

PILES PERFORMANCES BEHAVIOR OF MARINE STRUCTURES

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# PILES PERFORMANCES BEHAVIOR OF MARINE STRUCTURES

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For...

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## ABSTRACT

Selection, design and analysis of marine structure foundation are important in order to achieve the acceptable performance behaviour during its anticipated lifetime. Marine structures foundation selection and design are complicated because of the unique loading configurations, installation requirement and greater uncertainties in site investigation and selection of appropriate soil parameters. Published criteria for selection, design and analysis of marine structure foundations are very limited and currently unavailable. Whilst, obtaining a technical piling database for marine structure foundation design and construction requires time and experience. The objective of this study includes identifying the driving factors that contributed to the piles performances behaviour of marine structures and to analyse various piling properties in marine condition. The Phase 2 Development of the Deepwater Petroleum Terminal in Pengerang, Johor, was used as a case study. From the literature researches and available site investigations, the piles performances behaviour was determined and the analysis was tabulated in graphical forms. The findings of this study found that the piles performances behaviour of marine structure are correlated to each other such as pile bearing capacity, pile diameter, pile length, pile embedded depth and also pile loading. However, further studies and geotechnical modelling are needed to best justify the correlations in detail, in order to correctly determine the pile performances behaviour of marine structures.

## ABSTRAK

Proses pemilihan, reka bentuk dan analisis asas cerucuk struktur marin adalah penting bagi membolehkan ia mencapai prestasi yang sepatutnya di sepanjang tempoh hayat operasinya. Proses ini adalah rumit kerana konfigurasi bebannya yang unik, keperluan pembinaan yang pelbagai, ketidaktentuan di dalam penyiasatan tapak dan juga ketepatan di dalam memilih parameter tanah yang sesuai. Penerbitan khusus bagi menentukan kriteria pemilihan, reka bentuk dan analisis asas cerucuk struktur marin pula adalah sangat terhad dan jarang terdapat di pasaran. Proses mendapatkan pangkalan data teknikal bagi reka bentuk dan pembinaan asas cerucuk struktur marin pula memerlukan masa dan pengalaman. Objektif kajian adalah untuk mengenal pasti faktor-faktor yang menyumbang kepada proses pemilihan, reka bentuk serta analisis asas cerucuk struktur marin dan juga untuk menganalisa pelbagai sifat asas cerucuk struktur marin. Fasa 2 Pembangunan Terminal Petroleum Marin Laut Dalam di Pengerang, Johor, telah dijadikan sebagai kajian kes. Dari kajian literatur dan penyiasatan tapak, pelbagai sifat asas cerucuk telah ditentukan dan analisis yang diperolehi telah dijadualkan di dalam bentuk grafik. Hasil kajian mendapati bahawa sifat asas cerucuk struktur marin adalah berhubung kait antara satu sama lain seperti keupayaan galas cerucuk, diameter cerucuk, panjang cerucuk, kedalaman cerucuk tertanam dan juga beban cerucuk. Walau bagaimanapun, kajian lanjut dan permodelan secara geoteknikal adalah diperlukan untuk mendapatkan hubung kait yang lebih tepat dan terperinci bagi menentukan sifat asas cerucuk struktur marin.

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## LIST OF ABBREVIATIONS / SYMBOLS

$\phi$	-	Angle of shearing resistance
$\lambda$	-	Unit frictional resistance of pile
$\sigma_v'$	-	Effective overburden pressure
$\sigma_{vo}'$	-	Effective vertical stress
$A_b$	-	Pile base area
$A_s$	-	Pile shaft surface area
$C$	-	Undrained apparent cohesion
$C_c$	-	Compressions index
CD	-	Chart datum
$C_u$	-	Mean undrained shear strength
$d$	-	Pile thickness
$D$	-	Pile diameter
DVJV	-	Dialog-Vopak joint venture
$f_s$	-	Shaft resistance
HAT	-	Highest astronomical tide
Hs	-	Average maximum wave heights
$L$	-	Total pile length
LAT	-	Lowest astronomical tide
MSL	-	Mean sea level
N	-	Standard penetration test value
$N_q$	-	Bearing capacity factor
OBE	-	Operation basis earthquake
Pc	-	Pre-compressions stress
PGA	-	Peak ground acceleration

$q_b$	-	End bearing pressure
$Q_b$	-	End bearing resistance
$Q_s$	-	Skin friction resistance
$Q_u$	-	Ultimate pile capacity
SLS	-	Serviceability limit state
SPT	-	Standard penetration test
$S_u$	-	Undrained shear strength
SSE	-	Safe shutdown earthquake
UKC	-	Under keel clearance
ULS	-	Ultimate limit state
VLCC	-	Very large crude carrier

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background**

Marine structure foundations have been constructed throughout history and the earliest type of marine structure foundation appears to have been driven stakes or piles around the edges of water bodies. The soils supporting marine structure foundations are subjected to forces arising from the marine structure weight, the environmental load conditions, such as wind, wave, and current; and also imposed loads acting on the marine structure. Therefore, the design and selections of marine structure foundations are dependent upon the appropriate soil/rock properties (i.e. shear strength or bearing capacity, settlement, differential settlement, etc.). Hannigan et. al. (2006) stated that the foundation engineer must have a thorough understanding of foundation loads, subsurface conditions including soil/rock properties and behavior, the significance of special design events, foundation performance criteria, and current practices in foundation design and construction in the area where the work is to be done to arrive at the optimum foundation solution.



On top of that, the marine structure foundation must be selected, designed, and constructed to achieve acceptable performance behavior during its anticipated lifetime, where the foundation should be designed to carry the most severe static and variable loads without approaching the bearing capacity or causing excessive deformations with respect to maintaining the air gap, structural integrity and topside operation of the installation. The safety factor to be used depends on reliability of the soil data, load estimates, analytical methods and also the construction or installation technique of the marine structure foundation.

However, published criteria for selection, design and analysis of underwater marine structure foundations are very limited. According to Landris & Richard (2001), no written guidance for underwater foundation design and construction is currently available. API (1993) also added that, although the offshore industry has published guidelines for foundation design, installation, behavior and testing, the selection guidelines covering all possible types of underwater foundations are not commonly found in the literature.

## **1.2 Problem Statement**

Marine structures design and construction project is one of the rare project exist in Malaysia, thus not many skilled engineers and experienced consultants involved in the design of such facilities. Hence, it is important for us to know about the technical aspects as well as the driving factors that should be considered in designing a marine structure. Apart from that, marine structures foundation selection and design are complicated due to the unique loading configurations, installation requirement, greater uncertainties in site investigation and also determination of the appropriate soil parameters.

Obtaining a technical piling database for marine structure foundation design and construction requires time and also experience, where most of the technical expertise is only held by specialist design firms and also contractors. Thus, there is a need to study and analyse the piles performances behavior of marine structure in order to determined and obtained an optimum marine structures foundation design in term of cost and also its functions.

### **1.3 Objectives of the Study**

The main aim of this study is to investigate the piles performances behavior of marine structures, and to achieve this goal, several key objectives have been set, namely:

- i. To identify the driving factors that influences the design work of marine structure piles.
- ii. To analyse the design process of marine structure piles using structural and spread sheet software.
- iii. To analyse correlation of various piling properties in marine condition, such as pile bearing capacity, pile diameter, pile length, pile embedded depth and also pile loading, using spread sheet software.

### **1.4 Scope of the Study**

This study was conducted to seek the outlined objectives, based on the construction of the Marine Facilities Jetty 2 and Associated Dredging, Development of the Deepwater Petroleum Terminal Project in Pengerang, Johor, Malaysia.

In order to meet the said objective, the scope of this study will be focus on the following areas:

- i. Analyse the marine petroleum terminal piling structure using the structural and spread sheet software; following the relevant standards, guidelines and references.
- ii. The site investigation works are solely done for the above said structures.
- iii. The study is conducted only for the marine petroleum terminal pilings and only important aspects in determining piles performances behavior of a marine petroleum terminal will be studied.

## **1.5 Significant of the Study**

Designing a marine petroleum terminal foundation is rarely ventured by most foundation engineers or designers in Malaysia. This situation arises because projects based on the construction of ports or other marine structures are extremely rare in our country. Hence, this study is expected to provide a useful information and guidance to foundation engineers or designers who may be involved with the foundation design of marine petroleum terminal in the future.

In principle, the importance of this study is to determine the factors that need to be addressed and emphasized when designing a marine petroleum terminal foundation. This study will also clarify the actual situation of a marine petroleum terminal foundation design, based on what was learned through the literature review. In addition, the result of this study also aims to correlate the pile performances behavior of a marine structure, in order to get an optimum marine structure foundation design which is not only cost effective but also fulfill its functions.

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