CERTIFICATION OF APPROVAL

Pile Selection Methodology

by

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

This project entitled – 'Pile Selection Methodology'. The objective of this project is to establish pile selection methodology for different site characteristics. This manual consists of selection procedures for pile and pile driving equipment. The factors that govern the equipment selection include site investigation report which covers the deep boring and analysis of the test report, types of pile which covers the classification and the selection of pile types. Other factor is the pile driving system including noise, vibration and driving resistance were discussed deeply in this report. Bearing capacity and commercial factors were the aspects that affect the selection. Research, data gathering related to the subject, conceptual study were the methodology for this project. At the end of this project, a guideline was produced to assist the contractors to choose the right equipment for particular site conditions.

Keywords: Bearing Capacity, Site Investigation, Deep Boring, Equipment Selection.

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INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

The construction field nowadays is bringing more and more modern technology and machineries to the site. Some projects are having a timeline where certain jobs have to be completed before reaching the dateline. For the piling part, it takes a lot of time and work to finish the job in a given time frame. Some projects are comfortable in doing the piling job with hammer machine and some might not. There are differences between these type of piling machines and many factors involve in influencing the effectiveness at the construction site and how good the performance of the machines.

At the end of this project, a selection guide for pile shall be produced and for that, a thorough research about piling machines and type of piles need to be done in order to determine the best option in selecting equipment that can save cost and time.

Many factors govern the selection for pile. The factors are:

1. Commercial factors
2. Performance of equipment
3. Environmental effect (noise and vibration)
4. Type of piles

5. Site characteristics
6. Cost and time schedule

1.2 Problem Statement

Generally, Jack-In-Pile and Hydraulic Hammer machines are used for piling purpose at the construction site. Some projects need to use the Jack-In-Pile machine as the construction site is near the residential area. Others are just using the hammer machine as it is always available for use and easy to find. However, there are differences between these two piling machines as they are related to construction timeframe, method of work and the condition of the site location. In such cases, a small or edgy area like boundary of the site where need to construct retaining wall, hydraulic hammer is the most suitable piling machine to be used instead of jack-in because of the size is smaller and easy to move around the site. However, using a hammer machine can result in wall cracking and noise if it is near the residential area as it can produces more vibration to the soil.

1.2.1 Problem Identification

Basically, the problem in this study is, it is hard to determine the effectiveness of using these piling machines at the construction site in order to observe how these machines works and the behavior of the pile towards the soil characteristics at different places. The other part is to select proper pile driving equipment and installation methods that meets all the criteria for particular construction sites.

1.2.2 Significance of Project

The significance of this project is that at the end of this study, the manual for determination the type of piling machine to be used with respect to types of soil condition at different construction methods was produced that would help the contractors to choose the right equipment for particular site conditions.

1.3 Objectives and Scope of Study

The main objective of this project is to establish pile selection methodology for different site characteristics. It is important to see whether the usage of certain piling machine is right according to the site conditions and parameters considered include cost, time schedule and reliability. The first step of this study is to get a clear overview on piling equipments and work process. The soil characteristics are also considered to determine the efficiency of piling machine.

The scope of study involves the description of types of piles, advantages, disadvantages and usage of piles, equipment and installation methods. Proper equipment and installation methods are critical to prevent damage to the pile foundation during driving, to obtain adequate bearing capacity and to minimize the cost of installation. Special installation methods are sometimes required depending on the soil and environment. The types of pile influences the method selected for installation.

1.3.1 Relevancy of Project

This project is relevant to the study of Foundation and Earth Structure. This project is also relevant to the construction industry in order to determine the most effective way to select equipment for piling work.

CHAPTER 2
LITERATURE REVIEW

2.0 LITERATURE REVIEW

Nowadays, the construction sites are facing more challenge in completing the project with a given schedule. Piling is one of the jobs that need a lot of time and work to be completed. The types of machineries used for piling is depending on site condition whether it is suitable to use that particular type of pile driving machine.

This project is evolved from internship experience at the construction site that uses both types of machines in piling work. Different types of machines have different method of statement in pile driving. The popular driving method is always by using hammering. But, there are some distinctions between those machines in terms of the effectiveness at the site and performance in completing the piling job.

There are several types of pile driving equipment available in the market. The selection of pile driving system begins with the proper selection of pile and the hammer. Generally, pile should be chosen first. Pile is classified according to the amount of soil displacement that will occur during installation. The soil is disturbed by driving causing cohesive clays to remold and non-cohesion sands to change density.

A structure can be founded on piles if the soil immediately beneath its base does not have adequate bearing capacity. If the results of site investigation show that the shallow soil is unstable and weak or if the magnitude of the estimated settlement is not acceptable a pile foundation may become considered. Further, a cost estimate may indicate that a pile foundation may be cheaper than any other compared ground improvement costs. In the cases of heavy constructions, it is likely that the bearing capacity of the shallow soil will not be satisfactory, and the construction should be built on pile foundations. Piles can also be used in normal ground conditions to resist horizontal loads.

2.0.1 Jack-In-Pile

Jack piling apparatuses are usually confined to situations where piles must be driven into the ground with no significant vibration and noise is permitted. Several pile driving apparatuses have been proposed in the past. Several are discussed in "Pile Design and Construction Practice", third edition by M. J. Tomlinson, published in 1987.

Previously used jack piling apparatuses employ the use of a jack which bears down directly onto the top of the pile to be driven into the ground. These systems are frequently referred to as "jack-in piling systems". These systems are mainly used for underpinning foundations, but owing to their relative complexity, are not competitive with conventional piling systems and so are seldom used in new pile foundation works.

One previously used jack piling apparatus involves inserting a jack between the foundations to be under-pinned and the top of the pile to be driven into the ground. In this kind of system, the foundations themselves provide the reaction force to the jacking.

According to the present invention, there is provided a pile driving apparatus comprising: jack means for exerting a pile driving force in one direction onto a pile to be driven via transmission means and reaction means for providing a reaction force to the pile driving force wherein the longitudinal axis of the pile lies substantially parallel to but spaced apart from the one direction and the transmission means is configured to transmit the driving force from the one direction to the pile thereby enabling at least a part of the jack means to extend alongside the pile.

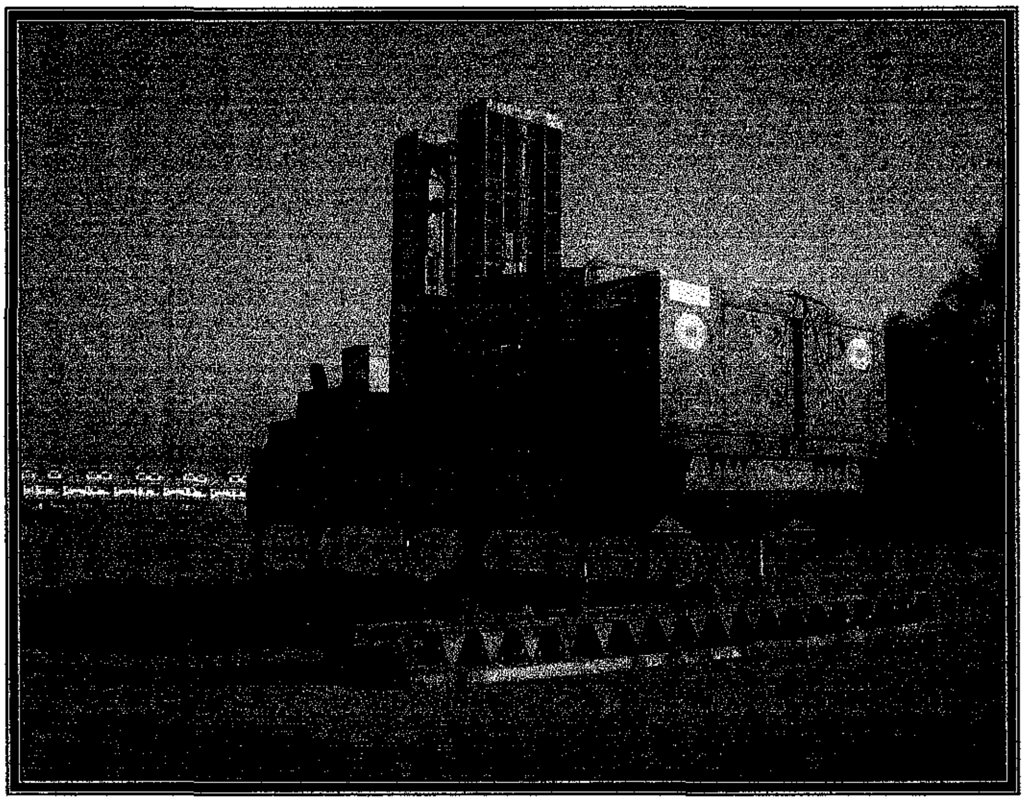


Figure 2.1: Jacked in Pile Equipment Gripped System YZY-200 Model

These systems are subject to many disadvantages. In particular, the setup and positioning of the pile, and mobilization of the Kentledge or ballast to provide the reaction is slow. Generally, a hydraulic jack is used, but is restricted to shorter strokes. This means that extensive use of dolly sections is required, at least six times to jack down one section of the pile. Moreover short and stout pile sections must be used, which means that the apparatus is only really suitable for larger bearing capacity piles (such as 40 tons above working load). These systems are also disadvantageous in that the extension pile procedure is slow, and the joining of consecutive piles together, frequently done by welding, is inefficient.

The method statement for Jack-In-Piles is provided in the Appendix A.

2.0.2 Hydraulic Hammer

A hydraulic hammer is a modern type of piling hammer used in place of diesel and air hammers for driving steel pipe, precast concrete, and timber piles. Hydraulic hammers are more environmentally acceptable than the older, less efficient, hammers as they generate less noise and pollutants.

Hydraulic pile hammer was developed for solving pollution problems as a high noise level and exhaust gas spattering pollution of diesel pile hammers. Hydraulic pile hammer is operated through a hydraulic power pack or a hydraulic power take-off from the base machine. It is classified by the weight of ram. Example is NH70 where the ram weight is 7.0 ton.

Figure 2.2: Hydraulic Hammer Junttan 7.0 ton

The latest development in piling is that both the size and the approved constructional loads of the driven piles have increase. In that more efficiency is required from the piling equipment to meet today's requirements. Some series of hydraulic impact hammers provide the maximum energy for the most demanding work sites.

Due to today's strict environmental regulations the use of diesel hammers has been limited in many countries. More and more diesel hammers are replaced with the latest high tech hydraulic impact hammers.

The method statement for pile driving is provided in the Appendix A.

2.1 SITE INVESTIGATION

2.1.1 Introduction

This data was obtained from the Soil Investigation Report done by the Kumpulan IKRAM Sdn Bhd according to the site visit to determine the pile foundation for the construction of 'Kompleks Pentadbiran Dan Pusat Transit Kesihatan Jabatan Hal Ehwal Orang Asli Sungai Siput , Perak Darul Ridzuan'.

The process in preparing the pile foundation was done according to the soil investigation results at the site and in lab which was made by IKRAM Utara.

These following tests have been carried out at the site:

1. 8 numbers deep boring test until reaches the maximum depth of 45m below the ground surface.
2. 46 numbers JKR Probe until reaches the maximum depth of 15m.

2.1.2 Deep Boring

Deep Boring test was done by the Rotary Wash Boring, Rotary Core Drilling and Continuous Sampling or any combination of these. This Deep Boring is done to explore the soil underground. The boreholes were drilled by the trained operator under the supervision of technician according to rules and specification given.

These machines are suitable for sampling, in-situ tests and core drilling as required in the standard. NW Casing of 87.5mm diameter is used in boring test to avoid wall sliding in the borehole. The deep boring log data is enclosed in Appendix B.

2.1.3 Analysis of Test Report

From the overall results of the Site Investigation Report, the soil profile for this type of soil conditions are mixed zone where hard layer was found at different depth which is from 16m until 42m. The soil type of this area is consists of silty sand that mixed with the gravel. The strength of the soil is gradually increasing with respect to depth.

For BH1, BH3, BH4 and BH 6, the strength of the soil is very low from the ground surface until 10m depth. At BH3 and BH4, the probability of having boulder (cannot be determined through deep boring test) was found at the depth of 15m and 27m. Layers of gravel was found at various depth which such as 42m at BH1, 30m at BH3, and 41m at BH6.

For BH2, BH5, BH7 and BH8, the depth is quite shallow compared with the previous four boreholes. Top layer of the soil showing a low strength of soil with the SPT value less than 6. Gravel layers were found at 21m for BH1, 16m for BH5, 15m for BH7 and 16m for BH8.

Base layer of the soil is different from one borehole point to another point which results in high probability that the pile would set at different depths. (2002 Laporan Penyiasatan Tapak dan Syor Asas Bangunan, Kumpulan IKRAM Sdn Bhd)

2.2 TYPES OF PILE

2.2.1 Classification of Piles

The British Standard Code of Practice for Foundations (BS 8004) places piles in three categories. These are as follows:

2.2.1.1 Large displacement piles

Include solid-section piles or hollow-section piles with a closed end, which are driven or jacked into the ground and thus displace the soil. All types of driven and cast-in-place piles come into this category.

2.2.1.2 Small displacement piles

Driven or jacked into the ground but have a relatively small cross-sectional area. They include rolled steel H- or I-sections and pipe or box sections driven with an open end such that the soil enters the hollow section. Where these pile types plug with soil during driving they become large displacement types.

2.2.1.3 Replacement piles

Formed by removing the soil first by boring using a wide range of drilling techniques. Concrete may be placed into an unlined or lined hole or the lining may be withdrawn as the concrete is placed. Preformed elements of timber, concrete, or steel may be placed in drilled holes. Types of piles in each of these categories are listed as follows:

Large displacement Piles (driven types)

1. Timber (round or square section, jointed or continuous)
2. Precast concrete (solid or tubular section in continuous or jointed units)
3. Prestressed concrete (solid or tubular section)

4. Steel tube (driven with closed end)
5. Steel box (driven with closed end)
6. Fluted and tapered steel tube
7. Jacked-down steel tube with closed end
8. Jacked-down solid concrete cylinder

Large displacement Piles (driven and cast-in-place types)

1. Steel tube driven and withdrawn after placing concrete
2. Precast concrete shell filled with concrete
3. Thin-walled steel shell driven by withdrawable mandrel and then filled with concrete

Small-displacement Piles

1. Precast concrete (tubular section driven with open end)
2. Prestressed concrete (tubular section driven with open end)
3. Steel H-section
4. Steel tube section (driven with open end and soil removed as required)
5. Steel box section (driven with open end and soil removed as required)

Replacement Piles

1. Concrete placed in hole drilled by rotary auger, baling, grabbing , airlift or reverse-circulation methods (bored and cast-in-place)
2. Tubes placed in hole drilled as above and filled with concrete as necessary
3. Precast concrete units placed in drilled hole
4. Cement mortar or concrete injected into drilled hole
5. Steel sections placed in drilled hole
6. Steel tube drilled down

Composite Piles

Numerous types of piles of composite construction may be formed by combining units in each of the above categories or by adopting combinations of piles in more than one category. Thus composite piles of a displacement type can be formed by jointing a timber section to a precast concrete section, or a precast concrete pile can have H-section jointed to its lower extremity. Composite piles consisting of more than one type can be formed by driving a steel or precast concrete unit at the base of a drilled hole, or by driving a tube and then drilling out the soil and extending the drill hole to form a bored and cast-in-place pile.

2.2.2 Selection of Pile Type

The selection of the appropriate type of pile from any of the above categories depends on the following three principle factors (Tomlinson M.J., 1994):

- The location and type of structure
- The ground condition
- Durability

2.2.2.1 Marine

Considering the first factor, some form of displacement pile is the first choice for a marine structure. A solid precast or prestressed concrete pile can be used in fairly shallow water but in deep water a solid pile becomes too heavy to handle and either a steel tubular pile or a tubular precast concrete pile is used. Steel tubular piles are preferred to H-sections for exposed marine conditions because of the smaller drag forces from waves and currents. Timber piles are used for temporary works in fairly shallow water. Bored and cast-in-place piles would not be considered for any marine or river structure unless used in a composite form of construction where extending the penetration depth of a tubular pile driven through water and soft soil to a firm stratum.

2.2.2.2 Land

Piling for a structure on land is open to a wide choice in any of the three categories. Bored and cast-in-place piles are the cheapest type where unlined or partly-lined holes can be drilled by rotary auger. These piles can be drilled in very large diameters and provided with enlarged or grout-injected bases and suitable to withstand high working loads. Augered piles are also suitable where it is desired to avoid ground heave, noise and vibration. Driven and cast-in-place piles are economical for land structures where light or moderate loads are to be carried but the ground heave, noise and vibration associated with these types may make them unsuitable for urban areas where stringent noise regulations are enforced. Timber piles are suitable for light to moderate loadings in countries where timber is easily obtained. Steel or precast concrete driven piles are not as economical as driven or bored and cast-in-place piles for land structures.

The second factor, *ground conditions* influences the material forming the pile and the method of installation. Firm to stiff cohesive soils favor the augered bored pile but augering without support of the borehole by a bentonite slurry cannot be performed in very soft clays or in loose soils for which driven or driven-and-cast-in-place piles would be suitable. Piles with enlarged bases formed by auger drilling can be installed only in firm to stiff or hard cohesive soils or in weak rocks. Driven and driven-and-cast-in-place piles cannot be used in ground containing boulders or other obstructions. These piles also cannot be used in soils subject to ground heave.

Driven-and-cast-in-place piles which employ a withdrawable tube cannot be used for very deep penetrations because of the limitations of jointing and pulling out the driving tube. For such conditions either a driven pile or a mandrel-driven thin-walled shell pile would be suitable. For hard driving conditions such as boulder clays or gravelly soils, a thick-walled steel tubular pile or a steel H-section can withstand heavier driving than a precast concrete pile of solid or tubular section. Thin steel shell piles are liable to tearing when being driven through soils containing boulders or similar obstructions.

The third factor, *durability* affects the choice of material for a pile. Although timber piles are cheap they are liable to decay above ground-water level and in marine structures they suffer damage by destructive mollusk-type organisms. Precast concrete piles do not suffer corrosion in saline water and rich well-compacted concrete can withstand attack from quite high concentrations of sulphates in soils and ground waters. Cast-in-place concrete piles are not so resistant to aggressive substances because of difficulties in ensuring complete compaction of the concrete. Steel piles can have a long life in ordinary soil conditions if they are completely embedded in undisturbed soil but the portions of a pile exposed to sea water or to disturbed soil must be protected against corrosion.

2.2.2.3 Cost

Having selected a certain types of pile as being suitable for the location and type of structures, for the ground conditions at the site, and for the requirements of durability, the final choice is then made on the basis of cost. However, the total cost of a piled foundation is not simply the quoted price per metre run of piling or cost per pile per kN or working load carried. The most important consideration is the overall cost of the foundation work including the main contractor's costs and overheads.

2.3 BEARING CAPACITY OF PILES

2.3.1 Ultimate Bearing Capacity

The ultimate bearing capacity of a pile used in design may be one three values: The **maximum load Q_{max}**, at which further penetration occurs without the load increasing. A **calculated value Q_f** given by the sum of the end-bearing and shaft resistances; or the load at which a **settlement of 0.1 diameter** occurs (when Q_{max} is not clear).

The **ultimate bearing capacity** (q_f) is the value of bearing stress which causes a sudden catastrophic settlement of the foundation (due to shear failure).

The **allowable bearing capacity** (q_a) is the maximum bearing stress that can be applied to the foundation such that it is safe against instability due to shear failure **and** the maximum tolerable settlement is not exceeded. The allowable bearing capacity is normally calculated from the ultimate bearing capacity using a factor of safety (F_s).

For large-diameter piles, settlement can be large, therefore a safety factor of 2-2.5 is usually used on the working load. A pile loaded axially will carry the load:

- partly by shear stresses (τ_s) generated along the shaft of the pile and
- partly by normal stresses (q_b) generated at the base.

The ultimate capacity Q_f of a pile is equal to the base capacity Q_b plus the shaft capacity Q_s.

$$Q_f = Q_b + Q_s = A_b \cdot q_b + \Sigma(A_s \cdot \tau_s) \qquad (2.1)$$

where A_b is the area of the base and A_s is the surface area of the shaft within a soil layer.

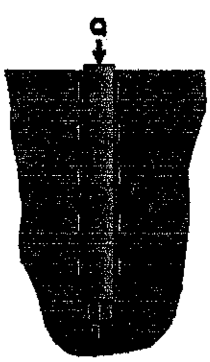


Figure 2.3: Load acted on pile resist by normal and shear stresses

Full shaft capacity is mobilized at much smaller displacements than those related to full base resistance. This is important when determining the settlement response of a pile. The same overall bearing capacity may be achieved with a variety of combinations of pile diameter and length. However, a long slender pile may be shown to be more efficient than a short stubby pile. Longer piles generate a larger proportion of their full capacity by skin friction and so their full capacity can be mobilized at much lower settlements.

The proportions of capacity contributed by skin friction and end bearing do not just depend on the geometry of the pile. The type of construction and the sequence of soil layers are important factors.

2.3.2 Driven piles in non-cohesive soils

Driving a pile has different effects on the soil surrounding it depending on the relative density of the soil. In loose soils, the soil is compacted, forming a depression in the ground around the pile. In dense soils, any further compaction is small, and the soil is displaced upward causing ground heave. In loose soils, driving is preferable to boring since compaction increases the end-bearing capacity.

In non-cohesive soils, skin friction is low because a low friction 'shell' forms around the pile. Tapered piles overcome this problem since the soil is recompacted on each blow and this gap cannot develop.

Pile capacity can be calculated using soil properties obtained from **standard penetration tests** or **cone penetration tests**. The ultimate load must then be divided by a factor of safety to obtain a working load. This factor of safety depends on the maximum tolerable settlement, which in turn depends on both the pile diameter and soil compressibility. For example, a safety factor of 2.5 will usually ensure a pile of diameter less than 600mm in a non-cohesive soil will not settle by more than 15mm.

2.3.3 Ultimate Pile Capacity

The ultimate carrying capacity of a pile is:

$$Q_f = Q_b + Q_s \tag{2.2}$$

The **base resistance**, Q_b can be found from Terzaghi's equation for bearing capacity,

$$q_f = 1.3\ c\ N_c + q_o\ N_q + 0.4\ \gamma\ B\ N_\gamma \tag{2.3}$$

The $0.4\ \gamma\ B\ N_\gamma$ term may be ignored, since the diameter is considerably less than the depth of the pile.

The $1.3\ c\ N_c$ term is zero, since the soil is non-cohesive.

The net unit base resistance is therefore

$$q_{nf} = q_f - q_o = q_o\ (N_q - 1) \tag{2.4}$$

and the **net total base resistance** is

$$Q_b = q_o\ (N_q - 1)\ A_b \tag{2.5}$$

The ultimate unit **skin friction** (shaft) resistance can be found from

$$q_s = K_s\ .\sigma'_v\ .\tan\delta \tag{2.6}$$

where;

σ'_v = average vertical effective stress in a given layer

δ = angle of wall friction, based on pile material and ϕ'

K_s = earth pressure coefficient

Therefore, the **total skin friction resistance** is given by the sum of the layer resistances:

$$Q_s = \Sigma(Ks\ .\sigma'_v\ .\tan\delta\ .A_s) \tag{2.7}$$

The self-weight of the pile may be ignored, since the weight of the concrete is almost equal to the weight of the soil displaced.

Therefore, the **ultimate pile capacity** is:

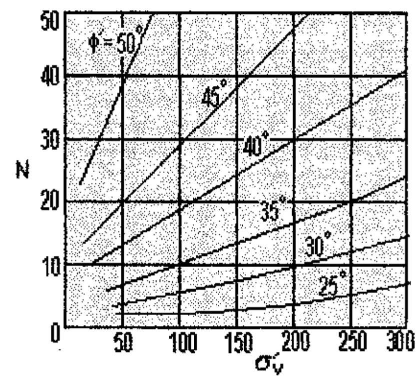
$$Q_f = A_b\, q_o\, N_q + \Sigma(Ks\, .\sigma'_v\, .\tan\delta\, .A_s) \qquad (2.8)$$

2.3.4 Standard Penetration Test

The standard penetration test is a simple in-situ test in which the N-value is the number of blows taken to drive a 50mm diameter bar 300mm into the base of a bore hole. Schmertmann (1975) has correlated N-values obtained from SPT tests against effective overburden stress as shown in the figure.

Figure 2.4: N-values against effective overburden stress (Schmertmann, 1975)

e.g. depth of soil = 5m, depth of water = 4m, unit weight of soil = 20kN/m³, σ'_v = 5m x 20kN/m³ - 4m x 9.81kN/m³ ≈ 60 kN/m²



Once a value for ϕ' has been estimated, bearing capacity factors can be determined and used in the usual way. Meyerhof (1976) produced correlations between base and frictional resistances and N-values. It is recommended that N-values first be normalized with respect to effective overburden stress:

$$\text{Normalized } \mathbf{N} = \mathbf{N_{measured}} \times 0.77 \log(1920/\sigma'_v) \qquad (2.9)$$

Table 2.1: Base, frictional resistance and N-values correlation (Meyerhof, 1976).

Pile type	Soil type	Ultimate base resistance q_b (kPa)	Ultimate shaft resistance q_s (kPa)
Driven	Gravelly sand Sand	40(L/d) N but < 400 N	2 N_{avg}
	Sandy silt Silt	20(L/d) N but < 300 N	
Bored	Gravel and sands	13(L/d) N but < 300 N	N_{avg}
	Sandy silt Silt	13(L/d) N but < 300 N	

Where;
L = embedded length
d = shaft diameter
N_{avg} = average value along shaft

2.3.5 Cone Penetration Test

End-bearing resistance

The end-bearing capacity of the pile is assumed to be equal to the unit cone resistance (q_c). However, due to normally occurring variations in measured cone resistance, Van der Veen's averaging method is used:

q_b = average cone resistance calculated over a depth equal to three pile diameters above to one pile diameter below the base level of the pile.

Shaft resistance

The skin friction can also be calculated from the cone penetration test from values of local side friction or from the cone resistance value using an empirical relationship:

At a given depth, $q_s = S_p . q_c$ (2.10)

where;

S_p = a coefficient dependent on the type of pile

Table 2.2: Values of S_p

Type of pile	S_p
Solid timber Pre-cast concrete Solid steel driven	0.005 - 0.012
Open-ended steel	0.003 - 0.008

2.3.6 Bored piles in non-cohesive soils

The design process for bored piles in granular soils is essentially the same as that for driven piles. It must be assumed that boring loosens the soil and therefore, however dense the soil, the value of the angle of friction used for calculating N_q values for end bearing and δ values for skin friction must be those assumed for loose soil. However, if rotary drilling is carried out under a bentonite slurry ϕ' can be taken as that for the undisturbed soil.

2.3.7 Driven piles in cohesive soils

Driving piles into clays alters the physical characteristics of the soil. In soft clays, driving piles results in an increase in pore water pressure, causing a reduction in effective stress; a degree of ground heave also occurs. As the pore water pressure dissipates with time and the ground subsides, the effective stress in the soil will increase. The increase in σ'_v leads to an increase in the bearing capacity of the pile with time. In most cases, 75% of the ultimate bearing capacity is achieved within 30 days of driving.

For piles driven into stiff clays, a little consolidation takes place, the soil cracks and is heaved up. Lateral vibration of the shaft from each blow of the hammer forms an enlarged hole, which can then fill with groundwater or extruded pore water. This, and 'strain softening', which occurs due to the large strains in the clay as the pile is advanced, lead to a considerable reduction in skin friction compared with the undisturbed shear strength (s_u) of the clay. To account for this in design calculations an adhesion factor, α, is introduced. Values of α can be found from empirical data previously recorded. A maximum value (for stiff clays) of 0.45 is recommended.

The ultimate bearing capacity Q_f of a driven pile in cohesive soil can be calculated from:

$$Q_f = Q_b + Q_s \tag{2.11}$$

where the skin friction term is a summation of layer resistance

$$Q_s = \Sigma(\ \alpha\ .s_u(avg)\ .A_s) \tag{2.12}$$

and the end bearing term is

$$Q_b = s_u\ .N_c\ .A_b \tag{2.13}$$

N_c = 9.0 for clays and silty clays.

2.3.8 Bored piles in cohesive soils

Following research into bored cast-in-place piles in London clay, calculation of the ultimate bearing capacity for bored piles can be done the same way as for driven piles. The adhesion factor should be taken as 0.45. It is thought that only half the undisturbed shear strength is mobilized by the pile due to the combined effect of swelling, and hence softening, of the clay in the walls of the borehole. Softening results from seepage of water from fissures in the clay and from the un-set concrete, and also from 'work softening' during the boring operation.

The mobilization of full end-bearing capacity by large-diameter piles requires much larger displacements than are required to mobilize full skin-friction, and therefore safety factors of 2.5 to 3.0 may be required to avoid excessive settlement at working load.

2.3.9 Carrying capacity of piles in layered soil

When a pile extends through a number of different layers of soil with different properties, these have to be taken into account when calculating the ultimate carrying capacity of the pile. The skin friction capacity is calculated by simply summing the amounts of resistance each layer exerts on the pile. The end bearing capacity is calculated just in the layer where the pile toe terminates. If the pile toe terminates in a layer of dense sand or stiff clay overlying a layer of soft clay or loose sand there is a danger of it punching through to the weaker layer. To account for this, Meyerhof's equation is used.

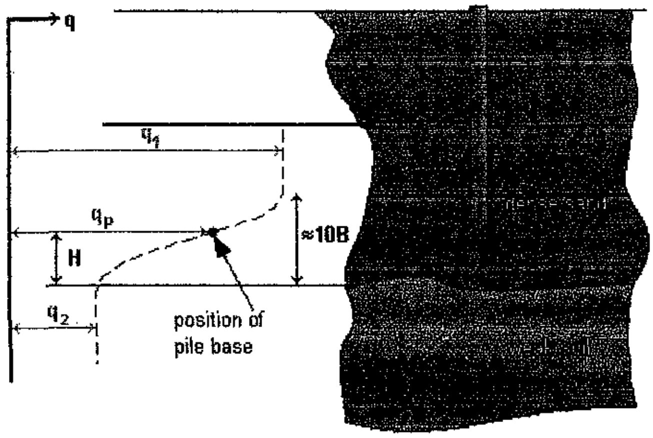


Figure 2.5: Base resistance at the pile toe

The base resistance at the pile toe is:

$$q_p = q_2 + (q_1 - q_2)H / 10B \qquad (2.14)$$

where B is the diameter of the pile, H is the thickness between the base of the pile and the top of the weaker layer, q_2 is the ultimate base resistance in the weak layer, q_1 is the ultimate base resistance in the strong layer.

2.4 PILE DRIVING SYSTEM

2.4.0 Introduction

There are a variety of pile driving hammers for the Contractor to choose from. Each has its own inherent advantages and disadvantages and the Contractor's selection is often dependent upon the project needs and what they have available or can readily get economically. Hammers advance piles with two different techniques, impact or vibration.

- *Impact Hammers* are hammers that advance the pile through "hitting" it with a ram, hence the name impact. Impact hammers may be lifted manually or automatically by steam, air or diesel, and may also be single or double-acting.

These hammers are sized by the maximum "rated energy" (foot-pounds) theoretically contained as kinetic energy in the ram just before impact. This rated energy is not necessarily absorbed by the pile.

- *Vibratory Hammers* advance the pile through vibration. Vibratory hammers are electrically or hydraulically powered, usually have a variable operating frequency range (vibrations per minute), and are generally rated by "eccentric moment" and "driving force" (tons) for a specified frequency.

2.4.1 Impact Hammers

2.4.1.1 Drop Hammers

The drop hammer is the simplest and oldest type of impact hammer. It consists of a guided weight (ram) that is lifted to a specified height (stroke) by a hoist line and released. Drop hammers are operated by raising the ram with the crane and then, at the desired height as judged by the crane operator, dropping the ram by allowing the winch to spool. Some of the available energy is used as kinetic energy in the winch and is not actually available to drive the pile. Drop hammers can damage the pile head if driving stresses are not controlled by limiting the stroke distance and supplying a cushion material (hammer cushion) between the anvils, which sits on the pile head, and ram. Theoretical or rated hammer energy is the product of the stroke times the ram weight. To arrive at actual energy delivered to the pile, proper allowances must be made for the effects of friction and interaction of the drive cap.

2.4.1.2 Open End Diesel

Hammer efficiency is a function of pile resistance and therefore the harder the driving the greater the efficiency. Diesel hammers can be equipped to permit the amount of fuel injected into the cylinder to be varied. This feature can be an asset when initially seating concrete pile. The energy transmitted to the pile can be controlled by limiting the amount of fuel supplied to the hammer, thereby yielding some control on the critical tensile stresses induced by driving. Diesel hammers combine medium ram weights and high impact velocities. The open-end diesel hammer requires a cushion material (hammer cushion) between the anvil and the helmet. Operating speeds are somewhat slower than the single-acting air-stem hammer ranging from 40 to 50 blows per minute. As the driving resistance increases, the stroke increases and the operating speed decreases.

Fuel is introduced into the cylinder, the ram drops (gravity) setting off an explosion, which thrusts the ram up and the process is repeated over and over. These hammers must be equipped with at least three fuel settings that permit ram height adjustment, which in turn, permits adjustment of the hammer energy used during driving.

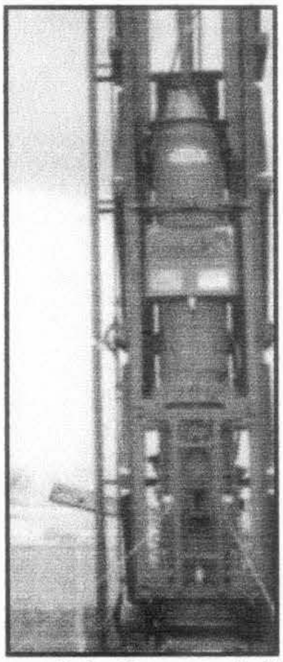


Figure 2.6: Open end diesel

Advantages:

- Very simple; dependable
- No additional support equipment required
- Lightest net weight per ft.lb. of energy
- Readily available

This picture shows some of the parts of the open end diesel hammer.

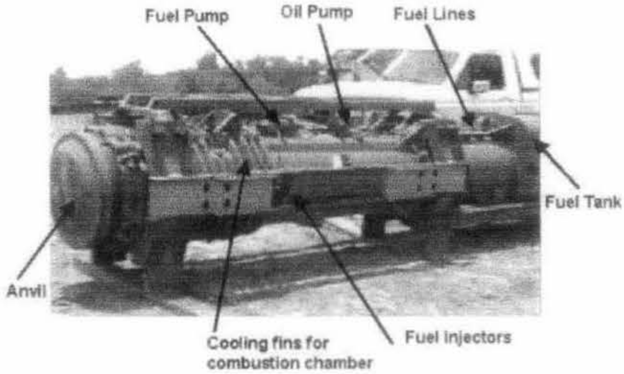


Figure 2.7: Components of open end diesel hammer

2.4.1.3 Closed End Diesel

These impact hammers operate differently from the open end in that the top is enclosed and the pressure build up in the bounce pressure chamber literally throws the ram back down. A gauge is attached to the bounce chamber to enable recording of the chamber pressure for inspection purposes, as the ram is not visible for determining stroke height. These are losing popularity due to their low efficiency rating and the difficulties in spotting operation problems.

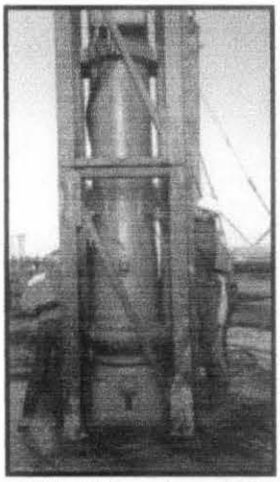


Figure 2.8: Closed end diesel

Advantages:

- No additional equipment required
- Drives piles faster
- Lightweight

2.4.1.4 Single-Acting Steam or Air Hammers

The single-acting hammer has been in use for many years, has been extremely well developed and can be used for most any pile-soil combination. This hammer type utilizes pressure from steam or compressed air to raise the ram and then automatically releases the pressure allowing the ram to fall freely and strike the drive cap.

Refer to Chapter 3 of Pile Selection Methodology.

2.4.1.5 Double-Acting Steam or Air Hammers

Double-acting and differential acting hammers utilize pressure from steam or compressed air to raise the ram in a manner similar to a single-acting hammer. The steam or compressed air is also utilized to supply additional energy to the ram on the downward part of the stroke.

Refer to Chapter 3 of Pile Selection Methodology.

Air hammers are the second most common hammers used. Steam hammers have all but disappeared from use. Both are impact hammers and unlike the diesel hammers, much cleaner while operating. However, while cleaner than diesel, it requires support equipment, such as a compressor to produce the air pressure. They are comparatively much heavier than the diesel hammers.

The air hammer is equipped with a slide bar, which provides for adjusting to either of two settings, full stroke or half stroke. Once set, the hammer delivers a constant stroke height on each blow, unlike the open end diesel.

Figure 2.9: Air/steam hammers

Advantages:

- Same stroke height for each impact
- Consistent operation rate
- Low impact velocity
- More efficient than diesel
- Cleaner exhaust than diesel

2.4.1.6 Hydraulic Hammers

The hydraulic hammers are probably the third most common and are impact hammers. The hammer energy on these can be controlled with precise pressure settings. In fact, rather than recording stroke height during driving, the Inspector records the pressure introduced on pressure gauges, on the hydraulic pump. The Inspector can also record stroke height by marking increments on the slide bar.

Like the air/steam hammers, these also require support equipment. A big drawback to these hammers is the need for a dedicated person to operate the hydraulic power unit and the need for experts when repairs are required.

Figure 2.10: Hydraulic hammers

Advantages:

- Controllable variable stroke
- High efficiency blow
- Low impact velocity
- Light weight
- Clean running, quieter

2.4.2 Vibratory Hammers

Vibratory hammers are available in high, medium, and low frequency ranges. High-frequency hammers are commonly known as "sonic hammers." The sonic hammer has had limited success and is seldom used. Vibratory hammers operate by utilizing electric or hydraulic motors to rotate eccentric weights and produce vertical vibrations. The vibrations reduce frictional grip of the soil and also permit the soil at the tip to be displaced. Additional biased static loads can often be provided by dead weight to enhance drivability. Leads are not required for use of a vibratory hammer but are normally required for desired driving accuracy. It is important that a rigid connection be maintained between the hammer and the pile, usually by means of a mechanical clamp, and a back-up system may be required to prevent release of the clamp in the event of a power failure.

Unlike the other hammers, these operate by vibrating piling into the ground. There is no requirement in the specifications relating to the inspection of these hammers. However, these hammers are typically used to install sheet piles. In the case of steel piles, the final 15 feet of driving for bearing must be performed with an impact hammer.

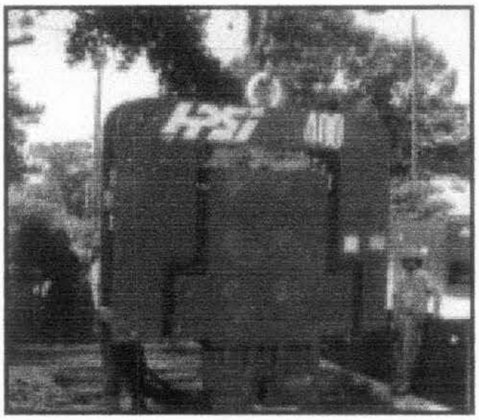


Figure 2.11: Vibratory hammers

2.4.3 Noise

The entire matter of allowable noise disturbance is subjective and should be carefully evaluated before seeking special methods to reduce its effect. Pile driving can generate high noise levels. In many cases, proper explanation of needs, development of alternative methods and job site arrangements, and/or judicious selection of hours of operation can eliminate confrontation.

Refer to Chapter 3 of Pile Selection Methodology.

2.4.4 Effects of Vibration

The vibration due to pile driving shall be considered if it can cause damaged to adjacent structure.

Refer to Chapter 3 of Pile Selection Methodology.

2.4.5 Driving Resistance

It is inevitable that the resistance experienced by the hammer pile system will vary as the soil varies on the jobsite and as the pile is being driven.

Refer to Chapter 3 of Pile Selection Methodology.

2.5 COMMERCIAL FACTORS

The Government may use either Government-owned equipment or rent pile driving equipment from a commercial source. First consideration should be given to the use of Government owned equipment, and a thorough search should be carried out to ascertain if such equipment is available. If suitable equipment cannot be located as a result of this investigation, then select rental equipment on the basis of the other criteria.

Refer to Chapter 3 of Pile Selection Methodology.

CHAPTER 3
METHODOLOGY

3.1 Research Work

For the first few weeks after the student received their title from supervisor, some research work regarding the topic will be done including data gathering.

3.2 Literature Review

Literature review was done according to previous research or thesis done by other person in order to collect as much information as possible in determining the scope of project. The topics covered about several types of piling machine. The study about site condition that suits what type of pile machine to be used was done in basis according to the Soil Investigation Report done by the Kumpulan IKRAM Sdn Bhd. A study on the Deep Boring Test is vital to relate it to the bearing capacity of soil.

3.3 Conceptual Study

Conceptual study was done in order to have the technical data and information regarding the apparatuses used in piling. Data gathering about all types of piling equipment and piles were done as part of producing the selection guide in determining the best option of pile driving system. Other parts that were discussed thoroughly in this report are the types of pile, bearing capacity and pile driving system.

3.4 Hazard Analysis

For this project, no lab required as it is a research project where the objective is to come out with a pile selection methodology. The project was done inside student's room in front of the computer all the time. Even though it only deals with the computer not machineries, there were still hazards occurred during completion of the project. Below here were some of the hazards:

a) Chair

   Sitting for long period of time can cause lower back pain caused by increase pressure. Sitting also hard on the legs and feet as the gravity tends to pool blood and create a sluggish return to the heart. In fact, the chair in the room is not an adjustable one.

b) Desk

   The desk in the room also is not an adjustable one. Different height of people need different adjustment but unfortunately standard furniture cannot accommodate everyone's need.

c) Work area

   Work area provided was not large enough to accommodate stuffs. It was not easy to move around with full range of motions.

d) Computing

   Laptop is not recommended as a primary computer but there weren't many choices. The students tend to stare at monitor more than 12 hours a day and it caused eye and neck strain. Furthermore, the laptop became hot with continuous usage and this can affect the hard disk.

e) Lighting

Lighting is a major contributing factor in visual discomforts. The blinds provided are in blue color and direct sunlight caused glaring and blurred to the eyes.

Steps to overcome hazards:

a) Chair

- Practice 'dynamic sitting', do not stay in one static position for a long time
- Sit upright in the chair with the low back against the backrest
- Thighs should be parallel to the floor and knees at about the same level as the hips
- Back of knees should not come in direct contact with the edge of the seat pan. There should be 2-4 inches between the edge of the seat and the back of the knee

b) Desk

- The work surface should have a matte finish to minimize glare or reflections
- The area underneath the desk should always be clean/uncluttered to accommodate the user's legs and allow for stretching

c) Work area

- Place the items use most frequently directly in front
- Avoid overcrowding computer work areas

d) Computing

- Maintain a comfortable viewing distance from screen; about 18-30 inches
- Attach an external mouse instead of using the small constricted touchpad or trackball
- Clean the screen regularly using appropriate antistatic cleaning materials
- Use notebook cooling pad to reduce the heat produce by the hard disk inside the laptop

e) Lighting

- Close blinds to reduce glare
- Place monitor at 90 degree angle to windows (where possible)

CHAPTER 4
RESULTS AND DISCUSSION

The manual of the Pile Selection Methodology is represented in Appendix. For this manual, ratings for each of the factor were done in order to prioritize what factor that is more important than others. For instance, grade 1 represents high emphasis, grade 2 represents medium emphasis and grade 3 represents low emphasis. Note that the ratings did not affect the selection procedure in determining types of pile.

Factors that govern pile selection	Ratings		
	High emphasis (1)	Medium emphasis (2)	Low emphasis (3)
TYPES OF PILE			
• Classification of pile	●	○	○
• Selection of pile type	●	○	○
• Pile identification	○	●	○
• Loading	○	●	○
• Specification of piles	○	●	○
PILE DRIVING SYSYTEM			
• Impact hammers	●	○	○
• Vibratory driver	●	○	○
• Equipment selection	●	○	○
• Hammer selection	○	●	○
BEARING CAPACITY			
• Ultimate bearing capacity	○	●	○
• Ultimate pile capacity	○	●	○
SITE INVESTIGATION			
• Subsurface conditions	●	○	○
• Design verification	○	●	○
• construction	○	○	●

For this project, the most important factor that governs the pile selection is the environment of the site. This includes the subsurface conditions as discussed in the manual. Subsurface investigation should be thorough, complete, and span the full range of site investigations. The types of soil in the construction site determine the types of pile to be used. This is where the site investigation report plays as the kick-start in determining the lithology and strength of the soil by calculating the bearing capacity of soil and the pile itself.

After that, all the small factors that contribute to the environment such as the noise and vibration should be considered. Pile driving operations produce considerable noise that may adversely influence the well-being of inhabitants of the area.

Vibrations can damage nearby structures. Structures adjacent to the construction should be monitored to assess their integrity prior to and during construction. Assessment of the integrity of adjacent structures is required prior to construction to determine the initial status of the structures.

Noise can interfere with the quality of life and cause hearing loss to people. High noise levels that are part of an impact hammer pile driving operation can and frequently do prevent installation of driven piles where people can be adversely affected. People within range of damaging noise levels should be protected with safety measures.

The second factor to be considered is the types of pile. A preliminary selection of the pile type may usually be made from a study of the foundation investigations. However, the nature of the structure, type of applied loads, and technical and economic feasibility must be considered in the determination of pile type. A wide range of pile types are available for applications with various soil types and structural requirements.

The third factor is the pile driving equipment. The piles usually installed by either impact hammer or vibratory driver. Results of the exploration program, wave equation analysis, driving of indicator piles with PDA, and pile load tests would assist the design of pile foundation, determine the pile and length to be installed and the driving energy.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The comparison and performance between all types of pile and pile driving equipments were determined in this project. Basically, the selection procedure is for Malaysian practice. The method used to do the project is through the study of the Site Investigation Report especially in Deep Boring Test to relate it to the soil bearing capacity at particular construction site. Different layers or soil profile has different strength or SPT value. The soil might range from very loose sand to hard layer. Then, the conceptual study about pile and pile driving equipment were discussed in the literature review. The environment contributes vital consideration in selecting pile such as the location, lithology, noise and vibration.

The soil type determined the type of pile to be used. The pile should be evaluated in terms of the load capacity and constructability where piles susceptible to damage during hard driving are less likely to penetrate hard strata or gravel and boulder zones. The performance of pile can be described in terms of structural displacements which may be just as harmful to a structure as an actual pile failure. Pile availability to be delivered to site on time also considered as the preliminary evaluation. For final evaluation, selection should be based mainly on relative cost. This evaluation should include the costs of structural or site modifications required to accommodate the foundation type.

The equipment selection based on the types of pile determined at earlier stage. These include commercial factors such as proximity and availability of machines, and also the size of equipment that is suitable for particular pile. This is important in measuring the performance of equipment in finishing the piling work without so many obstacles. Again, the types of pile driving equipment use depended on environment of the construction site.

The pile selection methodology listed out three main factors that govern the pile selection which are the site condition, types of pile and pile driving equipment. This manual is reasonable to be used by contractor for Malaysian practice.

5.2 RECOMMENDATION

This manual should be revised in order to achieve an ideal selection procedure to be used in determining types of pile for different site characteristics that will boost the performance of piling work.

Other factors that should be considered to be put inside the manual are monitoring of pile installation. These include the equipment operation, the pile installation, prevention of pile damage during driving and also the complications.

Case study for types of pile commonly used in Malaysia should be considered in order to have reference if such pile is to be installed. These include the background of study, the analysis of production pile installation, pile test program and also the lessons learned form such case.

The analysis and design of pile foundations should be considered in order to determine the optimum design criteria, the settlement of pile and also the pile group analysis.

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APPENDIX A

1. Method Statement for Pile Driving
2. Method Statement for Jacked In Piles

PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT RANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT, PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR PILE DRIVING

Submitted By :

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Fax : 03-7726 0170

METHOD STATEMENT FOR PILE DRIVING

1.0 SCOPE

This procedure refers only to the installation of the piles indicated. It does not include bored piles and jacked-in piles.

2.0 TYPE OF PILES

2.1 300mm Dia Spun Pile

3.0 LIST OF MANUFACTURERS

The Prestressed Spun Concrete Piles will be supplied by the following reputable manufacturers:

- Industrial Concrete Products Berhad (ICP) — As proposed on 15th February 2007

4.0 EQUIPMENT

4.1 The following types of Hydraulic shall be used:

300mm Dia Spun Pile - 7.0 Ton Hydraulic Hammer

Refer to Attachment 1 for hammer details.

All equipment will be tagged for use. A list of all equipment mobilized will be kept and updated.

4.2 Other Equipment

(a) 25 ton mobile crane
(b) Crusher attachment to hydraulic excavator
(c) mechanical cutter
(d) Pick up
(e) Generator
(f) Air compressor and jack hammers

ANSAH SDN BHD

METHOD STATEMENT FOR PILE DRIVING

5.0 PILE SET CALCULATION

5.1 Hiley Formula will be used to compute the estimated SET for each type of pile:

Hiley formula:

$$SET = AWh / fL \times (W+Pe^2) / (W+P) - C/2$$

Hammer Efficiency	A
Mass of Hammer	W
Drop of Hammer	h
Safety Factor	f
Pile Working Load	L
Total Mass	P
Coefficient of Restitution	e
Temporary Compression	C

5.2 Summary of Sets is attached. Set Calculations detailed with respect to hammer, drop and estimated penetration are given in *Attachment 2*

The actual SET values will be recomputed at site based on the variable parameters of actual pile length installed and the actual temporary compression recorded.

Hammer efficiency will be verified by preliminary PDA tests.

6.0 SITE PREPARATION

The access and working platform shall be prepared to a reasonable level and compacted to the consultants requirement (by others).

Piling work shall commence upon possession of site.

7.0 SETTING OUT

Boundry survey shall be carried upon possession of site based on the pre computation plan available. Setting out plan shall be submitted for checking and approval.

Main Contractor's surveyor will set out the pile positions based on the structure boundary.
Each pile position set out will be marked with a peg before installation.
Locations of initial piles for load testing will be obtained from Engineer or S.O's representative.

METHOD STATEMENT FOR PILE DRIVING

8.0 HANDLING, PITCHING, DRIVING AND EXTENSION

All handling and lifting will be at the designed lifting points and support points.

During pitching and driving the verticality of the pile will be continuously monitored and plumbed to ensure the pile is centrally in line with the pile axis to receive the hammer to prevent pile whip, twist or rotation.

Each pile shall be clearly marked with red ink at 300mm intervals along its length to enable the driving blows to be recorded at every 300mm depth of pile penetration.

The pile will be extended by butt-welding the steel plates on the pile heads. On completion of welding the slag will be chipped off and wire brushed to receive red-oxide paint.

Each pile shall be driven continuously until the specified set and / or depth has been reached. A detail record of the driving resistance over the full length of each pile shall be kept.

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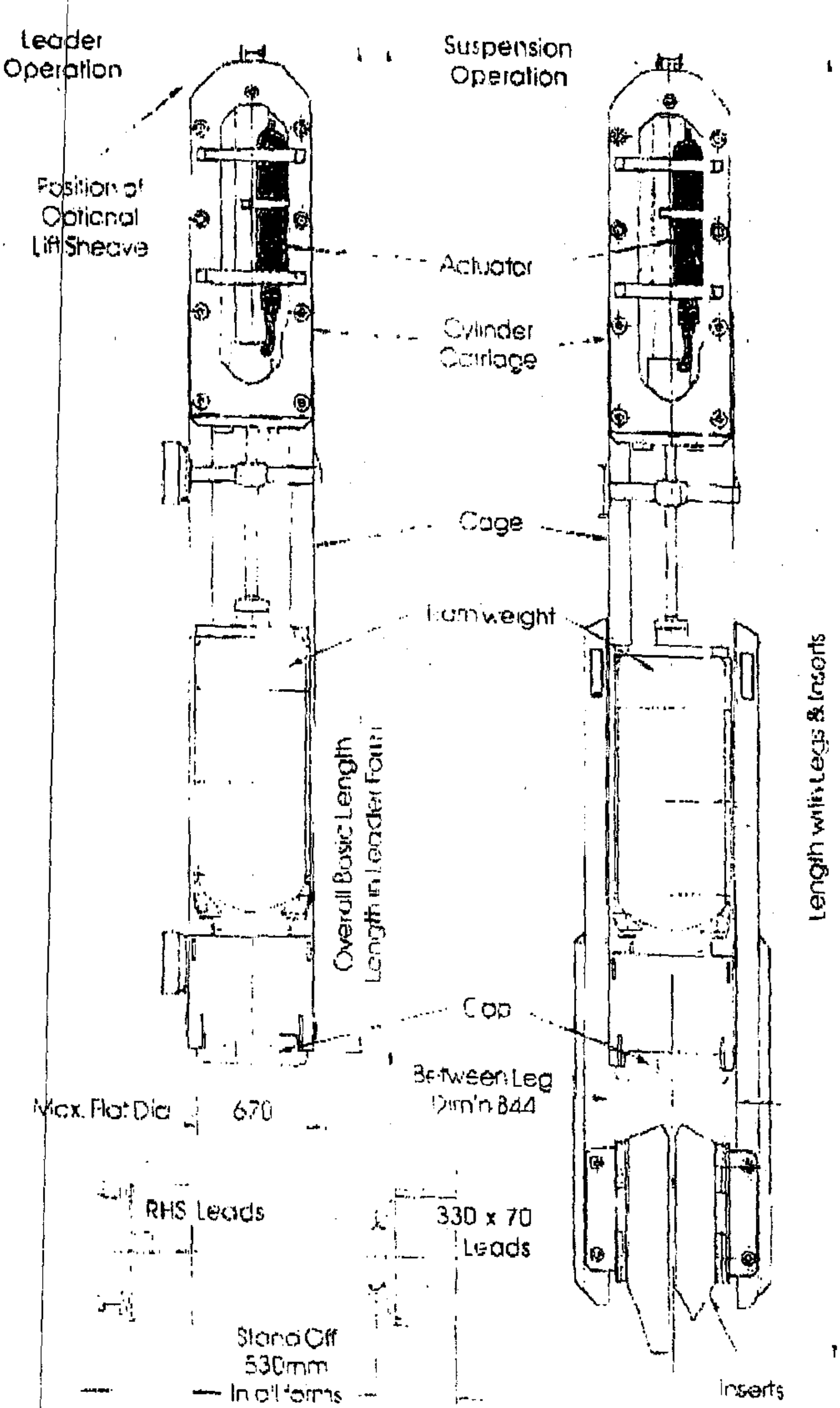
Leader Operation
Suspension Operation
Position of Optional Lift Sheave
Actuator
Cylinder Carriage
Cage
Ram weight
Overall Basic Length
Length in Leader Form
Length with Legs & Inserts
Cap
Between Leg Dim'n 844
Max. Flat Dia 670
RHS Leads
330 x 70 Leads
Stand Off 530mm In all forms
Inserts

Technical Data

357-9 SERIES HAMMERS Hammer Size		HH3	HH5	HH7	HH9
Ram Weight – Standard segmental form (Non-segmental can be supplied to special order)	Tonne lb	3 6610	5 11020	7 15430	9 19835
Ram Stroke	Metre ft	Variable 0.2 to 1.2) (Variable 0.66 to 3.94)			
Maximum Potential Energy	Kgm ft lb	3600 26025	6000 43375	8400 60725	10800 78075
Blow rate at max stroke when powered by BSP Hydropack	bpm	45	40	38	30
Hydraulic oil pressure required	bar psi	160 2350	210 3090	240 3530	265 3900
Hydraulic oil flow rate needed	Lit/min imp gpm	157 34	180 40	180 40	180 40
Basic Hammer Weight	Tonne lb	5.25 11575	7.25 15980	9.25 20390	11.25 24800
Driving Cap Weight (basic flat form)	Tonne lb	0.99 2180	0.99 2180	0.99 2180	0.99 2180
Overall Length Basic Hammer with flat cap	Metre ft	5.20 17.06	5.80 19.02	6.40 21.00	6.40 21.00
Overall Width Basic Hammer	Metre ft	0.76 2.49	0.76 2.49	0.76 2.49	1.25 4.10
Overall Depth Basic Hammer	Metre ft	0.82 2.69	0.82 2.69	0.82 2.69	0.82 2.69
Combined Hose Weight (full of oil)	Kg/Metre lb/ft	10 6.72	10 6.72	10 6.72	10 6.72
Weight of Hammer Assembly (excluding hoses) on Leaders with basic flat Cap	Tonne lb	6.30 13885	8.30 18295	10.30 22700	12.30 27110
Length of Hammer Assembly on Leaders	Metre ft	5.25 17.22	5.85 19.19	6.45 21.15	6.45 21.15
Weight of Hammer Assembly (excluding hoses) Suspended Operation	Tonne lb	7.10 15650	9.10 20065	11.10 24465	13.10 28870
Length of Hammer Assembly in Suspended Operation	Metre ft	7.00 22.96	7.55 24.76	8.10 26.57	8.10 26.57
Length of Pile Engagement in legs & inserts when Driving	Metre ft	1.44 4.72	1.44 4.72	1.44 4.72	1.44 4.72

1.44 figures are subject to variation according to needs dictated by pile

NOISE ENCLOSURE This optional extra increases width to 0.89m 2.92ft and depth to 0.97m 3.18ft. Extra weight is 0.46 tonne 1060lb on leader operation or 0.34 tonne 750 lb on suspended operation.

HYDROPACK FOR 357 SERIES

Dimensions	2.4 metre long 1.1 metre wide 2.3 metre high 7.87 ft long 3.6 ft wide 7.5 ft high
Operating Pressure	260 bar 3830 psi
Variable flow at high output	180 litre/min, 40 imperial gallons/min
Engine power – typical	112 Kw. 150 BHP
Engine (turbocharged diesel)	PERKINS T6 3544 Deutz BF6L913 Volvo TD61A
Fuel Tank Capacity nominal	260 litre, 57 imperial gallons.
Hydraulic Oil Capacity nominal	345 litre, 76 imperial gallons.
Hydropack weight	Dry 2.1 tonne 4630lb Full 2.6 tonne 5730 lb

Offshore 'Zone 2' Power Packs can be built to order. A basic specification can be provided for approval

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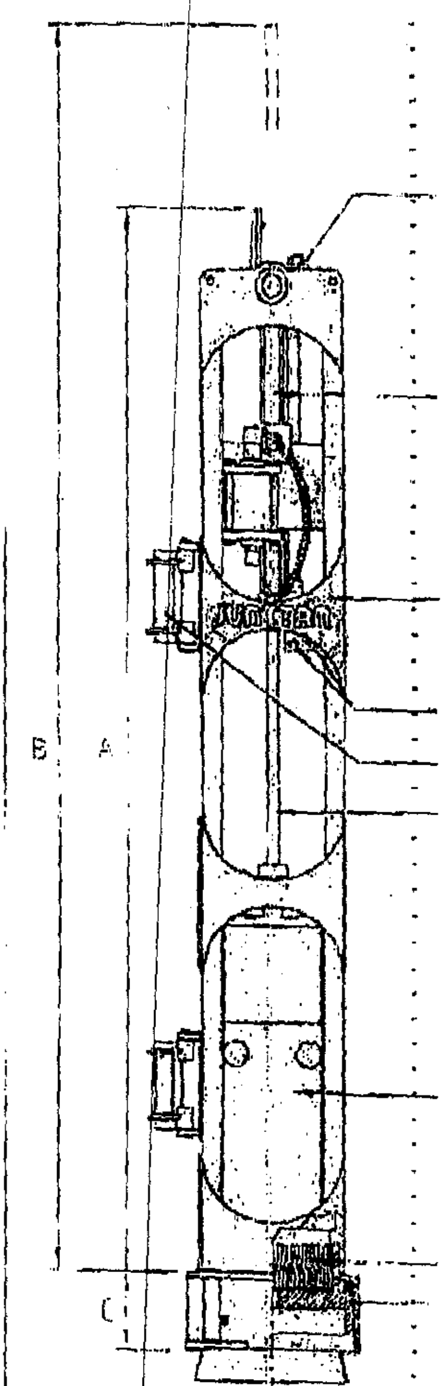
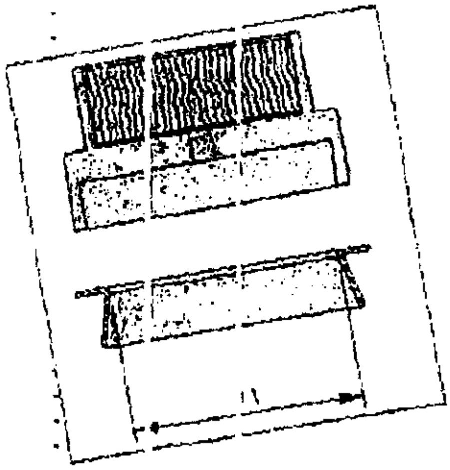
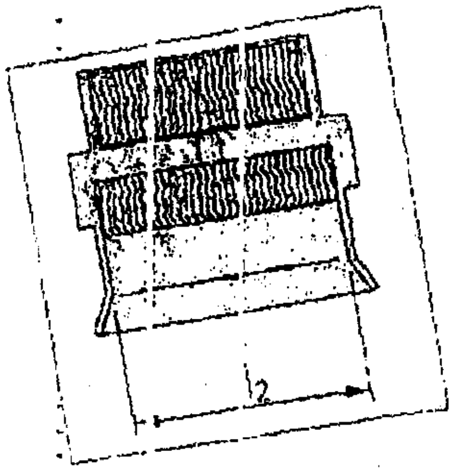
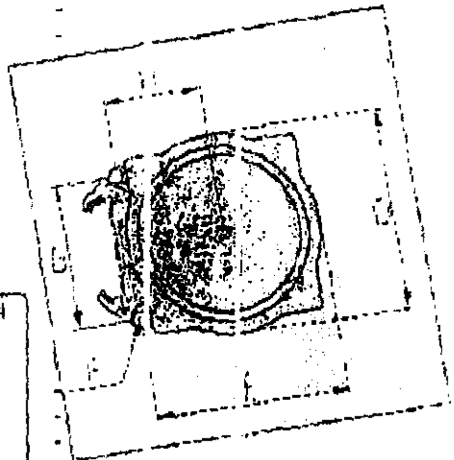




Drive cap type A



Drive cap type B



Cross section J-J

[illegible]	HHK-4	HHK-5	HHK-6	HHK-7	HHK-10	HHK-14
A	4940	5310	5680	6050	5950	6050
B	5900	6270	6640	7010	6915	7915
C	400	400	400	400	460	460
D	745	745	870	870	1300	1300
E	793	793	855	855	1150	1150
F ø	50	50	50	50	50	50
G	604	604	604	604	754	754
H	420	420	420	420	517	517
I1 max	615	615	750	750	900	900
I2 max	580	580	730	730	840	840

JUNTTAN

THE PREMIUM CHOICE WORLDWIDE

Junttan is pioneer in hydraulic piling hammers. First Junttan hydraulic hammers were built already in the end of 1970's. Now Junttan hydraulic hammer operate reliably in all conditions (at temperatures +40 to -30 C°) all over the world.

The extraordinarily versatile Junttan HHK hydraulic hammers are designed for driving all types of piles: pre-cast concrete, steel tube, sheet or profile, and timber.

ADJUSTABLE ENERGY

- Impact energy and blow rate can be easily adjusted according to soil conditions and pile used.

You need only one hammer on your rig for pile driving in both hard and soft soil without breaking pile.

ENVIROMENTAL ADVANTAGES

- Low total weight in relation to blow energy.

- All impact energy concentrates into center of the pile.
- Easy to maintain.
- Frame designed for long life.

ENVIRONMENTAL ADVANTAGES

- low impact noise
- no exhaust gas
- less vibration
- possible to use biodegradable hydraulic oil

EXCEPTIONAL PERFORMANCE

- Thanks to ingenious design of hydraulic system the hammer is simple in structure and extremely reliable. The valve is mounted directly on the cylinder, which minimizes losses caused by oil flow. Oil flow in both directions is smooth during lift phase. The hammer doesn't cause pressure peaks in hydraulic system.
- Steplessly adjustable blow rate and drop height.

UNMATCHED FLEXIBILITY

- The hammer can be operated by the hydraulic system of the rig, or by separate power pack. Easy to connect to different systems.
- The hammer can be mounted on all kinds of leaders, or can be free suspended.

TECHNICAL DATA

	HHK-4	HHK-5	HHK-6	HHK-7	HHK-[illegible]	HHK-[illegible]
OPERATING DATA						
Max. energy (kNm)	48	60	72	84	120	168
Max. drop height (mm)	1200	1200	1200	1200	1200	1200
Blow rate (blows/min)						
- at min. stroke	100	100	100	100	100	100
- at 500 mm stroke	60	60	60	60	60	60
- at max. stroke	30	30	30	30	30	30
WEIGHTS						
Ram block (kg)	4000	5000	6000	7000	10000	14000
Total hammer (kg) including drive cap type A	6300	7400	8600	9700	14500	20000
HYDRAULIC DATA						
Oil flow (l/revolution)	300	300	300	300	600	600
Operating pressure (bar)	140	150	160	185	150	185
Hoses: I.D. (mm)						
- pressure line	25	25	25	25	38	38
- return line	32	32	32	32	45	45
POWER PACK Required output (kW)						
Installation output at hammer	70	75	80	95	150	185

PILE SET CALCULATIONS

(Attachment 2)

PROJECT : PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI

LOCATION : SUNGAI SIPUT, PERAK DARUL RIDZUAN

MAIN-CON : INTEGRATED VEST (M) SDN BHD

Type of Hammer			7.0 Ton Hydraulic Hammer
Pile size	D	=	300mm Dia. Spun Pile
Pile Working Load	L	=	500 kN
Mass of Hammer	W	=	70 kN
Safety Factor on Load	f	=	2.00
Length of Pile	l	=	36 m
Mass of Pile	P1	=	42.20 kN
Mass of Driving Assembly	P2	=	9.9 kN
Total Mass (P1 + P2)	P	=	52.10 kN
Temporary Compression (assumed)	C	=	12 mm
Drop of Hammer	h	=	250 mm
Coefficient of Restitution (assumed)	e	=	0.3
Hammer Efficiency	A	=	0.80

HILEY FORMULA :

$$(SET)S + \frac{C}{2} = \frac{AWh}{fL} \times \frac{W + Pe^2}{W + P}$$

$$S = \left(\frac{AWh}{fL} \times \frac{W + Pe^2}{W + P}\right) - \frac{C}{2}$$

$$= \left(\frac{0.80 \times 70 \times 250}{2.0 \times 500} \times \frac{70 + 52.10 \times (0.3)^2}{70 + 52.10}\right) - \frac{12}{2}$$

$$= 14 \times 0.61) - 6$$

$$= 8.56 - 6$$

$= 2.56$ mm / blow

$= 25.64$ mm / 10 blows

The above set values are meant to be used as a guide only as actual values will differ for different ground conditions.

ANSAH SDN BHD

TOTAL P.10

PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR JACKED IN PILES

1.0 SCOPE

This procedure refers to the installation of jacked-in piles only.

2.0 TYPE OF PILES

- 250mm Diameter Spun Pile
- 300mm Diameter Spun Pile

3.0 LIST OF MANUFACTURERS

The piles will be supplied by the following reputable manufacturers:

Square Pile
- Industrial Concrete Products Berhad (ICP)
- Concrete Engineering Products Berhad (CEPCO)

Refer to Appendix 1 for pile brochure.

4.0 EQUIPMENT

4.1 Jacked – In Equipment – Gripped System

Jacked – In equipment YZY- 200

The equipment is using the 'Gripped' system. Dead weight will be added to achieve the required counter jacked – in force.

Refer to Appendix 2 for Equipment details.

ILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR JACKED IN PILES

.0 SCOPE

This procedure refers to the installation of jacked-in piles only.

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- 250mm Diameter Spun Pile
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4.0 EQUIPMENT

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Jacked – In equipment YZY- 200 .

The equipment is using the 'Gripped' system. Dead weight will be added to achieve the required counter jacked – in force.

Refer to Appendix 2 for Equipment details.

ANSAH SDN BHD 150787-H

PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR JACK-IN PILE

Submitted by,

ANSAH SDN BHD
37-C, Jalan SS 22/23,
Damansara Jaya,
47400 Petaling Jaya,
Selangor Darul Ehsan.

Tel: 03-77260323
Fax: 03-77260170

5.0 SITE PREPARATION

Submission will be on site specific basis if required.

6.0 SETTING OUT

Minimum of 3 control points will be established at each location so that any disturbed pile points can be re-established at ease and re-works avoided.

Setting-out will be based on the reference coordinates provided by the Engineer or architect. The main contractor's surveyor will set out the pile positions based on the structure boundary. Each pile position set out will be marked with a peg before installation.

Locations of initial piles for load testing will be obtained from Engineer or Architect.

7.0 HANDLING, PITCHING, INSTALLATION AND EXTENSION

7.1 All handling and lifting will be at the designed lifting points and support points.

During pitching and installation the verticality of the pile will be continuously monitored and plumbed to ensure the pile is centrally in line with the pile axis to receive the ram to prevent pile whip, twist or rotation.

Each pile shall be clearly marked with red ink at 300mm intervals along its length to enable the jacked in pressure/force to be recorded at every 300mm depth of pile penetration.

The pile will be extended by butt-welding the steels plate on the pile heads. On completion of welding the slag will be chipped off and wire brushed to receive anti rust paint.

PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR JACKED IN PILES

7.2 Installation of Pile

The vertical support structure of the jacked-in machine is plumbed to ensure verticality by means of a spirit level or plumb line. This is achieved by adjusting of all four stabilizers. Pile shall be lifted and inserted into the equipment by crane. The pile shall be position into the 'grip' of the equipment and gripped the pile body. Once the pile is vertical and in position, jacking commences.

During pile installation, the hydraulic pressure of main jacks is measured by the pressure gauge, and the corresponding pile penetration is recorded by the site staff at regular intervals. The pile may be extended by means of welding. Except for pile jointing, each pile is jacked in continuously until the required resistance or penetration is reached.

The required resistance is twice the pile working load as requested by the Engineer. The corresponding pressure in the main jacks and the penetration are recorded.

Refer to Appendix 3.

The portion of the installed piles which is above ground may be cut to enable movement of rig. Dolly or follower will be used if the pile set whilst the pile head is below ground but above cut off level. In such cases where the pile below cut off level or 2 meter deep, excavation method will be use in order to joint back the extension. Re-injection will be continued to a required loading.

7.3 Acceptance

The jacked-in force is determined by the Engineer. Once the required pressure correspond to the required jacked-in force is indicated in the pressure gauge, the pressure is held for 15 seconds. The set criteria is that the same required pressure is achieved consecutively for three times, each time held for 15 seconds and each settlement should not exceed 6mm.

Refer to Appendix 4 – Record Form

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PILING WORKS FOR KOMPLEKS PENTADBIRAN, KUARTERS DAN PUSAT TRANSIT KESIHATAN JABATAN HAL EHWAL ORANG ASLI (JHEOA) DI SUNGAI SIPUT PERAK DARUL RIDZUAN.

METHOD STATEMENT FOR JACKED IN PILES

8.0 SAFETY

8.1 Statutory safety requirements (General Duties of Employees, Section 24, Occupational Safety and Health Act, 1994)

Site-specific safety requirements, as set out in the contract; and the main Contractor's Environmental, Safety, Health and Security Plan.

8.2 HSE Officer

HSE Officer will coordinate all safety-related activities at the work site, and ensuring that all safety requirements are complied.

8.3 Pile Installation

Pile installation involves jacking and lifting. The potential hazards and the respective precautions are as follows:

Hazard	Precautions
1. Overturning	* Ensure ground is reasonably level. * Ensure equipment is level * Use matting is ground is soft. * Do not attempt to track across water ponded area
2. Pile falling during pitching	* Use approved wire ropes * Double loop of wire rope around the pile to avoid slipping (pile surface is smooth). * Do not drag the pile more than 12m from the piling leader. * Stay away from pile during dragging and pitching
3. Others	* Operator should always view at the worker working at the grip clamp and only grip the pile where operator is free from clamp * Ensure no worker is under the object when being lifted. * Regular checking of lifting cables, winch etc.

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8.4 Cutting of Piles

The work involves cutting of piles with mechanical driven diamond cutter at high speed. The risks and precautions are as follows:

Hazard	Precautions
1. Struck by flying material	* Stay at least 4m during cutting process
2. Dust	* Operator must wear dust mask
3. Cut by cutter	* Only experienced worker is allowed to work.
4. Falling of piles	* If piles above cut off level are more than 4m high, it should be supported by crane or clamped by the equipment.

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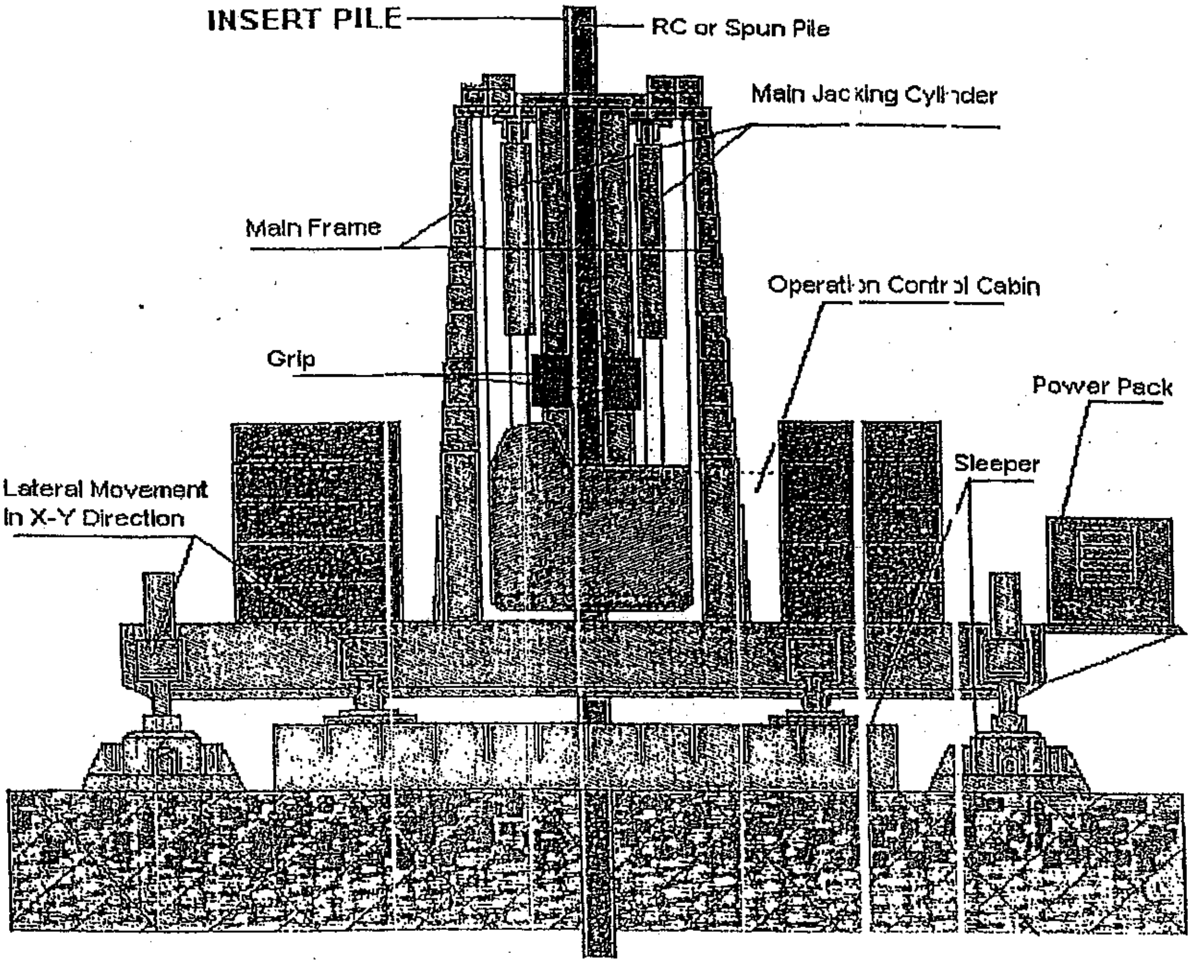
Appendix 2



CROSS SECTION OF YZY-200 & YZY 400 & YZY 600

1. Insert pile into the 'grip' of the equipment.
2. Grip the pile and detach the lifting sling / wire rope.
3. Final vertical check and positioning by moving in the X and Y direction.
4. Jacking commences.
5. If extension of pile is necessary insert the extension pile into the equipment until it sockets into the installed pile (about 0.75m protruding from the ground) and joined by electric arc welding.
6. Jacking recommences.
7. When the pile reaches certain depth and refuses penetration at the desired corresponding pressure, the pile may have set. This is confirmed by holding the desired pressure for 15 seconds and take the set. The procedure is repeated 3 times and if penetration ceases, then the pile is accepted.

Appendix 3

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PILE JACKED-IN MACHINE PRESSURE AND APPLIED JACKED-IN FORCE YZY-200 MODEL

YZY-200 Model
Pressure & Jacking Force Calculation

1) Jacking Force (2 Cylinders) $= \frac{2\,\Pi D^2 \times p}{4 \times 10{,}000} + S$

2) Jacking Force (4 cylinders) $= \frac{2(\Pi D_1^{\,2} + \Pi D_2^{\,2}) \times p}{4 \times 10{,}000} + S$

where
D = Diameter of Cylinder (mm)
P = Pressure in Mpa or n/mm²
S = Self weight of grip / clamp set-up = 5.0 ton

Hydraulic Pressure			Ø150 Cylinder 2 Pcs	Ø 150 Cylinder Pcs Ø 180 Cylinder 2 Pcs
MPa	Bar	Psi	Corresponding Force in Ton	Corresponding Force in Ton
1	10	145	8.5	13.6
2	20	290	12.1	22.2
3	30	435	15.6	30.9
4	40	580	19.1	39.5
5	50	725	22.2	48.1
6	60	870	26.2	56.7
7	70	1015	29.7	65.3
8	80	1160	33.3	74.0
9	90	1305	36.8	82.6
10	100	1450	40.3	91.2
11	110	1595	43.9	99.8
12	120	1740	47.4	108.4
13	130	1885	50.9	117.0
14	140	2030	54.4	125.7
15	150	2175	58.0	134.3
16	160	2320	61.6	142.9
17	170	2465	65.0	151.5
18	180	2610	68.6	160.1
19	190	2755	72.1	168.9
20	200	2900	75.6	177.4
21	210	3045	79.2	186.0
22	220	3190	82.7	194.6
23	230	3335	86.2	203.2
24	240	3480	89.8	211.9
25	250	3625	93.3	220.5
26	260	3770	96.8	229.1
27	270	3915	100.4	237.7
28	280	4060	103.9	246.3
29	290	4205	107.4	255.0
30	300	4350	112.0	264.6
31	310	4495	114.6	272.3
31.5	315	4567.5	116.3	276.4

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APPENDIX 4

Rig:

JACKED-IN PILING RECORD

Driven: ....

gn Working Load:...............................

Type/Size/Grade:...............................

No.:...

Start: ....

End: ....

R.L. - Ground: ....

R.L. - Top Ground: ....

R.L. - Cut-off Ground: ....

R.L. - Toe Ground: ....

Length of Pile from Cut-off Level: ....

Gauge Ref: ....

Reference	Str	1st Ext	2nd Ext	3rd Ext
al No.:				
Cast:				

TRATION (m)	PRESSURE (Mpa) 2 Cylinder	4 Cylinder	PENETRATION (m)	PRESSURE (Mpa) 2 Cylinder	4 Cylinder	PENETRATION (m)	PRESSURE (Mpa) 2 Cylinder	4 Cylinder	PENETRATION (m)	PRESSURE (Mpa) 2 Cylinder	4 Cylinder
0.3			12.3			24.3			36.3		
0.6			12.6			24.6			36.6		
0.9			12.9			24.9			36.9		
1.2			13.2			25.2			37.2		
1.5			13.5			25.5			37.5		
1.8			13.8			25.8			37.8		
2.1			14.1			26.1			38.1		
2.4			14.4			26.4			38.4		
2.7			14.7			26.7			38.7		
3.0			15.0			27.0			39.0		
3.3			15.3			27.3			39.3		
3.6			15.6			27.6			39.6		
3.9			15.9			27.9			39.9		
4.2			16.2			28.2			40.2		
4.5			16.5			28.5			40.5		
4.8			16.8			28.8			40.8		
5.1			17.1			29.1			41.1		
5.4			17.4			29.4			41.4		
5.7			17.7			29.7			41.7		
6.0			18.0			30.0			42.0		
6.3			18.3			30.3			42.3		
6.6			18.6			30.6			42.6		
6.9			18.9			30.9			42.9		
7.2			19.2			31.2			43.2		
7.5			19.5			31.5			43.5		
7.8			19.8			31.8			43.8		
8.1			20.1			32.1			44.1		
8.4			20.4			32.4			44.4		
8.7			20.7			32.7			44.7		
9.0			21.0			33.0			45.0		
9.3			21.3			33.3			45.3		
9.6			21.6			33.6			45.6		
9.9			21.9			33.9			45.9		
10.2			22.2			34.2			46.2		
10.5			22.5			34.5			46.5		
10.8			22.8			34.8			46.8		
11.1			23.1			35.1			47.1		
11.4			23.4			35.4			47.4		
11.7			23.7			35.7			47.7		
12.0			24.0			36.0			48.0		

ntries Made By:

lame:.................. ....

ignature:

Witnessed By:

Name:...... ....

Signature: ....

LAMPIRAN A

BOREHOLE LOG

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 28.08.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 1	Reduced level: meter	Supervisor : Umi
Sheet No: 1 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Light grey sandy CLAY of low plasticity with a little gravel.	0.00-0.30	D1 CLS									Top Soil
1.00	Very loose light grey clayey SAND of low plasticity with traces of gravel.	1.50-1.95	D2 SCL	0	1	0	1	1	1	3	50	
	- ditto -	3.00-3.45	-	0	1	0	0	1	1	2	Nil	
4.00	Very loose light grey SAND with a little gravel and traces of fine soil.	4.50-4.95	D3 S-F	0	1	1	0	1	1	3	50	
6.00	Very loose to loose light grey SAND with a little gravel and fine soil.	6.00-6.45	D4 S-F	0	1	1	1	1	1	4	50	
7.20	Very loose to loose light brown SAND with some gravel and a little fine soil.	7.50-7.95	D5 S-F	1	1	1	1	1	1	4	50	
9.00	Loose light brown SAND with a little gravel and traces of fine soil.	9.00-9.45	D6 S-F	1	1	1	2	1	1	5	50	
10.50	Very loose to loose light brown SAND with a little gravel and traces of fine soil.	10.50-10.95	-	0	0	0	1	0	1	2	Nil	
12.00	Soft yellowish grey SILT of high plasticity with traces of sand.	12.00-12.45	D7 MH	0	0	0	1	1	1	3	100	28.08.02 W.L 2.10m 29.08.02 W.L 4.50m
13.20	Medium stiff light grey SILT of high plasticity with a little sand and traces of gravel.	13.50-13.95	D8 MH	0	1	1	1	1	2	5	60	
15.00	Soft to medium stiff black grey CLAY of low plasticity with a little sand and traces of gravel.	15.00-15.95	D9 CL	1	1	1	1	1	1	4	90	
16.50	Stiff black grey gravelly SILT of intermediate plasticity with a little sand.	16.50-16.95	D10 MIG	1	2	2	3	3	3	11	80	
18.00	Stiff black grey sandy SILT of intermediate plasticity with a little gravel.	18.00-18.45	D11 MIS	1	2	2	3	4	4	13	80	
19.00	Stiff to very stiff black grey gravelly SILT of intermediate plasticity with a little sand.	19.50-19.95	D12 MIG	2	2	3	4	4	4	15	80	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 28.08.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 1	Reduced level: meter	Supervisor : Umi
Sheet No: 2 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mănsor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
21.00	Very stiff black grey gravelly SILT of intermediate plasticity with a little sand.	21.00-21.45	-	2	4	5	5	5	5	**20**	Nil	
22.00	Medium dense black grey clayey GRAVEL of low plasticity and with some sand.	22.50-22.95	D13 GCL	2	3	5	6	6	6	**23**	60	
24.00	Medium dense black grey GRAVEL with traces of sand and fine soil.	24.00-24.45	D14 G	3	4	4	6	6	7	**23**	60	
25.40	Medium dense black grey clayey GRAVEL of low plasticity with a little sand.	25.50-25.95	D15 GCL	4	6	6	7	8	8	**29**	60	
27.00	Very stiff black grey gravelly CLAY of low plasticity with a little sand.	27.00-27.45	D16 CLG	2	3	4	6	6	6	**22**	50	
28.00	Medium dense black grey silty GRAVEL of intermediate plasticity with a little sand.	28.50-28.95	D17 GMI	2	3	4	6	7	7	**24**	60	
30.00	Very stiff black grey gravelly SILT of low plasticity with some sand.	30.00-30.45	D18 MLG	2	3	4	4	10	10	**28**	60	
	- ditto -	31.50-31.95	-	2	3	4	5	2	6	**17**	Nil	
	- ditto -	33.00-33.45	-	2	3	4	5	5	5	**19**	Nil	
34.50	Very stiff black grey gravelly SILT of low plasticity with a little sand.	34.50-34.95	D19 MLG	2	4	6	6	5	6	**23**	50	
36.00	Very stiff black grey gravelly SILT of intermediate plasticity with a little sand.	36.00-36.45	D20 MIG	3	4	6	6	8	8	**28**	50	
37.50	Medium dense black grey GRAVEL with a little sand and traces of fine soil.	37.50-37.95	D21 G	3	5	5	7	8	8	**28**	50	
39.00	Dense black grey GRAVEL with a little sand and traces of fine soil.	39.00-39.45	D22 G	3	6	10	10	10	10	**40**	50	
40.30	Dense black grey silty GRAVEL of low plasticity with some sand.	40.50-40.95	D23 GML	4	10	10	12	12	12	**46**	50	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION	Form : IU / SI / 01
	DEEP BORING LOG	Date : 28.08.02

PROJECT :	**Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 1	Reduced level: meter	Supervisor : Umi
Sheet No: 3 of: 3	Type of Drill: Rotary	S.I. Officer : Arman mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
42.00	Very dense black grey silty GRAVEL of low plasticity with some sand.	42.00-42.16	-	4	6	50/10				50/10mm	Nil	
	- ditto -	43.50-43.645	-	10	50/70					50/70mm	Nil	
45.00	Hard black grey gravelly CLAY of low plasticity with a little sand.	45.00-45.32	D24 CLG	3	18	18	20	12/20		50/170mm	50	

END OF BOREHOLE AT 45.32m

Date	Casing	Depth	W.L
30.08.02	Nil	45.32m	6.00m

NOTES

N = Standard Penetration Test (S.P.T)	W.L = Water Level.	8 - 15 : Stiff	
UD = Undisturbed sample	CR = Core Recovery (mm)	15 - 30 : Very Stiff	
PS = Undisturbed piston sample	CRR = Core Recovery Ratio (%)	30 - Above : - Hard	
D = Disturbed Sample	RQD = Rock Quality Designation	NON COHESIVE SOIL (N)	
W.S = Washed Sample	Cls. = Classification (BS 5930)	0 - 4 : Very Loose	
C = Core Sample	COHESIVE SOIL (N)	4 - 10 : Loose	
W = Water Sample	0 - 2 : Very Soft	10 - 30 : Medium Dense	(Engineer/Geologist)
V.S = Vane Shear Test	2 - 4 : Soft	30 - 50 : Dense	
R/r = Recovery Ratio (%)	4 - 8 : Medium Stiff	50 - Above : Very Dense	

KUMPULAN IKRAM IKRAM UTARA

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION / DEEP BORING LOG	Form : IU / SI / 01
		Date : 08.09.02

PROJECT : Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 2	Reduced level: meter	Supervisor : Umi
Sheet No: 1 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Light grey clayey GRAVEL of low plasticity with some sand.	0.00-0.30	D1 GCL									Top Soil
1.20	Loose light grey SAND with some gravel and fine soil.	1.50-1.95	D2 S	1	1	2	1	2	2	7	60	
3.00	Loose light grey SAND with a little gravel and fine soil.	3.00-3.45	D3 S-F	1	2	2	2	2	2	8	60	
4.20	Medium dense light grey clayey SAND of low plasticity with a little gravel.	4.50-4.95	D4 SCL	2	1	3	2	3	3	11	60	
6.00	Soft light grey sandy CLAY of low plasticity with a little gravel.	6.00-6.45	D5 CLS	1	0	0	1	1	1	3	80	
7.20	Medium stiff light grey SILT of very high plasticity with traces of sand and gravel.	7.50-7.95	D6 MV	1	1	1	1	1	2	5	80	
9.00	Medium stiff grey sandy CLAY of intermediate plasticity with a little gravel.	9.00-9.45	D7 CIS	1	1	2	2	1	1	6	60	
	- ditto -	10.50-10.95	-	2	3	1	1	2	2	6	Nil	
12.00	Medium stiff grey sandy CLAY of intermediate plasticity with traces of gravel.	12.00-12.45	D8 CIS	1	2	1	1	1	2	5	60	
13.50	Stiff black grey sandy CLAY of intermediate plasticity with a little gravel.	13.50-13.95	D9 CIS	2	2	4	3	3	3	13	60	
15.00	Medium dense black grey clayey GRAVEL of low plasticity with some sand.	15.00-15.95	D10 GCL	2	3	4	4	4	4	16	60	
16.30	Medium dense black grey GRAVEL and sand with a little fine soil.	16.50-16.95	D11 G-F	4	3	4	4	5	5	18	60	
18.00	Medium dense black grey clayey GRAVEL of low plasticity with a little fine soil.	18.00-18.45	D12 GCL	2	4	4	5	5	6	20	60	
19.10	Medium dense black grey clayey SAND of low plasticity and gravel.	19.50-19.95	D13 SCL	2	4	5	6	6	6	23	60	02.09.02 W.L : 3.0m

:UMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 02.09.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak		
›rehole No: BH 2	Reduced level: meter	Supervisor : Umi	
ıeet No: 2 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor	

EPTH (neter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
:1.00	Very dense black grey clayey SAND of low plasticity and gravel.	21.00-21.075	-	6	50 10					50 10mm	Nil	03.09.02 W.L : 2.0m
:2.00	Strong dark grey striped white slightly weathered fair LIMESTONE.	22.00-23.50	C1	-	-	-	-	-	-	-	-	CR : 1425mm CRR : 95% RQD : 50%
	- ditto -	23.50-25.00	C2	-	-	-	-	-	-	-	-	CR : 1350mm CRR : 90% RQD : 60%
	- ditto -	25.00-26.50	C3	-	-	-	-	-	-	-	-	CR : 1500mm CRR : 100% RQD : 60%

END OF BOREHOLE AT 45.32m

Date	Casing	Depth	W.L
30.08.02	Nil	45.32m	6.00m

IOTES

ı = Standard Penetration Test (S.P.T)	W.L = Water Level.	8 - 15 : Stiff
JD = Undisturbed sample	CR = Core Recovery (mm)	15 - 30 : Very Stiff
›S = Undisturbed piston sample	CRR = Core Recovery Ratio (%)	30 - Above : - Hard
) = Disturbed Sample	RQD = Rock Quality Designation	NON COHE SIVE SOIL (N)
V.S = Washed Sample	Cls. = Classification (BS 5930)	0 - 4 : Very Loose
: = Core Sample	COHESIVE SOIL (N)	4 - 10 : Loose
V = Water Sample	0 - 2 : Very Soft	10 - 30 : Medium Dense
/.S = Vane Shear Test	2 - 4 : Soft	30 - 50 : Dense
/r = Recovery Ratio (%)	4 - 8 : Medium Stiff	50 - Above : Very Dense

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(Engineer/Geologist)

IKRAM

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 05.09.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 3	Reduced level: meter	Supervisor : Umi
Sheet No: 1 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Light grey sandy CLAY of intermediate plasticity with a little gravel.	0.00-0.30	D1 CIS									Top Soil
1.00	Medium stiff greyish sandy CLAY of low plasticity with a little gravel.	1.50-1.95	D2 CLS	1	1	1	2	2	2	7	50	
3.00	Loose greyish SAND with a little gravel and traces of fine soil.	3.00-3.45	D3 S-F	1	1	2	2	2	2	8	50	
4.30	Loose greyish SAND with a little gravel and fine soil.	4.50-4.95	D4 S-F	1	2	1	2	2	1	6	50	
6.00	Loose to medium dense greyish SAND with some gravel and traces of fine soil.	6.00-6.45	D5 S-F	1	2	3	3	2	2	10	50	
7.20	Loose greyish SAND with some gravel and traces of fine soil.	7.50-7.95	D6 SF	1	2	1	1	2	1	5	50	
9.00	Soft to medium stiff greyish sandy CLAY of low plasticity with a little gravel.	9.00-9.45	D7 CLS	1	1	1	1	1	1	4	60	
10.40	Medium stiff greyish sandy CLAY of low plasticity with a little gravel.	10.50-10.95	D8 CLS	1	1	2	2	1	1	6	70	
12.00	Soft greyish sandy CLAY of low plasticity with traces of gravel.	12.00-12.45	D9 CLS	1	0	1	1	0	1	3	90	
13.00	Medium stiff to stiff greyish CLAY of intermediate plasticity with a little sand and traces of gravel.	13.50-13.95	D10 CI	1	2	2	2	2	2	8	50	
15.00	Hard greyish CLAY of intermediate plasticity with a little sand and traces of gravel.	15.00-15.16	-	2	2	50/10				50 / 10mm	Nil	
	- ditto -	16.50-16.585	-	10	50/10					50 / 10mm	Nil	
18.00	Hard black grey CLAY of intermediate plasticity with a little sand and traces of gravel.	18.00-18.45	D11 CI	2	4	6	6	10	10	32	50	
19.20	Very stiff black grey gravelly CLAY of low plasticity with a little sand.	19.50-19.95	D12 CLG	2	3	4	6	6	6	22	50	

JMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 05.09.02

PROJECT : Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

rehole No: BH 3	Reduced level: meter	Supervisor : Umi
eet No: 2 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

EPTH (eter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
1.00	Very stiff black grey SILT of high plasticity with traces of sand and gravel.	21.00-21.45	D13 MH	2	4	6	6	6	6	24	50	
2.10	Hard black grey SILT of high plasticity with traces of sand and gravel.	22.50-22.95	-	2	3	4	8	8	10	30	Nil	06.09.02 W.L. : 2.0m
4.00	Hard black grey gravelly SILT of intermediate plasticity with some sand.	24.00-24.45	D14 MIG	2	3	6	10	10	10	36	50	
5.40	Dense black grey clayey GRAVEL of low plasticity with some sand.	25.50-25.95	D15 GCL	3	4	6	6	12	18	42	50	
	- ditto -	27.00-27.45	D16 GCL	2	10	10	10	12	12	44	50	
8.00	Dense black grey GRAVEL with a little sand and fine soil.	28.50-28.95	D17 G-F	4	8	10	12	12	12	46	50	
0.00	Very dense black grey GRAVEL with a little sand and fine soil.	30.00-30.31	D18 G-F	10	10	20	22	8 / 10		50 / 160mm	50	
	- ditto -	31.50-31.595	-	12	50 / 20					50 / 20mm	Nil	
3.00	Very dense black grey clayey GRAVEL of low plasticity with some sand.	33.00-33.245	D19 GCL	2	10	25	25 / 20			50 / 95mm	50	
4.40	Very dense black grey GRAVEL with some sand and traces of fine soil.	34.50-34.73	D20 G-F	10	18	42	8 / 5			50 / 80mm	50	
	- ditto -	36.00-36.115	-	25	25 / 40					50 / 115mm	Nil	

END OF BOREHOLE AT 36.115m

Date	Casing	Depth	W.L
08.09.02	Nil	36.115m	10.00m

OTES

= Standard Penetration Test (S.P.T)	W.L = Water Level.	8 - 15 : Stiff
ID = Undisturbed sample	CR = Core Recovery (mm)	15 - 30 : Very Stiff
'S = Undisturbed piston sample	CRR = Core Recovery Ratio (%)	30 - Above : - Hard
= Disturbed Sample	RQD = Rock Quality Designation	NON COHE SIVE SOIL (N)
V.S = Washed Sample	Cls. = Classification (BS 5930)	0 - 4 : Very Loose
= Core Sample	COHESIVE SOIL (N)	4 - 10 : Loose
V = Water Sample	0 - 2 : Very Soft	10 - 30 : Medium Dense
'.S = Vane Shear Test	2 - 4 : Soft	30 - 50 : Dense
/r = Recovery Ratio (%)	4 - 8 : Medium Stiff	50 - Above : Very Dense

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(Engineer/Geologist)

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 22.08.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 4	Reduced level: meter	Supervisor : Umi
Sheet No: 1 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Greyish SAND with a little gravel and fine soil.	0.00-0.30	D1 S-F									Top Soil
0.50												
	Loose to medium dense greyish SAND with some gravel and traces of fine soil.	1.50-1.95	D2 S-F	1	2	2	3	3	2	10	50	
3.00	Loose brownish grey clayey SAND of low plasticity with a little gravel.	3.00-3.45	D3 SCL	1	1	2	1	1	1	5	50	
4.20	Loose greyish clayey SAND of low plasticity with a little gravel.	4.50-4.95	D4 SCL	1	1	2	2	1	2	7	50	
6.00	Stiff greyish sandy CLAY of low plasticity with a little gravel.	6.00-6.45	D5 CLS	1	1	2	2	2	3	9	50	
7.20	Medium stiff greyish sandy SILT of intermediate plasticity with a little gravel.	7.50-7.95	D6 MIS	1	1	2	3	1	1	7	50	
8.70	Stiff to very stiff light grey sandy CLAY of intermediate plasticity with a little gravel.	9.00-9.45	D7 CIS	1	2	3	4	4	4	15	70	
10.40	Very stiff light grey sandy/gravelly CLAY of intermediate plasticity.	10.50-10.95	D8 CIS/ CIG	2	2	3	5	5	5	18	60	
12.00	Stiff black grey striped white sandy SILT of low plasticity with a little gravel.	12.00-12.45	D9 MLS	2	1	2	4	4	4	14	80	
13.10	Very stiff black grey striped white gravelly CLAY of intermediate plasticity with a little sand.	13.50-13.95	D10 CIG	2	2	4	4	4	4	16	80	
15.00	Very stiff black grey striped white gravelly SILT of low plasticity with some sand.	15.00-15.45	D11 MLG	2	4	4	4	6	6	20	90	
16.20	Hard black grey gravelly CLAY of intermediate plasticity with a little sand.	16.50-16.95	D12 CIG	2	3	10	10	8	8	36	50	
18.00	Dense black grey clayey GRAVEL of low plasticity with some sand.	18.00-18.45	D13 GCL	2	4	10	10	10	10	40	50	
19.20	Very stiff black grey gravelly SILT of low plasticity with some sand.	19.50-19.95	D14 MLG	2	4	6	6	8	8	28	60	22.08.02 W.L : 4.0m 23.08.02 W.L : 3.0m

KUMPULAN IKRAM SDN. BHD.
IKRAM UTARA
(PULAU PINANG)

SITE INVESTIGATION
DEEP BORING LOG

Form : IU / SI / 01
Date : 22.08.02

PROJECT : Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 4 | Reduced level: meter | Supervisor : Umi

Sheet No: 2 of: 3 | Type of Drill: Rotary | S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
21.00	Medium dense black grey clayey GRAVEL of low plasticity with some sand.	21.00- 21.45	D15 GCL	2	3	4	4	10	10	28	60	
22.20												
	Dense black grey clayey GRAVEL of low plasticity with some sand.	22.50- 22.95	D16 GCL	2	4	5	6	12	12	35	60	
24.00	Medium dense black grey silty GRAVEL of low plasticity with some sand.	24.00- 24.45	D17 GML	2	4	10	10	8	8	36	60	
25.50	Hard black grey sandy SILT of low plasticity with some gravel.	25.50- 25.95	D18 MLS	2	6	10	10	10	10	40	50	
27.00	Very dense black grey silty GRAVEL of low plasticity with a little sand.	27.00- 27.45	D19 GML	4	10	12	12	14	12	50 300mm	50	
28.10												
	Very dense black grey clayey GRAVEL of low plasticity with a little sand.	28.50- 28.81	D20 GCL	6	10	18	29	3 10		50 160mm	50	
30.00	Medium dense black grey clayey GRAVEL of low plasticity with a little sand.	30.00- 30.45	-	2	4	4	5	5	5	19	Nil	
	- ditto -	31.50- 31.95	-	2	5	5	5	6	6	22	Nil	
33.00	Very dense black grey GRAVEL with a little sand and traces of fine soil.	33.00- 33.305	D21 G-F	4	20	21	24	5 5		50 155mm	60	23.08.02 W.L : 6.0m 24.08.02 W.L : 3.5m
34.20												
	Very dense black grey GRAVEL with some sand and a little fine soil.	34.50- 34.785	D22 GF	7	17	25	25 60			50 135mm	50	
36.00	Very dense black grey GRAVEL with a little sand and fine soil.	36.00- 36.225	D23 G-F	4	19	50				50 75mm	50	
	- ditto -	37.50- 37.72	-	10	27	23 70				50 145mm	Nil	
	- ditto -	39.00- 39.125	-	29	21 50					50 125mm	Nil	

JMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 22.08.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak		
rehole No: BH 4	Reduced level: meter	Supervisor : Umi	
ıeet No: 3 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor	

EPTH (ıeter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
	END OF BOREHOLE AT 39.125m											

Date	Casing	Depth	W.L
24.08.02	Nil	39.125m	8.00m

NOTES

N = Standard Penetration Test (S.P.T)	W.L = Water Level.	8 - 15 : Stiff	
UD = Undisturbed sample	CR = Core Recovery (mm)	15 - 30 : Very Stiff	
PS = Undisturbed piston sample	CRR = Core Recovery Ratio (%)	30 - Above : - Hard	
D = Disturbed Sample	RQD = Rock Quality Designation	NON COHE SIVE SOIL (N)	
W.S = Washed Sample	Cls. = Classification (BS 5930)	0 - 4 : Very Loose	
C = Core Sample	COHESIVE SOIL (N)	4 - 10 : Loose	
W = Water Sample	0 - 2 : Very Soft	10 - 30 : Medium Dense	(Engineer/Geologist)
V.S = Vane Shear Test	2 - 4 : Soft	30 - 50 : Dense	
R/r = Recovery Ratio (%)	4 - 8 : Medium Stiff	50 - Above : Very Dense	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION	Form : IU / SI / 01
	DEEP BORING LOG	Date : 21.08.02

PROJECT :	**Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**		
Borehole No: BH 5	Reduced level: meter	Supervisor : Umi	
Sheet No: 1 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor	

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Greyish clayey SAND of low plasticity with a little gravel.	0.00-0.30	D1 SCL									Top Soil
1.20												
	Very loose greyish clayey SAND of low plasticity with a little gravel.	1.50-1.95	-	1	0	0	0	0	1	1	Nil	
	- ditto -	3.00-3.45	D2 SCL	0	0	0	0	0	1	1	50	
4.20												
	Very soft to soft greyish sandy SILT of high plasticity with a little gravel.	4.50-4.95	D3 MHS	0	1	0	0	1	1	2	100	
6.00	Very loose to loose greyish clayey SAND of low plasticity with a little gravel.	6.00-6.45	D4 SCL	0	1	1	1	1	1	4	90	
7.40												
	Loose greyish clayey SAND of low plasticity with a little gravel.	7.50-7.95	D5 SCL	0	1	1	1	2	1	5	90	
9.00	Medium stiff greyish grey CLAY of intermediate plasticity with a little sand and traces of gravel.	9.00-9.45	D6 CI	1	2	1	1	2	2	6	100	
10.10												
	Dense black grey clayey SAND of low plasticity with some gravel.	10.50-10.95	D7 SCL	2	2	3	10	10	10	33	80	
12.00	Dense black grey clayey GRAVEL of low plasticity with some sand.	12.00-12.45	D8 GCL	2	3	10	10	10	12	42	60	
13.20												
	Hard greyish gravelly SILT of intermediate plasticity with a little sand.	13.50-13.95	D9 MIG	2	3	4	8	10	10	32	60	
14.90												
	Dense black grey GRAVEL with some sand and traces of fine soil.	15.00-15.45	D10 G-F	2	3	10	10	10	10	40	60	
16.30												
	Very dense black grey GRAVEL with a little sand and fine soil.	16.50-16.86	D11 GF	10	12	12	18	<u>20</u> 60		<u>50</u> 210mm	60	
	- ditto -	18.00-18.16	-	10	20	<u>50</u> 10				<u>50</u> 10mm	Nil	
	- ditto -	19.50-19.58	-	21	<u>50</u> 5					<u>50</u> 5mm	Nil	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 21.08.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 5	Reduced level: meter	Supervisor : Umi
Sheet No: 2 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
21.00	Very dense black grey GRAVEL with some sand and traces of fine soil.	21.00-21.285	D12 G-F	5	19	29	21/60			50/135mm	50	
	- ditto-	22.50-22.69	D13 G-F	10	18	50/40				50/40mm	50	
	END OF BOREHOLE AT 22.50m											

Date	Casing	Depth	W.L
22.08.02	Nil	22.50m	0.50m

NOTES

N = Standard Penetration Test (S.P.T)
UD = Undisturbed sample
PS = Undisturbed piston sample
D = Disturbed Sample
W.S = Washed Sample
C = Core Sample
W = Water Sample
V.S = Vane Shear Test
R/r = Recovery Ratio (%)

W.L = Water Level.
CR = Core Recovery (mm)
CRR = Core Recovery Ratio (%)
RQD = Rock Quality Designation
Cls. = Classification (BS 5930)

COHESIVE SOIL (N)
0 - 2 : Very Soft
2 - 4 : Soft
4 - 8 : Medium Stiff
8 - 15 : Stiff
15 - 30 : Very Stiff
30 - Above : - Hard

NON COHESIVE SOIL (N)
0 - 4 : Very Loose
4 - 10 : Loose
10 - 30 : Medium Dense
30 - 50 : Dense
50 - Above : Very Dense

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(Engineer/Geologist)

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 25.08.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak		
Borehole No: BH 6	Reduced level: meter	Supervisor : Umi	
Sheet No: 1 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor	

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE								N Blows	R/r %	REMARKS
		DEPTH (meter)	No. (Cls.)	Field Test								
				75 mm	75 mm	75 mm	75 mm	75 mm	75 mm			
0.00	Greyish SAND with a little gravel and traces of fine soil.	0.00-0.30	D1 S-F									Top Soil
0.80	Very loose greyish SAND with traces of gravel and fine soil.	1.50-1.95	D2 S	1	0	0	1	1	1	3	50	
2.70	Very loose greyish SAND with some gravel and a little fine soil.	3.00-3.45	D3 S-F	1	1	0	1	0	2	3	50	
4.20	Very soft greyish sandy CLAY of intermediate plasticity with traces of gravel.	4.50-4.95	D4 CIS	0	0	0	0	0	1	1	60	
6.00	Very soft to soft greyish sandy CLAY of intermediate plasticity with traces of gravel.	6.00-6.45	D5 CIS	0	0	1	0	0	1	2	70	
7.10	Very soft greyish sandy CLAY of intermediate plasticity with traces of gravel.	7.50-7.95	D6 CIS	0	1	0	0	0	1	1	90	
9.00	Medium stiff greyish sandy CLAY of low plasticity with a little gravel.	9.00-9.45	D7 CLS	1	2	2	2	1	2	7	50	
10.40	Loose greyish clayey SAND of low plasticity with some gravel.	10.50-10.95	D8 SCL	1	2	1	2	2	1	6	50	
	- ditto -	12.00-12.45	-	1	2	2	1	2	3	8	Nil	
13.50	Loose to medium dense greyish clayey SAND of low plasticity wi some gravel.	13.50-13.95	-	1	2	2	2	3	3	10	Nil	
15.00	Stiff greyish grey striped white CLAY of low plasticity with traces of sand and gravel.	15.00-15.45	D9 CL	1	2	3	3	3	3	12	70	
16.20	Stiff to very stiff greyish grey striped white gravelly CLAY of low plasticity with a little sand.	16.50-16.95	D10 CLG	2	3	4	3	4	4	15	80	
18.00	Very stiff dark grey striped white CLAY of low plasticity with traces of sand and gravel.	18.00-18.45	D11 CL	2	3	4	6	6	6	22	80	
19.30	Very stiff dark grey striped white CLAY of intermediate plasticity with traces of sand and gravel.	19.50-19.95	D12 CI	2	4	3	7	7	6	23	80	25.08.02 W.L : 2.0m 26.08.02 W.L : 4.5m

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 25.08.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 6	Reduced level: meter	Supervisor : Umi
Sheet No: 2 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
21.00	Very stiff black grey gravelly CLAY of low plasticity with some sand.	21.00-21.45	D13 CLG	2	3	4	4	5	7	**20**	50	
22.00	Medium dense black grey GRAVEL with some sand and traces of fine soil.	22.50-22.95	D14 G-F	2	3	4	5	6	6	**21**	60	
24.00	Very stiff black grey gravelly CLAY of intermediate plasticity with a little sand.	24.00-24.45	D15 CIG	3	4	4	6	6	8	**24**	60	
25.20	Medium dense black grey clayey GRAVEL of low plasticity with some sand.	25.50-25.95	D16 GCL	2	4	6	6	4	10	**26**	50	
27.00	Medium dense black grey GRAVEL with a little sand and traces of fine soil.	27.00-27.45	D17 G	2	4	10	4	6	6	**26**	50	
	- ditto -	28.50-28.95	-	2	3	6	6	6	6	**24**	Nil	
	- ditto -	30.00-30.45	-	2	4	10	4	4	4	**22**	Nil	
31.00	Medium dense black grey GRAVEL with a little sand and traces of fine soil.	31.50-31.95	D18 G	2	4	4	8	8	6	**26**	50	
33.00	Medium dense black grey GRAVEL with a little sand and fine soil.	33.00-33.45	D19 G-F	2	4	6	6	6	6	**24**	50	
34.50	Dense black grey GRAVEL with a little sand and fine soil.	34.50-34.95	-	2	3	10	10	12	14	**46**	Nil	
	- ditto -	36.00-36.45	-	2	8	10	10	10	10	**40**	Nil	26.08.02 W.L : 3.0m 27.08.02 W.L : 5.0m
37.00	Dense black grey GRAVEL with a traces of sand and fine soil.	37.50-37.95	D20 G	2	8	10	10	10	12	**42**	50	
39.00	Dense black grey GRAVEL with a little sand and fine soil.	39.00-39.45	D21 G-F	2	4	10	10	12	16	**48**	50	
40.00	Hard black grey gravelly CLAY of low plasticity with a little sand.	40.50-40.95	D22 CLG	2	8	12	12	12	14	**50** 300mm	50	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 25.08.02

PROJECT : Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 6	Reduced level: meter	Supervisor : Umi
Sheet No: 3 of: 3	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
42.00	Hard black grey gravelly CLAY of low plasticity with a little sand.	42.00-42.17	-	10	18	50/20				50/20mm	Nil	
43.20	Dense black grey GRAVEL with a little sand and traces of fine soil.	43.50-43.95	D23 G-F	2	4	10	12	12	12	46	50	
45.00	Dense black grey GRAVEL with a little sand and fine soil.	45.00-45.45	D24 G-F	3	4	10	12	12	14	48	50	

END OF BOREHOLE AT 45.45m

Date	Casing	Depth	W.L
27.08.02	Nil	45.45m	6.00m

NOTES

N = Standard Penetration Test (S.P.T)
UD = Undisturbed sample
PS = Undisturbed piston sample
D = Disturbed Sample
W.S = Washed Sample
C = Core Sample
W = Water Sample
V.S = Vane Shear Test
R/r = Recovery Ratio (%)

W.L = Water Level.
CR = Core Recovery (mm)
CRR = Core Recovery Ratio (%)
RQD = Rock Quality Designation
Cls. = Classification (BS 5930)

COHESIVE SOIL (N)
0 - 2 : Very Soft
2 - 4 : Soft
4 - 8 : Medium Stiff
8 - 15 : Stiff
15 - 30 : Very Stiff
30 - Above : - Hard

NON COHESIVE SOIL (N)
0 - 4 : Very Loose
4 - 10 : Loose
10 - 30 : Medium Dense
30 - 50 : Dense
Very Dense

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(Engineer/Geologist)

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 19.08.02

PROJECT : Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 7	Reduced level: meter	Supervisor : Umi
Sheet No: 1 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
0.00	Greyish SAND with some gravel and traces of fine soil.	0.00-0.30	D1 S-F									Top Soil
1.00	Loose greyish SAND with a little grael and fine soil.	1.50-1.95	D2 S-F	1	1	1	2	1	1	5	50	
2.50	Very loose to loose brownish grey clayey SAND of low plasticity with a little gravel.	3.00-3.45	D3 SCL	1	1	1	1	1	1	4	50	
4.00	Loose brownish grey SAND and gravel with traces of fine soil.	4.50-4.95	D4 S	1	1	1	1	2	1	5	50	
6.00	Medium stiff brownish grey CLAY of high plasticity with a little sand and traces of gravel.	6.00-6.45	D5 CH	1	1	1	1	1	2	5	60	
7.30	Loose greyish clayey SAND of low plasticity with some gravel.	7.50-7.95	D6 SCL	1	1	1	2	2	1	6	70	
9.00	Stiff greyish CLAY of intermediate plasticity with a little sand and traces of gravel.	9.00-9.45	D7 CI	1	1	2	2	3	2	9	100	19.08.02 W.L : 2.0m 20.08.02 W.L : 3.5m
10.50	Medium dense greyish silty SAND of low plasticity with a little gravel.	10.50-10.95	D8 SML	1	2	2	3	3	3	11	90	
12.00	Medium dense greyish SAND with some gravel and traces of fine soil.	12.00-12.45	D9 S-F	2	2	1	3	3	4	11	60	
13.20	Stiff yellowish grey striped white sandy CLAY of low plasticity with traces of gravel.	13.50-13.95	D10 CLS	1	3	4	2	3	3	12	60	
15.00	Very dense black grey GRAVEL with a little fine soil and sand.	15.00-15.36	D11 GF	4	10	21	22	7 / 60		50 / 210mm	50	
	- ditto -	16.50-16.745	-	8	18	42	8 / 20			50 / 95mm	Nil	
	- ditto -	18.00-18.305	-	4	10	18	27	5 / 5		50 / 155mm	Nil	
19.30	Very dense black grey GRAVEL with some sand and traces of fine soil.	19.50-19.80	D12 G-F	10	10	27	23			50 / 150mm	50	

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 19.08.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 7	Reduced level: meter	Supervisor : Umi
Sheet No: 2 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	75 mm	75 mm	75 mm	75 mm	75 mm	N Blows	R/r %	REMARKS
21.00	Very dense black grey GRAVEL with a little sand and traces of fine soil.	21.00-21.21	D13 G-F	12	20	50 60				50 60mm	50	

END OF BOREHOLE AT 21.21m

Date	Casing	Depth	W.L
20.08.02	Nil	21.21m	3.00m

NOTES

N = Standard Penetration Test (S.P.T)
UD = Undisturbed sample
PS = Undisturbed piston sample
D = Disturbed Sample
W.S = Washed Sample
C = Core Sample
W = Water Sample
V.S = Vane Shear Test
R/r = Recovery Ratio (%)

W.L = Water Level.
CR = Core Recovery (mm)
CRR = Core Recovery Ratio (%)
RQD = Rock Quality Designation
Cls. = Classification (BS 5930)

COHESIVE SOIL (N)
0 - 2 : Very Soft
2 - 4 : Soft
4 - 8 : Medium Stiff
8 - 15 : Stiff
15 - 30 : Very Stiff
30 - Above : - Hard

NON COHESIVE SOIL (N)
0 - 4 : Very Loose
4 - 10 : Loose
10 - 30 : Medium Dense
30 - 50 : Dense

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(Engineer/Geologist)

KUMPULAN IKRAM SDN. BHD. IKRAM UTARA (PULAU PINANG)	SITE INVESTIGATION DEEP BORING LOG	Form : IU / SI / 01 Date : 18.08.02

PROJECT : **Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak**

Borehole No: BH 8	Reduced level: meter	Supervisor :	Umi
Sheet No: 1 of: 2	Type of Drill: Rotary	S.I. Officer :	Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE DEPTH (meter)	SAMPLE No. (Cls.)	Field Test 75 mm	Field Test 75 mm	Field Test 75 mm	Field Test 75 mm	Field Test 75 mm	Field Test 75 mm	N Blows	R/r %	REMARKS
0.00	Greyish SAND and gravel with traces of fine soil.	0.00- 0.30	D1 S									Top Soil
1.20	Very loose greyish SAND with some gravel and traces of fine soil.	1.50- 1.95	D2 S	4	2	1	0	0	1	2	70	
3.00	Very soft to soft greyish sandy CLAY of intermediate plasticity with traces of gravel.	3.00- 3.45	D3 CIS	1	0	0	1	0	1	2	100	
4.20	Soft to medium stiff greyish CLAY of intermediate plasticity with some sand and traces of gravel.	4.50- 4.95	D4 CI	1	1	0	1	1	2	4	100	
6.00	Medium stiff greyish sandy CLAY of intermediate plasticity with traces of gravel.	6.00- 6.45	D5 CIS	1	1	1	2	1	2	6	100	
7.30	Loose greyish SAND with some gravel and a little fine soil.	7.50- 7.95	D6 S-F	1	2	2	1	1	2	6	50	
9.00	Loose greyish SAND and gravel with traces of fine soil.	9.00- 9.45	D7 S-F	1	2	2	1	2	2	7	50	
10.50	Stiff purplish grey SILT of low plasticity with traces of sand and gravel.	10.50- 10.95	D8 ML	2	3	3	3	2	3	11	90	
12.00	Very stiff black grey gravelly SILT of intermediate p;lasticity with a little sand.	12.00- 12.45	D9 MIG	2	3	4	6	6	6	22	80	
13.20	Very stiff black grey SILT of intermediate plasticity with a little sand and gravel.	13.50- 13.95	D10 MI	2	3	4	4	6	6	20	80	
15.00	Dense black grey GRAVEL with a little sand and fine soil.	15.00- 15.45	D11 G-F	4	6	10	6	6	10	32	70	
16.40	Very dense black grey GRAVEL with some sand and a little fine soil.	16.50- 16.95	D12 GF	6	6	12	12	10	16	50 30mm	50	
18.00	Very dense black grey GRAVEL with a little fine soil and sand.	18.00- 18.445	D13 GF	6	9	12	18	8	12 70	50 295mm	60	
19.50	Very dense black grey GRAVEL with some sand and traces of fine soil.	19.50- 19.84	D14 G-F	4	10	18	18	14 40		50 190mm	50	

KUMPULAN IKRAM SDN. BHD.
IKRAM UTARA
(PULAU PINANG)

SITE INVESTIGATION
DEEP BORING LOG

Form : IU / SI / 01
Date : 18.08.02

PROJECT :	Pembinaan Kompleks Pentadbiran Dan Transit Kesihatan JHEOA, Sungai Siput, Perak

Borehole No: BH 8	Reduced level: meter	Supervisor : Umi
Sheet No: 2 of: 2	Type of Drill: Rotary	S.I. Officer : Arman Mansor

DEPTH (meter)	DESCRIPTION OF SOIL, COLOUR CONSISTENCY, RELATIVE DENSITY GRAIN SIZE, TEXTURE ETC.	SAMPLE		Field Test						N Blows	R/r %	REMARKS
		DEPTH (meter)	No. (Cls.)	75 mm	75 mm	75 mm	75 mm	75 mm	75 mm			
21.00	Very dense black grey GRAVEL with traces of sand and fine soil	21.00-21.235	D15 G-F	10	18	42	8 / 10			50 / 85mm	50	
	- ditto -	22.50-22.585	-	18	50 / 10					50 / 10mm	Nil	

END OF BOREHOLE AT 21.21m

Date	Casing	Depth	W.L
20.08.02	Nil	21.21m	3.00m

NOTES

N = Standard Penetration Test (S.P.T)
UD = Undisturbed sample
PS = Undisturbed piston sample
D = Disturbed Sample
W.S = Washed Sample
C = Core Sample
W = Water Sample
V.S = Vane Shear Test

W.L = Water Level.
CR = Core Recovery (mm)
CRR = Core Recovery Ratio (%)
RQD = Rock Quality Designation
Cls. = Classification (BS 5930)

COHESIVE SOIL (N)
0 - 2 : Very Soft
2 - 4 : Soft
8 - 15 : Stiff
15 - 30 : Very Stiff
30 - Above : - Hard

NON COHESIVE SOIL (N)
0 - 4 : Very Loose
4 - 10 : Loose
10 - 30 : Medium Dense
30 - 50 : Dense

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(Engineer/Geologist)

UNIVERSITI
TEKNOLOGI
PETRONAS

PILE SELECTION METHODOLOGY

By: Nur Aqilah Mohamed Rahim

Bachelor of Engineering (Hons)

(Civil Engineering)

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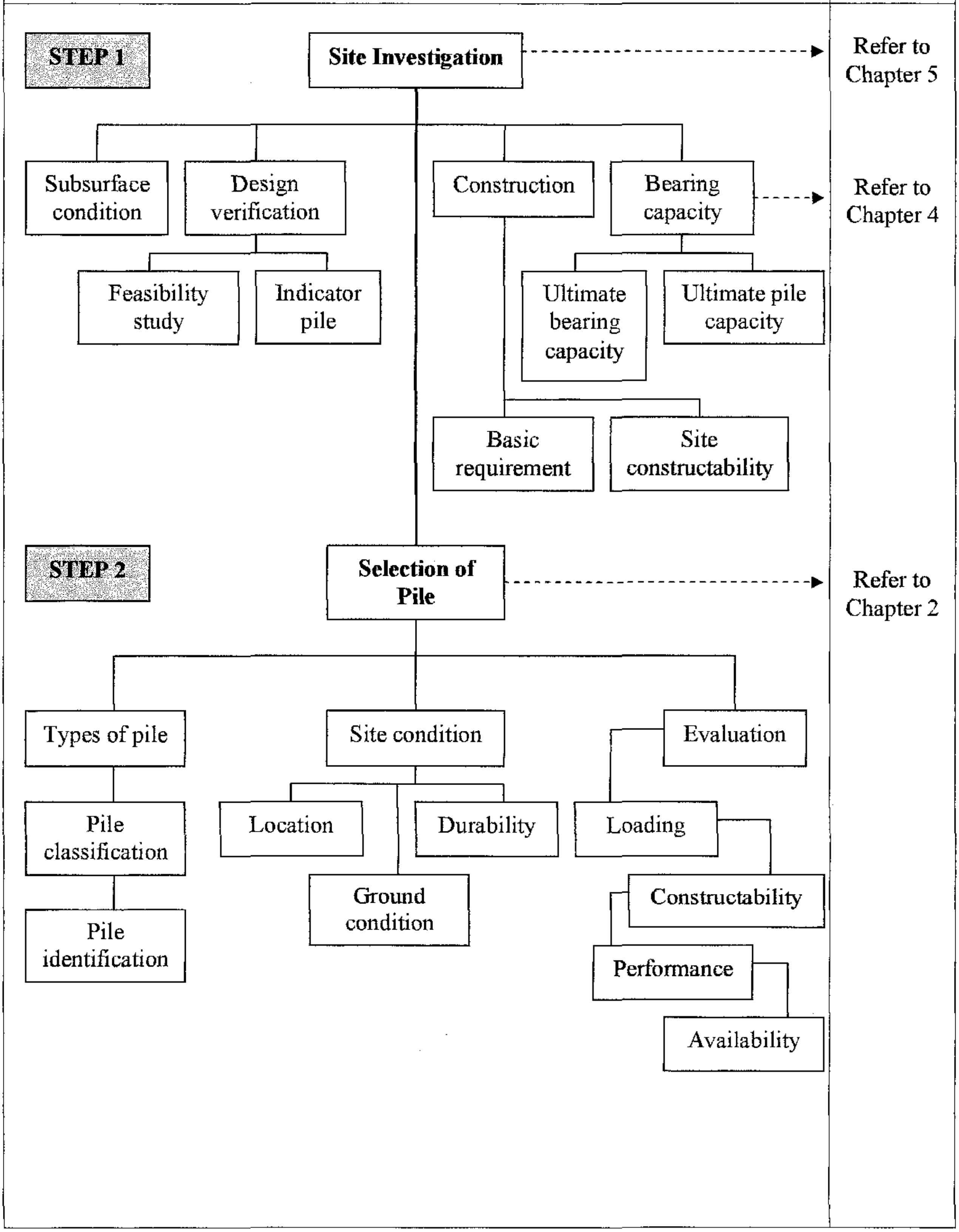
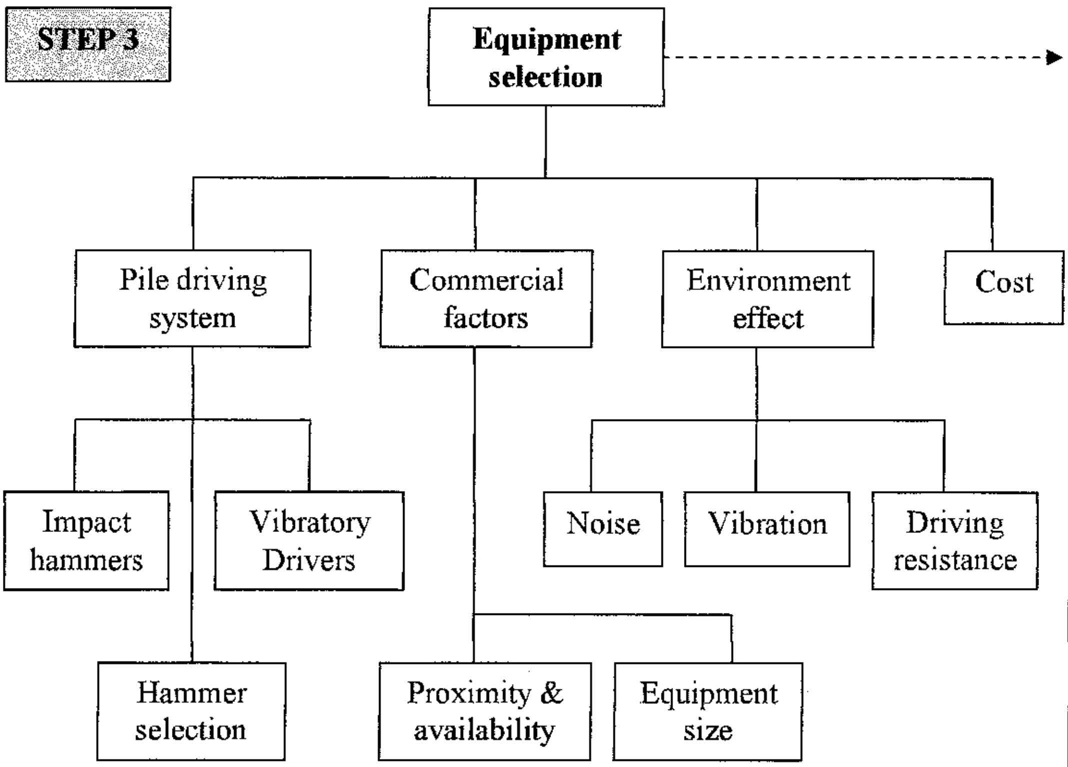
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

PILE SELECTION METHODOLOGY

PILE SELECTION METHODOLOGY

Selection Procedure	Reference



PILE SELECTION METHODOLOGY	
Selection Procedure	**Reference**
	Refer to Chapter 3

PURPOSE: This document presents selection procedures in determining pile and pile driving equipment.

SCOPE: Descriptions of types of pile, advantages and disadvantages usage of piles and pile driving equipment including factors that affect the selection which are site investigation, types of pile, pile driving equipment, bearing capacity and commercial factors.

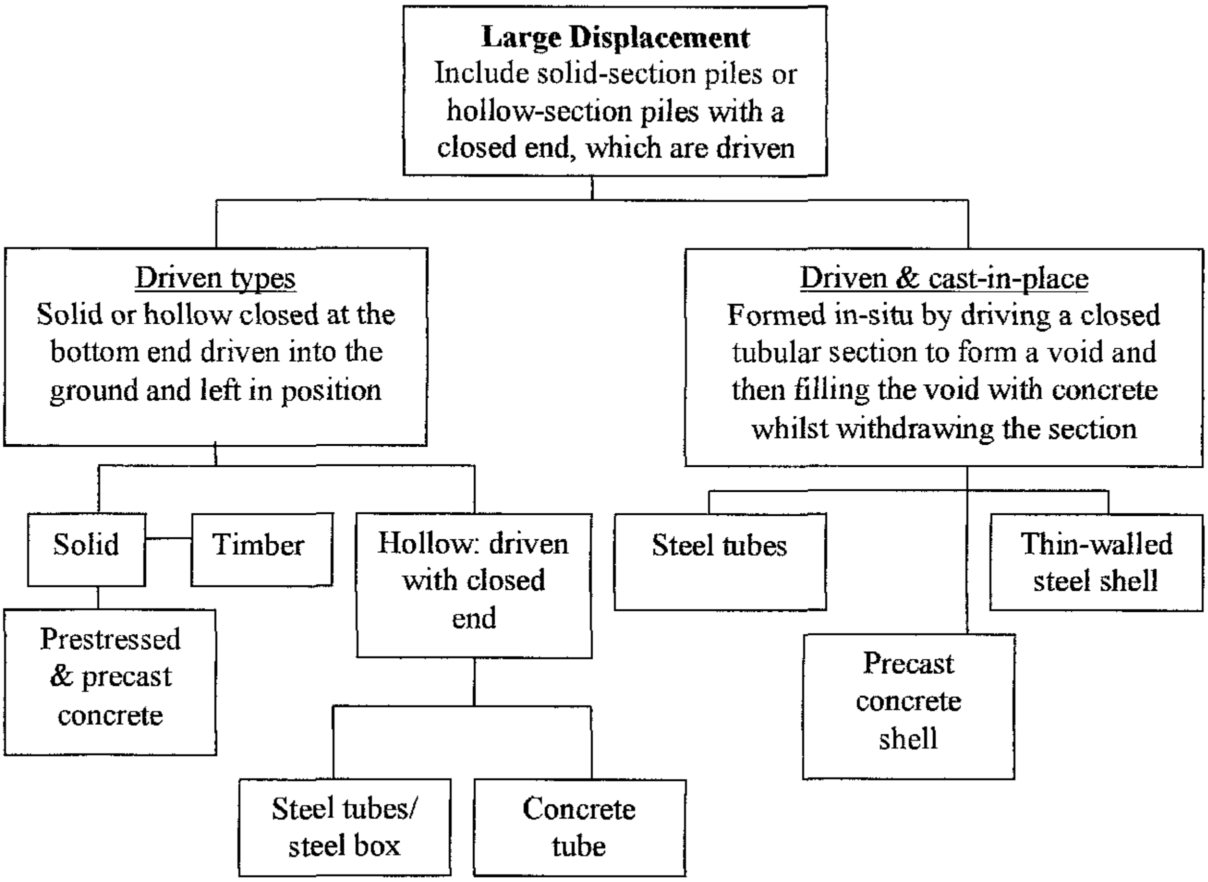
DESCRIPTION OF PILES: The type of pile influences the method selected for installation. For example, impact hammers may not be able to drive timber or closed-end pipe piles into firm ground without damage to the pile.

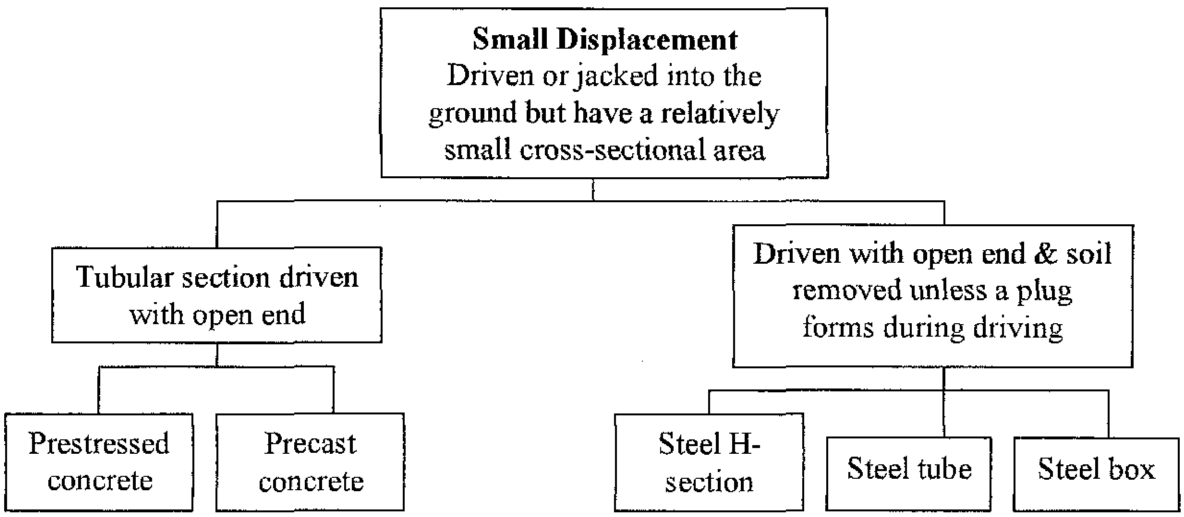
a) Types of pile

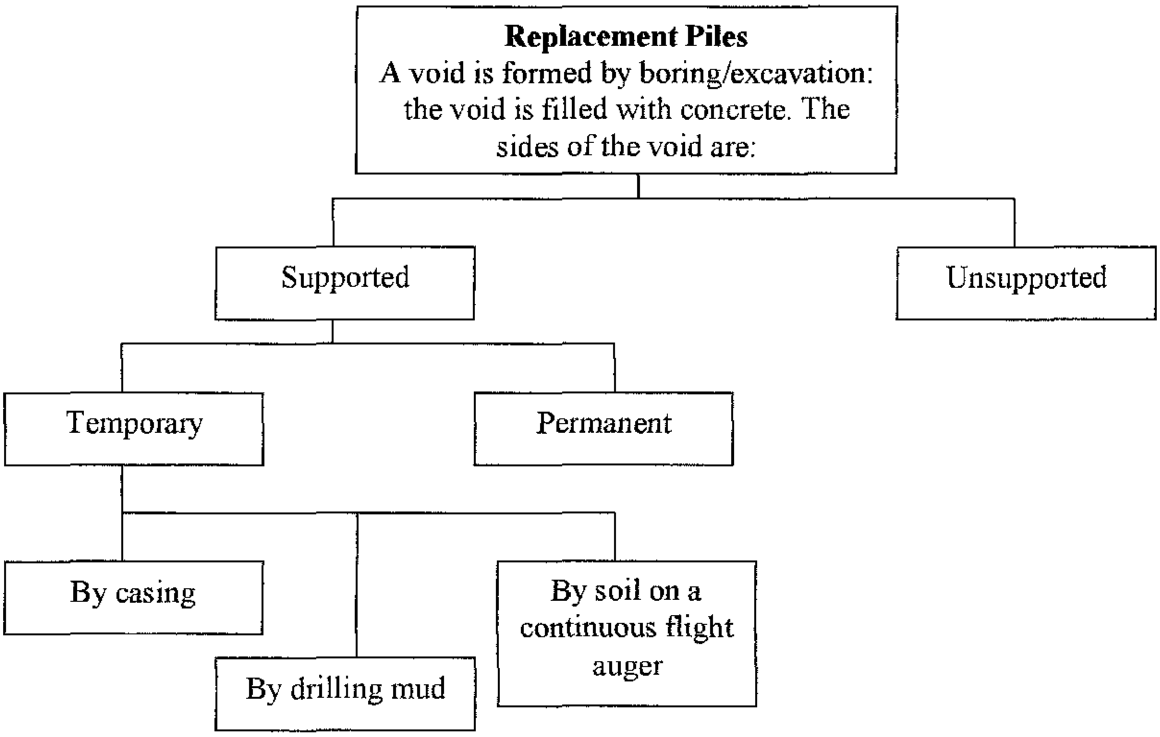
Piles are classified according to the amount of soil displacement that will occur during installation. The soil is disturbed by driving causing cohesive clays to remold and cohesionless sands to change density. The displaced soil can cause the ground surface around the pile to heave. Pile driving can also cause the area around the pile to settle due to densification of a sand foundation material when driving non-displacement piles.

(i) Displacement:

These piles have a relatively large cross-sectional area. Driving these piles displaces the soil a relatively large amount and can cause significant ground heave.


Large Displacement
Include solid-section piles or hollow-section piles with a closed end, which are driven
Driven types
Solid or hollow closed at the bottom end driven into the ground and left in position
Driven & cast-in-place
Formed in-situ by driving a closed tubular section to form a void and then filling the void with concrete whilst withdrawing the section
Solid
Timber
Hollow: driven with closed end
Steel tubes
Thin-walled steel shell
Prestressed & precast concrete
Precast concrete shell
Steel tubes/ steel box
Concrete tube

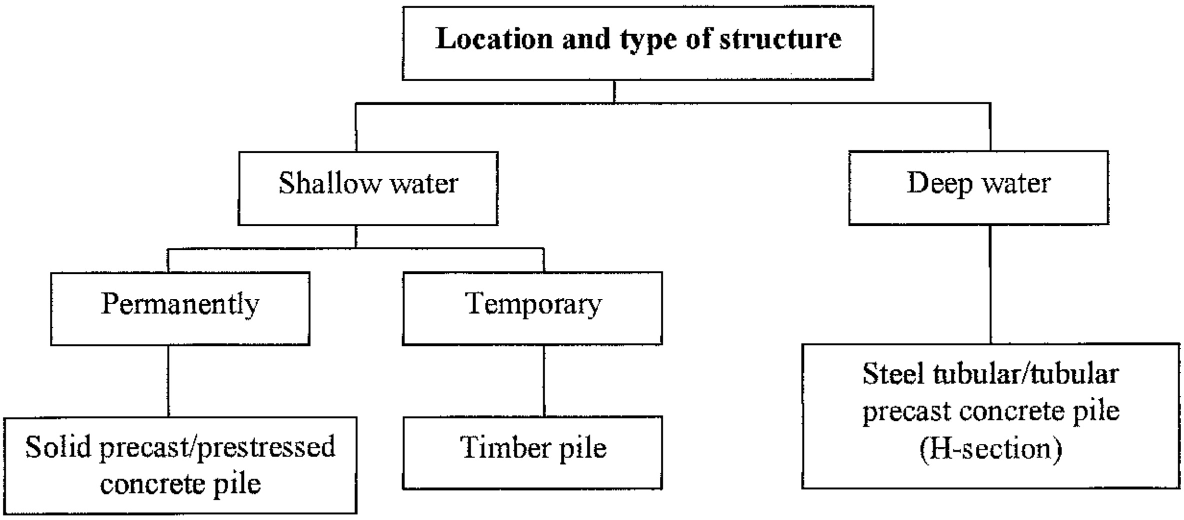

Small Displacement
Driven or jacked into the ground but have a relatively small cross-sectional area
Tubular section driven with open end
Driven with open end & soil removed unless a plug forms during driving
Prestressed concrete
Precast concrete
Steel H-section
Steel tube
Steel box


Replacement Piles
A void is formed by boring/excavation: the void is filled with concrete. The sides of the void are:
Supported
Unsupported
Temporary
Permanent
By casing
By drilling mud
By soil on a continuous flight auger

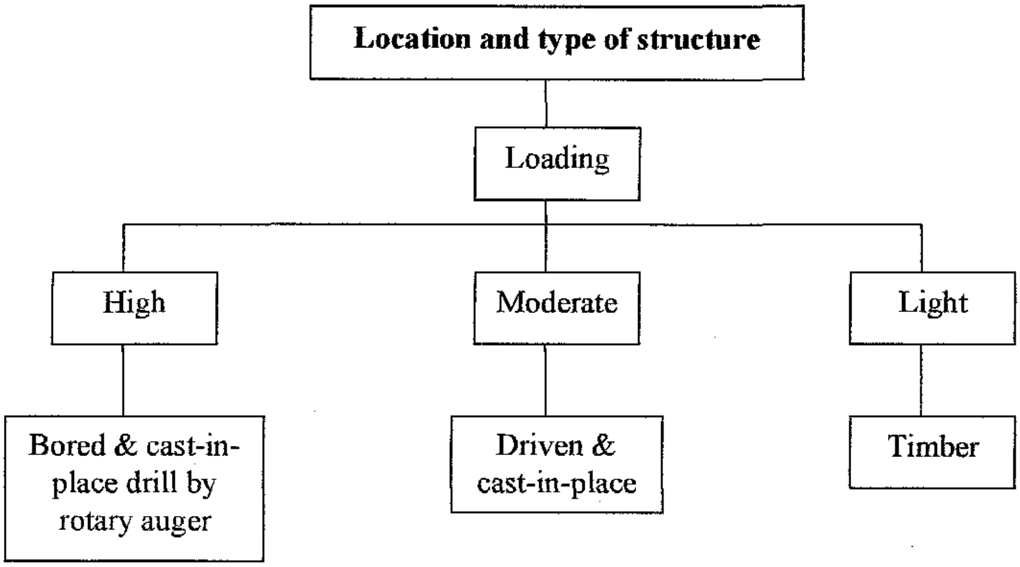
The selection of the appropriate type of pile depends on the following three principle factors:

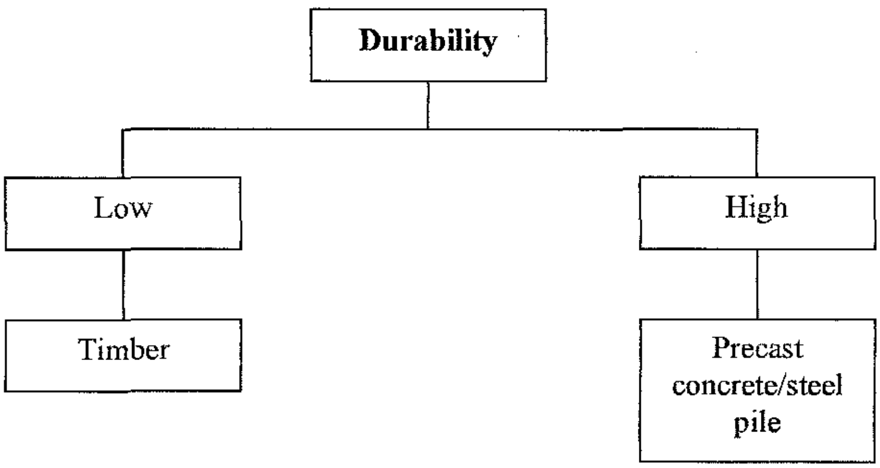
- The location and type of structure
- The ground condition
- Durability

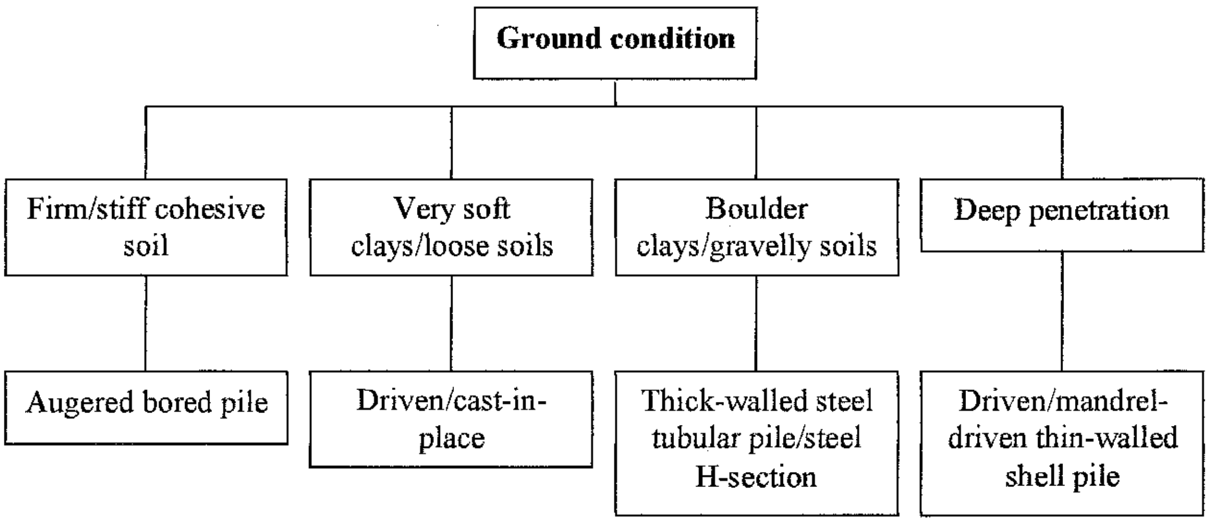
Site Condition: Marine



Site Condition: Land







Evaluation of Pile Types:

(1) *Load Capacity and Pile Spacing*

Prime importance is the load carrying capacity of the piles. In determining the capacity of a pile foundation, it is important to consider the pile spacing along with the capacity of individual piles. The lateral load resistance of the piles may also be important since lateral loads can induce high bending stresses in a pile.

(2) *Constructability*

The influence of anticipated subsurface and surface effects on constructability must be considered. Piles susceptible to damage during hard driving are less likely to penetrate hard strata or gravel and boulder zones. Soil disturbance or transmission of driving vibrations during construction may damage adjacent piles or structures. Pile spacing and batters must be selected to prevent interference with other structural components during driving. The ease of cutting or splicing a pile may also affect constructability.

(3) *Performance*

The pile foundation must perform as designed for the life of the structure. Performance can be described in terms of structural displacements which may be just as harmful to a structure as an actual pile failure. The load capacity should not degrade over time due to deterioration of the pile material.

(4) *Availability*

Piles must be available in the lengths required, or they must be spliced or cut off. Project scheduling may make lead time an important consideration, since some piles may require up to 6 months between order and delivery.

Preliminary Evaluations:

All identified foundation alternatives should first be evaluated for suitability for the intended application and cost. For piles, this evaluation should be based on the capacity, availability, constructability, and expected performance of the various types of piles. Initial evaluation of non-pile alternatives should be based on similar criteria. This will limit further studies to those foundation alternatives which are reasonably feasible. During this initial evaluation, it may also be possible to eliminate from consideration obvious high-cost alternatives.

Final Evaluations:

The final evaluation and selection should be based mainly on relative costs of the remaining alternatives. This evaluation should include the costs of structural or site modifications required to accommodate the foundation type. Cost and other factors may be important in the selection. Differences in delivery or installation schedules, levels of reliability of performance, and potential construction complications may be considered. When comparing a pile foundation to another type of foundation, it will be necessary to develop a preliminary pile layout to determine a reasonable estimate of quantities.

Table 1: Timber Pile Specification

LENGTH	9 - 18 M (30 - 60 FT)
MATERIAL SPECIFICATION	ASTM D 25
DESIGN STRESSES	DOUGLAS FIR - 8.27 MPA (1.2 KSI) RED OAK - 7.58 MPA (1.1 KSI) SOUTHERN PINE - 8.27 MPA (1.2 KSI) EASTERN HEMLOCK - 5.52 MPA (0.8 KSI)
DRIVING STRESSES	3 TIMES THE ABOVE DESIGN STRESSES
DESIGN LOADS	100 - 500 KN (10 - 50 TONS)
DISADVANTAGES	DIFFICULT TO SPLICE VULNERABLE TO DAMAGE IN HARD DRIVING TIP MAY HAVE TO BE PROTECTED VULNERABLE TO DECAY UNLESS TREATED AND PILES ARE SUBMERGED OR DRY SUBJECT TO MECHANICAL WEAR
ADVANTAGES	LOW INITIAL COST EASY TO HANDLE READILY CUT TO REQUIRED LENGTH PERMANENTLY SUBMERGED PILES ARE RESISTANT TO DECAY
APPLICATION	NOT RECOMMENDED IN DENSE GRAVEL OR TILL FRICTION PILES IN SAND, SILT, OR CLAY

Table 2: Precast Concrete Pile Specification

LENGTH	12 - 15 M (40 - 50 FT) 18 - 30 M (60 - 100 FT)
MATERIAL SPECIFICATION	ACI 318 FOR CONCRETE ASTM A-615 FOR REINFORCING STEEL
DESIGN STRESSES	REINFORCED 0.33 F'C (COMPRESSION); USE GROSS CROSS STRESSES SECTION TO DETERMINE ALLOWABLE LOADS PRESTRESSED 0.33 F'C (COMPRESSION), MINIMUM EFFECTIVE PRESTRESS 4.8 MPA (0.7 KS) MINIMUM F'C 34.5 MPA (5.0 KSI)
DRIVING STRESSES	REINFORCED COMPRESSION - 0.85 F'C TENSION - 3 (F'C)$^{1/2}$ PRESTRESSED COMPRESSION - 0.85 F'C - EFFECTIVE PRESTRESS TENSION - 3 (F'C)$^{1/2}$ + EFFECTIVE PRESTRESS
DESIGN LOADS	SPECIFICALLY DESIGNED FOR A WIDE RANGE OF LOADS
DISADVANTAGES	HIGH INITIAL COST VULNERABLE TO DAMAGE FROM HANDLING UNLESS PRESTRESSED PRESTRESSED DIFFICULT TO SPLICE
ADVANTAGES	HIGH LOAD CAPACITIES CORROSION RESISTANCE POSSIBLE HARD DRIVING READILY CUT TO REQUIRED LENGTH
APPLICATION	LOADS UP TO 4 MN (400 TONS) FRICTION AND/OR END BEARING PILES HIGH BENDING RESISTANCE

Table 3: Steel Pipe Pile Specification

LENGTH	12 - 36 M (40 - 120 FT)
MATERIAL SPECIFICATION	ASTM A36 FOR CORE ASTM A252 FOR PIPE ACI 318 FOR CONCRETE
DESIGN STRESSES	62 MPA (9 KSI); HIGHER STRESSES PERMITTED IF PILE LOADTESTS ARE PERFORMED AND EVALUATION CONFIRMS SATISFACTORY RESULTS 83 MPA (12 KSI) IF THE PILE IS END BEARING ON ROCK AND IF THE PILE IS EXPECTED TO PENETRATE THROUGH SOIL DEPOSIT WITHOUT OBSTRUCTIONS
DRIVING STRESSES	0.9 YIELD STRENGTH OF THE STEEL FY 217 MPA (31.5 KSI) FOR ASTM A252, FY = 241 MPA (35 KSI) 279 MPA (40.5 KSI) FOR ASTM A252, FY = 310 MPA (45 KSI)
DESIGN LOADS	0.8 - 1.2 MN (80 - 120 TONS) WITHOUT CORES 5.0 - 14.9 MN (500 - 1500 TONS) WITH CORES
DISADVANTAGES	HIGH INITIAL COST DISPLACEMENT FOR CLOSED END PIPE DIFFICULT TO HANDLE WITHOUT DAMAGE TIP SHOULD BE PROTECTED DURING DRIVING
ADVANTAGES	NO DISPLACEMENT FOR OPEN END PIPE CORROSION RESISTANCE CAN BE OBTAINED HIGH LOAD CAPACITIES READILY CUT TO REQUIRED LENGTH CAPABLE OF HARD DRIVING
APPLICATION	HIGH BENDING RESISTANCE FOR LATERALLY LOADED UNSUPPORTED LENGTH FRICTION AND/OR END BEARING PILES

Table 4: Concrete Cast in Shell Driven with Mandrel

LENGTH	3 - 16 M (10 - 120 FT), BUT USUALLY 15 - 24 M (50 - 80 FT)
MATERIAL SPECIFICATION	ACI 318 FOR CONCRETE
DESIGN STRESSES	33% OF 28-DAY CONCRETE STRENGTH, WITH INCREASE TO 40% OF 28-DAY STRENGTH PROVIDING (1) CASING IS MINIMUM 14-GAUGE THICKNESS (2) CASING IS SEAMLESS OR SEAMS ARE WELDED (3) RATIO OF STEEL YIELD STRENGTH FY TO CONCRETE 28-DAY STRENGTH IS NOT LESS THAN 6 (4) PILE DIAMETER IS NOT GREATER THAN 0.43 M (17")
DESIGN LOADS	SPECIFICALLY DESIGNED FOR A WIDE RANGE OF LOADS
DISADVANTAGES	SOIL DISPLACEMENT THIN SHELL MAY BE DAMAGED DURING DRIVING DIFFICULT TO SPLICE AFTER CONCRETE PLACEMENT
ADVANTAGES	INITIAL LOW COST TAPERED OR STEP-TAPERED SHELL CAN PROVIDE HIGHER BEARING CAPACITY THAN STRAIGHT MONOTUBE SHELL IN GRANULAR SOIL CAN BE INTERNALLY INSPECTED AFTER DRIVING LOW STEEL USE
APPLICATION	LOADS USUALLY UP TO 1.0 MN (100 TONS) FRICTION AND/OR END BEARING PILES HIGH BENDING RESISTANCE

Table 5: Concrete Cast in Shell Driven without Mandrel

LENGTH	9 - 24 M (30 - 80 FT)
MATERIAL SPECIFICATION	ACI 318 FOR CONCRETE
DESIGN STRESSES	62 MPA (9 KSI); HIGHER STRESSES PERMITTED IF PILE LOADTESTS ARE PERFORMED AND EVALUATION CONFIRMS SATISFACTORY RESULTS 83 MPA (12 KSI) IF THE PILE IS END BEARING ON ROCK AND IF THE PILE IS EXPECTED TO PENETRATE THROUGH SOIL DEPOSIT WITHOUT OBSTRUCTIONS
DESIGN LOADS	0.5 - 0.7 MPA (50 - 70 TONS)
DISADVANTAGES	DISPLACEMENT OF SOIL DIFFICULT TO SPLICE AFTER CONCRETE PLACEMENT TIP SHOULD BE PROTECTED DURING DRIVING
ADVANTAGES	CAN BE REDRIVEN SHELL IS NOT EASILY DAMAGED INTERNALLY INSPECTED AFTER DRIVING LOW SOIL DISPLACEMENT WHEN DRIVEN
APPLICATION	HIGH BENDING RESISTANCE FRICTION PILES

Table 6: Steel HP Section Piles

LENGTH	12 - 30 M (40 - 100 FT)
MATERIAL SPECIFICATION	ASTM A36
DESIGN STRESSES	62 MPA (9 KSI); HIGHER STRESS PERMITTED IF BASED ON LOAD TESTS 0.9FY, FY = STEEL YIELD STRENGTH 223 MPA FOR ASTM A36, FY = 248 MPA (36 KSI) 310 MPA FOR ASTM A572 OR A690, FY = 345 MPA (50 KSI)
DESIGN LOADS	0.4 - 19.2 MPA (40 - 200 TONS)
DISADVANTAGES	VULNERABLE TO CORROSION CAN BE DEFLECTED BY OBSTRUCTIONS CAN BE DAMAGED BY OBSTRUCTIONS; TIP SHOULD BE PROTECTED DURING HARD DRIVING
ADVANTAGES	AVAILABLE IN MANY SIZES AND LENGTHS HIGH CAPACITY EASY TO SPLICE CAN PENETRATE HARD, RESISTANT SOIL OR ROCK IF TIP PROTECTED DRIVES WITHOUT SOIL HEAVE
APPLICATION	FRICTION PILES, END BEARING PILES HIGH BENDING RESISTANCE

Table 7: Composite Piles

LENGTH	18 - 60 M (60 - 200 FT)
MATERIAL SPECIFICATION	ACI 318 FOR CONCRETE ASTM A36 FOR STRUCTURAL STEEL ASTM A252 FOR STEEL PIPE ASTM D25 FOR TIMBER
DESIGN STRESSES	33% OF 28-DAY CONCRETE STRENGTH 62 MN (9 KSI) FOR STRUCTURAL AND PIPE SECTIONS SEE TABLE 1 FOR TIMBER WEAKEST MATERIAL GOVERNS ALLOWABLE STRESSES
DESIGN LOADS	3 - 10 MN (30 - 100 TONS), WEAKEST MATERIAL GOVERNS ALLOWABLE LOAD
DISADVANTAGES	DIFFICULT TO OBTAIN GOOD JOINT BETWEEN DISSIMILAR MATERIALS EXCEPT FOR THE PIPE COMPOSITE PILE
ADVANTAGES	LOW COST HIGH CAPACITY FOR PIPE AND HP COMPOSITE PILES INTERNAL INSPECTION POSSIBLE FOR PIPE COMPOSITE PILES EASY TO ADD SECTIONS NO SOIL HEAVE
APPLICATION	ANCHORS RESIST TENSION FORCES SUCH AS FROM EXPANSIVE SOIL OR UPLIFT LOADS REMEDIAL REPAIR

References	PILE SELECTION METHODOLOGY
	Pile Identification

General

Structures may be founded on rock, on strong or weak soils, cohesive or non-cohesive soils, above ground level, below water level, etc. The type of foundation used to support a structure depends on local conditions. Three basic types of foundations are available: soil-founded, various types of piles, and piers or caissons. Each of these foundation types has many subcategories. The following paragraphs provide a short description and evaluation of the various pile types.

Piles

The purpose of a pile foundation is to transfer and distribute load through a material or stratum with inadequate bearing, sliding or uplift capacity to a firmer stratum that is capable of supporting the load without detrimental displacement. A wide range of pile types is available for applications with various soil types and structural requirements. A short description of features of common types of piles follows:

(1) Steel H-Piles

Steel H-piles have significant advantages over other types of piles. They can provide high axial working capacity, exceeding 400 kips. They may be obtained in a wide variety of sizes and lengths and may be easily handled, spliced, and cut off. H-piles displace little soil and are fairly easy to drive. They can penetrate obstacles better than most piles, with less damage to the pile from the obstacle or from hard driving. The major disadvantages of steel H-piles are the high material costs for steel and possible long delivery time for mill orders. H-piles may also be subject to excessive corrosion in certain environments unless preventive measures are used. H-piles may be specified according to ASTM A 36 or ASTM A 572.

(2) Steel Pipe Piles

Steel pipe piles may be driven open or closed-end and may be filled with concrete or left unfilled. Concrete filled pipe piles may provide very high load capacity, over 1,000 kips in some cases. Installation of pipe piles is more difficult than H-piles because closed-end piles displace more soil, and open-ended pipe piles tend to form a soil plug at the bottom and act like a closed-end pile. Handling, splicing, and cutting are easy. Pipe piles have disadvantages similar to H-piles (i.e., high steel costs, long delivery time, and potential corrosion problems). Pipe piles may be specified according to grade by ASTM A 252.

(3) Precast Concrete

Precast concrete piles are usually prestressed to withstand driving and handling stresses. Axial load capacity may reach 500 kips or more. They have high load capacity as friction piles in sand or where tip bearing on soil is important. Concrete piles are usually durable and corrosion resistant and are often used where the pile must extend above ground. However, in some salt water applications durability is also a problem with precast concrete piles.

(4) Cast-in-Place Concrete

Cast-in-place concrete piles are shafts of concrete cast in thin shell pipes, top driven in the soil, and usually closed end. Such piles can provide up to a 200-kip capacity. The material cost of cast-in-place piles is relatively low.

(5) Mandrel-Driven Piles

Mandrel-driven piles are thin steel shells driven in the ground with a mandrel and then filled with concrete. Such piles can provide up to a 200-kip capacity. They offer the advantage of lesser steel costs since thinner material can be used than is the case for top-driven piles. The heavy mandrel makes high capacities possible. Mandrel-driven piles may be very difficult to increase in length since the maximum pile length that can be driven is limited by the length of the mandrel available at the site.

(6) Timber

Timber piles are relatively inexpensive, short, low capacity piles. Long Douglas Fir piles are available but they will be more expensive. They may be desirable in some applications such as particular types of corrosive groundwater. Loads are usually limited to 70 kips. The piles are very convenient for handling. Untreated timber piles are highly susceptible to decay, insects, and borers in certain environments. They are easily damaged during hard driving and are inconvenient to splice.

a) Usual

Usual loads refer to conditions which are related to the primary function of a structure and can be reasonably expected to occur during the economic service life. The loading effects may be of either a long term, constant or an intermittent, repetitive nature. Pile allowable loads and stresses should include a conservative safety factor for such conditions. The pile foundation layout should be designed to be most efficient for these loads.

b) Unusual

Unusual loads refer to construction, operation or maintenance conditions which are of relatively short duration or infrequent occurrence. Risks associated with injuries or property losses can be reliably controlled by specifying the sequence or duration of activities, and/or by monitoring performance. Only minor cosmetic damage to the structure may occur during these conditions. Lower factors of safety may be used for such loadings, or overstress factors may be applied to the allowable for these loads. A less efficient pile layout is acceptable for these conditions.

c) Extreme

Extreme loads refer to events which are highly improbable and can be regarded as emergency conditions. Such events may be associated with major accidents involving impacts or explosions and natural disasters due to earthquakes or hurricanes which have a frequency of occurrence that greatly exceeds the economic service life of the structure. Extreme loadings may also result from a combination of unusual loading effects. The basic design concept for normal loading conditions should be efficiently adapted to accommodate extreme loading effects without experiencing a catastrophic failure. Extreme loadings may cause significant structural damage which partially impairs the operational functions and requires major rehabilitation or replacement of the structure.

The hammer approved for use should be examined in the field to assure that the hammer is in good condition and operating as close as possible to its rated capacity in accordance with procedures provided by the manufacturer. Hammer efficiency may be influenced by items such as the operating pressure, wear of moving parts, lubrications, drive cap cushions, driving resistance, batter angle, and the relative weights of the hammer and pile.

Operating pressure at the hammer (for steam and air hammers), stroke distance and operation rate (blows per minute) must be checked regularly while driving piles with any type of impact hammer. Variations in these values usually signify changes in hammer energy and efficiency, or pile damage. Steam- or air-powered automatic-type hammers also require special supplemental equipment, including adequately sized hoses, power source and fuel, and self-powered air compressor or boiler with a water supply for steam. A brief description of the various hammers and general recommendations follows.

IMPACT HAMMER PILE DRIVING SYSTEM

Impact hammers are hammers which drive the pile by first inducing downward velocity in a metal ram. Upon impact with the pile accessory, the ram creates a force far larger than its weight, which, if sufficiently large, then moves the pile an increment into the ground. Impact hammers can be divided into two categories, external combustion and internal combustion.

(1) External Combustion Hammers

External combustion hammers are hammers which burn the fuel that provides the energy for the operation of the hammer outside of the hammer itself. These hammers have external power sources such as the crane itself, steam boilers, air compressors, and/or hydraulic power packs to provide the energy to move the ram upward, and in some hammers, downward as well. The various types of external combustion hammers are detailed below.

(a) Drop Hammers

The drop hammer is the oldest type of pile driving hammer in existence. The hammer is connected to a cable which is attached to a winch on the crane. The hammer is raised to the desired stroke. The winch has a clutch on it that then allows the operator to release the hammer, which falls by its own weight and strikes a pile cap and the pile. Drop hammers are mainly used on very small jobs and for small piling.

The drop hammer is a comparatively simple device that is easily maintained, portable, relatively light, and does not require a boiler or air compressor. The drop hammer is most suitable for very small projects that require relatively small, lightweight timber, steel, or aluminum piles. Due to its slow operating rate, usually 5 to 10 blows per minute, this type of hammer is used only when the cost of bringing in a more sophisticated hammer would not be economical.

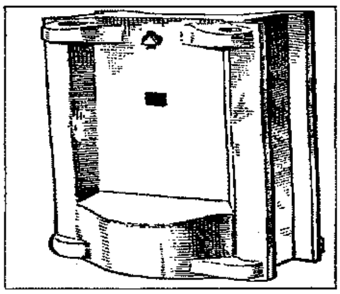


Figure 3.1: Typical drop hammer (Figure 3-3, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

(b) Single-Acting Air/Steam Hammers

These hammers use steam or compressed air to raise the ram. At a point in the upstroke, the valve is moved and the ram floats to the top of the stroke; the ram then falls by its own weight and makes impact. These hammers are generally referred to as "air/steam" because they can be operated by air or steam; a few are operable by only one or the other. Hammer operation is automatic and generally in the range of 40 to 60 blows per minute. In comparison to the drop hammer, single-acting hammers operate at much faster speeds, have shorter stroke distances and possess considerably larger ram weights.

A hammer cushion may or may not be utilized within the drive cap, and its use is largely dependent on the recommendations of the hammer manufacturer. Hammer efficiency can be checked by observation of the ram stroke and hammer operation rate. If the hammer maintains the specified stroke and operating speed, it can be reasonably assumed the hammer is functioning properly. A single-acting hammer may lose considerable driving energy when used to drive battered piles. This energy loss can be attributed to a reduction in the height of the ram's vertical fall and increased friction between the piston and cylinder wall and between the ram and the columns.

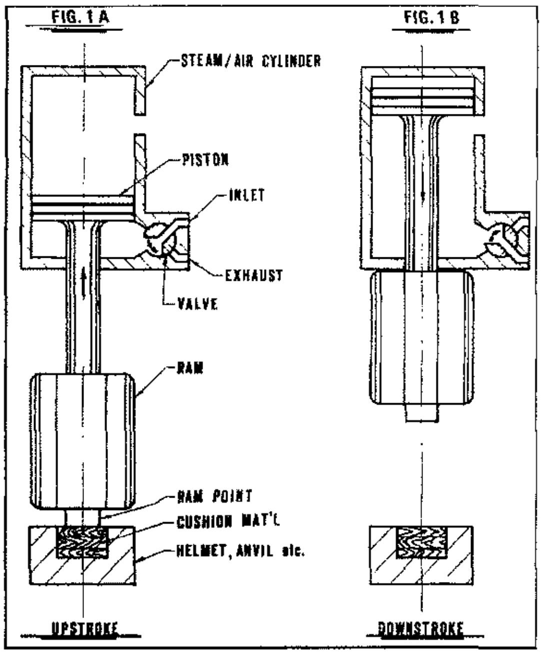


Figure 3.2: Single-acting steam/air hammer (Figure 5-1, Permission to reprint granted by Deep Foundation Institute (Item 31))

(c) Double-Acting Air/Steam Hammers

These hammers are similar to the single-acting hammers except that, upon upstroke valve turnover, they apply steam or air pressure to the top of the piston. This enables the stroke to be shorter, as it accelerates the ram to the desired impact velocity more quickly than with single-acting hammers. This makes a higher blow rate possible, which is advantageous in some situations. Double-acting hammers are especially popular in driving sheet piling where vibratory hammers cannot penetrate the soil or where they are favorable economically.

The combination of pressure on the downstroke and a short stroke distance results in an operating rate generally ranging from 90 to 150 blows per minute. These hammers can deliver impact energies comparable to the single-acting hammers at approximately 1.5 to 2.0 times the operating rate.

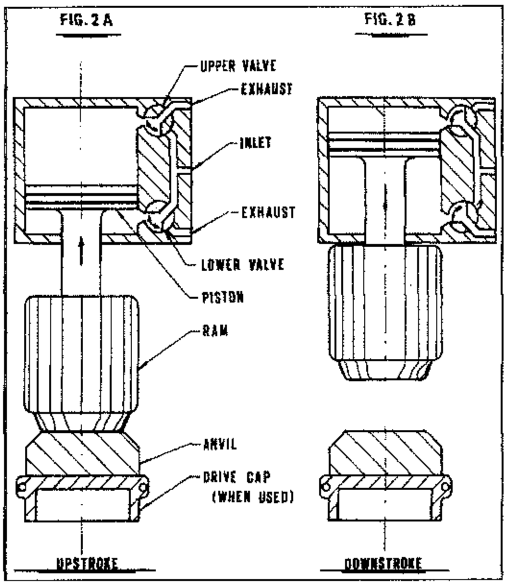


Figure 3.3: Double-acting steam/air hammer (Figure 5-2, Permission to reprint granted by Deep Foundations Institute (Item 31))

(d) Differential-Acting Air/Steam Hammers

These are similar to double-acting hammers except that the air or steam is constantly pressurized under the piston. This allows for a simpler valve configuration than with a double-acting hammer with similar operating characteristics.

The types of impact hammers are normally closed at the top, and the stroke cannot be monitored during driving. Actual field operation should be at the full hammer speed as listed by the manufacturer, since the rated hammer energy quickly reduces at lesser speeds. These hammer types may be used without leads (when not required for piles) and may be inverted and rigged for use as pile extractors. Best performance is usually obtained when driving wood or non-displacement steel piles into sands, but the hammers may be used in any type soil.

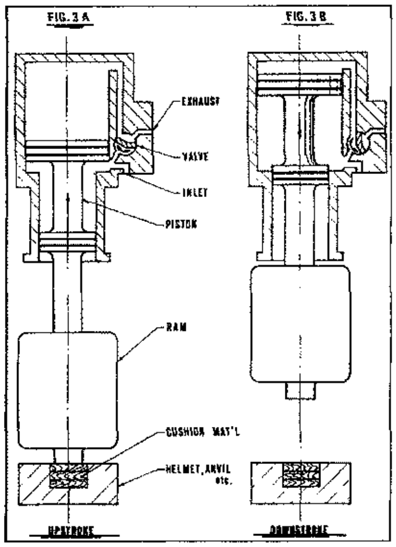


Figure 3.4: Differential-acting steam/air hammer (Figure 5-3, Permission to reprint granted by Deep Foundations Institute (Item 31))

(e) <u>Hydraulic Impact Hammers</u>

These hammers substitute hydraulic fluid for air or steam, and it is applied to the piston to move the ram. Hydraulic impact hammers can be single acting, double acting, differential acting, or other variations. Most but not all hydraulic hammers employ the use of an electric valve operated with a variable timer. The timer allows for very flexible control of the output energy.

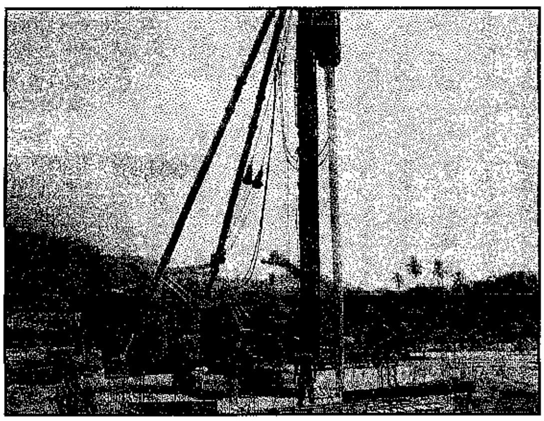
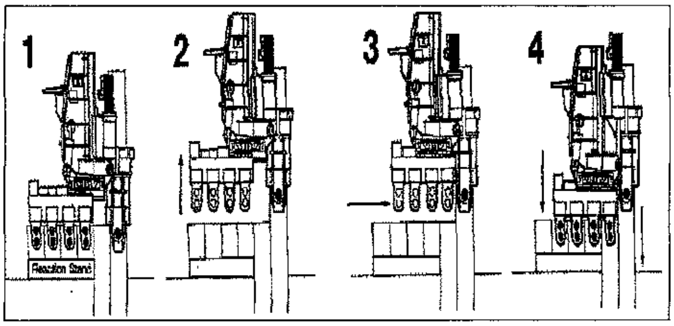


Figure 3.5: Hydraulic impact hammer

(f) Jacking

Pile jacking machines are not true impact hammers but act by simply pushing the pile into the ground. They are most effective when the soil resistance is lower than the maximum ram force and when there are neighboring piles to jack against (such as with sheet piling). They are most advantageous when vibrations and noise must be minimized.



Operating Cycle:

(1) The jack is set on the reaction standard for the installation of the first two sheet piles.

(2) The jack moves by elevating its travel carriage while supporting itself on the last installed pile.

(3) The travel carriage then slides forward.

(4) The travel carriage lowers itself and drops onto the installed sheet piles and continues its hydraulic installation process. After the third or fourth piles are driven, the jack moves off the reaction stand and travels independently on the piles.

Figure 3.6: Pile jacking device. (Figure 3-11, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

(2) Internal Combustion Hammers

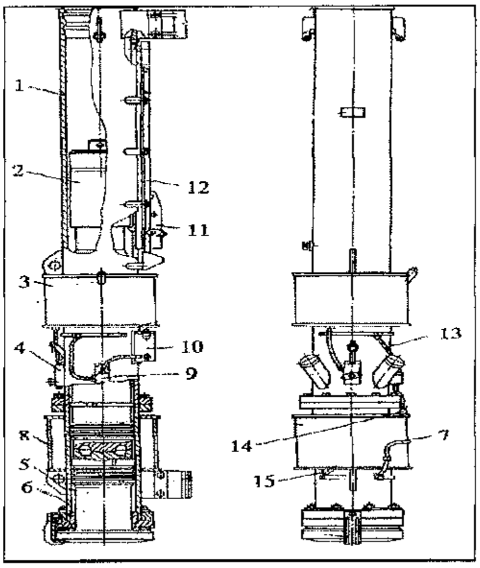
These hammers burn the fuel that powers them inside of the hammer, and for the most part, the diesel hammers are the only constituent of this class.

(a) Open-end Diesel Hammers

The open-end diesel hammer also known as the single-acting diesel hammer, is self-contained, economical, light in weight, and easy to service. The fuel is injected into the cylinder while the ram drops. When the ram strikes the anvil the fuel is atomized and ignited, explodes and forces the anvil down against the pile and the ram up. This supplies energy to the pile in addition to that induced by impact of the ram. The sequence repeats itself automatically provided that sufficient pile resistance is present.

The piston, with the assistance of the starting device driven from the winch of the pile driving rig or hydraulically, is raised to an upper position. At this point, it is released by the starting device and falls down under its own weight. Before the bottom of the ram passes the exhaust ports, the piston pushes the fuel pump lever, and fuel from the pump is supplied to the spherical recess of the anvil (some models directly inject atomized fuel into the combustion chamber). At the bottom of the stroke, the piston impacts the anvil. The energy of impact is divided between fuel vaporization and its mixing with heated air and driving of the pile. After a short period of time, the air-fuel mixture is ignited, and because of the pressure of the expanding exhaust gases the piston is raised up and additional driving impulse is transmitted to the pile.

Open-end diesel hammers are best suited for medium to hard driving conditions. They do not tend to operate well in soft soils because of the driving resistance required for compression and ignition. These are perhaps the most commonly used hammers mainly due to their availability and simplicity. The term "open end" comes from the top of the hammer being open, therefore it can actually being observe the ram going up and coming down as it delivers the blow. These are impact hammers and the recording of blow counts is the general method of inspection.



Parts:

(1) Upper Cylinder

(2) Piston

(3) Fuel Tank

(4) Fuel Pump

(5) Lower Cylinder Lubrication

(6) Anvil Block

(7) Oil Hose for Anvil Block

(8) Water Tank

(9) Oil Pump

(10) Oil Tank

(11) Starting Device or Crab

(12) Staring Device or Crab Guide

(13) Oil Hose for Ram Rings

(14) Filling Throat Plug

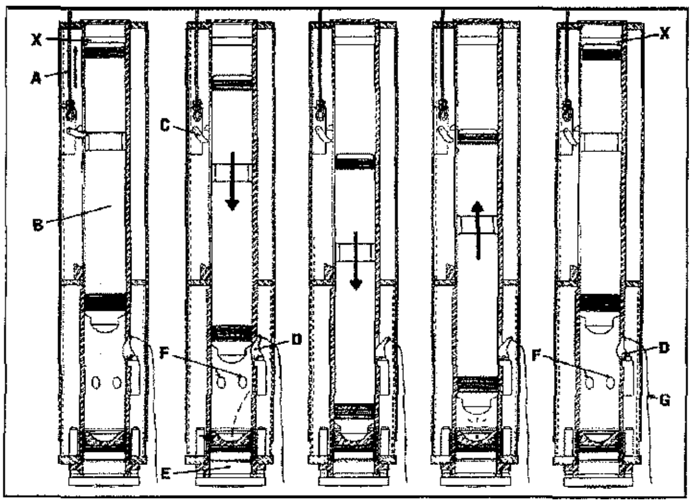
(15) Drain Throat Plug Lubrication

Figure 3.7: Typical open-end diesel hammer. (Figure 3-13, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

(b) Closed-end Diesel Hammers

The closed-end diesel hammer, also known as the double-acting diesel hammer, is similar to the open-end hammer, except that a closed top and bounce chamber (air tank) are provided at the upper end of the cylinder. The stroke is shortened from that of the open-end hammer by creating a cushion of compressed air in the bounce chamber and between the ram and the closed upper end of the cylinder. This results in operating speeds of about 80 blows per minute. Some closed-end hammers are convertible to the single-acting mode, thereby giving the contractor further flexibility.

These are similar in operating principle to the open-end type except that a compression chamber or vacuum is employed on top of the piston to assist the ram in the down stroke. This speeds up the blow rate of the hammer, but some of these hammers have a heavier ram relative to the energy than the open-end type.



A. Lifting Line from Crane
B. Ram
C. Starting Device
D. Fuel Pump
E. Anvil
F. Exhaust Ports
G. Fuel Pump Lever Rope
X. Compression Chamber

Figure 3.8: Typical closed-end diesel hammer. (Figure 3-14, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

VIBRATORY DRIVERS

A vibratory pile driver is a machine that installs piling into the ground by applying a rapidly alternating force to the pile. Vibratory hammers are available in high, medium, and low frequency ranges.

Vibratory hammers are most efficient for installing non-displacement type piles in sand. Clay soils tend to dampen the vibration of the hammer, thereby retarding penetration. When used in clay materials, the low frequency hammer has been more successful since it has more of a chopping effect than the medium-frequency hammer which is normally used for sands. These hammers are not very effective in penetrating obstacles, large cobbles or stiff clays.

Vibratory hammers are generally not suitable for the installation of most concrete piles and are seldom used on timber piles. When used for the right combination of pile and soil, vibratory hammers can install production piles at a rate much faster than any type of impact hammer. For example, it would not be uncommon to drive a 60-foot steel H-pile in sand in less than 5 minutes. An added advantage of the vibratory hammer is that it can extract piles as easily as it can drive them, requiring no new equipment set-up.

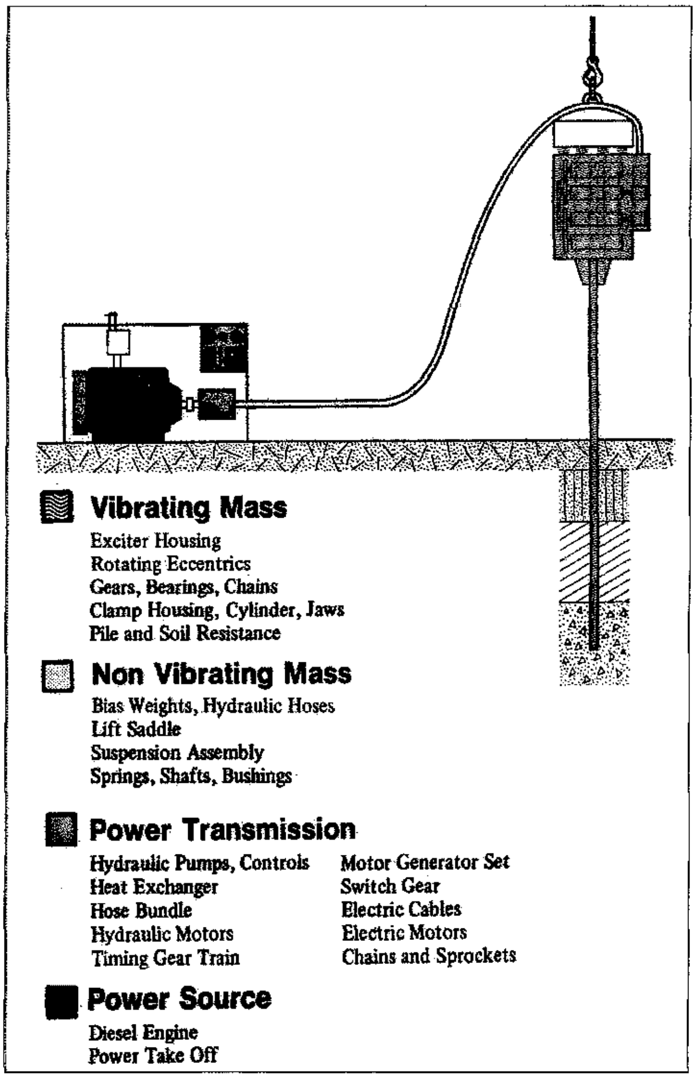


Figure 3.9: Vibratory driver/extractor system (Figure 5-6, Permission to reprint granted by Deep Foundations Institute (Item 31))

a) Low-frequency Hammers

These are vibratory drivers with a vibrator frequency of 5 to 10 Hz, used primarily with piles with high mass and toe resistance such as concrete and large steel pipe piles. They tend to have large eccentric moments to achieve their dynamic force with high resultant amplitudes.

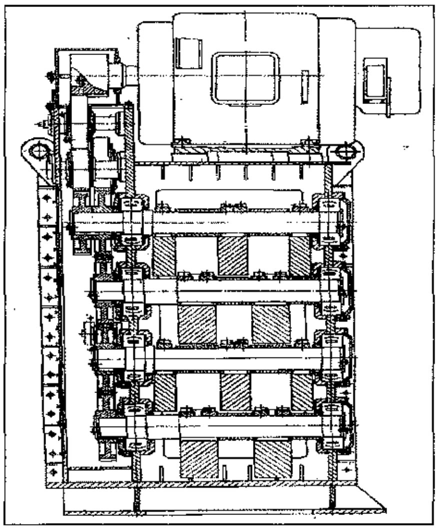


Figure 3.10: Low-frequency vibratory hammer. (Figure 3-19, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

b) Medium-frequency Machines

These are drivers with a vibrator frequency of 10 to 30 Hz, used for piling such as sheet piles and small pipe piles. These machines make up the majority of vibratory pile drivers in use today, since they combine the dynamic force necessary to excite the soil, the correct frequency to properly interact with most soils, and the sufficient amplitude to get through the hard spots in the soil.

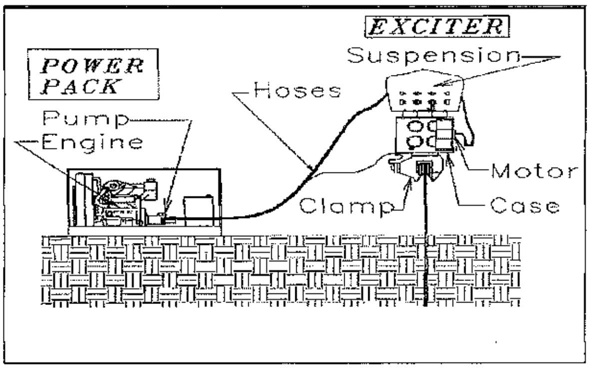


Figure 3.11: Medium frequency vibratory hammer. (Figure 3-20, Technical Instructions of Pile Driving Equipment, US Army Corps, (1998))

c) High-frequency Machines

These consist of all machines which vibrate at frequencies of more than 30 Hz. They are of two basic types. The first are machines in the 30 to 40 Hz range which are designed primarily to minimize vibration of neighboring structures. The primary advantage of these machines is their lowered transmission of ground excitation to neighboring structures. The frequencies of these machines are not high enough to improve driving. In some cases, these machines have problems in overcoming toe resistance.

EQUIPMENT SELECTION

a) Commercial factors

Proximity and Availability

The importance of using readily available equipment cannot be overemphasized. Unless the requirements of the foundation dictate otherwise, equipment selected should be in reasonable proximity to the job site, available from more than one source, and in time for construction.

Size of equipment

Larger equipment is generally less available than smaller equipment. Use of large equipment that is not readily available will result in delays and, with rental equipment and higher rental rates, will add to the cost of the job.

b) Noise

The entire matter of allowable noise disturbance is subjective and should be carefully evaluated before seeking special methods to reduce its effect. Pile driving can generate high noise levels. In many cases, proper explanation of needs, development of alternative methods and job site arrangements, and/or judicious selection of hours of operation can eliminate confrontation.

Impact hammers produce the highest sound pressure levels. There are two primary types of noise which are produced by an impact hammer. The first is impact noise produced by the ram striking the pile. The second type of noise is produced by the operating steam, air, or diesel exhaust as it is exhausted from the cylinder. Impact sound can exceed 140 decibels during pile driving operations. Unprotected personnel exposed to these high sound levels can incur permanent hearing loss that becomes worse over extended periods of time. A qualified industrial hygienist should be consulted to prescribe the appropriate hearing protection necessary to preserve hearing.

Impact Noise

Cushion material can be used to reduce the noise levels as well as modify the impulse duration as required by soil type and piling composition. Also, when driving steel piles, a canvas hood should be provided to reduce noise.

Hammer Exhaust Noise

The exhaust noise can also be reduced through the use of an exhaust muffler. Any device attached to the hammer must be secured properly to prevent it from being jarred loose during driving.

Preboring and the use of vibratory hammers may produce lower sound pressure levels but may not be less disturbing than the use of an impact hammer. This depends upon the interaction of the pile and the soil, and whether the hammer and pile resonate in a way that produces high noise levels. Where noise must be completely eliminated, jacking and screwing methods are likely to provide the least disturbance.

c) Effects of vibration

The vibration due to pile driving shall be considered concerning possible damage to adjacent construction. Damage due to vibration is a function of both amplitude and frequency. If there are adjacent structures susceptible to vibration damage, then preliminary investigations should be conducted and vibration monitoring should be done during pile load tests and actual driving if necessary. Some vibration reduction techniques are given below. With impact hammers, this might indicate use of a smaller hammer or a double acting hammer as opposed to a single acting model.

With vibratory hammers, this indicates the use of a high frequency, low amplitude vibratory hammer. If these resources fail, it may be necessary to adopt a method of foundation installation other than pile driving. Vibratory hammers typically cause more ground vibration than impact hammers.

d) Driving resistance

It is inevitable that the resistance experienced by the hammer pile system will vary as the soil varies on the jobsite and as the pile is being driven. Both low and high resistance situations call for attention to special conditions. Although low and high resistance will be encountered in driving, pile refusal should never be defined or required with impact hammers for blow counts in the low or high resistance.

Low Resistance

Impact Hammers

Low resistance for impact hammers is generally defined when the number of blows of the hammer is less than 14 blows/centimeter (36 blows/foot). Under these conditions, several possible events must be watched for, including tension cracking in concrete piles, the result of excessive energy returning from the pile toe and not going into the soil and inability to use a diesel hammer because it cannot start in low-resistance conditions. Especially on concrete piles, the hammer energy should be reduced during the first part of a pile's penetration to avoid both pile and hammer damage. If moderate to high resistance was anticipated, then low resistance suggests that the soils analysis requires reexamination. Consistent low resistance on a job can also indicate that the hammer selected is too large.

Vibratory Hammers

Vibratory hammers experience little difficulty in operation due to low resistance. The largest problem with these hammers in low resistance is keeping the pile straight, especially since a vibratory hammer is generally run free hanging from the crane, and there is little or no lateral support for the system. If a vibratory hammer is operating at a high hydraulic pressure or amper-age during low resistance driving, then there may be difficulty with the vibratory hammer's operation.

High Resistance

Impact Hammers

High resistance for an impact hammer is any resistance above 94 blows/centimeter (240 blows/foot). Under these conditions, excessive rebound may take place, damaging the hammer and pile top; the pile may be severely damaged by hitting an underground obstruction; and the job may be seriously elongated, which may create contract problems. Consistently high resistance on a job may indicate that the hammer is too small for the job.

Vibratory Hammers

With vibratory hammers, the main problem with high resistance is overloading the hammer. If the hammer operates at consistently full hydraulic pressure or amperage during driving, the hammer is probably too small for the job, and may also overheat or fail in another fashion. Serious mechanical failure of the hammer is also likely if the toe of the pile has contacted rock. High resistance will also lead to excessive clamp heating and wear, and steel piling should not be driven at penetration speeds less than one foot/minute.

e) Cost

Once a pile type satisfies all other criteria, relative cost becomes a major consideration. For comparisons between types of piles, it may be adequate to compare the pile cost per load capacity. A comparison between unit capacity costs may lead to an obvious exclusion of certain pile types. The cost evaluation should include all expenses related to and dependent on the pile foundation. Such costs may include additional expense for storage or splicing.

They may include pressure-relief systems used to reduce uplift pressures and thus control pile loads. In addition, any required modifications to the structure to accommodate the piles should be included in a comparative cost estimate.

The pile-driving accuracy affects substantially the driving cost. For this reason it is necessary to take into account the requirements placed on the driving accuracy in the design solutions for pile foundations. Extremely rigid requirements should not be placed on the pile-driving accuracy, since they result in a considerable increase in the cost of the pile-driving work. The pile-driving accuracy should be determined from the constructional solutions for the pile foundations. It is recommended that the construction organizations in charge of pile-driving work have at their disposal pile-driving machines permitting the driving of piles within a wide range of tolerances.

Piling contractor is unlikely to quote a fixed price based on a predetermined length of pile. Extra payment will be sought of the piles are required to depths greater than those predicted at the tendering stage. Thus a contractor's previous experience of the ground conditions in a particular locality is important in assessing the likely pile length on which to base his tender. Experience is also an important factor in determining the extent and cost of a preliminary test piling program. This preliminary work can be omitted if a piling contractor can give an assurance from his knowledge of the site conditions that be comply with the engineer's requirement for load-settlement criteria. The cost of test piling can then be limited to that of proof-loading selected working piles.

If this experience no available, preliminary test piling may be necessary to prove the feasibility of the contractor's installation method and to determine the load-settlement relationship for a given pile diameter and penetration depth. If a particular piling system is shown to be impracticable, or if the settlements are shown by the test loading to be excessive, then considerable time and money can be expended in changing to another piling system or adopting larger diameter or longer piles. During this period, the main contractor continues to incur the overhead costs of his site organization and he may well claim reimbursement of these costs if the test piling work extends beyond the time allowed in the timeline. To avoid such claims it is often advantageous to conduct the preliminary test piling before the main contractor commences work on the site.

Finally, a piling contractor's resources for supplying additional rigs and skilled operatives to make up time lost due to unforeseen difficulties and technical ability in overcoming these difficulties are factors which may influence the choice of a particular piling system.

HAMMER SELECTION

(1) *General*

Hammer selection may be the most important aspect of pile installation. In some installations only one hammer type may be applicable for the pile-soil combination, while for others several types may suitable. Evaluation must consider the need to use pile penetration rate as the means to end driving, the ability to drive the pile without structural damage or reducing soil capacity, the ability to obtain penetration rates within the desired band, and the realization that some hammer types may cause reduced capacities for identical pile lengths. In general, wave equation analysis supplemented by engineering experience and judgment should be the basis for hammer approval and criteria such as allowable driving stresses, desired penetration rates, and any other data used as a basis for approval that are clearly defined in the specifications.

(2) *Size*

Selection for a particular hammer must consider the pile's anticipated driving resistance, ultimate capacity, pile stresses expected during driving, and pile set-up. The hammer type and size used for production should always match that used in the test program because a different hammer would most likely result in a different capacity. The designer or contractor may designate a number of hammers for the test program when warranted. Any changes in hammer type or size will usually require additional testing.

(3) *Vibratory hammers*

Require special attention as they have been shown to yield reduced capacity at work loads in some cases. Another reason for special attention is that there is no reliable way to evaluate driving resistance and driving induced stresses in piles as can be done for impact driven piles via pile driving analyzer and wave equation analysis. However, the potential economic

advantage of a vibratory hammer cannot be discounted without adequate consideration, especially for large projects. Specifications can be written to require dual driving and load test programs if needed to address additional pile length and penetration limitations.

Other engineering and construction agencies have permitted the use of a vibratory hammer but require a percentage of production piles be driven or struck with an impact hammer to determine relative capacity. In cases where tests indicate that additional pile length can be attributed to the hammer type, increased cost should be the responsibility of the contractor. The contractor may determine if the additional cost for testing and monitoring would be offset by increased production rate.

ULTIMATE BEARING CAPACITY

The ultimate bearing capacity of a pile used in design may be one three values: The **maximum load Q_{max}**, at which further penetration occurs without the load increasing. A **calculated value Q_f** given by the sum of the end-bearing and shaft resistances; or the load at which a **settlement of 0.1 diameter** occurs (when Q_{max} is not clear). This can be found in Terzaghi's equation.

$$Q_f = Q_b + Q_s = A_b \,.\, q_b + \Sigma(A_s \,.\, \tau_s)$$

Where;

Q_b = base capacity

Q_s = shaft capacity

A_b = the area of the base

A_s = the surface area of the shaft within a soil layer

q_b = normal stresses generated at the base

τ_s = shear stresses generated along the shaft of the pile

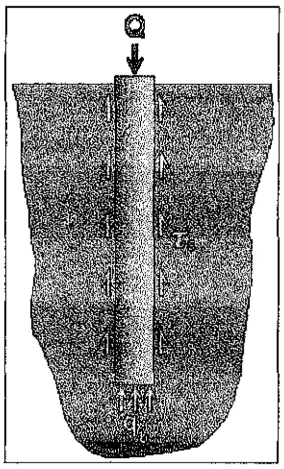


Figure 4.1: Load acted on pile resist by normal and shear stresses

ULTIMATE PILE CAPACITY

The **base resistance**, Q_b can be found from Terzaghi's equation for bearing capacity,

$$q_f = 1.3\ c\ N_c + q_o\ N_q + 0.4\ \gamma\ B\ N_\gamma$$

The net unit base resistance is therefore

$$q_{nf} = q_f - q_o = q_o\ (N_q - 1)$$

and the **net total base resistance** is

$$Q_b = q_o\ (N_q - 1)\ A_b$$

The ultimate unit **skin friction** (shaft) resistance can be found from

$q_s = K_s\ .\sigma'_v\ .\tan\delta$

where;

σ'_v = average vertical effective stress in a given layer

δ = angle of wall friction, based on pile material and ϕ'

K_s = earth pressure coefficient

Therefore, the **total skin friction resistance** is given by the sum of the layer resistances:

$Q_s = \Sigma(Ks\ .\sigma'_v\ .\tan\delta\ .A_s)$

The self-weight of the pile may be ignored, since the weight of the concrete is almost equal to the weight of the soil displaced.

Therefore, the **ultimate pile capacity** is:

$Q_f = A_b\ q_o\ N_q + \Sigma(Ks\ .\sigma'_v\ .\tan\delta\ .A_s)$

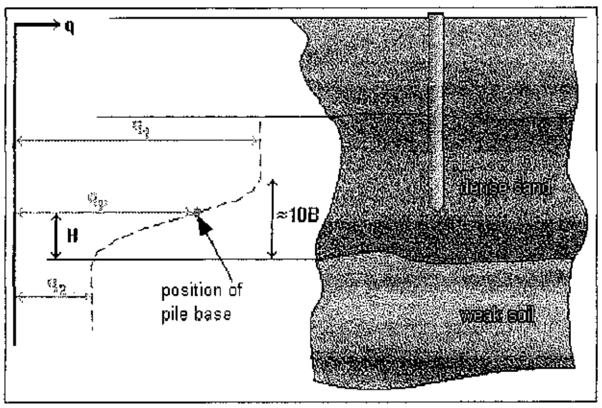


Figure 4.2: Base resistance at the pile toe

SUBSURFACE CONDITIONS

The first consideration in the design of a structural foundation should be the subsurface investigation. The data from such investigations should be evaluated. A preliminary selection of the pile type may usually be made from a study of the foundation investigations. However, the nature of the structure, type of applied loads, and technical and economic feasibility must be considered in the determination of pile type, length or spacing.

These investigations should be planned to gain full and accurate information beneath and immediately adjacent to the structure. The borings should be of sufficient depth below the pile tip to identify any soft, settlement-prone layers. The type of soil-boring will be determined by the type of soil profile that exists. In a clay layer or profile, sufficient undisturbed samples should be obtained to determine the shear strength and consolidation characteristics of the clay. The sensitivity of the clay soils will have to be determined, as strength loss from remolding during installation may reduce ultimate pile capacity. Shrink-swell characteristics should be investigated in expansive soils, as they affect both capacity and movement of the foundation.

Since most structures requiring a pile foundation require excavation that changes the in situ soil confining pressure and possibly affects the blow count, the standard penetration test commonly performed in granular soils will probably be of limited use unless the appropriate corrections are made. Where gravels or cobbles are expected, some large diameter soil borings should be made in order to collect representative samples upon which to determine their properties. An accurate location of the soil borings should be made in the field and a map provided in the design documents. Geologic interpretations should be provided in the design documents in the form of geologic maps and/or profiles. The accompanying text and/or maps should fully explain the stratigraphic of the subgrade as well as its engineering geology characteristics.

(1) If the boring data reveal that timber piles would not be damaged by driving, such type may be considered. Steel bearing piles may be desirable if boulders or hard strata are present in the area of pile driving. In deposits of sands, silts, and clays that are relatively free of boulders, consideration should be given to the use of concrete piles. However, considerable difficulty and problems often occur in driving displacement piles in granular soils such as sands, silty-sands, and sandy silts.

(2) The load-bearing stratum or strata can be selected from a study of the soil profiles and characteristics of the soil. By estimating the required length of penetration into the load-bearing material, the lengths of piles may be reasonably approximated. In designing friction pile foundations, advantage should be taken of increased capacity with greater depths by favoring fewer piles with greater lengths.

(3) The ultimate axial load capacity of a single pile is generally accepted to be the total skin friction force between the soil and the pile plus the tip capacity of the pile, which are dependent on the subsurface conditions. The ultimate axial capacity of individual friction piles depends primarily upon the type of soil: soft clay, stiff clay, sand, or stratified soil layers. In soil deposits that contain layers of varying stiffness, the ultimate axial pile capacity cannot be equal to the sum of the peak strength of all the materials in contact with the pile because the peak strengths are not reached simultaneously. Failure is likely to be progressive. The existence of boulders or cobbles within foundation layers can present driving problems and hinder determination of ultimate axial capacity of a single pile.

DESIGN VERIFICATION

The design will be checked in the field prior to or during initial installation of the piles that had been selected to be sure that the pile foundation will have adequate capacity to support the expected loads. This field check will consist of a feasibility analysis, installation of indicator piles with pile driver analyzer (PDA) equipment and wave equation analysis. Indicator piles will be driven prior to load testing. Pile load tests are recommended and should be completed for economically significant projects. Driving of indicator piles and load tests should be handled in a separate contract from the construction project or as a minimum accomplished prior to the ordering of the bulk of the production piles. Pile lengths should be determined based on final results from the indicator and pile load tests.

a. <u>Feasibility of Foundation Selection.</u>

The type of pile, length, and dimensions selected during the design process will be checked to be sure that this is the most economical and suitable foundation to support the expected loads for the soils observed during the exploration program.

(1) *Examination of Exploration Data*

A thorough exploration program will have been completed to evaluate the design parameters used to determine the optimum foundation. The program should span the full range of site conditions.

(a) Decisions to limit pre-design and preconstruction site investigation efforts to save money and time have risks. These risks could potentially result in catastrophic cost escalation or delays due to encountering changed conditions. Avoidance of such a situation requires professional judgment and customer education.

(b) Data from the exploration program should be made available to designers and prospective bidders and contractors and should include complete boring logs showing all encountered strata, locations of changes in strata, and locations of groundwater including perched and artesian pressures.

(c) Cobbles and boulders should be indicated because they may interfere with the driving of piles.

(d) Landfills often contain poorly compacted materials and may not provide soils that will provide adequate pile capacity.

(e) The soil actually encountered during installation of the piles may not provide the penetration resistance that was expected from results of the soil exploration program. A variety of problems can be encountered leading to unexpected behavior of the driven pile. Costly delays from unexpected pile behavior can be minimized by driving indicator piles with PDA equipment and by performing load tests.

b. Indicator Piles

Indicator piles are the same as the actual production piles used to support the structure. These piles are driven at the start of construction to provide information on the behavior of the piles during their installation and to provide an assessment of the actual capacity of the piles. Indicator piles are usually designed to be part of the production piles that support the structure.

(1) *Driving of Indicator Piles*

Depending on the job size of the production piles, 2 to 5 percent is typically driven as indicator piles at locations specified by the design engineer or at locations that may have inadequate pile capacity.

(a) Locations where indicator piles should be driven include the corners, edges, and center of the site where piles are to be installed.

(b) Indicator piles should be driven at locations where the soil exploration program indicated relatively low standard penetration resistances, loose sands, or soft clays.

(c) The driving of indicator piles in loose sands or some clay soils may indicate penetration resistances that are too low to provide adequate pile capacity. Driving the piles may also cause pore water pressures to increase and further reduce the penetration resistance. Dissipation of pore water pressures over time will cause the penetration resistance to increase and lead to a pile with greater capacity.

(d) An indicator pile should be driven where the soil is dense sand, silt, or where the soil is a stiff, fissured clay, friable shale, or a clay stone. Pore water pressures in these soils may decrease while driving and cause the penetration resistance to increase substantially. The penetration resistance may get so great as to exceed the capacity of the selected pile driving system and to exceed the capacity of the selected pile to take the driving stresses. This is soil relaxation.

(2) *Pile Driving Analyzer*

PDA is recommended while driving the indicator piles to increase the reliability of wave equation analysis. PDA equipment measures signals from two strain transducers and two accelerometers bolted to the pile near its top. These two different sets of measurements are interpreted to provide force versus time and velocity versus time plots of the pile driving. Soil input data such as skin and toe resistances and the distribution of skin resistance can be modified to cause the force and velocity versus time plots to match. This calibrates the wave equation analysis.

(a) Driving stresses calculated by wave equation from PDA results can be checked to be within allowable stresses.

(b) The PDA results when output on an oscilloscope can be interpreted by the PDA technician to indicate the quality of the pile that had been driven and signs of any damage as a result of driving the pile.

(c) The PDA results can indicate the effectiveness of different pile driving systems and assist selection of the best system for pile installation.

CONSTRUCTION

Successful construction requires a well-written contract, unobstructed access to the site, efficient production methods, and adequate contractor experience.

(1) Basic Requirements

Specifications in the contract documents of the pile foundation will be clearly presented and easily understood. These specifications should be flexible to maximize economy, yet rigid enough to result in the desired foundation. The Government should be permitted to focus on the contractor's compliance with specifications and ability of the equipment and methods used by the contractor to produce structurally sound piles driven within established tolerances and capable of developing the required capacity.

(a) Contracts should not be awarded when scope or design is not finalized. Careful consideration of all potential problems and factors affecting contract performance is essential prior to any contract modification.

(b) Specifications should indicate whether the piles are to be driven to the design penetration resistance or to a specified bearing stratum.

(c) Specifications should indicate the minimum penetration into the bearing stratum, if the piles are to be driven to a specified bearing stratum. The specification should also give the resistance to where (blows/inch) the piles should be driven if they are end bearing piles.

(d) Specifications should indicate the intended function of the piles such as resistance to compression, tension or uplift, negative skin friction from compaction or consolidation of adjacent soil, and lateral loads.

(e) Specifications should include provision for contractor and Government responsibilities when using PDA equipment. The PDA may be useful to indicate hammer efficiency, driving energy delivered to the pile, driving stresses, pile capacity, and possible damage to the pile.

(2) Site Constructability

The site should be prepared for optimum construction efficiency.

(i) *Topography of Land Sites*

The site should be prepared for efficient movement of the pile rig, for access to and from the site, for delivery of materials, and for storage of equipment and materials.

(a) The site should have adequate drainage to prevent water from ponding. Dewatering will be provided unless specifications allow for wet installation.

(b) The construction area should be level to facilitate driving of the piles, unless construction is required on a slope. Sloping surfaces may require field adjustment of the pile location if the actual surface differs from the reference plane used in the plans to show the pile location.

(ii) *Surface Soils*

The top soil should be gravel, sands, or clays with low plasticity index $PI < 12$ and liquid limit $LL < 35$ to provide mobility. Lime can be sprinkled on the surface of high plasticity clays to improve mobility in wet weather.

(iii) *Overhead Clearance*

The pile driving rig, boom, leaders, and clearance required when rising and placing the pile in the leader should be determined and checked to be sure that clearance at the site is adequate.

(iv) *Coordination*

Proper scheduling of delivery of equipment and materials is required to provide continuous operation of the work.

(a) Site preparation should be completed on schedule to avoid delays in delivery of materials and equipment.

(b) Piles to be driven should be prepared by completing any preparatory splicing, cutting, and inspection prior to the time of actual installation.

APPENDIX A
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