# STUDY OF PILE INTEGRITY AND DYNAMIC ANALYZER SYSTEM FOR BEARING CAPACITY MEASUREMENT

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## ABSTRACT

Construction on peat is very challenging especially where the peat is of varying depth with low shear strength and bearing capacity. There is a need to provide a simple and reliable method to determine the in-situ undrained shear strength and bearing capacity. The idea of an instrumented composite pile for foundation on peat is derived from a novel combination of structural and geotechnical concept. The use of lightweight and high strength material for the foundation is to resolve the construction problem on peat. The instrumented steel composite pile is designed by considering the controlled density characteristics of the foamed concrete having a density which matches the density of peat. Foamed concrete of density 1300 kg/m$^3$ was cast into the profiled steel casing of strength 275N/mm$^2$. The site test was conducted at Parit Nipah, Batu Pahat. The design of instrumented pile is based on the use of a full size pile to determine frictional and bearing capacity. The comparison with the value of undrained shear strength (Su) obtained from vane shear field test produced results which forms the basis of performance evaluation. Field test results indicated that the bearing capacity of peat could range between 5 to 12 times Su. Further tests on greater depth of peat under static and dynamic loading conditions are proposed on other test sites to verify the accuracy and reliability of this novel method.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

Peat has been indentified as one of the problematic soils in Malaysia. Three million hectares or 8% of the country is covered with peat. There are two types of peat deposit, the shallow deposit is less than 3 m thick while the thickness of deep peat deposit in Malaysia could exceed 15 m. Currently the utilization of peat land in Malaysia is quite low although construction on marginal land such as peat has become increasingly necessary for economic reasons. Engineers are reluctant to construct on peat because of difficulty to access the site and other problems related to unique characteristics of peat. (Roslan Hashim, 2008)

The main problem related to building and road construction on peat is that the low shear strength and bearing capacity. The idea to resolve the problem is to modify and stabilize the peat in order to accommodate the load on the peat. Piled raft is a common type of foundation that could be used. Pile are columnar and slenderness elements in a foundation which have the function of transferring load from the superstructure through weak compressible strata to stiffer soil.

A composite pile made of foamed aggregate concrete encased within profiled steel casing is a new method in the construction on peat. This study covers the characteristics of the composite pile in terms of physical and mechanical properties.

The controlled density materials is used to produce composite pile of same density with peat. Profiled steel casing is designed to enhance its mechanical and physical properties. The instrumented composite pile (ICP) is designed to determine the in-situ properties of peat under static and dynamic loading. It could be an alternative method to the ane shear test commonly used to determine the engineering properties of peat.

## 1.2 Problem Statement

Peat is by nature complex and variable and its properties are difficult to classify with precision. Peat is a problematic soil with many adverse physical and mechanical properties such as soil surface subsidence, high water table, loose soil structure and contain high volume of underground woody debris (Abdullah, 2007).

Construction in the area of peat is challenging particularly peat with extreme low shear strength and bearing capacity. Generally this soil is considered as a soft soil as it has high settlement value even under moderate loading condition. Hence, peat is very much unsuitable for supporting foundations in its natural state (Islam, 2010).

To implement the pile foundation on peat is difficult it is because peat is vulnerable to lateral movement when subjected to vertical load. Knowing the problematic properties of peat, the instrumented composite pile was designed to suit the engineering performance of peat. The instrumented composite piles was made by encasing controlled density foamed concrete with profiled galvanized steel casing. The ICP is used as an apparatus to determine the properties of soil based on the equation of ultimate bearing capacity (qu) and undrained shear strength (Su) under static and dynamic loading.

## 1.3 Objective of Study

The objectives of this study include:

i. To design and fabricate instrumented composite pile to determine geotechnical performance of pile on peat.
ii. To determine the properties of the soil directly on site with the instrumented composite pile, under static and dynamic loading conditions
iii. To establish the relationship between bearing capacity and undrained shear strength of peat.

## 1.4 Scope of Study

This study evaluates the performance of instrumented composite pile under static and dynamic loading on peat. The study covers the mix design of foamed concrete as a controlled density material to form an integral part of the ICP.

The fabrication of galvanized steel casing was outsourced. The casting of foamed concrete into the steel casing was done in UTHM.

The field tests were conducted in Parit Nipah, Batu Pahat that have the undrained shear strength (cu) of 0 kPa to 5 kPa. The value is obtained by making the field vane shear test.

## 1.5 Significance of Study

The result of this study is expected to provide some insight on the limitations of existing methods of determining bearing capacity of peat. The process involves:

i. Exploration of innovative ideas on geo-structural approach to address geotechnical problems on peat.
ii. Laboratory and field tests with the composite pile to verify hypothesis
iii. To investigate the limitations of vane shear filed test against instrumented composite pile to establish a relationship between ultimate bearing capacity (qu) and undrained shear strength (Su) under static and dynamic loading conditions.

## 1.6 Summary

This study is based on the idea of using a full size controlled density composite pile as an apparatus to determine the engineering properties of peat in-situ, The novelties lies in the use of foamed concrete as a controlled density material to match the density of peat. The structural integrity is provided by a profiled galvanised steel casing. This alternative method when fully developed is expected to increase the confidence level of the properties of peat in situ thus reducing the uncertainty and cost of construction on peat. The extension of the method could lead discovery to resolve the problems of excessive differential settlement of raod on peat. The intensive research into the alternative method of determining ultimate bearing capacity (qu) and undrained shear strength (Su) of peat is a positive step towards sustainable construction on peat.

# CHAPTER 2

# LITERATUR REVIEW

## 2.0 Introduction

Piling system has been used as foundation for supporting various structures mainly found on the low bearing capacity soil. There are numerous types of piles which are extensively used in the construction industry. The difference pile system will serve difference purposes in different type of soil and site conditions.

Generally most of the piles are designed to be driven to set on to the hard strata or anchor to the rock firmly. meet the requirements of the bearing capacity which However pile section also can generate certain percentage of resistance through skin friction that produced between the pile and soil.

This chapter is to review the current system of piles which have been commonly used in pile foundation system on peat to understand the requirements of the pile system and practical usage in field and the challenges of handling construction on the low bearing capacity and shear strength of peat.

## 2.1 Pile Foundations

Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface. The main components of the foundation are the pile cap and the piles. Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main types of materials used for piles are wood, steel and concrete. Piles made from these materials are driven, drilled or jacked into the ground and connected to pile caps. Depending upon type of soil, pile material and load transmitting characteristics pile are classified accordingly.

### 2.1.1 Historical Perspective

Pile foundations have been used a load carrying and load transferring system for many years. The design of pile foundation on peat are related to its engineering properties.

The driving of bearing piles to support structures is one of the earliest examples of the art and science of piled foundation. The early example of piled foundation were steel piles that have been used since 1800s and concrete piles about 1990. The industrial revolution brought important changes to pile driving system through the invention of steam and diesel driven machines.

More recently, the growing need for housing and construction has forced authorities and development agencies to exploit lands with poor soil characteristics. This has led to the development and improved piles and pile driving systems. Today there are many advanced techniques of pile installation (Ongkhatiam, 2004).

### 2.1.2 Function of Piles

Piles are columnar elements in a foundation which have the function of transferring load from the superstructure through weak compressible strata or through water, onto stiffer or more compact and less compressible soils or onto rock. They may be required to carry uplift loads when used to support tall structures subjected to overturning forces from winds or waves. Piles used in marine structures are subjected to lateral loads from the impact of berthing ships and from waves. Combinations of vertical and horizontal loads are carried where piles are used to support retaining walls, bridge piers and abutments, and machinery foundations (Tomlinson.M, 2008).

### 2.1.3 Classification of piles with respect to mode of load transmission

The classification of pile with respect to mode of load transmission and functional behavior are:

a) End Bearing Piles (Point Bearing Piles)

The base of the pile rests on firm soil such as rock, very dense sand or gravel. The load of the structure is transmitted through the pile into this firm soil. As the base of the pile bears the load of the structure, it is known as an end-bearing pile. These piles transfer their load on to a firm stratum located at a considerable depth below the base of the structure and they derive most of their carrying capacity from the penetration resistance of the soil at the toe of the pile. The pile behaves as an ordinary column and should be designed as such. Even in weak soil a pile will not fail by buckling and this effect need only be considered if part of the pile is unsupported, i.e. if it is in either air or water. Load is transmitted to the soil through friction or cohesion. But sometimes, the soil surrounding the pile may adhere to the surface of the pile and causes "Negative Skin Friction" on the pile.

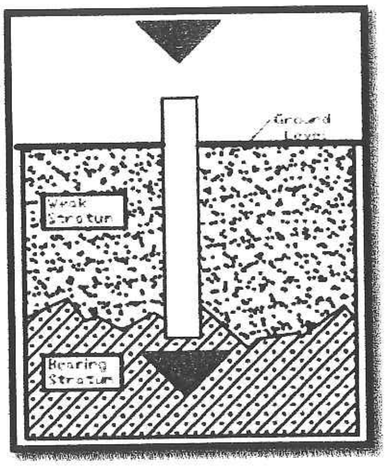



Figure 2.1: End Bearing Pile

b) Frictional Piles (Point Bearing Piles)

Friction piles come into use when the firm soil is deep underground, where it becomes expensive to use end-bearing piles. The piles are driven through the penetrable soil (softer soil) for some distance and load of the structure is transmitted to the penetrable soil by skin friction or cohesion between the soil and the surface of the pile. The process of driving such piles does not compact the soil appreciably. These types of pile foundations are commonly known as floating pile foundations.

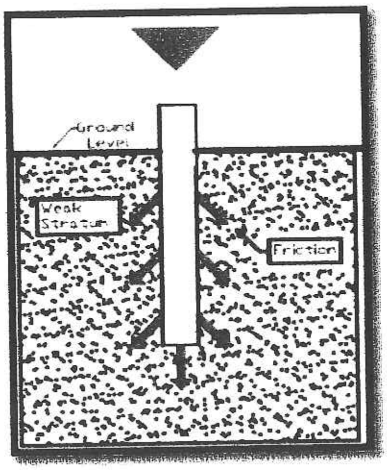



Figure 2.2: Friction Pile

### 2.1.4 Classification of piles with respect to type of material

General characteristics of pile design and construction of common types of piles used by JKR and in private development are discussed in the following paragraphs. These information briefs are very useful by using Figure 2.3 and Figure 2.4 to determine type of pile for a particular situation (Ongkathiam,2004).

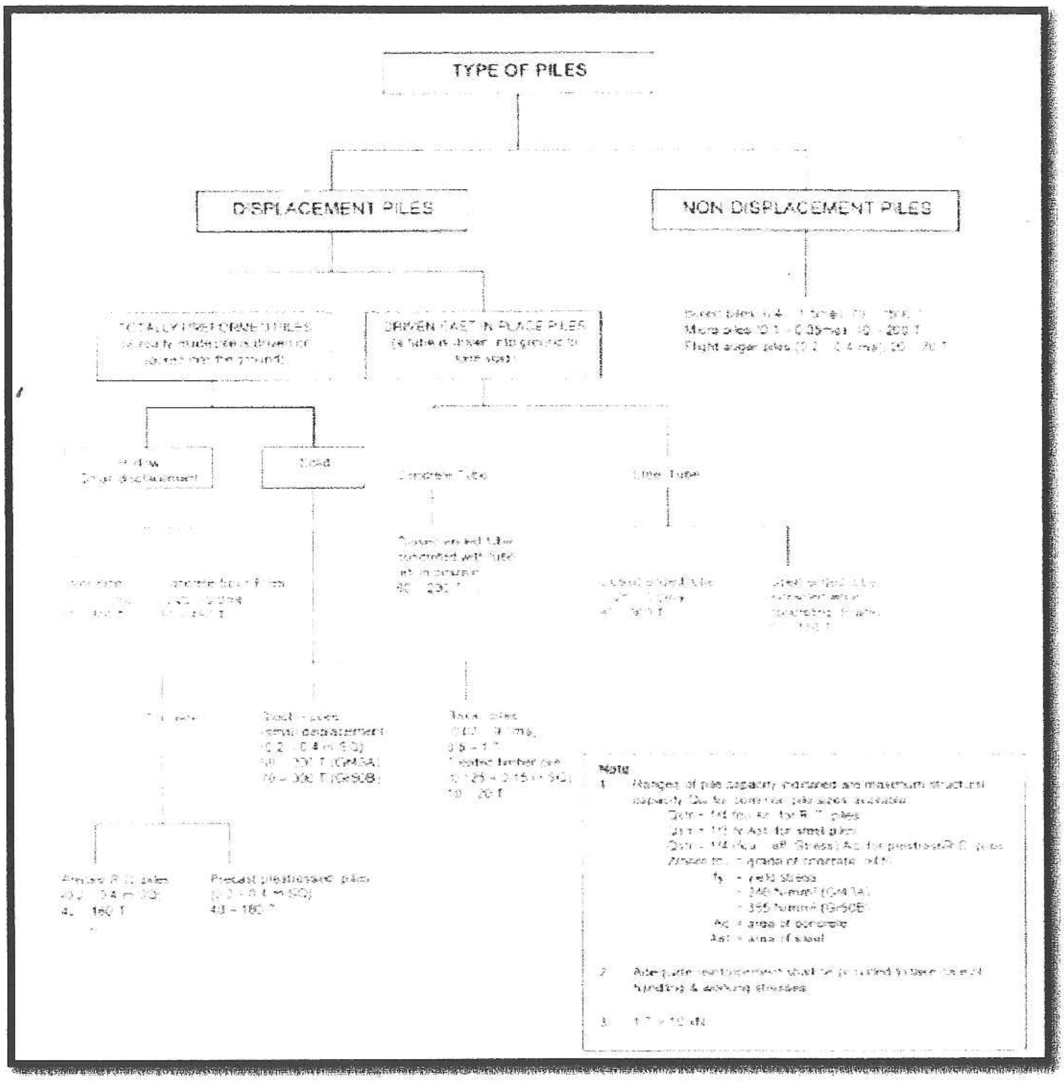



Figure 2.3: Classification of Piles

| DESIGN CONSIDERATIONS / TYPE OF PILE | | | BAKAU PILES | TIMBER PILES | RC PILES | PSC PILES | SPUN PILES | STEEL H PILES | STEEL PIPE PILES | JACKED PILES | BORED PILES | MICROPILES | AUGERED PILES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PREFORMED PILES | | | | | | | | | | |
| SCALE OF LOAD (STRUCTURAL) | COMPRESSIVE LOAD PER COLUMN | <100 KN | ✓ | ✓ | ✓ | ? | ? | ? | ? | ✓ | x | ? | ✓ |
| | | 100-300 | ✓ | ✓ | ✓ | ? | ? | ✓ | ✓ | ✓ | x | ✓ | ✓ |
| | | 300-600 | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | 600-1100 | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | | 1100-2000 | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | | 2000-5000 | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | | 5000-10000 | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | x | ✓ | ✓ | x |
| | | >10000 | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | x | ✓ | ? | x |
| GEOTECHNICAL – BEARING TYPE | MAINLY END BEARING (D=Anticipated depth of bearing) | <5m | ? | ? | ? | ? | ? | ? | ? | x | ✓ | ✓ | ? |
| | | 5-10m | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ✓ |
| | | 10-20m | ? | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | 20-30m | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | 30-60m | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ |
| | MAINLY FRICTION | | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ✓ | ? | ✓ |
| | PARTLY FRICTION + PARTLY END BEARING | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ |
| GEOTECHNICAL – TYPE OF BEARING LAYER | LIMESTON FORMATION | | ? | ? | ? | ? | ? | ✓ | ✓ | ✓ | ? | ✓ | ✓ |
| | WEATHERED ROCK / SOFT ROCK | | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | ROCK (RQD > 70%) | | x | x | ? | ? | ? | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | DENSE / VERY DENSE SAND | | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| GEOTECHNICAL – TYPE OF INTERMEDIATE LAYER | COHESIVE SOIL | SOFT SPT < 4 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ |
| | | M. STIFF SPT = 4 - 15 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | V. STIFF SPT = 15 - 32 | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | HARD SPT > 32 | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | COHESIONLESS SOIL | LOOSE SPT < 10 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | M. DENSE SPT = 10 - 30 | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | DENSE SPT = 30 - 50 | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | V. DENSE SPT > 50 | x | x | ✓ | ✓ | ✓ | ✓ | ✓ | ? | ✓ | ✓ | ? |
| | SOIL WITH SOME BOULDERS / COBBLES (S SIZE) | S < 100mm | x | ? | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ? |
| | | 100-1000mm | x | x | ? | ? | ? | ✓ | ✓ | ? | ✓ | ✓ | x |
| | | 1000-3000mm | x | x | ? | ? | ? | ? | ? | ? | ? | ✓ | x |
| | | >3000mm | x | x | ? | ? | ? | ? | ? | ? | ? | ✓ | x |
| GROUND WATER | ABOVE PILE CAP | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | BELOW PILE CAP | | x | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| ENVIRONMENT | NOISE + VIBRATION COUNTER MEASURES REQUIRED | | ✓ | ✓ | ? | ? | ? | ? | ? | ✓ | ✓ | ✓ | ✓ |
| | PREVENTION OF EFFECTS ON ADJOINING STRUCTURES | | ? | ? | ? | ? | ? | ? | ? | ✓ | ? | ✓ | ✓ |
| UNIT COST | (SUPPLY & INSTALL) RM/TON/M | | 0.5-2.5 | | 0.8-2.0 | | | 1.0-1.5 | | 1-2 | 0.5-2 | 1.5-[illegible] | 1-2.5 |

LEGEND

✓ INDICATES THAT THE PILE TYPE IS SUITABLE

x INDICATES THAT THE PILE TYPE IS NOT SUITABLE

? INDICATES THAT THE USE OF PILE TYPE IS DOUBTFUL OR NOT COST EFFECTIVE UNLESS ADDITIONAL MEASURES TAKEN

Table 2.1: Pile selection chart

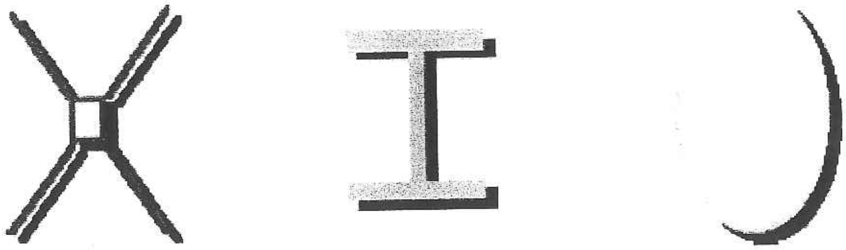
The classifications of pile with respect to type of material are:

a) Timber Pile

Timber pile are made of tree trunks with the branched carefully trimmed off, usually treated with preservative, and driven with the small end as point. The timber should be in good condition and should not to be attached by insect. For timber piles of length less than 14 meters, the diameter of the tip should be greater than 150 mm. The timber piles are cheaper than steel or concrete piles. Engineers should consider possible future construction activities that could trigger lowering of the groundwater level.

b) Steel Pile

There are usually rolled HP shape or pipe piles. Steel piles are suitable for handling and driving in long lengths. Their relatively small in cross-sectional are combined with their high strength makes penetration easier in firm soil. They can be easily cut off or jointed by welding. If the pile is driven into a soil with low pH value, then there is risk of corrosion, but risk of corrosion is not as great as one might thick. In this way the corrosion process can be prolonged up to 50 years. Normally the speed of corrosion is 0.2-0.5 mm/year and, in design, this value can be taken as 1mm/year



(a) (b) (c)

Figure 2.4: Cross Section of Pile : (a) X- shape, (b) H- shape and (c) steel pipe

c) Concrete Pile

Precast reinforced concrete piles or fabricated concrete pile in a central casting yard to the specified length, cured and then shipped to the construction site. Usually of square, triangle, circle or octagonal section, they are produced in short length in one meter intervals between 3 to 13 meters. They are pre-cast so that they can be easily connected together in order to reach to the required length. This will not decrease the design load capacity. Reinforcement is necessary within the pile to help withstand both handling and driving stresses. Pre stressed concrete piles are also used and are becoming more popular than ordinary pre cast as less reinforcement is required.

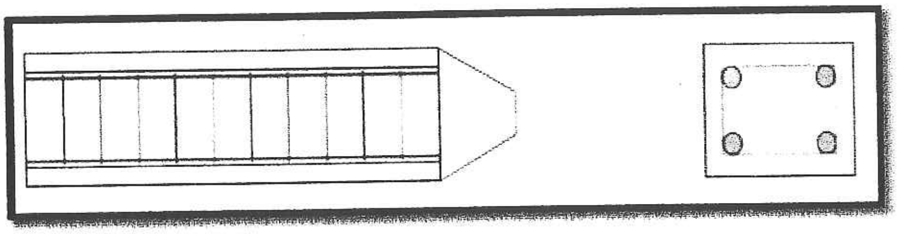


Figure 2.5: Reinforced concrete piles

d) Composite Pile

Piles that consist of two or more different types of materials are known as composite piles. As indicated earlier, part of a timber pile which is installed above ground water could be vulnerable to insect attack and decay. To avoid this, concrete or steel pile is used above the ground water level, whilst wood pile is installed under the ground water level. For example Precast Concrete Piles with H-Section are not economical for lengths more than 60 ft. For this reason an H section is attached at the end. Further H sections are very capable of penetrating hard soil stratas and boulders. Skin friction is much larger in the concrete section due to larger diameter.

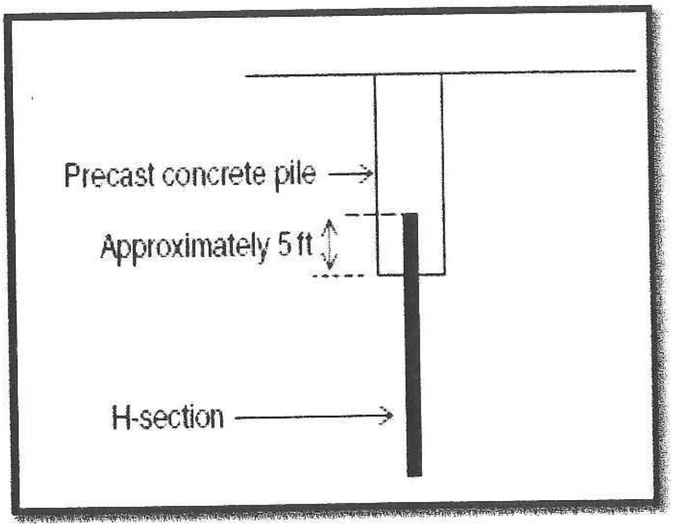



Figure 2.6: Precast Concrete Piles with H-Section

### 2.1.5 Single Pile Design

a) Basically, pile design should comply with three basic requirements:

i. Ultimate limit state, i.e. adequate geotechnical and structural capacity to resist the design ultimate loads;
ii. Serviceability limit state , i.e. lateral deflection, vertical & differential settlement are within the design ultimate loads;
iii. Durability aspect, i.e. pile should be durable and not suffer deterioration during the design life (>75 years) by aggressive chemical.

b) Other important design criteria that should be considered are:

i. Possible scour and its effect on pile capacity and stability
ii. Pile group effect
iii. Effect of pile installation on nearby existing piles or facilities
iv. Negative friction of pile in settling ground
v. Additional lateral loads for piles near slopes or in unstable ground.

| Method of Determining Pile Capacity | Minimum FOS | | |
|---|---|---|---|
| | Compression | Tension | Lateral |
| Theoretical or empirical method based on adequate SI but not verified by load tests | 3.0 | 3.5 | 3.0 |
| Theoretical or empirical method based on adequate SI but not verified by adequate load tests | 2.0 | 3.5 | 2.0 |

Table 2.1: Factor of Safety (FOS) for pile design: shows the recommended FOS for pile foundation by JKR Teknik (Jalan) 20/98

### 2.1.6 Pile Testing

#### 2.1.6.1 Static Load Pile Testing

Static load test is also known as axial compression pile load test. It consists of two anchor piles located on either side of a test pile. A reaction beam is placed on top of the piles and the test pile is loaded by utilizing a hydraulic jack placed centrally on top of the test pile ( Hariz, 2009).

Static load testing methods are applicable to all pile types, on land or over water, and may be carried out on either production piles or sacrificial trial piles. Trial piles are specifically constructed for the purpose of carrying out load tests and therefore, are commonly loaded to failure. Testing of production piles however, is limited to prove that a pile will perform satisfactorily at the serviceability or design load, plus an overload to demonstrate that the pile has some (nominated) reserve capacity.

This study is based on the application of static load concept to determine undrained shear strength and bearing capacity. The bearing capacity (qu) is defined as the average load per unit area required to produce failure by rupture of a supporting soil mass. The allowable bearing capacity value is defined as the maximum pressure that can be permitted on foundation soil, giving consideration to all pertinent factors, with adequate safety against rupture.

$$\text{Ultimate Bearing Capacity, } qu = \frac{\text{Load, } N}{\text{The area bearing surface, } A}$$

The undrained shear strength (Su) is an important parameter in the theoretical basis of skin friction in soils. In this study, the value of undrained shear strength (Su) can be obtain from the field vane shear test and the interpretation of the equation the loads effect to the skin friction.

$$\text{Undrained Shear Strength, } su = \frac{\text{Shear, } N}{\text{The pile surface that contact with soil, } A}$$

Therefore, the dynamic load testing is a high strain test method for assessing pile performance. Over the last 15 years, it has been the predominant means of pile load testing worldwide. Dynamic load testing involves impacting the head of a pile with a piling hammer or drop weight and measuring the resultant strains and accelerations. These measurements are used to quantify the pile and soil behaviour in response to the applied dynamic force. The required the allowable load that can accommodate the load is important in this test and based on the settlement by the penetration performance.

$$\text{Allowable Load on the Pile, } (Q_v)_{all} = \frac{2WH}{S+1}$$

W = Weight of striking parts of hammer

H = Effective height of fall in feet

S = Average net penetration in mm per blow of driving set (Driving Graph Set)

## 2.2 Materials used in Instrumented Composite Pile

### 2.2.1 Foamed Concrete

Foamed aggregate is derived from foamed concrete produced in specified sizes ranging from 40 mm to100 mm. The compressive strength of foamed concrete depends on the density, water/cement ratio and cement content. The density of the foam can have an influence on the ultimate strength, particularly for the lower density foamed concretes. Uniformly sized small bubbles tend to produce higher ultimate strength at all densities. Studies on the effect of void size on the compressive strength indicated that the total volume of void of around 40% with void size about 0.1 mm tends to achieve the optimum performance in terms of consistency and strength. Foamed aggregate made of biomass silica of density around 1200 kg/m3 achieved compressive strength of around 10 MPa.(Loon, L.,Y., 2009).

| |
|---|
| Air<br>(20 % – 70%) |
| Fined Aggregate<br>(very good < 4 mm) |
| Water<br>(Water – Cement ratio= 0.4 – 0.8) |
| Cement<br>(300 kg/m3 – 500 kg/m3) |

Fig. 2.7 : Examples of lightweight foamed concrete content (Ikram, 2008)

Pervious concrete is a composite material consisting of coarse aggregate, Portland cement and water. It is different from normal concrete as the mixture contains no fines in it. The aggregate is usually of a single size and is bonded together by a cement paste. The result is a concrete with a high percentage of interconnected voids that allow the penetration of water through the material matrix. Normal concrete has a void ratio around 3-5% and pervious concrete has higher void ratios from 18-40% depending on its application. Pervious concrete differs from normal concrete in several other ways. Pervious concrete has lower compressive strength, higher permeability and a lower density. Its compressive strength could be 65% lower than the normal concrete.

### 2.2.2 Galvanized Steel

Galvanizing is an attractive and economical means of corrosion protection for a wide variety of commercial and industrial steel articles. The outer surface of a galvanized coating is made up of zinc crystals, sometimes quite large, known as "spangles," the well-known zinc bloom pattern. These spangles are often quite bright. This ductile zinc surface layer commonly comprises at least 40% and as much as 80-90% of the total coating thickness. Galvanizing some steels produces zinc-iron layers that grow right through to the surface, producing a matte gray rather than bright finish. Both of these coatings are equivalent in protective value. (Dr. Mehrooz,)

The steel grade S355 was used in design composite pile. The steel grade S 355 operates at a yield stress about 30% more than S 275. The BS EN 10025 with the high tensile and impact performance with reduced cost. (G.D.Taylor,2002).

## 2.3 Peat

Peat has been identified as one of the problematic soils found in Malaysia. Three million hectares or 8% of the country is covered with peat (Huat et al. 2004). On the west coast of Malaysian Peninsular, the deposits are formed in depressions consisting predominantly of marine clay deposits or a mixture of marine and river deposits especially in areas along river courses. There are two types of peat deposit, the shallow deposit is usually less than 3 m thick while the thickness of deep peat deposit in Malaysia exceeds 5 m ( Roslan Hashim, 2008).

In general, peat is a soil with high organic content, in cold and humid environments where dead hygrophytes have been deposited over a long period of time without fully decomposing. The term peat refers to highly organic soils derived primarily from plant remains. In geotechnical engineering, all soils with organic content greater than 20% are known as organic soil, and peat is an organic soil with organic content more than 75% (Eng Chun Wei,2005).

Peat exhibits unique characteristics, such as:

i. High natural moisture content
ii. High compressibility including significant secondary and tertiary compression
iii. Low shear strength
iv. High degree of spatial variability
v. Potential for further decomposition as a result of changing environmental condition

According to ASTM D2487, peat soil is under the division of Highly Organic Soils, with the symbol Pt, and there is no specific grain size for peat soil. Besides, a Malaysian Soil Classification for organic soils includes the two factors, which are organic content and degree of humification as shown in Table 2.2.

| Soils group (See note 1) | | Sub-group and laboratory identification | | | | | Sub-group name | Field Identification |
|---|---|---|---|---|---|---|---|---|
| | | Description | Group Symbol | Sub-group symbol | Liquid Limit % | Degree of Humification | | |
| ORGANIC SOILS and PEATS | SLIGHTLY ORGANIC SOILS<br>Organic Content 3% - 20% | Slightly Organic SILT<br>Slightly Organic Clay | Mo<br>Fo<br>Co | Mo<br>Clo<br>Clo<br>Cho<br>Cvo<br>CEo | <35<br>35-50<br>50-70<br>70-90<br>>90 | | Slightly Organic SILT (Sub-divide like Co)<br>Slightly Organic CLAY of low plasticity<br>Slightly Organic CLAY of intermediate plasticity<br>Slightly Organic CLAY of high plasticity<br>Slightly Organic CLAY of very high plasticity<br>Slightly Organic CLAY of extremely high plasticity | Usually very dark to black in color, small amount of organic matter may be visible. Often has distinctive organic smell |
| | ORGANIC SOILS<br>Organic Content 20% - 75% | ORGANICS SOILS | O | | | | Subdivision of Organic Soil is difficult, as neither the plasticity tests nor the humification tests are reliable for them As such a "best attempt" is the probable outcome of subdivision leading to descriptions such as "Fibrous ORGANIC SOILS" or "Amorphous ORGANIC SOIL of Intermediate Plasticity" | |
| | PEATS<br>Organic Content | PEAT | Pt | Ptf<br>Pth<br>Pta | | H1-H3<br>H4-H6<br>H7-H10 | Fibric or Fibrous Peat<br>Hemic or Moderately Decomposed Peat<br>Sapric or Amorphous Peat | Dark brown to black in color. Material has low density so seems light. Majority of mass is organic so if fibrous the whole mass will be recognizable plant remains. More likely to smell strongly if highly humified |

Table 2.2: Organic soils and peat section of Malaysia Soil Classification Systems

### 2.3.1 Physical Characteristics

There are some unique physical properties of peat deposit, which should be taken into consideration. According to Been (1981), the important soil properties when considering one-dimensional consolidation are the permeability and compressibility. Both of which can be deduced from the measurements of density and pore water pressure. Hence the properties below are quite important:

i. Moisture content. The moisture content of peat ranges from 100 to 1300 %, on a dry basis.
ii. Ash content. The ash content of the peat of the west coast of Peninsular Malaysia is less than 10% showing a very high content of organic matter. The organic matter content is highly variables as the mineral content ranges from 10% to as high as 65%.
iii. Bulk density. Normally the bulk density for the top 30 cm of the peat is low and varies from 0.1 to 0.2 g per cubic centimeters in peat of the Peninsular Malaysia.
iv. The rate of subsidence of peat deposit is very high, it ranges from 50cm to 100cm

### 2.3.2 Chemical Characteristics

There are some unique parameters of chemical properties of peat deposit:

i. pH. Generally, peat soils are very acidic with very low pH values, ranging from 3.0 to 4.5
ii. Electrical conductivity. The electrical conductivity values of peat soils are low, that is less than 1 ds/m. However this can be influenced by the area condition, for instance, in coastal area, the values can be up to 5 ds/m.
iii. Organic carbon. The values of organic carbon can be around 30% to 40%.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

Methodology in this study is based on the the fundamental theory of end bearing and frictional resistance of piles. The experimental procedures involved the design and fabrication of pile and the evaluation of its performance on peat. The shape, size and weight were carefully considered in order to overcome several limitations related to testing on site.

## 3.2 Research Flow Chart

The research methodology is summarized in the flow chart shown in Figure 3.1. The activities throughout the research consists of two major parts namely the design and fabrication of the prototype of instrumented composite pile and the second part is to determine its performance under static and dynamic loading at the Parit Nipah, Batu Pahat.

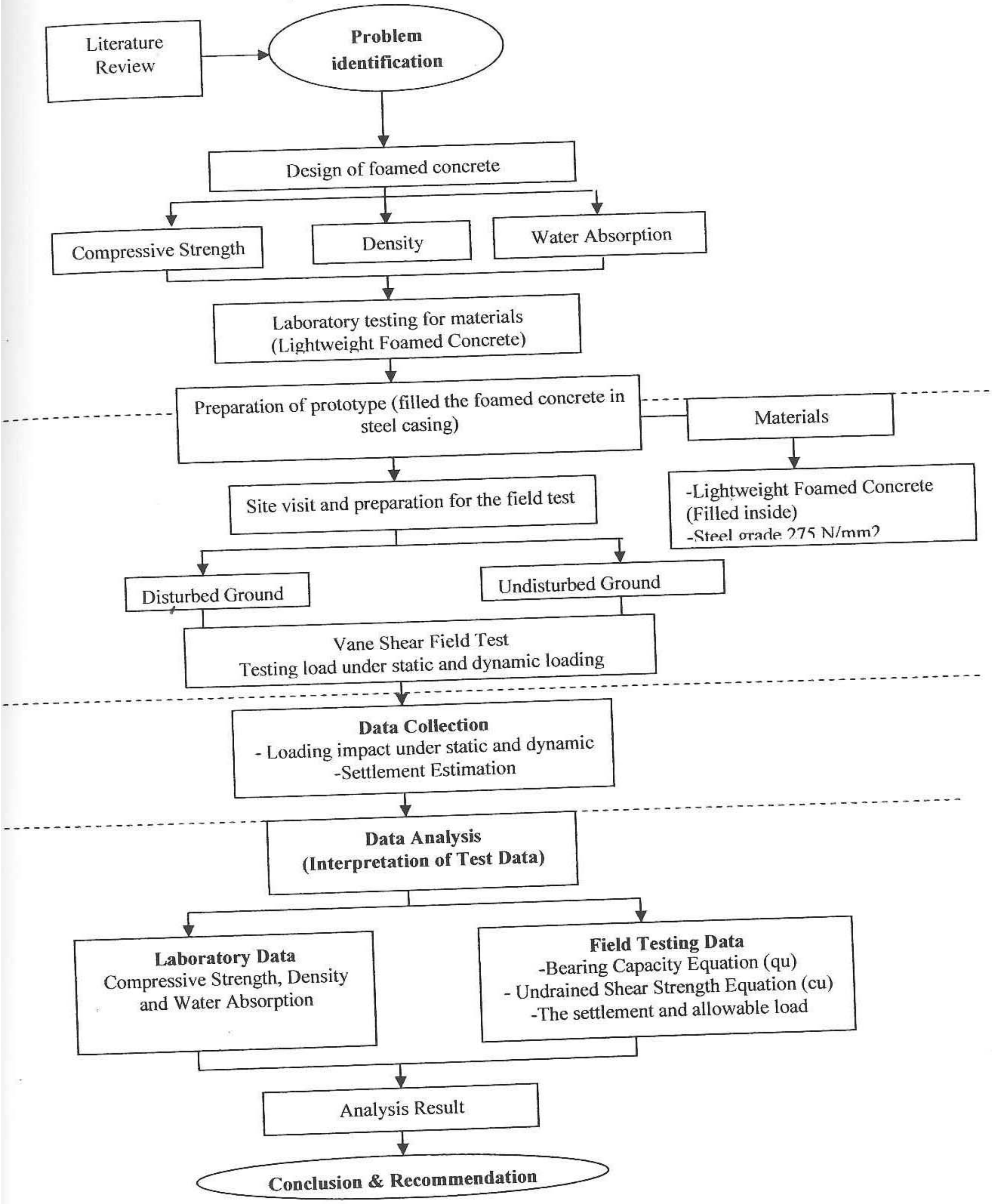



Figure 3.1 : Flow chart of research activities

## 3.3 Problem Identification

Identification of problem is important to ensure the objectives of study are relevant to main problem. The focus of this study highlights challenges related to the construction of road on peat. Considerations were made on the suitability of materials that can match the density of peat and the type of pile foundation that can be economically applied on peat with low shear strength and bearing capacity.

## 3.4 Literature Review

At this part of the study, a collection of information and knowledge of related topics were made. This involved research through various journals, case studies, proceedings and magazines. The challenge of this study is about innovation related to the design and fabrication of instrumented composite pile suitable for use as an apparatus on peat. The literature review provided good fundamental understanding of the state-of-the-art related to the scope of study.

## 3.5 Design of the instrumented composite pile

The pile foundation must be designed to transfer the foundation loads down through the piles to obtain the load resistance. The design of the prototype is related to the peat properties with very low shear strength and bearing capacity.

The instrumented pile was designed based on combination of bearing and friction concept of pile under static and dynamic loading. During pile driving, the rate of pile penetration provides a good indicator of the soil properties. The ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure. In addition, the instrumented composite pile is designed based on the effect of density and the shape of pile. It was meant to provide effective load transfer, taking into consideration the bearing capacity and frictional resistance of peat. It is an alternative method to obtain the value of undrained shear strength and bearing capacity based on established principle of soil mechanics.

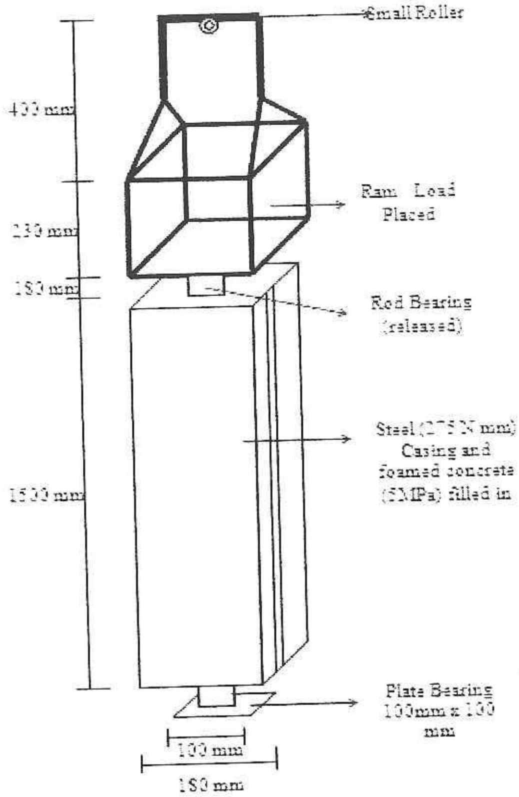



Figure 3.2 : Instrumented Composite Pile Design

### 3.6 Fabrication of the Instrumented Composite Pile

The prototype of the instrumented composite pile was made by encasing the lightweight foamed concrete with profiled galvanized steel. Steel is to provide structural integrity and durability while achieving controlled density. It will be used as an apparatus to determine qu and Su in-situ.

#### 3.6.1 Lightweight Foamed Concrete

Lightweight foamed concrete is a low strength controlled density material suitable for the modification of peat. The compressive strength of foamed concrete depends on the density, water and cement content. The density of the foam can have an influence on the ultimate strength, particularly for the lower density foamed concrete. (Lee, et. al. 2009). Mixture of the lightweight foamed concrete is 400 kg/m$^3$ cement, 400 kg/m$^3$ fine sand, 200 kg/m$^3$ water and 0.4.m$^3$ of foam to produce foamed concrete of density 1200 kg/m$^3$. It was used in the fabrication of the instrumented composite pile as shown in Figure 3.3.

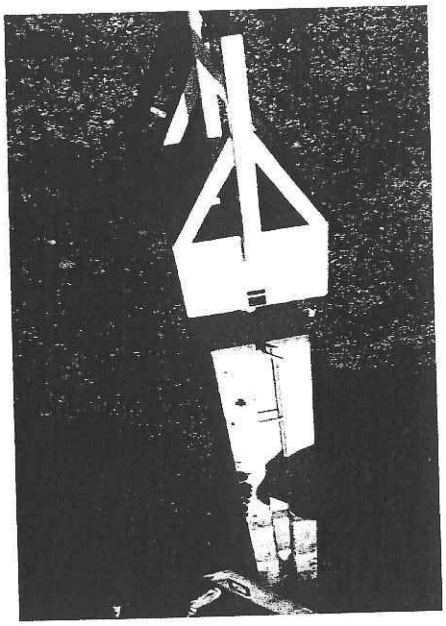


Figure 3.3 : Instrumented Composite Pile

### 3.6 Test Site Location

The field test was conducted at Parit Nipah, Batu Pahat. Figure 3.4 shows a Googlemap location of Parit Nipah. The location was selected based on logistics and cost factors apart from the properties of peat on site. This site may be accessed head west along Jalan Kluang towards Jalan Manis and turn right at Jalan Durian.

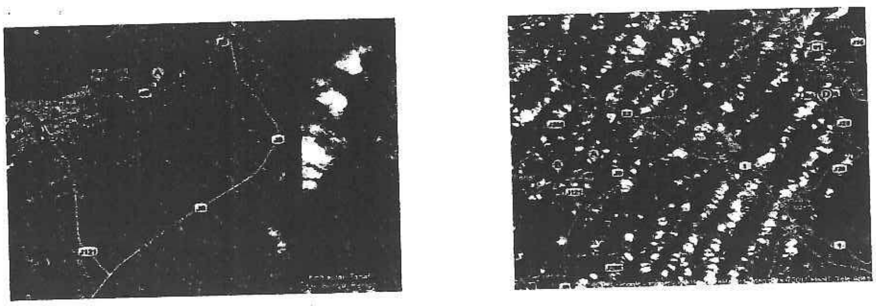


Figure 3.4 : Location Site, Parit Nipah