjimatkan yang mana dapat mengatasi masalah hakisan pantai ini. Kajian ini telah dijalankan untuk menyiasat tindak balas pantai terhadap penambakan pantai (*beach nourishment*) dan sistem *Pressure Equalization Modules* (PEM). Objektif utama kajian ini adalah penentuan kedalaman tertutup (*closure depth*) dan keberkesanan sistem dalam merawat hakisan pantai. Kedalaman tertutup telah dikenalpasti menggunakan kedua-dua data iaitu data ukur bersiri dan formula empirikal. Kaedah Perubahan Kedalaman Tetap telah digunakan dan kedalaman tertutup sebelum dan selepas pemasangan sistem PEM telah disiasat. Kajian menunjukkan bahawa beberapa kedalaman tertutup boleh berlaku di sepanjang garis ukur. Kedalaman tertutup selepas pemasangan sistem PEM didapati lebih dalam dan lokasi titik kedalaman tertutup jauh menghala ke tengah laut khususnya di bahagian selatan pantai. Persamaan Hellemeier didapati lebih tinggi dengan lebihan purata 76 % bagaimanapun mendedahkan bahawa persamaan ini masih kukuh bagi menentukan nilai had teratas untuk $h_{c.}$ Persamaan ringkas telah dicipta bagi pantai Teluk Cempedak dalam menentukan kedalaman tertutup dan boleh disamakan dengan 0.98 kali ketinggian ombak $H_{0.137.}$ Daripada data ukur juga, jumlah isipadu pasir and ketinggian pantai didapati lebih tinggi di kawasan pemasangan sistem PEM selepas tiga tahun pemantauan dijalankan. Umumnya, hasil keputusan menunjukkan bahawa kadar hakisan telah menurun. Ini menunjukkan bahawa sistem PEM berupaya mengumpul pasir sekaligus melambatkan proses hakisan. Walaubagaimanapun, berdasarkan kepada jumlah pengagihan isipadu pasir, jelas menunjukkan bahawa pengumpulan pasir hanya terjadi di bahagian utara pantai manakala proses hakisan masih berlaku di bahagian selatan pantai. Berdasarkan kepada bentuk pengagihan bagi ketinggian pantai pula, secara keseluruhannya, bahagian atas pantai lebih cembung berbanding sebelumnya yang mana ianya lebih cekung. Fenomena ini menunjukkan bahawa sistem PEM menyumbang kepada pengumpulan pasir seterusnya meningkatkan ketinggian pantai pada jarak 10 m hingga 55 m menghala ke arah laut. Bagaimanapun, keadaan ini hanya berlaku di kawasan-kawasan tertentu sahaja. Keberkesanan PEM dari segi peningkatan ketinggian pantai hanya berlaku di CH 400 hingga CH 800 sementara di CH 900 menghala ke selatan pantai pula menunjukkan penurunan peratus keberkesanan.

Ini menunjukkan bahawa pengumpulan pasir terjadi di bahagian utara pantai manakala proses hakisan masih berlaku di bahagian selatan pantai. Oleh yang demikian, berdasarkan kepada data ukur bagi 4 tahun kerja pemantauan, terdapat sebahagian kawasan pantai yang mendatangkan manfaat daripada sistem PEM manakala sebahagiannya lagi masih mengalami proses hakisan.

TABLE OF CONTENTS

PART B: PRESSURE EQUALIZATION MODULE (PEM) SYSTEM

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CED	Coastal Engineering Division
CEM	Coastal Engineering Manual
CH	Chainage
cm	centimeter
DID	Department of Irrigation and Drainage Malaysia
EDM	Electronic Distance Measuring
FDC	Fixed Depth Change
h_c	Depth of Closure
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LSD	Land Survey Datum
m	meter
mm	millimeter
MSL	Mean Sea Level
MHW	Mean High Water
MHHW	Mean Higher High Water
MLHW	Mean Lower High Water
MLW	Mean Low Water
MHLW	Mean Higher Low Water

MLLW	Mean Lower Low Water
MMD	Malaysian Meteorological Department
MRCB	Malaysia Resource Corporation Berhad
NOS	National Ocean Survey
PEM	Pressure Equalization Modules
SDDC	Standard Deviation Depth Change
SSMO	Synoptic Shipboard Meteorological Observation
USGS	U.S Geological Survey Quadrangles

LIST OF SYMBOLS

A	profile scale parameter with dimensions of length to the 1/3 power
D_{16}	size of material of which 16% is finer
D_{50}	size of material of which 50% is finer
D_{84}	size of material of which 84% is finer
D_c/ h_*/ h_c	closure depth
g	gravity
h	water depth at distance y from the shoreline
h_{Ci}	depth of closure, innershore; from profile survey
h_{cm}	depth of closure, middleshore; from profile survey
h_{co}	depth of closure, outershore; from profile survey
H_e	non breaking significant wave height that is exceeded 12 hour per t years or (100/730t)% of the time
$H_{0.137}$	significant wave height exceeded 12 hours in a year
$\overline{H}$/H_s	annual mean significant wave height
m	fore shore slope of the beach profile
t	time
T_e	wave period associated with H_e

y	equilibrium beach profile
v_b	amplitude of the wave induced bottom velocity
ρ	mass densities of water
ρ_s	mass densities of sediment
σ_H	standard deviation

LIST OF APPENDIX

CHAPTER I

INTRODUCTION

1.1 Introduction

Land based activities and natural physical processes have resulted in significant modifications of the shorelines in many countries, with drastic effects on the coastal geomorphology as well as on the coastal infrastructures. There is an urgent need to introduce new and cost-effective measures that can mitigate the impacts on the shorelines. In many locations, coastal erosion is a significant problem with dramatic effects on the coastline. The impact on coast-near infrastructures and property can be massive. Until now the urgent need for coastal erosion protection, has forced society to use costly solutions with bulky constructions and beach nourishment, where the dredging part of the process is very hostile to the marine environment.

Coastal protection can generally be divided into hard engineering and soft engineering (Ghazali, 2005). Hard engineering structures such as revetments, seawalls, bulkheads and groynes are considered traditional erosion protection structures with distinct functions. These are typically constructed of quarry stones or concrete units. Seawalls and revetments are constructed parallel to the shoreline and form a barrier between waves and the coast. Whilst preventing any further loss of material landwards, waves reflected by the seawall causes scouring at the toe in front of the seawall and eventual lowering of the beach. Thus where recreational space is concerned, the use of seawalls and revetments are not beneficial in the long run as the end result is a deepening or steepening of the sea bed in front of the structure resulting in loss of beach space.

The term ‘soft engineering’ is normally used to describe methods that depart from hard protection structures that use quarry stones or concrete blocks as the main structural component. The use of sand either as a fill material placed directly on the eroding beach or encased within geotextiles are amongst the methods that qualify as soft engineering. In beach nourishment, loose sediments are imported and placed on the target beach to form a wider beach berm as a buffer for waves. The ‘new’ beach will then continue to be shaped by the natural forces i.e. wind, wave and tidal currents, to an equilibrium shape. Beach nourishment is now common and is the preferred method of protecting or rehabilitating eroding recreational beaches (Ghazali, 2004). The construction process however involves dredging, transport and placement of sand in a marine environment which causes water quality problems, habitat displacement and stress to marine life. Beach nourishment is also considered semi-permanent and requires replenishment as time progresses.

Beach nourishment, also called artificial nourishment, replenishment, beach fill, and restoration, comprises the placement of large quantities of good quality sand within the near-shore system usually to address a continuing deficit of sand, manifested by shoreline recession (Dean, 2002). The term nourishment applies to both the initial placement of material and to later nourishments for the projects where multiple placements occur. The terms beach nourishment may be used to differentiate between material that is placed on the sub-aerial beach and its underwater extensions from profile nourishment or berm placement which involves the placement of material offshore with the anticipation that either the material will provide protection to the shore from erosion by reducing the effects of waves.

SIC, Skagon Innovation Centre (Jakobsen, 2007) has invented an environmentally friendly coastal protection system. The SIC system is based on Pressure Equalization Modules (PEM). A long term and comprehensive test of the efficiency has been carried out on the west coast of Denmark. Furthermore, a three year scientific research programme was performed in year 2005. The obtained result shows that the system is far more efficient than conventional methods such as groins, breakwaters, and sand nourishment. Due to the well-known lee side erosion effect, groins and breakwaters create even greater erosion in adjacent coastal areas. Furthermore, Jakobsen reported that sand nourishment by dredging is in general terms a very expensive approach (about 130,000 USD/km/year in Denmark), but unfortunately, it is an inefficient solution since usually the sand will disappear during the first spring period.

1.2 Statement of Problem

The evolution of the coast is produced by natural processes that occur on a broad time scale ranging from hours to millennia. Beach erosion is one such process that occurs when the losses of beach sediment exceed the gains. As this volume of sediment decreases, the beaches become narrower. When backed by fixed developments, beaches are unable to respond naturally to changes, resulting in a cessation of beach/dune interactions, instability of the fronting beach, and a reduction of sediment inputs into the sediment budget. In the absence of development, coastal erosion is not a hazard. The presence of large and expensive communities in the coastal zone creates the potential for major disasters resulting from erosion. Erosion is typically episodic, either with the shore recovering afterward or with the episodes being cumulative and leading to a progressive retreat of the shoreline and property losses. The erosional impact on properties depends on the width of the buffering beach and on the nature of the beach as defined by the morphodynamics model of Wright and Short (1983).

Malaysia has about 4809 km of coastline. Of the 4809 km of coastline, about 1415 km is at present subject to erosion of various degree of severity (Annual Report DID, 2007). Along the coast, sediment is continuously being moved. When the rate of sediment entering and leaving the coast equals, the coast is said to be in dynamic equilibrium. Erosion occurs when, over a period of time, the volume of sediment transported out is greater than that transported into the coast. It follows that the reverse will result in accretion. The erosion process occurs continuously and as a result, the beach slowly retreats. This is normally indicated by the formation of beach scarp along the coast.

Erosion may be amplified during monsoon period when high water levels, associated with the season, result in waves breaking directly against the scarp, causing loss of material. Though, some of this material might be returned to the shore by the swells after the monsoon, the quantity returned is normally much less; hence the nett result is erosion. Control of coastal erosion has now become an important economic and social need. Table 1.0 shows the list of coastal erosion areas in Malaysia. From this table, it can be concluded that 73.40 % or 52.1 km of the total length of coastline in Pahang area has been eroded. To this end, the government is implementing a strategy to control the erosion problem. The government has spent about RM 15,400,000.00 to invest in a new system for control of coastal erosion called the Pressure Equalization Module (PEM). The system has been successfully installed at the Teluk Cempedak beach in Pahang and is the first coastal erosion project applying this method in Malaysia and Asia **(**Annual Report DID, 2004**)**.

Table 1.0: List of Coastal Erosion Areas in Malaysia

State	**Length of Coastline**	**Length of Coastline Having Erosion**			**Total Length of Coastline Having Erosion**	
		Category 1	**Category 2**	**Category 3**		
	(km)	**CRITICAL EROSION (km)**	**SIGNIFICANT EROSION (km)**	**ACCEPTABLE EROSION (km)**	**(km)**	**(%)**
State		**Length Critically Eroded**				
Perlis	20	4.4	3.7	6.4	14.5	72.50
Kedah	148	31.4	2.2	6.9	43.5	29.40
Pulau Pinang	152	42.4	19.7	1.1	53.2	41.60
Perak	230	28.3	18.8	93.1	140.2	61.00
Selangor	213	63.5	22.3	66.1	151.9	71.30
N.Sembilan	58	3.9	7.7	12.9	24.5	42.20
Melaka	73	15.6	15.1	6	36.7	50.30
Johor	492	28.9	50.3	155.6	234.8	47.70
Pahang	271	12.4	5.2	37.6	52.1	73.4
Terengganu	244	20	10	122.4	152.4	62.50
Kelantan	71	5	9.5	37.6	52.1	73.40
W.P Labuan	59	2.5	3	25.1	30.6	51.90
Sarawak	1035	17.3	22.3	9.6	49.2	4.80
Sabah	1743	12.8	3.5	279.2	295.5	17.00
Total	4809	288.4	193.3	932.8	1,415	29.41 %
		6.0 %	4.0 %	19.4 %		

Source: Annual Report, Department of Irrigation and Drainage, (DID) Malaysia (2007)

Based on the Detailed Design Report 2006, Teluk Cempedak beach has a history of erosion. The beach area has undergone slow and steady erosion that has resulted in the narrowing of the beach area, which has affected adversely on the recreational and tourist activity in this area. Although the beach is classified as stable under the National Coastal Engineering Study (NCES) of 1985, at present the average retreat rate is estimated to be 0.8 m/year. If protective measures are not taken, the beach eventually will be eroded, and the ocean waves approach the land will endanger the properties located along the beachfront and in the hinterland. At present, coastal structures of various designs had been built to protect the public recreational areas occupying the northern part of the beach and the hotels on the southern part. However more efforts are needed to protect and develop the beach to be among the best tourists' attractions in Malaysia.

1.3 Objectives of Study

The main objective of this study is to investigate the response of the Teluk Cempedak beach due to installation of the Pressure Equalization Module (PEM) system. The specific objective of this study is to determine the depth of closure due to the installation of the Pressure Equalization Modules (PEM) system as well as to evaluate the PEM effectiveness based on total sand volume and beach level retained on the beach after a specific time period. A comparison of results before and after the installation of PEM system has been successfully investigated.

1.4 Scope of Study

1.4.1 Study Area

The location of the study area is at Teluk Cempedak on the East Coast of Peninsular Malaysia near the town of Kuantan (see Figure 1.1). Teluk Cempedak is situated in a pocket bay adjacent to Hyatt- and Sheraton Hotel and has a total length of 1100 metres. The beach called Teluk Cempedak is one of the main tourist attractions in Pahang, where there are hotels and eateries occupying the northern portion of the beach, while Hyatt and Sheraton hotels are situated in the southern part. The beach is located between the headlands of Tanjung Pelindung Tengah and Tanjung Tembeling, with Sungai Cempedak draining into the northern end of the bay. This river drains Bukit Pelindung and discharges some sediment and moderately polluted water from developed areas within its catchment. The bay has been developed for public recreation as well as for local and international tourism activities.

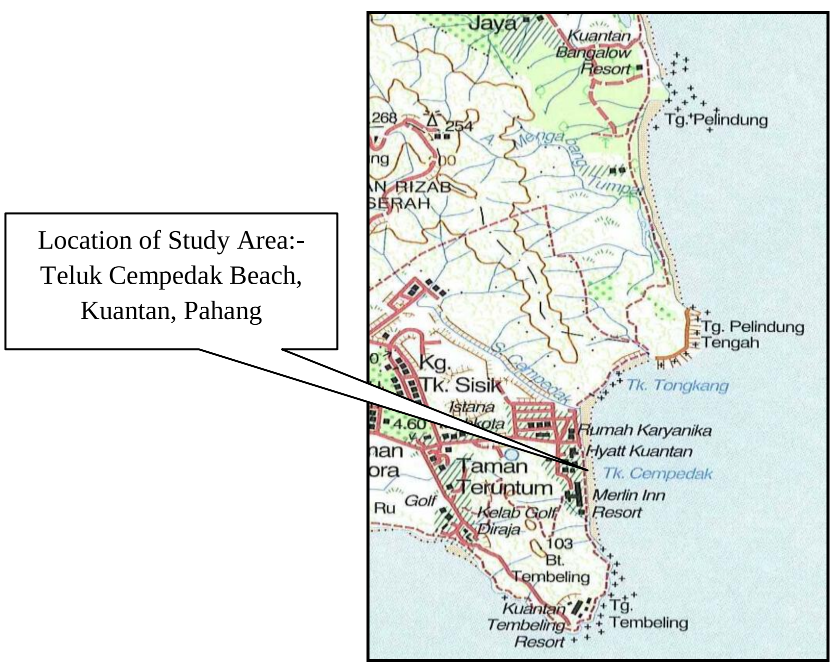

Figure 1.1: The Location of Study Area at Teluk Cempedak Beach, Kuantan

1.4.2 Data Collection and Analysis

Data collection is the most important part of this study. Data made available in this study comprise the following:-

(i) Profile survey data.
(ii) Bathymetric data.
(iii) Wave data.
(iv) Wind data.
(v) Tidal data.
(vi) Bed sediment data.

A detailed description of this data is discussed in the following chapter. This data had been used to determine the depth of closure by using analytical procedure. Data analysis involves the following scope of work:-

(a) Compiling, plotting and comparing series of survey data.

(b) Analysis of wave data to obtain the significant wave height and wave period.

(c) Analysis of sediment data for determination of mean particle size (D_{50}).

(d) Determination of closure depth using Hellemeier equation (1981).

1.4.3 Determination of Closure Depth

Depth of closure is an important concept in coastal engineering that defines the seaward limit of significant net sediment transport along a wave-dominated sandy beach profile over a period of time and is used to establish shoreline and volume change relationships. The depth of closure can be observed along a specific segment of coast in a series of profiles taken over a period of years as the depth at which the profiles consistently come together within the accuracy of the survey procedures. (Robertson *et al*, 2008).

Ferreira (2003) reported that the depth of closure is the depth that separates the active cross-shore profile from a deeper zone where the sediment transport is much weaker and where morphological changes are less perceptible. He suggested that this depth should be determined by morphological comparison, existing some formulations (e.g. Hallermeier, 1981, Birkemeier, 1985) that can be used for estimating a standard annual value for each coastal region when a morphological approach cannot be used.

1.5 Terminology Used in This Study

1.5.1 Beach Nourishment

Beach nourishment involves the placement of large quantities of sand or gravel in the littoral zone to advance the shoreline seaward. Such nourishment can be used to create or to maintain a recreational beach or to build out the shore in order to improve the capacity of the beach to protect coastal properties from wave attack (Komar,1998). Beach nourishment represents a soft solution and is the only form of shore protection that attempts to maintain a naturally appearing beach.

1.5.2 Closure Depth

According to Nicholls *et al* (1998) in their *Coastal Engineering Technical Note*, they claimed the depth of closure for a given or characteristic time interval is the most landward depth seaward of which there is no significant change in bottom elevation and no significant net sediment transport between the near-shore and the offshore.

1.5.3 Equilibrium Profile

Equilibrium beach profile is conceptually the result of the balance of destructive versus constructive forces (Dean, 2002). The beach profile is the variation of water depth with distance offshore from the shoreline. In nature, the equilibrium profile is considered to be a dynamic concept, for the incident wave field and water level change continuously in nature; therefore, the profile responds continuously. By averaging these profiles over a long period, a mean equilibrium can be defined.

1.5.4 Pressure Equalization Module System

Pressure Equalization Module (PEM) system is a new innovative system originated from Denmark for beach erosion control. The system was successfully installed in many countries all over around the world including Australia, Ghana, Denmark as well as Malaysia. It is designed to stimulate accretion of sand on certain beaches and to slow down the erosion process in some other beaches. PEM system is radically different from other protection measures where hard structures like concrete walls, rock embankment and groynes are used. This system has low impact on the aesthetics of the beach area and thus represents a more environmental friendly coastal protection method. It is assumed that under PEM influence the groundwater table in the beach will be lower and the swash infiltration-exfiltration rate will decrease, that will cause decreasing of intensity of the beach erosion in the swash zone.

1.6 Importance of Study

By the end of this study, the results presented will provide some base line information for local engineers in order to suggest a better plan for beach protection in other location by using a combination of PEM system and beach nourishment. Based on the findings of this study, the following expected results can be drawn:-

(a) The depth of closure will be higher as well as the point of closure will be further seaward and the width of the beach will be wider due to the effect of the PEM system.

(b) From this study, engineers will be able to utilize an analytical model, specific to the local conditions, to predict depths of closure for areas where the beach has been installed with a PEM system.

(c) The Pressure Equalization Modules system is expected to effectively create a new beach by enhancing infiltration and sediment deposition.

(d) An effective PEM in combination with beach nourishment will be able to extend the lifetime of a nourished beach considerably. This technique of using a soft engineering approach could be applied to other beaches as well.