Correction Factor for Methods of Installation of Piles Group in Sandy Iraqi Soils

Assist.Prof.Dr A'amal Abdul Ghani Al-Saidi
Civil Engineering Department, College of Engineering, University of Baghdad
dr_aamal@yahoo.com

ABSTRACT

Many problems are facing the installation of piles group in laboratory testing and the errors in results of load and settlement are measured experimentally may be happened due to select inadequate method of installation of piles group. There are three main methods of installation in-flight, pre-jacking and hammering methods. In order to find the correction factor between these methods the laboratory model tests were conducted on small-scale models. The parameters studied were the methods of installation (in-flight, pre-jacking and hammering method), the number of piles and in sandy soil in loose state. The results of experimental work show that the increase in the number of piles value led to increase in load carrying capacity of piled raft and decrease in settlement value for three methods of installation. The response of increases load capacity for hammering method is the same value of pre-jacking method at the number of piles less than (N=2), while when the number of piles are beyond (N=3 to 9). The load capacity of hammering method is more than pre-jacking method and the correction factor of method of installation depend on the type of method of installation and the piles number. The increase in carrying capacity by hammering method is due to mobilize the dynamic soil structure interaction (soil-pile and pile-pile interaction) and the change in properties for surrounding soil for loose state of sand is more effective than static soil structure interaction mobilize by pre-jacking method. The correction factor of increase in load capacity and the correction factor of the percentage of settlement reduction for pre-jacking and hammering methods are compared with in-flight method of installation are changed with the number of piles and these values are increased with increasing the number of piles.

Keywords: methods of installation; number of piles; correction factor ; experimental work.

معامل التصحيح لطرق انشاء مجموعة الركائز في الترب الرملية العراقية

الاستاذ المساعد الدكتور امال عبد الغني السعيدي
قسم المدني / كليه الهندسه / جامعه بغداد

الخلاصة

العديد من المشاكل تواجه انشاء مجموعة الركائز في الفحوص المختبرية والاخطاء الحاصلة في نتائج الاحمال والهبوط المقاسة مختبريا قد تحصل نتيجة اختيار الطريقة غير الملائمة في انشاء مجموعة الركائز . هنالك ثلاث طرق رئيسية لانشاء مجموعة الركائز (in-flight , pre-jacking and hammering method) ولاجل الحصول على معامل التصحيح بين هذه الطرق اجريت مجموعة فحوصات لموديلات مختبرية مصغرة . العوامل التي تمت دراستها طريقة انشاء الركائز وعدد الركائز في تربة رملية مفككة .
نتائج الفحوصات المختبرية بينت ان استجابة الزيادة في قابلية التحمل لكلا الطريقتين (pre-jacking and hammering method) هي ذاتها لحد (N=2) ولكن عندما تزداد عدد الركائز من (3 - 9) فان الزيادة في قابلية التحمل لطريقة (hammering method)اكثر من طريقة (pre-jacking) كما ان معامل التصحيح يعتمد على طريقة انشاء الركائز وعددها . الزيادة في قابلية التحمل لطريقة (hammering method) نتيجة تحفيز التفاعل الديناميكي بين الركيزة و التربة (تفاعل تربة-ركيزة و ركيزة- ركيزة) والتغير في خواص التربة الرملية المجاورة في حالتها المفككة هي اكثر فعالية من التفاعل الستاتيكي بين الركيزة والتربة لطريقة (pre-jacking) .
كما ان معامل التصحيح للزيادة في قابلية التحمل ونقصان نسبة الهبوط لكلا الطريقتين(pre-jacking and hammering method) ومقارنتها مع طريقة(in-flight) يتغير مع عدد الركائز ويزداد بزيادتها .

الكلمات الرئيسيه :- طرق الانشاء،عدد الركائز،معامل التصحيح،عمل مختبري .

1. INTRODUCTION

Piled raft is a composite geotechnical foundation system consisting of piles, raft and soil and the behavior of piled raft governed by different interactions (pile-pile, pile-raft and soil-pile-raft). A geotechnical assessment for the design of such a foundation system therefore needs to consider not only the bearing capacity of the pile elements and the raft elements, but their combined capacity and interaction under serviceability loading **Katzenbach et al., 1998**. However, usually three methods are used to install pile model in sand. These methods are listed below, **Linggang, 2006.**
1) In-Flight Pile Installation
2) Pre jacking Method
3) Hammering Method
And these methods governed by mobilize the soil-structure interaction, such as for jacking method the static soil structure interaction will be mobilized while dynamic soil structure interaction mobilize for hammering method. **Katzenbach et al. 1998 and 2000** illustrated that the piled raft foundation indicates a new understanding of soil – structure interaction under static loads as shown in **Fig.1**. The contribution of the rafts as well as the piles is taken into consideration to satisfy the proof of the ultimate load capacity and the serviceability of a piled raft as an overall system.
Giretti 2009 performed a series of centrifuge tests on models of rigid circular piled rafts in loose saturated sand employing both non displacement and displacement piles. The main aim of the tests of the effects the soil–pile (S–P) interaction is mainly governed by the pile installation procedure that is adopted; these procedures range from non-displacement to displacement methods.
In this paper, in order to determine the correction factor for methods of installation of piles group in sand, experimental work were carried out and the parameters studied are:

1- Method of installation (in-flight , pre-jacking and hammering method)
2- The number of piles (N)
3- Diameter of piles is Dp=11.30mm, spacing between piles 3Dp and relative density of sand is 30%.

2. EEXPERIMENTAL WORK:

A series of model loading tests were conducted inside a steel box of dimensions (600X600X700mm) depth, made of steel plate of 3mm thickness, stiffened with 3 lines of 25mm angle sections, provided with 280 *220mm hatch for sand refilling as shown in Plate (1). The base was stiffened with additional 3 mm steel plates and 25 mm steel angle frame and stiffeners, in order to prevent concentration of the load exerted from the piston on a small area.

The internal faces of the box were covered with polyethylene sheets in order to reduce the slight friction which might be developed between the box surface and soil. Scaling laws were followed in the design of the model to eliminate the model stress error and boundary effects.

The square aluminum raft model was a 120mm in dimension and thickness (t_r=15mm). The aluminum model of piles employed in the tests (d_p=11.30mm), where dp is the pile diameter.

2.1. Static Loading Measurement: A conventional compression machine with digital control system was used to apply the axial loading on footing model. The load on the footing was measured using proving ring of 3KN capacity. The settlement of pile raft model was measured by two dial gauges (0.001mm, division) fixed on the edges of the footing by two magnetic holders as shown in Plate (2). The installation of piles group by in-flight system method as shown in Plate (3) to control the installation of piled raft system and prevent the inclination and eccentricity of the model, the center of piled raft model must coincide with the center of the sand container and the center of the loading system, the pre-jacking method of installation of piles group in soil by using the compression machine can be noticed in Plate (4). Plate (5) shows the installation of piles group by hammering method by using known weights ranges from (0.5 to 1kg)

2.2. Soil Used

2.2.1 Sand properties:

Poorly graded sand was used in the tests. The sand was placed in the test box at unit weight of approximately15.3 kN/m^3 (relative density=30%). The properties of sand are given in **Table (1)**.

2.2.2 Mechanical properties of sand

The mechanical properties of used sand that have been extracted from the results of tests using triaxial test (UU test) and direct shear test are listed in **Table 1.**

2.3 Mechanical Properties of Aluminum Used

The aluminum specimen used to model raft and piles were tested in accordance to the **ASTM** (**B557–06**) specifications. Yield strength **(**fy**)**, tensile strength (fu), elongation (e) and Poisson's ratio (*v*). The results mechanical properties of aluminum used under tensile test are listed in **Table (2).**

3. RESULTS AND DISCUSION

Figs. 2 to 7 show the measured load-settlement curves for piled raft at (N=1, 2,3,4,6 and 9), s=3dp, tr=15mm and Dr =30% (where N is the piles number, s: spacing between piles, tr: raft thickness and Dr: relative density of sand). In general the results show increasing the number of piles value led to increase in load carrying capacity of piled raft and decrease in settlement value for three methods of installation.

Fig. 8 shows the computed maximum load and maximum settlement versus the increased in the number of piles. It is clear that the maximum load carried by piled raft increase from (0.35 to 0.82), (0.38 to 1.49) and (0.38 to 1.83 kN) and the maximum settlement decreased from (6 to 1.3), (4.2 to 0.7) and (4.2 to 0.5mm) with increasing the number of piles from (N= 1 to 9) for in-flight, pre-jacking and hammering methods, respectively.

Fig. 9 shows the computed increased in load carrying capacity is equal to $\{load_{\text{(pre-jack or hammering method)}} / load_{\text{in-flight method}}\}$ versus the increase in the number of piles for pre-jacking and hammering methods. The response of increased load capacity for hammering method is the same value of pre-jacking method at the number of piles less than (N=2), while when the number of piles beyond (N=3 to 9) it is clear that the load capacity will be increased from (1.42 to 2.23) for hammering method and (1.355 to 1.82) for pre-jacking method, in other words the correction factor of method of installation depends on the type of method of installation and the piles number. For hammering method it is clear that the increase in carrying capacity more than pre-jacking method because the dynamic soil structure interaction mobilized by hammering method (soil-pile and pile-pile interaction) and the change in properties for surrounding soil for loose state of sand is more effective than static soil structure interaction mobilize by pre-jacking method.

The correction factor of increase in load capacity for pre-jacking and hammering methods are compared with in-flight method is defined by equations below:

Log(Load)=0.227 Log(N)+0.073…(pre-jacking)

Log(Load)=0.334 Log(N)+0.043…(hammering)

Where (N is the piles number)

Fig. 10 shows the computed percentage of settlement reduction (Sr%) is equal to $\{1-(Settlement_{\text{pre-jacking or hammering methods}} / Settlement_{\text{in-flight method}})\}$ for pre-jacking and hammering methods versus the increase in the number of piles. This figure shows the percentage of settlement reduction increases from (30 to 46%) and (30 to 62%) with increasing the number of piles (N=1 to 9) for pre-jacking and hammering methods, it is clear from the results above that the hammering method is more effective in settlement reduction compared with the pre-jacking method especially when the number of piles are beyond (N=2).

The correction factor of the percentage of settlement reduction (Sr%) for pre-jacking and hammering methods are compared with in-flight method of installation is illustrated below:

Log(Sr%)=0.168Log(N) + 3.476 … (pre-jacking)

Log(Sr%)=0.28Log(N) + 3.43 …..(hammering)

CONCLUSIONS

1- The increase in the number of piles value led to increase in load carrying capacity of piled raft and decrease in settlement value for three methods of installation.
2- The response of increased load capacity for hammering method is the same value of pre-jacking method at the number of piles less than (N=2), while when the number of piles are beyond (N=3 to 9). The load capacity of hammering method is more than pre-jacking method.
3-The correction factor of method of installation depends on the type of method of installation and the piles number.
4-The increase in load carrying capacity by hammering method is due to mobilize the dynamic soil structure interaction (soil-pile and pile-pile interaction) and the change in properties for surrounding soil for loose state of sand is more effective than static soil structure interaction mobilized by pre-jacking method.
5-The correction factor of increase in load capacity and the correction factor of the percentage of settlement reduction (Sr%) for pre-jacking and hammering methods are compared with in-flight method of installation are changed with the number of piles and these values are increased with increasing the number of piles.

REFRENCES

- ASTM (B557 – 06) Standard *Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products*".
- ASTM D422-2001, *Standard Test Method for Particle Size-Analysis of Soils.*
- ASTM D4253-2000, *Standard Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table*.
- ASTM D4254-2000, *Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density*.
- ASTM D854-2005, *Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer*.
- Daniela Giretti 2009. *Modeling of Piled Raft Foundations in Sand* Ph. D. Thesis, University of degli Studi di Ferrara..
- Katzenbach, R., Arslan, U., Moormann, C. and Reul, O. 1998, *Piled Raft Foundation – Interaction Between Piles and Raft*, Darmstadt Geotechnics, Darmstadt Univ. of Technology, No. 4, pp. 279-296.
- Katzenbach, R., Arslan U. and Moormann, C. 2000, *Piled Raft Foundations in Germany* Chapter 13 in Design Applications of Raft Foundations, J. A. Hemsley (ed.), Thomas Telford Ltd., London, U.K, pp. 323.
- Linggang, K. 2006, *Behaviour of Piles Group Subjected to Torsion, Ph.D.* Thesis Science and Technology University, Hong Kong.

Table 1. Properties for Sand Used.

Property		Values
Specific Gravity, Gs		2.65
Dry Unit Weight (γ_d) of Sand	Maximum unit weight, γ_{dmax}	17.9kN/m^3
	Minimum unit weight, γ_{dmin}	14.4 kN/m^3
Void Ratio(e) of Sand	Maximum void ratio (e_{max})	0.81
	Minimum void ratio (e_{min})	0.45
Dry Unit Weight Used (γ_d)	Loose state, γ_{dused}	15.3
Void Ratio Used (e)	Loose state (e_{used})	0.73
Friction Angle (Ø°)	Loose state	28.81°
Poissons Ratio (v)	Loose state	0.30
Modulus of Deformation (E_s, kN/m^2)	Loose state	10000

Table 2. Mechanical Properties of the Used Aluminum Alloy.

Property	**Value**
Modulus of Elasticity (GPa)	70
Minimum % of Elongation (e)	10
Assume Poisson's Ratio (*v*)	0.33

Plate 1. The sand container of used.

Plate 2. Arrangement of the Proving Ring and Dial Gauge During Loading.

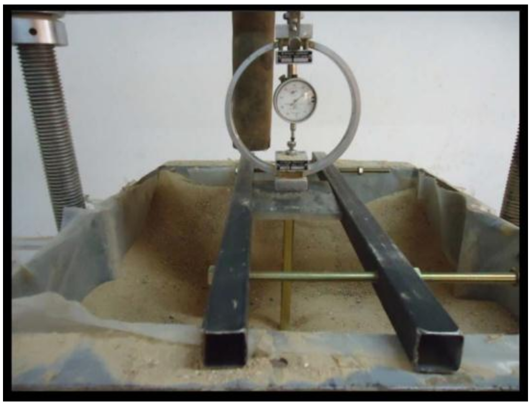

Plate 3. In-Flight Method of Pile Installation System.

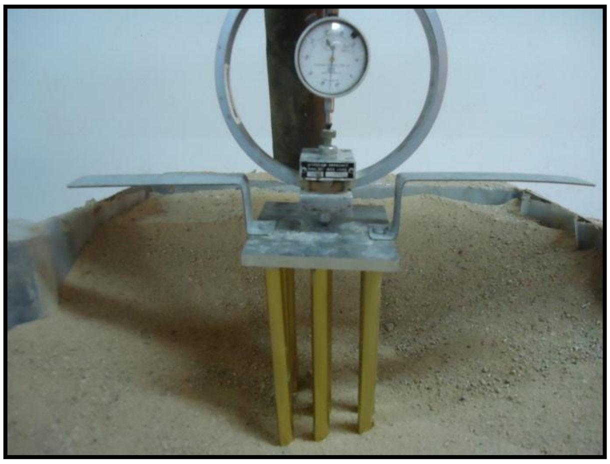

Plate 4. Pre-Jacking Method of Piles Installation System.

Plate 5. Hammering Method of Piles Installation System.

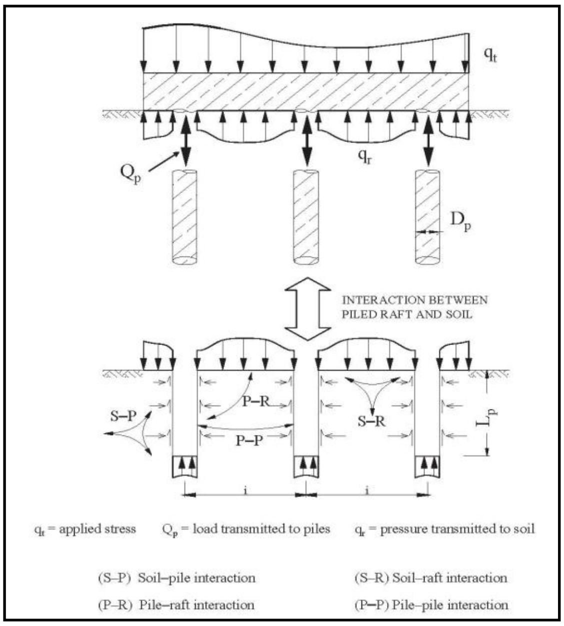

Figure 1. Static Soil-Structure-Interaction of Piled Rafts (**after Katzenbach al., 1998**).

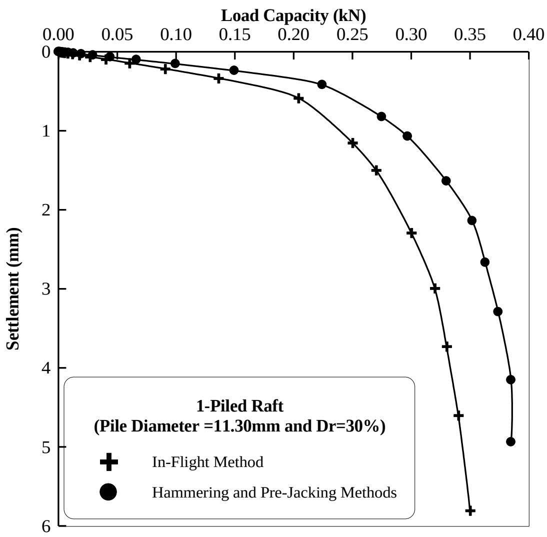

Figure 2. Load –Settlement curves for 1-Piled Raft.

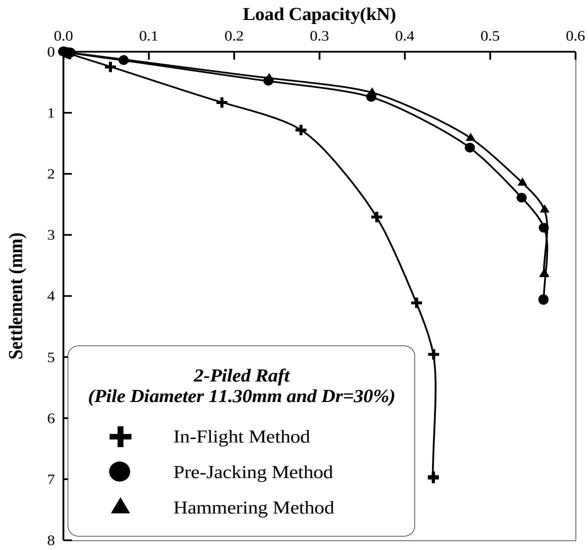

Figure 3. Load –Settlement curves for 2-Piled Raft.

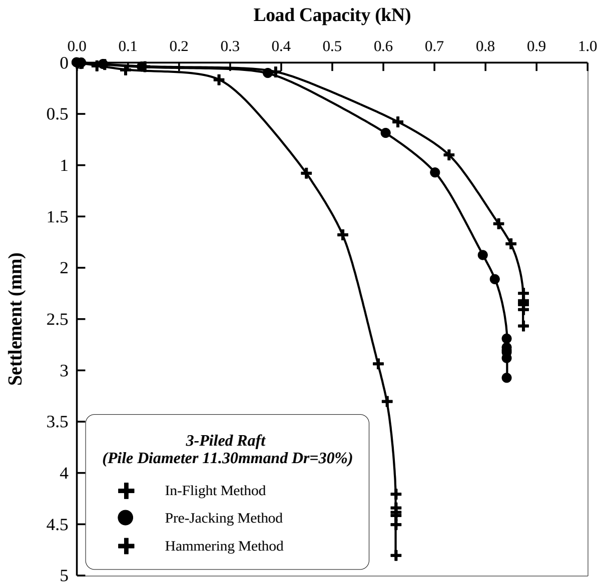

Figure 4. Load –Settlement curves for 3-Piled Raft.

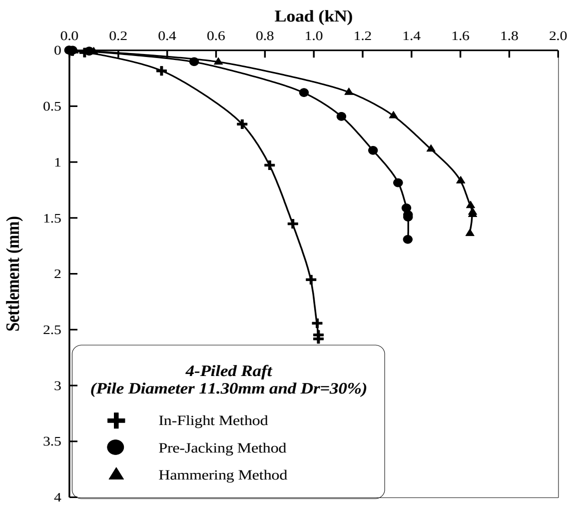

Figure 5. Load –Settlement curves for 4-Piled Raft.

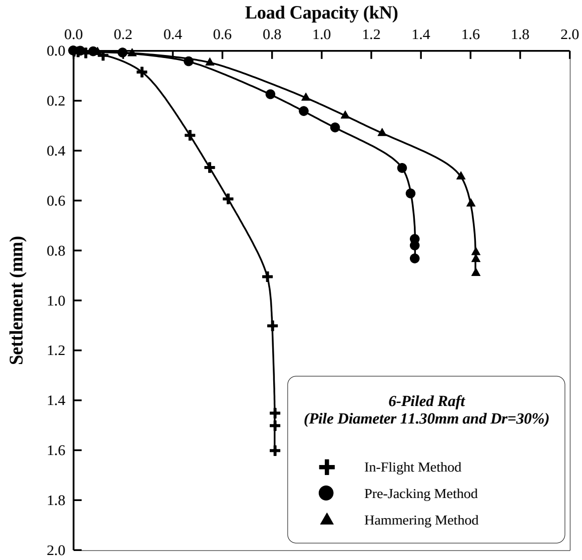

Figure 6. Load –Settlement curves for 6-Piled Raft.

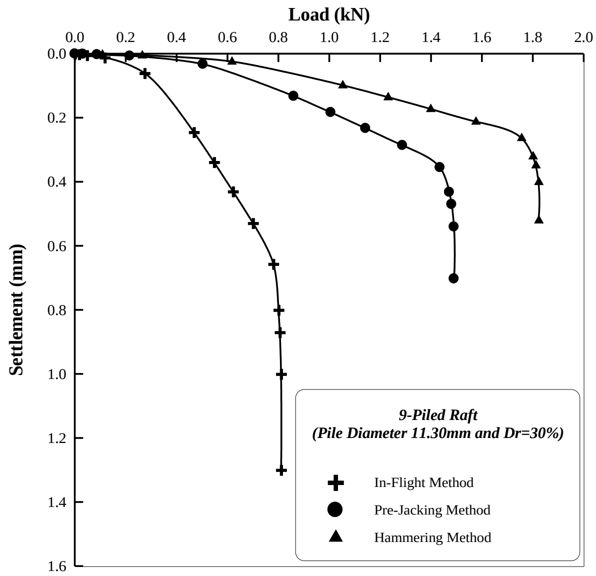

Figure 7. Load –Settlement curves for 9-Piled Raft.

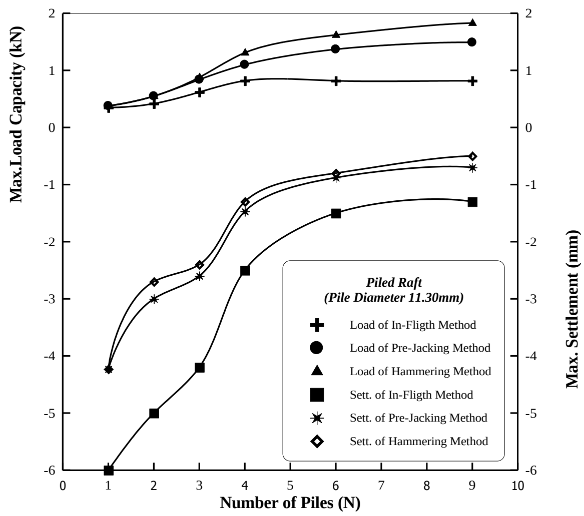

Figure 8. Max. Load and Max. Settlement Versus The Number of Piles.

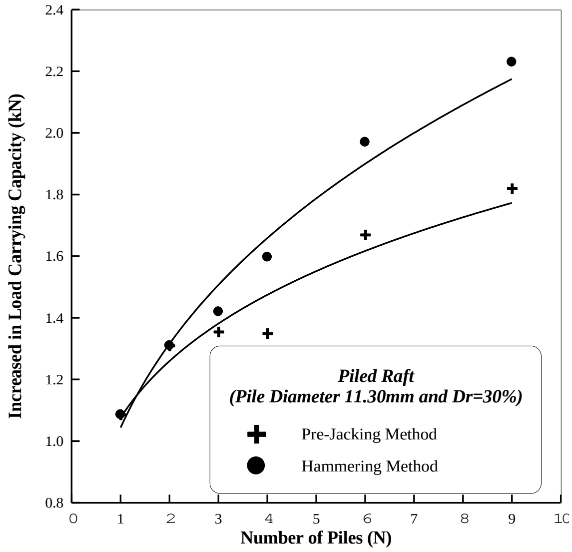

Figure 9. Increased in Load Capacity versus the Number of piles

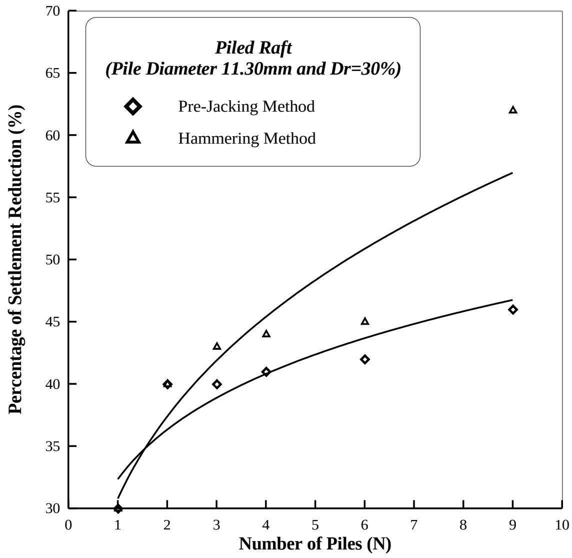

Figure 10. Percentage of Settlement Reduction Versus The Number of Piles.