The Performance Evaluation of Lightweight Concrete Piles on UTHM's Soft Soil under Static and Dynamic Loading Tests

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Abstract

Light-weight concrete generally has low density and low strength compared with normal concrete, the use of the lightweight concrete for piling is still very rare due to high porosity and underestimate the strength. This research was done to find out the performance of light weight concrete piles (LCP's) which were made by Palm Oil Clinker (POC) and Foamed Concrete (FC) and to compare their performance with normal concrete pile (NC). Conventional static load test (slow maintained load test, SM) using kenteledge system to obtain pile capacities were performed for those three type of piles (NC, POC and FC) embedded in soft soil at RECESS, UTHM, Batu Pahat. Performance of piles were also evaluated using Pile Driving Analyzer (PDA) in dynamic loading. The results shows close correlation between static and dynamic test results and the stresses of compression and tensile under both loadings were within the allowable limit state thus, the application of LCP's for deep foundation on soft soil is feasible.

Keywords: Light-weight concrete piles; Load Test ; L-S Curve, Pile Driving Analysis

1. INTRODUCTION

Comparisons between dynamic and static estimates of pile capacity have been reported widely in the literature (Broms 1981,1985; Felenius 1988; Barends 1992; Goble and Likins 1996; Townsend 1996). However, there's no loading-settlement curve and distribution of friction and toe capacity yet for lightweight concrete pile which driven into soft soil. In this case, the light weight concrete piles (LCP) which has 6 m length and 150x150 mm square in sizes, have been produced and driven into soft soil to evaluate their performance and comparing them with normal concrete (NC) pile.

In this research, evaluation and observation were made to the full-scale load test and pile driving analysis results of three type of piles of Normal Concrete (NC) pile, Palm Oil Crinkled (POC) pile and Foam Concrete (FC) pile. Those piles were fully instrumented with vibrating wire strain gauge before driving into soft soil at RECESS, UTHM, Batu Pahat then load tested to failure. Subsequently, the Pile Driving Analyzer (PDA) was used to monitor their performance under dynamic loading. The force and acceleration measurements were recorded by a pile analyzer system. In this system, one pair of strain transducers and one pair of accelerometers with built-in amplifiers were normally bolted onto the pile below the pile head. During pile driving, the signals from the transducers were transmitted by a connector box hung below the pile head to the analyzer that was kept in a monitoring station on the ground. The analyzer received the signals from the transducers, calculated and displayed the values of impact force, maximum force, developed energy, and a computed estimate of the mobilized soil resistance. Application of variable impact energy to the piles were recorded to obtain the proper and optimum energy needed to drive the piles.

This paper presents results from the site investigation, pile load test data (SM test and strain gauge measurement) and PDA test results for NC, POC and FC at RECESS site in Batu Pahat, Johor, Malaysia. Test results were analyzed and the ultimate capacities of the piles were calculated and compared with the measured values.

2. SITE INVESTIGATION

A geotechnical investigation program was performed to provide a significant amount of information on the site stratigraphy and the shear strength of the sub surface soil. The characteristic of the site was revealed by performing site investigation, using drilling machine to obtain soil sample, soil description, SPT test and collected in bore hole record.

The geotechnical investigations indicated that the site was underlain predominantly by soft to very soft clay to a maximum 30 m depth as shown in the Appendix A. Prior studies in the vicinity of the RECESS site indicated that bedrock is at about 35-40 m below the surface (Laidin 2004). Also shown in the Appendix A, Geotechnical parameters and 5.5 m depth of pile position below the surface, ground water is located 0.5 m below the soil surface.

3. TEST PILES

3.1 POC, FC and NC piles

The piles to be tested consist of two light-weight concrete piles (LCP) and one normal concrete pile (NC) as for control. Producing two LCP's of Palm oil concrete and foamed concrete need special ingredients of palm oil clinker and foam respectively. Palm oil clinker is brought from the Palm Oil Mill as a by product of combustion process, this clinker which is more lighter than normal coarse aggregate is used to replace the coarse aggregate as for normal concrete

(a) (b)

Fig. 1(a) Foam as the ingredient for FC concrete
(b) Palm oil clinker as replacement to coarse aggregate

Foam generation requires a foaming agent and a foam generator as shown in the Fig.1(a). Foaming agent is based on a protein-hydrolisation and is bio-degradable. It causes no chemical reaction with the surrounding matrix but serves solely as wrapping material for the air to be encapsulated in the concrete (or mortar). A foam generator is developed from a compressed air vessel incorporating a foaming compartment which allows the foaming agent to be agitated by a stream of compressed air.

The material formulation for 1000 kg/m^3 foamed concrete consist of 320 kg of cement, 640 kg of sand , 150 litre of water and 625 litre of foam.

Cement and sand were mixed first, water was then added to the mix to form a slurry. Foam was then added to achieve controlled density. If 1 litre of this mix weighs 1 kg then the density is 1000 kg/m^3 (normal concrete has density of 2400 kg/m^3). Curing is the same as normal concrete. Every pile is a pre-cast pile with dimension 150 mm x 150 mm and has a total pile length of 6 meter.

3.2Instrumentation

The piles were also instrumented with vibrating wire strain gauge as well as data recorder to obtain measurement on the load distribution along the embedded length of the pile. Those 3 vibrating wire strain-gauges were installed at 1 meter, 3.25 meter and 5.5 meter from the top of pile as shown in the Fig. 2.

The strain, ε were recorded during SM test. The load at the point will then be calculated by the following relationship (Prakash and Sharma, 1990) with assuming that strain in the steel is equal to the strain in the concrete at the same level (Liknaswaran and Kobarajah, 2007):

$Q_{va} = AE\varepsilon$
(1)

where

Q_{va} = load in the pile at the location of the strain gauge
A = cross section area of the pile
E = modulus of elasticity of the pile material
ε = strain gauge reading

Then, toe and friction capacity can be determined with using equation below:

$(Q_v)_{ult.} = Q_p + Q_f$
(2)

with
Q_p = the end-bearing capacity
Q_f = the frictional capacity


Fig. 2: Installing the strain gauge prior to driving

4. LOAD TESTS ON NC, POC AND FC PILES

4.1 S-M loading test set-up and procedures

The objective of the pile load test was to estimate the ultimate vertical compressive capacity of the piles. The Fig. 3 shows a dead load of concrete block of about 100 kN was placed on top of kenteledge beam, the load applied to the pile through hydraulic jack. A load cell was inserted between the jack and the beam to better define the applied load. Vertical deformation of pile under the applied load was measured using two dial gauges. The piles were loaded in accordance with the ASTM D 1143 *Standard test method for piles under static axial compressive load* known as S-M test method.

Fig. 3: S-M pile loading test is underway

The maximum anticipated test load of 30 kN was applied in eight steps and was kept constant, as practicaly as possible, during each load step. The maximum load was kept on the pile until failure occurred at the condition where pile head displacement = 0.1 D. Failure in this case was defined when it become impossible to hold the maximum load at above displacement because of the relatively fast deformation rate. Once failure occurred, the pile was unloaded from the maximum load in four steps. During the tests, the deformation obtained from the two dial gauges were carefully monitored to detect signs of eccentric loading. Although the deformations from these two gauges were not exactly the same, the difference (< 0.25 mm) was too small to suspect significant eccentric loading (I Nabil, 1999).

4.2 L-S Curve

The results of the S-M test to those of three piles (NC, POC, and FC) was illustrated in the Figure 4. To interpret how much the ultimate capacity of these piles, several methods might be used. One of the methods is Chin's method was used resulting in 20 kN, 22 kN and 26 kN for NC, POC and FC pile respectively. The Fig. 4 also shows characteristic of friction pile which indicates the abruptly sharp curve before failure for those NC, POC and FC piles.

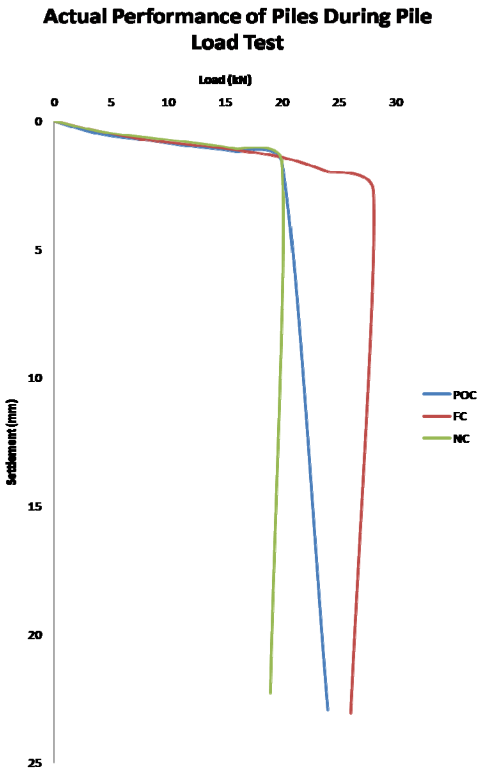
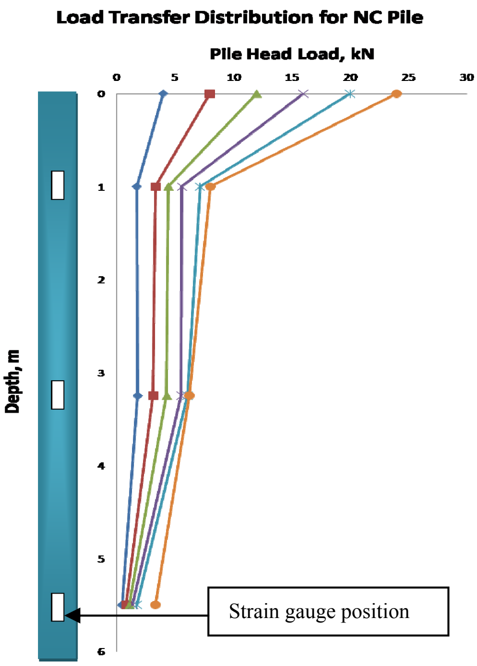


Fig. 4: L-S for tested piles (NC, POC, and FC)

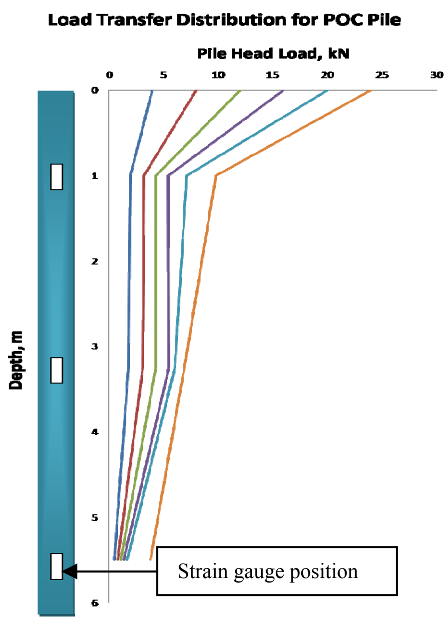
4.3 Load transfer distribution

During SM test, the distribution of friction and point bearing capacity were obtained by installing strain gauges at 1, 3.25 and 5.5 m from top of the pile, each strain gauge was connected to the display unit to measure the strain at respective point under applied loading..

Measurements of strain were then converted to loads by using Equation (1), and load transfer distribution was obtained as shown in the Fig. 5. The graph shows the distribution pattern of load transferred to point and friction / skin of the pile, all of the three piles exhibit small amount of end bearing capacity compared to skin resistance. This is in close correlations with L-S curve results.



(a)



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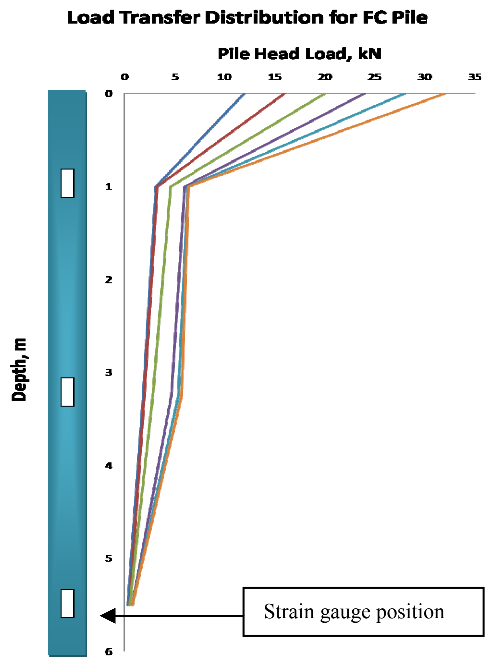


(c)

Fig. 5: Load transfer distribution versus depth of pile a). NC pile b). POC pile and c)FC pile from strain gauge measurement

The results are tabulated in the Table 2 indicates that all of the piles capacity are in friction resistance, however the end bearing capacity contributes small amount of total capacity. This is due to the fact that soil condition along the pile length is soft clay with zero N value.

Table 2: Total Load transfer distribution to Q_p and Q_f

Type of pile	Load, kN		
	$(Q_v)_{ult.}$	Q_p	Q_f
NC	20	3.3	16.7
POC	24	3.8	20.2
FC	28	2.2	25.8

5. DYNAMIC LOADING TEST MONITORING ON NC, POC AND FC PILES

5.1 Energy Balance Anaysis / Pile driving formula

To accomplish the measurement of ultimate capacity, the calculation using Pile driving formula was used based on data available. According to MD. Braja (1999), Engineering News Formula are used to calculate the ultimate capacity of the pile during driving. The Ultimate capacity is determined by:

$$R_s = \frac{\eta W_h}{s+c} \qquad (3)$$

where :
R_s = Mobilized static soil resistance
Wr = weight of the ram
h = height of fall of the ram
s = penetration of pile per hammer blow / permanent set
η = hammer efficiency
c = elastic movement of the pile

Different amounts of delivered energy were imparted to the piles by varying drop height of the ram mass around 0.2 to 0.5 m. The results was tabulated and compared in Table 5 and Table 6 are in close agreement with other available method.

5.2 Wave Anaysis

The governing equation that describes the motion of the stress wave through an elastic rod in the axial direction is given by :

$$\frac{\partial^2 w}{\partial t^2} = c^2 \frac{\partial^2 w}{\partial z^2} \qquad (4)$$

Where at a position z along the bar and a time t, the pile displacement is *w* and a wave speed is *c* (Timoshenko and Goodier 1970).
By solving equation (4) and deriving the upward and downward components of Force F from the net force and particle velocity *v* at the instrumentation level, an expression for the static pile capacity

$$R_s = 0.5(1 - j_c)(F + Zv)_t + 0.5(1 + j_c)(F - Zv)_{t+2L/c} \qquad (5)$$

Where j_c= damping coefficient and Z = impedance of the pile. The return time is given by *2L/c* which is the time taken for the stress wave to propagate down the pile (length L)and return to the instrumentation level.
The deduced mobilized soil resistance R_s can be very sensitive to the value adopted for the damping parameter j_c . However, the above expression can provide useful guidance on the static pile capacity measured by dynamic test. Transducer can be attached anywhere on the pile, though it should be noted that transferred energy decreases down the pile and blow eccentricity increases closer to the pile top. Typically, the transducers are mounted at a distance of 2-3 pile diameter from the pile top such that a uniform stress wave is recorded with sufficient energy and minimal blow eccentricity.

To follow the above requirement, the transducers was positioned 30-40 cm (2-2.7 x pile width) away from pile top as shown in the Fig. 6 (a).

(a) (b)
Fig. 6: (a) Setting up transducers , (b) Completed PDA setup

Basically, a foundation pile is monitored during the impact with a hammer. By mounting strain and acceleration transducers near the pile top, signals are supplied to the PDA system. With the complete connection of those equipment, transducers and cables it is able to monitor PDA and Dynamic Loading Test . With PDA the pile head is struck repeatedly with an impact driving hammer during pile installation. The pile capacity is obtained by signal matching with software attached in the PDA computer.

Driving would start when the soil resistance exceeds the combined weight of the pile and the hammer system.

Pile driving analysis monitors the pile driving process to determine the pile stresses and transferred energy during driving. Strain is measured from the hammer impact while acceleration is measured from the resultant pile motion. The test data from each blow, or from selected blows, is recorded and calculated by the PDA to produce the ultimate driving resistance of the pile.

5.3 Input parameter for PDA tests

To obtain the different respond among those three piles POC, FC and NC, special input parameters and special precautions should be paid to certain parameters.

Soil data :
1. Unit weight = 15 kN/m^3
2. Shear strength = 5 kPa
3. Soil Impedance, *Jc* = 0.65

Hammer data :
1. Weight of hammer = 100 kg
2. Drop height (vary from 0.2 – 0.5 m)

Table 3: Tabulation of data for pile input PDA test

	NC	POC	FC	Remarks
Unit weight (kN/m^3)	24	18	15	
Strength, (MN/m^2)	45	25	15	G-45 is standard Minimum of concrete grade
Stiffness, E_c (GN/m^2)	25	14	8	
Particle velocity (m/s)	3800	3600	3400	

The deduced mobilized soil resistance R_s can be very sensitive to the value adopted for soil damping coefficient *Jc* (D. Bruno, 1999). This *Jc* can be obtained by performing static test, where no static load test are carried out, guidelines for *Jc* published by Rausche et al. 1985 can be of an alternatives value.

Another sensitive parameter is Stiffness of concrete material,E_c , for NC, POC and FC, these value were adopted from the formula of concrete stiffness for different density (ND. Kenneth, 1998).

$$E_c = 33(w_c)^{1.5}\sqrt{f_c'} \quad \text{(psi)} \qquad (6)$$

where : w_c = unit weight of concrete (pcf)
$f_{c'}$ = maximum uniaxial strength of concrete (psi)

The study by D. Bruno and M.F. Randolph (1999) on PDA tests to Piles Driven Into Dense Sand, revealed that an increase in input hammer energy results in a decrease in pile displacements (s and c), and hence, leads to higher mobilized soil resistance. This facts can be understand due to :
- Increasing impacted energy leads to densify the sandy soil
- Permanent set (s) and elastic movement of the pile (c) decrease leads to increasing capacity.

Different with the result above, this study results which focused on the PDA tests on driven floating piles (NC, POC and FC) in soft clay as shown in the Figure 8 (a, b and c) reveals that energy given to the piles will increase the capacity to a certain value before turning down. This phenomena can be described as follow :
- No densification effect to the clay soil during driving.
- Higher energy impacted leads to high permanent set , s.

In this case, the capacity increases due to increasing energy imparted to the pile and low value of s. Whereas the curves turning down are due to increasing permanent set (s).

Based on the volatile value resulted from PDA due to some sensitive input parameters (Impacted energy, Pile Impedance, Soil damping, Pile stiffness) it is prudent to calculate the reference value of ultimate capacity prior to perform PDA test.

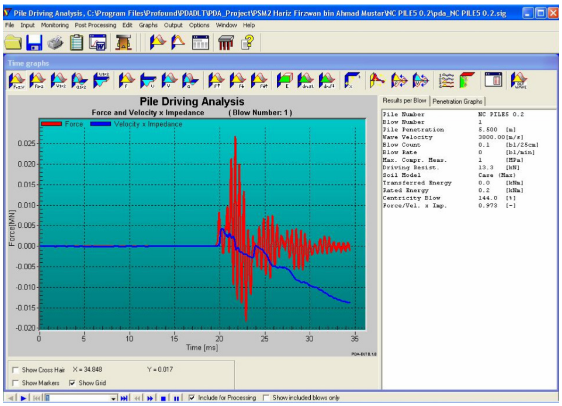


Fig. 7. The typical result of PDA test

5.4 Tensile and Compressive stresses in Piles

The analysis was performed using the computer program TNOWAVE and the typical results are shown in the Fig. 7. The program default values were used for the damping and quake parameters for the subsurface materials, also the program default values were used for hammer properties. The maximum tensile and compressive stresses in the pile are shown in the Table 4. To reduce the tensile stresses, Gerwick and Brauner (1978) suggested the use of thicker cushion has been proven successful. Those data in Table 4 is an also evident that the modified hammer (100 kg in weight) equipped with 10 mm cushion thickness to follow the thicker cushion suggestion is capable of driving the pile without generating significant tensile or compressive forces to the pile.

The calculated maximum compressive stresses in the pile do not exceed the grade of each concrete type which is below the design strength of the concrete.
Tensile strength is calculated using standard formula
(ND. Kenneth , 1998)

for Normal Concrete (NC) :

$$0.5 f_c'^{0.5} \text{ (MPa)} \quad (7)$$

for POC and FC :

$$0.3 f_c'^{0.5} \text{ (MPa)} \quad (8)$$

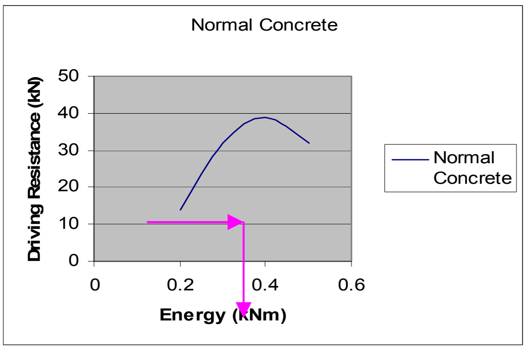
The results were tabulated in the Table 4. Refer to this table, This data measurement and comparison indicates the pile is safe under such compressive and tensile stresses. For compression stresses, the maximum stresses of 2.35, 3.3 and 3.75 MPa appear on NC,POC and FC respectively. Those compression stresses are much lesser than their strength of 45, 25 and 15 MPa of NC,POC and FC respectively. In this case, the safety factor is quite high. For tensile stresses, those tensile stresses values of 2.95, 0.72 and 0.8 MPa for the respective NC, POC and FC are slightly less than those maximum tensile strength values of 3.4, 1.5 and 1.2 MPa of NC, POC and FC respectively. In the case of tensile stresses, the safety factors are small. To increase safety factor, the grade of lightweight concrete can be increased to the certain level of safety in line with the advancement of concrete technology.

Table 4: Comparison of concrete grade and maximum compression and tension

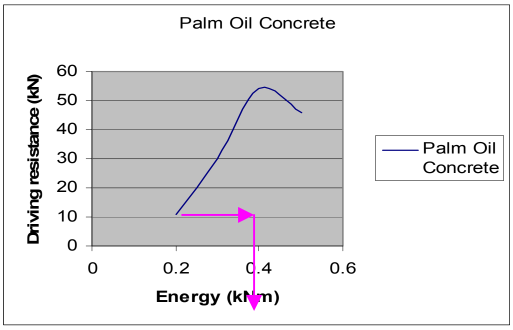
Pile type	Concrete Grade (MPa)	Energy (kNm)	Max. Compr. (MPa)	Maximum Tension (MPa)	Max. Tensile strength NC (MPa)	Max. Tensile strength POC,FC (MPa)
NC	45	0.2	1.35	0.99	3.4	
		0.3	1.65	1.70	3.4	
		0.4	2.35	2.90	3.4	
		0.5	1.40	2.95	3.4	
POC	25	0.2	1.10	0.32		1.5
		0.3	1.25	0.46		1.5
		0.4	3.30	0.65		1.5
		0.5	2.70	0.72		1.5
FC	15	0.2	1.65	0.01		1.2
		0.3	1.35	0.30		1.2
		0.4	2.50	0.41		1.2
		0.5	3.75	0.80		1.2

6. CORRELATION BETWEEN STATIC AND DYNAMIC LOADING TEST

Data measured and calculated by pile driving analyzer during dynamic loading test are compiled into table in the Appendix B, before testing performed, the way of performing PDA test some info should be gathered such as hammer weight, drop height and soil conditions. Static loading test is a reference to be used to determine the optimum energy required to obtain the ultimate driving resistance in PDA testing. Therefore, an optimum energy must be obtained by correlating the results obtained from both tests.



(a)



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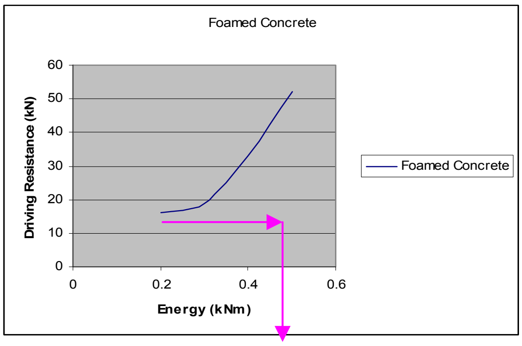

(c)

Fig. 8: Optimum energy for; (a) POC pile (b) NC pile and (c) FC pile

Shown in the Fig. 8 the results was plotted into the graph of energy vs ultimate driving resistance. It can be noted that the pattern of giving energy rises the driving resistance increases until the certain point, for POC and NC the maximum energy was clearly appeared whereas for FC the maximum driving resistance will appear by giving additional energy a little bit higher than 0.5 kNm.

The optimum energy is obtained by plotting the respective ultimate capacity of each pile types resulted from static loading test intersects with each curves was tabulated in the Table 5.

Table 5: Optimum energy required for each pile

Pile type	Driving Resistance (kN)	Optimum energy (kNm)
NC	20	0.22
POC	24	0.28
FC	28	0.36

Clearly mentioned in this Table 5 and Table 6 that as the pile lighter the impact energy and the driving resistance are higher. The proper way of using PDA is that the approached capacity calculated using PDF formula or common formula using soil and pile data should be calculated prior to testing and the test should be done many times to obtain the proper capacity.

Table 6: Results of PDA and pile driving formula

Pile type	Energy (kNm)	Q_p (kN)	Q_f (kN)	Pile capacity according to PDA (kN)	Pile set (penetration (m) / blow)	Pile capacity according to PDF (kN)
NC	0.22	3	17	20	5.6×10^{-4}	20.83
POC	0.28	4	20	24	9.6×10^{-4}	25.55
FC	0.36	4	24	28	9.8×10^{-4}	32.78

The comparison of ultimate bearing capacity was made and tabulated in the Table 7. It indicates that the capacity of the 6.0 m long pile were different depend on density of pile. Meyerhoff formula solely calculate the capacity without considering pile density, it based only on strength of clay and pile size whereas the others (PDF, PDA, SM test and Strain gauge) do. As clearly shown in the Table 7, the static capacity by Meyerhof for NC, POC and FC are similar as 20.9 kN.

Table 7: Comparison of the results

Pile type	**Ultimate capacity (kN)**					**Remarks**
	S-M test	**strain gauge**	**PDA**	**PDF**	**Meyerhoff formula**	
NC	20	20	variable	20.83	20.9	Variable depends on sensitive parameters
POC	22	24	variable	25.55	20.9	
FC	26	28	variable	32.78	20.9	

The energy balanced method / PDF provide reasonably good approximations. However, based on the observations, pile capacity estimates from energy balance method were highly dependant on input energy and provided less accurate estimations as the measured static pile capacity increased. Therefore, to obtain the selected capacity, more data available is better.

7. CONCLUSION

The conclusions can be made as follow:

1. Pile driving analyzer (PDA) and Static loading test (S-M test and strain gauge measurements), have shown significant difference of driving resistance between each piles. Foam concrete pile is the most resistance (30 % bigger than NC pile) and followed by palm oil concrete pile (10 % bigger than NC pile), this is due to decreasing its own density. The load transfer distributions of point and friction capacity also can be described in both tests shows those three piles (NC, POC and FC) exhibit similar type of friction pile.
2. Driving resistance of pile in soft soil from PDA increases proportionally with the energy of the impact goes up to certain point before turning down, special precautions to input parameter should be paid and all parameters should be sufficient and as accurate as possible. An estimation of energy to be imparted is interdependency, it is wise to determine the best and proper blow impact which should be given to a pile (drop height and hammer weight) to measure ultimate driving resistance. Too big or too low energy given to a pile will mislead the true capacity of a pile, calculation of capacity using available formula should be made prior to give certain energy to the pile even if the final set has been determined. This preparation should be done as control and reference value.
3. The PDA evaluation of the two pile type of POC and FC also proves that the compression and tension during driving are within tolerable limit. The other severe conditions of transporting and handling have been underway safely before being tested. Those are the evidence and facts that piles can be made safely by lightweight concrete (POC and FC) for deep foundation on soft soil to retain particular structures. The weaknesses of high porosity can be solved by coating the reinforcement by bitumen or epoxy resin whereas to increase the grade of LCP's, some additives might be used (A.M Neville and J.J Brooks, 2001).

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Appendix A
The data result from the selected Bore hole of Site Investigation on RECESS UTHM soft soil.

Depth (m)	Soil description	Classification	Atterberg Limit test				Consolidation Test 1-D				Triaxial test				In situ test
			MC	LL	PL	PI	Cv	Cc	Cs	p_c	C' kPa	ϕ'	Ct kPa	ϕ_t	SPT
0 - 2.0	Top soil														0
2.0 - 2.5	Silty clay		57	53	19	34	3.7	0.364	0.056	19	5.0	7.5			0
2.5 - 4.5	Very soft, CL	CL													0
4.5 - 5.0	Silty clay,soft						0.9	0.51		21					0
5.0 – 12 **PILE POSITION**	Silty clay, soft														0 - 2
12 - 12.5	Silty clay, soft CL	CL	57	68	27	41					42	1.8			1
12.5-18.0	Silty clay, soft CH														1
18 – 18.5	Medium stiff, silty Clay + fine sand	CH	65	85	29	56									3
18.5-24	Medium stiff, silty Clay + fine sand														5
24-24.5	Medium stiff, silty Clay + fine sand+gravel	CL	27	52	24	28									9
24.5-27	Medium stiff, silty Clay + fine sand+gravel														17
27-27.5	Hard,dark grey,sandy silt	CL	29	43	23	20									50
27.5-31.7 End of bore hole	Hard,dark grey,sandy silt + traces of gravel														50

Appendix B

Data obtained from the computation of ultimate driving resistance at increased energy

Pile Number	Location	Pile Type	Pile Size (mm × mm)	Penetration Depth (m)	Soil Type	Hammer Type	Rated Energy (kNm)	Transferred Energy (kNm)	Blow Count (Number of Blow)	Maximum Compression Calculated from Profound (MPa)	Maximum Tension Calculated from Profound (MPa)	Driving Resistance from PDA Test (kN)
FCPILE6	RECESS	FC	150×150	5.5	Silty clay	impact	0.2	0.09	5	1.65	0.01	16
	RECESS	FC	150×150	5.5	Silty clay	impact	0.3	0.06	5	1.35	0.30	18.8
	RECESS	FC	150×150	5.5	Silty clay	impact	0.4	0.09	5	2.5	0.41	33
	RECESS	FC	150×150	5.5	Silty clay	impact	0.5	0.20	5	3.75	0.8	52
POCPILE2	RECESS	POC	150×150	5.5	Silty clay	impact	0.2	0.01	5	1.10	0.32	11.2
	RECESS	POC	150×150	5.5	Silty clay	impact	0.3	0.03	5	1.25	0.46	30.2
	RECESS	POC	150×150	5.5	Silty clay	impact	0.4	0.02	5	3.3	0.65	54
	RECESS	POC	150×150	5.5	Silty clay	impact	0.5	0.07	5	2.7	0.42	45.5
NCPILE5	RECESS	NC	150×150	5.5	Silty clay	impact	0.2	0.02	5	1.35	0.99	14.4
	RECESS	NC	150×150	5.5	Silty clay	impact	0.3	0.03	5	1.65	1.7	32.1
	RECESS	NC	150×150	5.5	Silty clay	impact	0.4	0.08	5	2.35	2.9	38.9
	RECESS	NC	150×150	5.5	Silty clay	impact	0.5	0.15	5	1.4	2.95	31.5

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