The Effect of Improvement Surrounding Soil on Driven Pile Friction Capacity

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Abstract

There is very close relation between the pile capacity and surrounding soil conditions . In cohesionless soil the pile effected on surround soil by compact loose ,cohesionless deposits through a combination of pile volume displacement and driving vibrations .the pile foundation usually designed to exceed the weak soil to the firm deposit .in this study we shall try to improve the weak soil surround the pile and observe the effect of improvement on pile capacity for driven pile.

The improvement suggested in this study is compacting for surrounding soil . for this purpose we prepare testing program by selection two types of sand soil one as the origin soil and the other as improving soil (soil will be compacted and replace surround pile model) . pile model prepared for this purpose is consist of reinforcement steel bar covered with cement mortar , 50 kN automatic electromechanical compression machine was used for testing load-settlement test on pile model. The Testing procedure includes changing the diameter of soil compacted around pile model and execute the load settlement test and compare the results.

Key words: compaction, pile model , pile model capacity ,load-settlement curves ,

Introduction

Evaluation of pile bearing capacity is still a subject of many researches. Several researches mentioned that, the calculated pile bearing capacity by conventional methods often gives poor agreement with the load test results (Kraft, 1991; Randolph et al., 1994,). The ultimate bearing capacity and settlement of a pile depend mainly on the density index of the sand.

However, if a pile is driven into sand the density index adjoining the pile is increased by compaction due to soil displacement (except in dense sands, which may be loosened). The soil characteristics governing ultimate bearing capacity and settlement, therefore, are different from the original characteristics prior to driving This fact, in addition to the heterogeneous nature of sand deposits, makes the prediction of pile behavior by analytical methods extremely difficult. for relatively long flexible pile which are commonly used for foundation of offshore structure .pile shaft resistance represents the major component in total pile capacity when the pile are subjected to cyclic loading . failure can occur at very low load level in some sand soil (chan and hanna, 1980). Compaction is the process of increasing the density of a soil by packing the particles closer together with a reduction in the volume of air; there is no significant change in the volume of water in the soil. In general, the higher the degree of compaction the higher will be the shear strength and the lower will be the compressibility of the soil. The dry density of a given soil after compaction depends on the water content and the energy supplied by the compaction equipment (referred to as the compactive effort) (GRAIC,2004).

There are many researchers and projects consulta- tive studied the replacing all soil for specific depth to improve the soil strength and liquefaction resistance like (Risk of the ground liquefaction in the Fraser Delta / British Columbia: Protection of a liquid gas tank by means of vibro replacement (Chambosse, 1983 Khalifa Bin Zayed National Stadium, Abu Dhabi: Vibro stone columns around bored piles (2009**)** Soil improvement by means of Vibro Compaction: Fort Calhoun Nuclear Station(Fischer et al., 1972),) in this study replacing and compacting only the surrounding studied.(SONDERMAN,2011)

Literature Review

Skin friction of pile is controlled by coefficient of earth pressure and angle of adhesion δ between soil and pile. The value of K_s is critical to the evaluation of the shaft friction and is the most difficult to determine reliably because it is dependent on the stress history of the soil and the changes which take place during installation of the pile (Tomlinson,1994)] Driving the pile will increase the horizontal soil stress from the original K_o value; while boring process will tend to loosen the soil which in turn will lead to reduce the horizontal stress.

The value of δ may be measured in interface shear test for the particular pile material, but for the cases where the test is not available, it can be assumed equal to $\emptyset_{c.v}$ (Fleming et al., 2008). Variations of maximum achieved friction angle in the standard shear tests with normal or confining

pressure had been reported by different researchers (Veiskarami et al., 2011). This variation achieved by changing stress is called 'stress level effect' and considered as one of the major factors causes for scale effect. The shear strength of the sandy soil mainly depends on angle of internal friction and this friction angle is highly dependent on stress level. There is a problem arise with question 'did this variation have a great effect on bearing capacity' and ' if it did, what value of friction angle should be used for safe and economical design'. Many researchers studied the variation of friction angle of sand with stress level. Results of previous researchers shows that the load - settlement relations approximately have the same trend shape for both relative densities of sand (dense and medium sand) with all embedment ratios. When the loading process on the pile is starting, the pile settlement response seems to be very close to linear relation due to small settlement value. After this stage and with continuing loading process, the non-linear behavior of soil appears and provides a visible curvature as soil elements start to fail causing a significant increase in rate of settlement and provide a hyperbolic shape for load - settlement relation It can be seen from load - settlement curves for both dense and medium sands that the punching type failure is control for all stresses ranges and as embedment depth increases the capacity of piles increases for all range of stresses (AKOOBI,2012) the end bearing capacity is much higher than the shaft resistance in laboratory dimensions and the shafts resistances contribution in the total capacities for piles are very low. when lengths of piles increase the end bearing, shaft, and total capacities are increased. The increase in end bearing with length gives an indication about increasing in bearing capacity factor as embedment ratio increase. The reason that the mobilized end bearing capacity is much higher than shaft resistance may be attributed to high friction angle mobilized in such low stresses and the dependency of end bearing capacity of piles on angle of internal friction In case of higher stresses range the mobilized end bearing capacity start to become less than shaft resistance and the difference between them increase as lengths of piles increase. This behavior also attributed to the reduction of internal friction angle due to increasing in stress level in such dimensions. Same behavior can be noticed for medium sand. In low stress level, the end bearing capacity is larger than shaft resistance and as stress level increases, the difference between end bearing and shaft resistance decreases until shaft resistance becomes larger than end bearing . It can be noticed also, that the end bearing capacity of medium sand is less than the end bearing capacity of dense sand by a significant amount but the shaft resistance of dense sand is higher than the shaft resistance of medium sand this is attributed to the difference between angles of adhesion between pile and surrounding soil. From the observations discussed above, it can be concluded that the stress level has a significant effect on end bearing capacity and insignificant effect on shaft resistance and the care should be taken in extrapolating the results from a model pile in small scale dimensions (low stress level) to field dimensions (high stress level) and for such extrapolating a stress level factor should be used for safe and economical design for pile in sand. Pile dimension have significant effect on pile capacity increasing the pile length means more stress generated at the pile interface along its length and will lead to increase pile capacity. Also, increasing the diameter of pile means increasing in the surface area of the shaft contact with the surrounding soil which in turn will lead to increase in the shaft resistance. In addition, increasing the diameter of pile means more end bearing resistance area of pile. (AKOOBI,2012)Improvement of horizontal bearing capacity by composite ground foundation method The composite ground foundation is a new type of foundation that remarkably improves the horizontal bearing capacity by considering the mechanical interaction effect of the improved ground and pile which are installed as one body . Traditionally, the ground and foundation structure are considered as independent models, for example, in the case of pile foundation, the load resistance characteristics of soft ground and pile are considered independently in the analysis. new construction methods are being studied in order to restrain horizontal displacement and lessen the number of piles, and consequently ,reduce the construction's total cost, using Deep-Mixing-Method (DMM) which reinforces ground resistance by pouring cement in peripheral ground. The "composite ground foundation method," that is defined herein, is a foundation practice which expects positive effect of interaction between the improved ground in-situ and the existing pile(MAEDA,2007). The distribution of shear stresses in soil-pile interface along pile shaft is random, non-linear and its tendency to increase with increasing overburden pressure(AKOOBI,2012). Bearing capacity of the model pile increases with increasing the Rate of loading .The relationship between the compressive Bearing capacity and the loading rate can be represented by a Straight line on alog-log plot(AL-MAHADIB,1999).depending on previous studies we shall replacing surround soil around pile and compact it then drive the pile model with changing the diameter of area improved with compaction and length of pile model drove in soil and observe the results of load-settlement for each case separately

Expermantal Work

Many steps adopted to perform the testing program started with soil tests to determine soil parameters for two types of soil. The soil Characteristics shown in Table (1)and (2) the soil types divided to two types the, first considered as natural soil and other as replacing soil around pile model which will be compacted. chemical test was made to understand the effect of chemical components on soil behavior after compaction .The pile model shown in fig (14) connect to compression device as shown in fig(16) .the embedded length of piles was located to drive it into soil (100,150) mm. The container filled with soil (type 1) , the arm of device are dropped down approaching to the specific length by using the screw to lower the arm as shown in fig (12). Then the compression device adjusted and operated for a constant rate of settlement (1.27 mm/min) (strain control test). The method of driving pile is executed by screw down the arm of compression device until the pile model driven to desire length as shown in fig (15). And because of setting of the device on constant rate of settlement the pile will be loaded by jacking it by compression device arm movement. The results obtained are considers as original case (without improvement). the results are represented in figures fig(1) and fig(2).soil (type2) used for improve the surrounding soil by compacting it by steel bar and adding water according to amount of optimum moisture content obtained from proctor test(11.8%) maximum dry density was equaled to(18.5 kN/ m^3) for soil type (2). (p v c pipe) used as case to contain compacted soil around pile model(casing pipe) As shown in fig(13). The soil with optimum moisture content adding by equal layers (3cm) for each layer compacted by constant number of blows for each layer (blows according to casing pipe diameter). The casing pipe was pulled at same time of compaction ,to prevent the adhesion between the pipe and compacted soil .and to ensure the interlocking between the compacted soil and soil around. After compaction of improvement soil (type 2), pile will drive into compacted soil by screw down device arm. after approaching the desire length the device operating and load-settlement reading appearing on device display this reading using to plot load-settlement curves which using to estimation the pile capacity by two tangent method.

Table 1: soil type (1) characteristics

No	Index property	Value
1.	Specific gravity (Gs)	**2.61**
2.	D_{10} (mm)	**0.116**
3.	D_{30}(mm)	**0.211**
4.	D_{60}(mm)	**0.337**
5.	Coefficient of uniformity(C_u)	**2.91**
6.	Coefficient of curvature(C_c)	**1.14**
7.	Maximum dry unit weight (kN/m^3)	**17.42**
8.	Minimum dry unit weight (kN/m^3)	**14.20**
9.	Maximum void ratio	**0.803**
10.	Minimum void ratio	**0.469**
11.	Angle of internal friction (ϕ)	**43**
12.	C VALUE	**0**
13.	Soil classification (USCS)	**SP**

Table. 2: soil type(2) characteristics

No	Index property	Value
1.	Specific gravity (Gs)	**2.54**
2.	D_{10} (mm)	**0.096**
3.	D_{30}(mm)	**0.231**
4.	D_{60}(mm)	**0.409**
5.	Coefficient of uniformity(C_u)	**4.26**
6.	Coefficient of curvature($C_{c)}$	**1.36**
7.	Maximum dry unit weight (kN/m^3)	**17.56**
8.	Minimum dry unit weight (kN/m^3)	**14.03**
9.	Maximum void ratio	**0.776**
10.	Minimum void ratio	**0.418**
11.	Angle of internal friction (∅)	**44.4**
12.	(C) VALUE	**0**
13.	Soil classification (USCS)	**SP-SM**
14.	Maximum density due to compaction (kN/m^3)	**18.5**
15.	Optimum moisture content	**11.8%**

Table .3:. Chemical tests for soil type (2)(al ekhidhar sand)

PH	SO_3	TSS	Organic	Gypsum
8.16	**3.2**	**6.0**	**6.2**	**6.9**

Results and Discussions:

The following results are obtained from

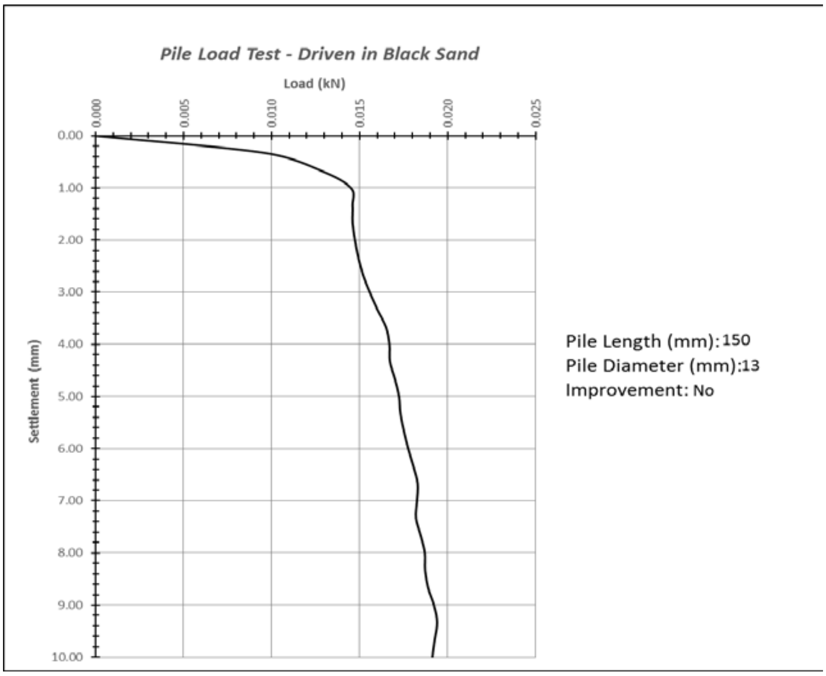

Figure 1: pile length 150 mm without improvement estimated pile load capacity(0.015 kN)

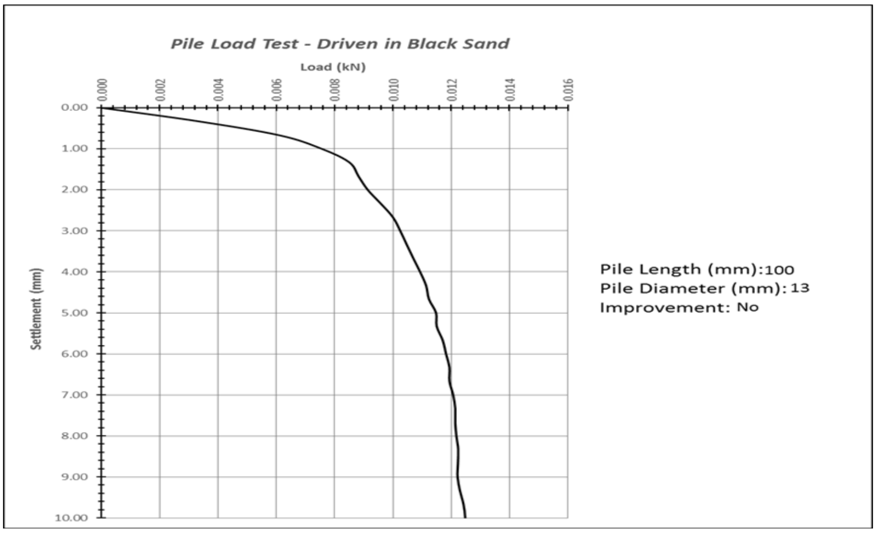

Figure 2:. Pile model length (100 mm) without improvement estimated pile load capacity(0.0095 kN)

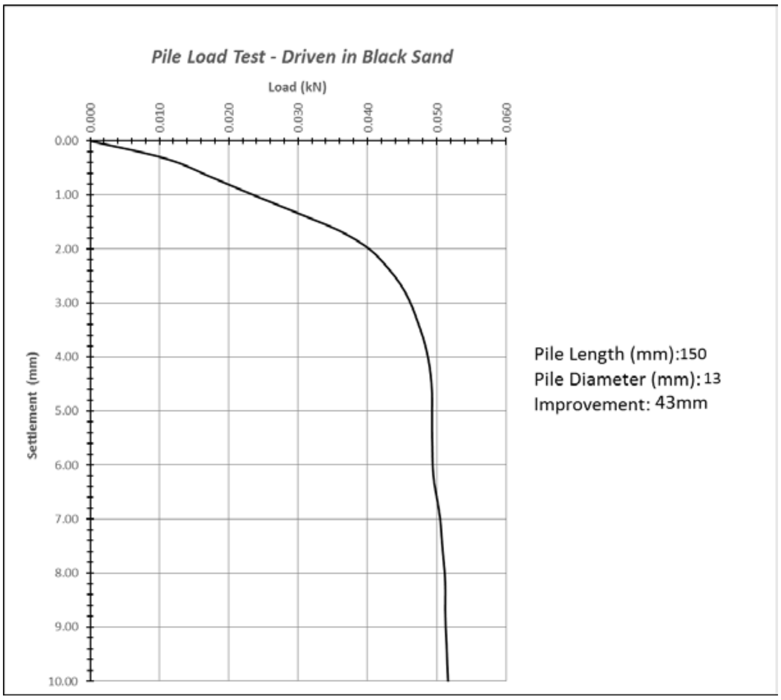

Figure 3:.pile model length (150mm) diameter of improvement(43mm) estimated pile load capacity(0.047 kN)

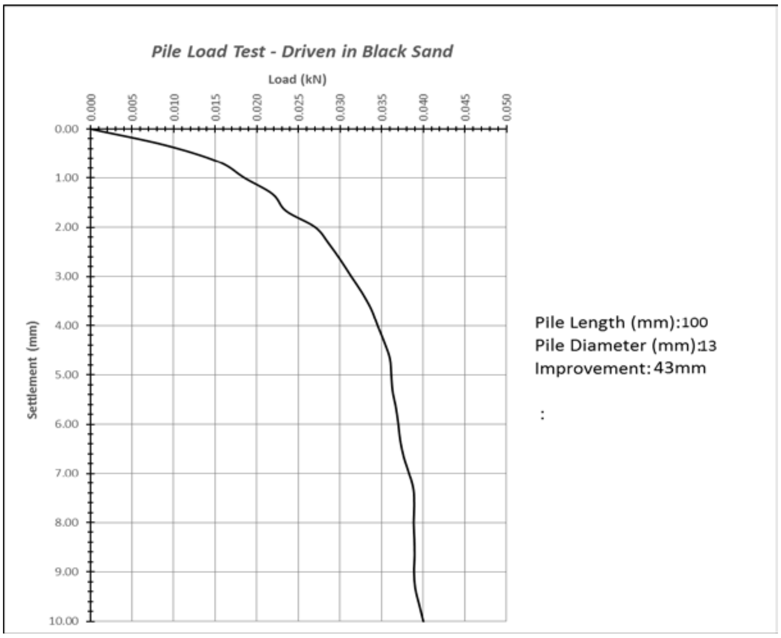

Figure 4: Pile model length (100mm) diameter of improvement (43mm) estimated pile load capacity (0.033 kN)

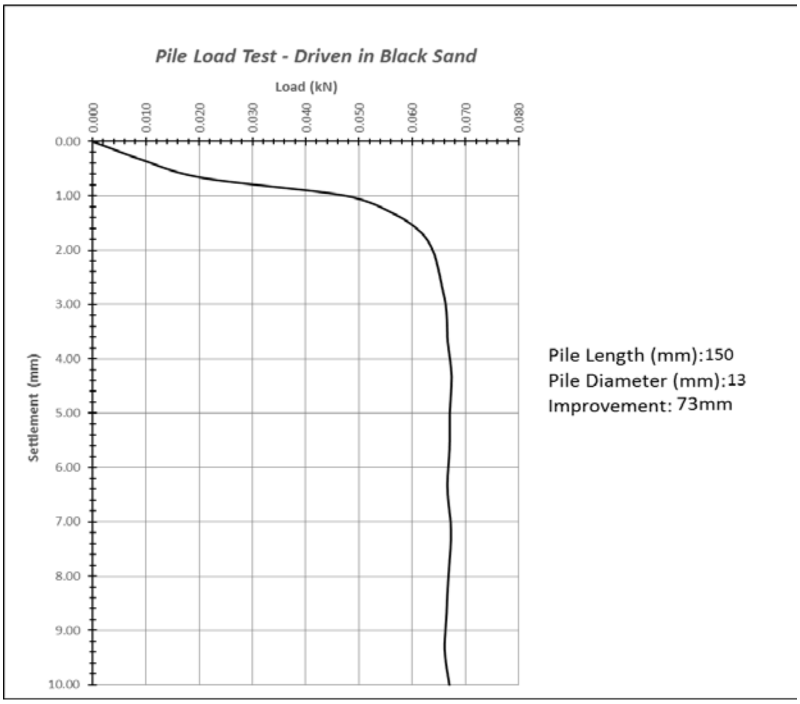

Figure 5: pile model length (150mm) diameter of improvement(73mm) estimated pile load capacity(0.067 kN)

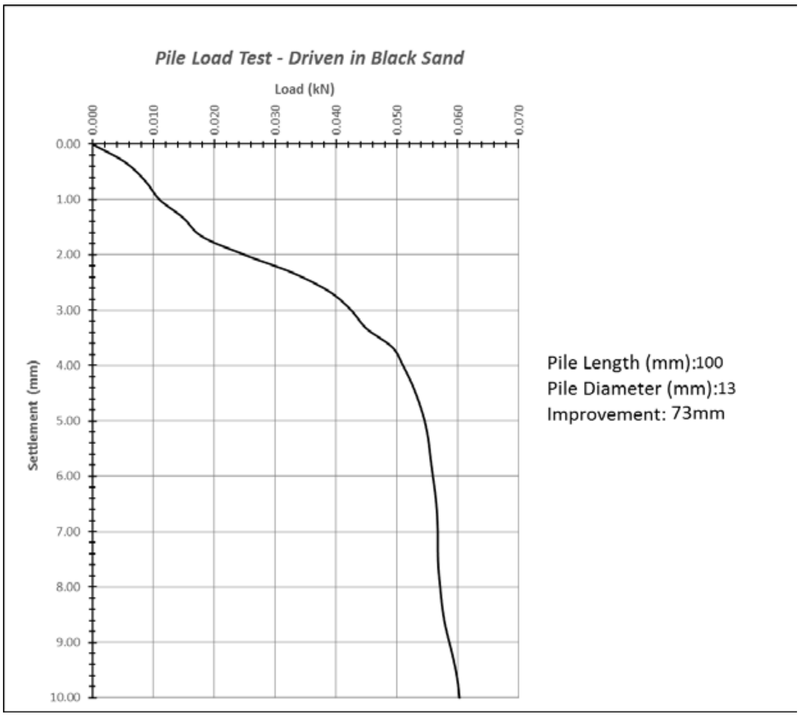

Figure 6: pile model length (100mm) diameter of improvement(73mm) estimated pile load capacity(0.056 kN)

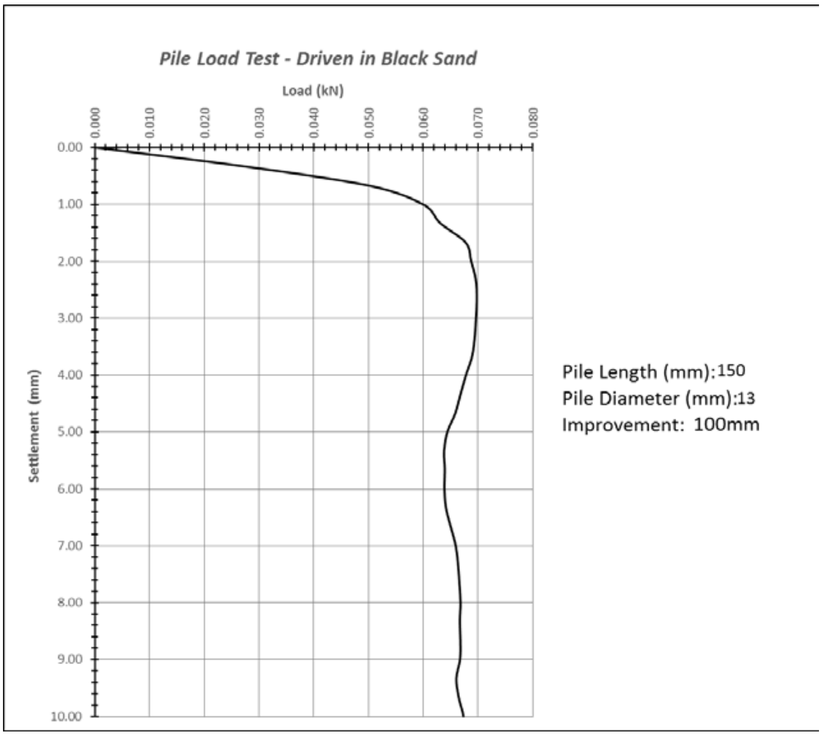

Figure7:. pile model length (150mm) diameter of improvement(100mm) estimated pile load capacity(0.07 kN)

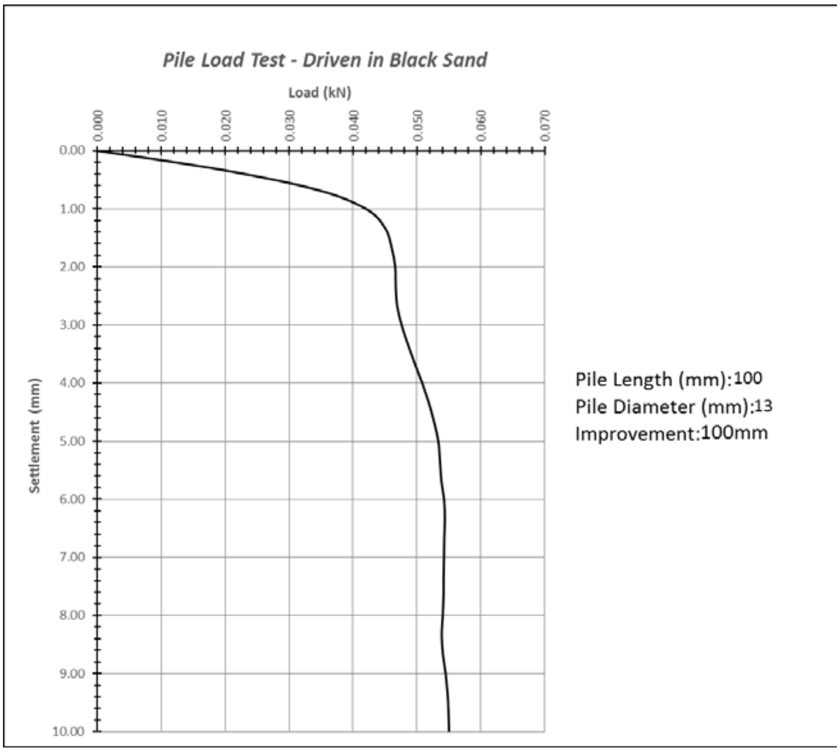

Figure 8:. pile model length (100mm) diameter of improvement(100mm) estimated pile load capacity(0.058 kN)

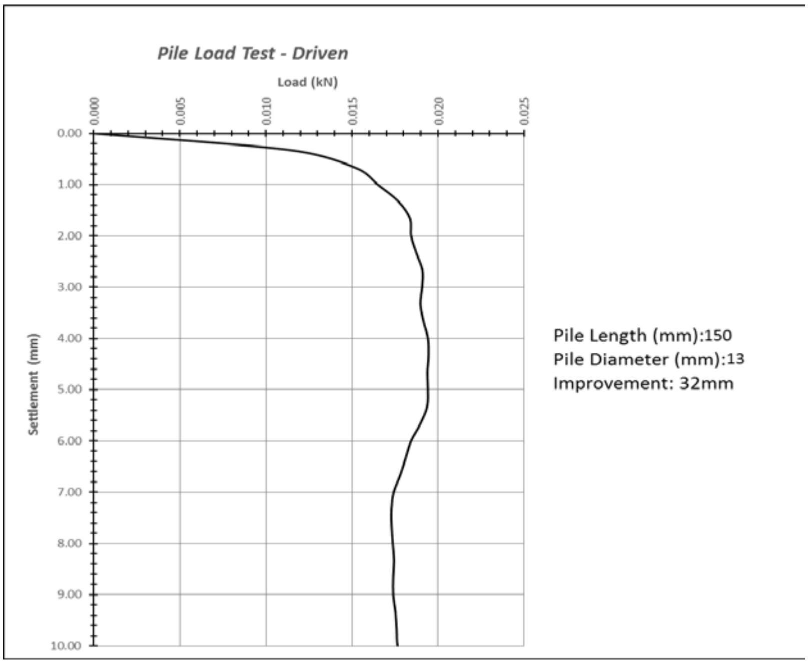

Figure 9: pile model length (150mm) diameter of improvement(32mm) estimated pile load capacity(0.0195 kN)

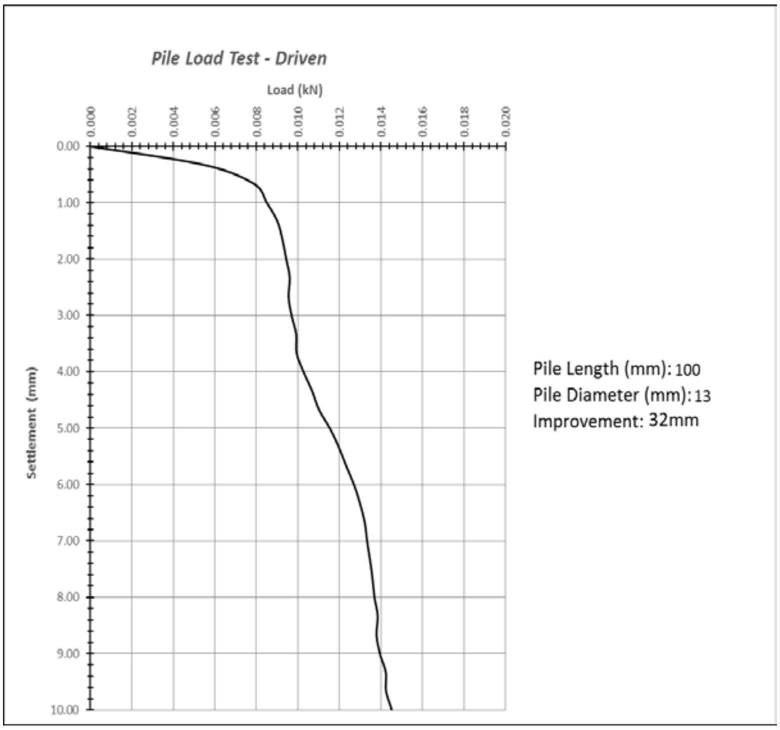

Figure 10: pile model length (100mm) diameter of improvement(32mm) estimated pile load capacity(0.0114 kN)

After determine the pile-load capacity for each test results curve relation between the diameter of improvement around pile and pile load capacity was plotted as shown below fig (11). This will give an observation for the improvement behavior of pile (with and without) improvement. The compaction significant effect on pile load

Capacity . this effect increases with the increasing of the diameter of improving soil around pile model specially in (43 mm)diameter Around the pile model and this effect start to be rather lighter beyond this limit with the increasing of diameter of improvement around pile model approaching to be insignificant effect on pile load capacity. That's because of effect of compaction appear by rearrange the soil particles and increase the interlocking between particles and make the compacted block firmer and that naturally increase friction between the block and pile model .the value of cohesion of soil particles will increase by compaction that's lead for increase the friction factor between the compacted block and pile model .the density of soil around pile model increase that's lead for increase friction but this effect according to experimental work may inserted in specific range around pile mode so beyond limits of (43mm) this effect start to be lighter . but there is reverse effect its appear because of driving the pile model presents in collapse almost part of soil compacted block and divided into parts as shown in fig (15). the collapse parts will work just as frictional part but it may give higher strength if it remained as one block. that's lead for conclusion it may give higher load capacity in case of bored pile with improvement which is keep the compacted block as one block

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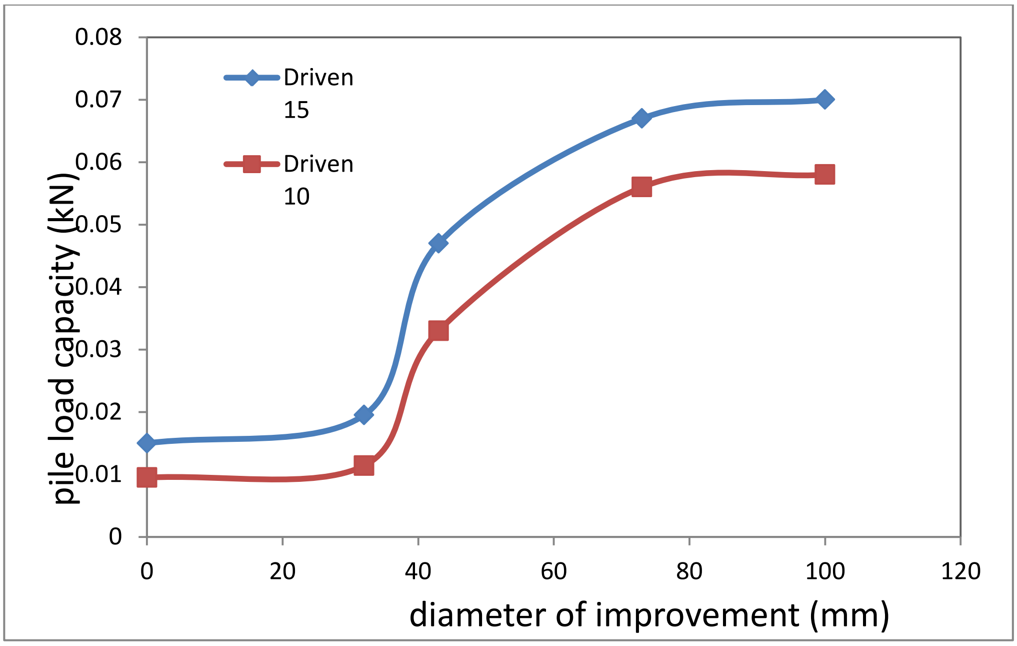

Figure 11: the relation between pile load capacity and diameter of improvement

Conclusions:

1-pile model capacity determine as (0.015,0.0095)kN for (150,100) mm length respectively in case without improvement but its value increase for (0.047, 0.33) kN for (150,100) length respectively after improve the soil surrounds pile model with the most economic diameter (43 mm) around in this study and with length equal to embedded length of pile model . pile model capacity increase to (0.067 and 0.056 kN) for (150,100 mm) respectively in case of improvement of (73 mm) around pile .and its increase to (0.07 and 0.058 kN) for (150 ,100mm) respectively in case of improvement (100 mm) And its has little effect on the pile load capacity when the improvement are was with diameter of (32 mm) as shown the pile load capacity effect start to be lightly .this mean best choice of improvement is about (43 mm) and beyond this limit the improvement not effected as much as in this case if the distance of improvement around pile model connect with pile model diameter . the distance (43mm) (D) from face of pile model with respect to pile model diameter(D). (73 mm) equal (2D) from face of pile model. And(100 mm) equal to(3D) from face of pile .table (4) shows the percentage of increment of pile load capacity compare with natural case for each length and distance of improvement around pile model. The increment of pile load capacity for length (150 mm) increase in case of(0.5D) was estimated (30%) and (20%) for length (100mm) .and (213%) for length (150 mm) ,(135%) for length (100mm) in case of (D) of improvement. And (346%) for length of (150mm),(300%) for length (100mm) in case of (2D).and (366%) for length of (150 mm) ,(314%) for length (100mm) in case of (3D).

2-table (4) gives observation improvement with distance (D,2D) from face of pile will give noticeable increment in pile load capacity, the distance (D) consider best distance of improvement for economic consideration.

3-compaction of surrounding soil effect on soil under pile tip and soil surrounding pile and make it dense and rise value of angle of internal friction

4- the method of installation for pile effected on soil .and compacted soil block improved around pile .

Recommendations .

1-determine the best choice for improvement and most economic selection and determine reality for future studies on prototype.

2-studying effect of compaction surrounding soil on pile tip

3-studying the pile installation effect on soil improvement

Table .4: Percentage of increment for pile capacity for each case

Type	Length (mm)	Improvement (0.5D) Percentage of increment %	Improvement (D) Percentage of increment%	Improvement (2D) Percentage of increment %	Improvement (3D) Percentage of increment %
Driven	150	30	213	346	366
	100	20	135	300	314

Appendix

Figure 12: Drive the pile model to require length in both case improvement and without .

Figure 13: Using P.V.C pipe as case to excute the improved soil

Figure 14:Pile model used in tests

Figure 15: Collapsing compacting soil block due to driving pile model

Figure16: Compression device

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تأثير تحسين التربة المحيطة على قابلية تحمل (الاحتكاك) للركيزة المغروسة

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الخلاصة:

هناك علاقة وثيقة بين قابلية تحمل الركيزة للأحمال وظروف التربة المحيطة بها. ففي الترب الضعيفة تتعرض التربة المحيطة بالركيزة لعملية رص نتيجة عملية غرز الركيزة وعملية الاهتزاز المصاحبة لغرزها. عادة تصمم الركائز لتجاوز الترب والطبقات الضعيفة ونقل الاحمال للترب الاقوى والاشد .في هذه الدراسة سنحاول تقوية التربة الضعيفة المحيطة بالركيزة وملاحظة تأثير ذلك على قابلية تحمل الركيزة المغروزة . عملية التحسين المقترحة في هذه الدراسة هي رص التربة المحيطة .تم تهيئة برنامج تجارب يتألف من اختيار نوعي رمل لهذا الغرض واحدة تمثل التربة الاصلية المحيطة والثانية تمثل التربة المقترحة كتربة بديلة وتتعرض للرص حول الركيزة .تم تهيئة مقترح نموذج للركيزة مكون من قطعة من حديد التسليح مغطى بمونة السمنت . تم استخدام جهاز قوة انضغاط ذو قابلية (50kN) لغرض تنفيذ تجارب (load-settlement). يتضمن برنامج التجارب الخاص بهذه الدراسة تغيير قطر التربة المحيطة المعرضة للرص حول نموذج الركيزة وتنفيذ التجارب وعمل مقارنات بين النتائج.

كلمات مفتاحية :عملية الرص، نموذج للركيزة، قابلية تحمل النموذج، منحنيات لنتائج فحوصات الحمل-الهطول