Finite Element Analysis of Circular Piles under Dynamic Loads

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Fulfillment of the Requirements for
the Degree of Master of Science
in
Civil Engineering

By

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بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا

عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ

صدق الله العلي العظيم

To

My Family

Certification

I certify that this thesis entitled " **Finite element analysis of circular piles under dynamic loads**" which is submitted by Sa'ad Fahad Resan had been made under my supervision at the University of Basrah , College of Engineering Department of Civil Engineering ,in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

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Examination Committee Report

We certify that we have read this thesis titled **" Finite Element Analysis of Circular Piles Under Dynamic Loads"** as examining committee , which is been submitted by**" Sa'ad Fahad Resan "**and examined the student in its contents .In our opinion, the thesis is adequate for award of degree of **"Master of Science in Civil Engineering"**.

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Finally, I extend my sincere graduate to my family for their help, kindness during the time of hardship.

Sa'ad Fahad Resan

ABSTRACT

In the present study, finite element technique is adopted to study the response of single pile and pile group with circular section embedded in homogeneous clay soil under the excitation of dynamic loads.

The pile is modeled by discreting it into a series of interconnected beam segment elements. The pile – soil interaction is modeled by Winker type model as a series of springs having normal and tangential stiffness. The properties of these springs are calculated based on the "p-y","t-z" and "q-z" curves methods recommended by the American Petroleum Institute recommendations. These curves had been modified in the case of pile group in order to take into account the elastic effect between piles in the group. The dynamic equilibrium equations of the system are solved to calculate the forced vibration.
Fortran power station software is used to calculate "p-y","t-z" and “q-z" curves as well as (ANSYS 5.4) computer software which is used to model and analyze the problems which are considered in this study.

Two examples are considered as an application on modeling and analysis procedure . The first example deals with the dynamic response of a single pile with different stiffness factors, dynamic load types and pile head condition . The second example deals with the dynamic response of pile group with different groups sizes , pile group spacing, and dynamic load type.

Clearly it has been found that the amplitude of pile head under harmonic load is 0.61 of that under transient load with the same head condition and the type of dynamic load applied has reliable effect not only on pile head amplitude but also on pile response.

The response of single pile with horizontal and vertical modes of vibration to the dynamic load is markedly different when the pile is stiff and indicating clearly the effect of pile spacing and group size on group deformation and response.

CONTENTS

LIST OF FIGURES

LIST OF SYMBOLES

A	Cross sectional area of the frame element.
A_s, A_c	Dimensionless factor to determine p-y curve of sand and clay
[B]	Element strain-displacement matrix.
[C]	Viscous damping matrix.
c_u	Undrained shear strength of the soil.
D	Diameter of the frame element.
d	Diameter of the pile.
[D]	Elasticity matrix containing the appropriate material properties
[d]	Derivative operators matrix.
E	Modulus of elasticity.
E_s	Elastic modulus of the soil
$F(t)_I$	Vector of inertia forces acting on node masses
$F(t)_D$	Vector of viscous damping or energy dissipation force
$F(t)_S$	Vector of internal forces carry by the structure.

$F(t)$	Vector of externally applied loads
$\{f^e\}$	Nodal force vector.
f_{mi}	p-multiplier factor.
G	Shear modulus.
i	Number of in line rows.
j	Number of side by side rows.
J	Empirical factor (0.5 for soft clay, 0.25 for stiff clay).
$\{q\}$	Nodal displacement vector.
K	The static stiffness matrix for the system of structural element.
K	Modulus of initial subgrade reaction
K_{RA}	Interaction factor.
M	Mass matrix (lumped or consistent)
l	Frame element length.
[N]	Shape function matrix.
n	Number of pile in the group.

t	Time.
u_i	Nodal displacement at node i in the axial direction.
$\{u^e\}$	Element displacement vector.
v_i	Nodal displacement at node i in the local Y direction.
$\{U\},\{\acute{U}\}$ *and* $\{\ddot{U}\}$	Absolute node displacement, velocity and acceleration vectors respectively.
w_i	Nodal displacement at node i in the local Z direction.
S	Spacing between piles in group in direction of load.
S''	Spacing between piles in group in direction perpendicular to direction of load.
p_g	Dynamic load applied to pile group.
x	Depth along pile length.
x_r	Depth to transition point along pile length.
y_{50}	Deflection @ 50% of ultimate load.
z_e	Elastic axial displacement of the head of a single pile .
z_s	Axial single pile displacement for load equal to p.
θ_{xi} ,θ_{yi} *and* θ_{zi}	Nodal rotations at node i around the local X,Y and Z axes respectively.

ω	Natural circular frequency.
ξ	Modal damping ratio
η *and* δ	Raylengh damping parameters
ε_{50}	Strain corresponding to 50% of the ultimate unconfined triaxial load.
Ø	The angle of internal friction of the sand layer.
$[\Phi]$	Modal shape matrix
γ'	Submerged unit weight of soil.
$\{\epsilon\}$	Element strain vector.
Ω	Circular frequency of the wave=2л/t
ρ	Mass density of steel pile
μ	Poisson's ratio of the steel.
μ_s	Poisson's ratio of the soil.

CHAPTER ONE

INTRODUCTION

CHAPTER ONE
INTRODUCTION

1-1 General:

Most of marine structures, offshore structures, towers,…etc. are resting on piles. These piles in general taken on the ground. In some cases these piles carry sever dynamic loads generated from the effect of wind, waves, impacts, machine loads, earthquake …etc. in which case static analysis is not sufficient, and dynamic analysis become a requirement to calculate the effect of the loads on the structure, foundation, and supporting soil [1].

This study considers large diameters circular piles which are able to withstand high axial and lateral dynamic loads. The response of the pile foundation in many cases covers the response of the supported structures and their integrity. The analysis and interaction within structure-soil system is often simplified if the soil and the structure are treated separately [2]; therefore, modeling of problems considered in this research depend on separating of pile and analysis it as a structural element. In general the method followed in the analysis of pile foundation depends on the type of piles used and the type of loading. Different procedures have been used for the dynamic analysis of piles; the differences are because of the differences in the treatment of the soil medium in the analysis [3].

1-2 Dynamic Analysis:

Dynamic analysis is a technique used to determine the dynamic response of a structure under the action of any general time-dependent loads. To achieve a completed dynamic analysis, both free vibration and forced vibration analysis should be achieved to determine the vibration characteristics (natural frequencies and mode shapes) of a structure while it is being designed and to determine the time-varying displacements, strains, stresses and forces in the structure as it responded to dynamic loading conditions [4]. In general, the dynamic analysis of structural systems is a direct extension of static analysis. The elastic stiffness matrices are the same for both dynamic and static analysis [5].

1-3 Applications of Circular Pipe Piles Foundations:

Steel pipe piles are commonly used in bridge foundations. The foundations of large bridges are provided as dolphins with piles positioned diagonally at different angles and in different directions. Because steel pipe piles are concreted to function as a composite structure have high resistance to bending and buckling, the pile footings can be built in water. The use of caisson techniques allows all concreting down to the lowest pile tip to be carried out in dry conditions. This facilitates inspection and there by ensures proper quality control. Most bridges, such as small cross-water bridges, over-and under passes, flay over, etc, can be built on foundations consisting of a single steel pipe pile which in most cases can be connected to the deck directly without bearings. This contributes to safe, economical and rapid construction. For example the pipe pile foundations of railway bridges can be built during short traffic interruptions. With the largest (D=1220 mm) steel pipe pile, when properly installed, an allowable bearing capacity of 9 MN can be achieved enough even for heavy bridges [6].

In offshore structures, circular pipe piles foundations which are usually contain groups of pipes of large diameter are commonly used. The pile heads are connected rigidly to the structure so that only horizontal and vertical movements with negligible rotation of piles heads are permitted at mud line where the pile head taken on the ground[7]. Because of the large horizontal and axial loads developed by the wave action on the piles and the high flexibility of the steel tubes the deflections of the piles and deformations of the surrounding soil are relatively large. For this reason the analysis of offshore pile foundations should be performed with methods which consider non-linear soil behavior [8], on the other hand the design of offshore piles requires consideration of the effects of cyclic loading on the axial permanent deformations of the pile head.

1-4 Object and Scope of the Study:

The main objective of this research is to present a procedure for dynamic analysis of large diameter steel piles with circular section under the excitation of dynamic loads by finite element method. Piles are represented by frame elements supported by elastic spring, "p-y "(load-deflection) approach is used to model the soil in the action of horizontal loads and "t-z" and "q-z" approaches is used to model the soil in the action of vertical loads. Computer software (ANSYS 5.4) program had been used for modeling the problems and for complementing dynamic analysis of these problems under consideration.

The study is divided into six chapters. The current chapter is the first. Chapter two briefly reviews the available literature concerned with the problem. Chapter three presents the finite element modeling and the dynamic analysis formulations used for these types of problems. The effect of pile - soil interaction and its mathematical representation are dealt with in chapter four. Different applications of the present study which concerned to indicate the evaluation of the dynamic effect on a single pile with (free head and fixed head) and pile group are presented in chapter five. In chapter six the overall conclusions from the present study and recommendations for future works.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO
LITERATURE REVIEW

2-1 Introduction:

The response of piles and pile groups to dynamic excitation had been the subject of many investigations over the past decade. A review of the research indicate that although some outstanding efforts exist in the published literature the scope of some of the solution procedures developed are restricted and cannot always be extended to the generalized analysis of pile and pile groups subjected to axial and lateral loading.

This chapter deals with the available literature concerned with the single pile and pile groups under cyclic axial and lateral load. Finite element methods which used for this subject are also reviewed in this chapter. And finally a review for soil- structure interaction is presented.

2-2 General Dynamic Response of Pile Foundation:

Novak, in 1977 [9], presented an approximate analytical solution for the vertical dynamic stiffness and damping of the soil-pile system. The theoretical response is compared with experimental results. He had been found that the motion of pile tip cannot be neglected unless the pile is extremely long or the tip rests on a very rigid layer, lack of fixity of the tip reduces the stiffness and significantly increases the damping, with increasing length, the stiffness of a floating pile increases while stiffness of an end bearing pile decreases, the damping of floating piles is larger than that for end bearing piles, the vertical dynamic response of a structure supported by piles can be much smaller with floating piles than with and bearing piles and the relaxation of pile improves the agreement between the theory and experiments.

Meith, in 1980 [10], presented a method of force-coupling the nonlinear response of a pile foundation to the linear response of a structure, the method successively corrects the three boundary forces and three boundary moments for each pile at the pile-structure interface by comparing the nonlinear response of the pile –soil system to linear quasi-tangent modulus response, convergence is assumed when all six values per pile are within a stated tolerance. This technique had been employed in the analysis of approximately 40 major and a number of smaller offshore structures in the Gulf of Mexico and has been found to be an efficient and accurate way of coupling a structure to its foundation. It is shown that this method accounts for certain lateral nonlinearity that are inherent in most pile-soil system response and why these can produce large errors using other modeling techniques.

Harry, **in 1981** [11], performed an extension of an elastic-based analysis of a statically loaded pile which uses a total stress approach to incorporate the effects of cyclic loading, and which involved an interaction analysis to determine the ultimate load capacity and the cyclic, stiffness of the pile after a given number of load cycles of a given manipulated. He clearly shown that the ultimate load capacity and cyclic stiffness decrease with increasing number of cycles N and increasing cyclic load level. The effect of N becomes more significant when the cyclic load Pc (half peak to peak) approaches 50% of the static ultimate load, cyclic degradation begins at the top of the pile and progress downward as P_c or N increases, resulting in gradual transfer of load to lower parts of the pile, the crucial factor in determining the mount of cyclic degradation is the critical shear strain for skin friction, the static distribution of soil modulus and skin friction have a marked effect on the cyclic degradation and the relative loss in ultimate load capacity and cyclic stiffness is more sever if soil modulus and skin friction are uniform with depth than if they increase with depth .

Feng and Megerhof, in 1987 [12], used a numerical technique to solve nonlinear simultaneous equations. A new method of analysis is developed for design of eccentric and / or inclined loaded rigid pile in clay. The method takes account of the non-linear strain-stress characteristics of the soil around the piles and can be used for round, rectangular and other symmetric rigid piles. The computed results using this method were found to be in good agreement with the measured values of same field stats and laboratory model tests.

Harry, in 1989 [13], developed an analysis for the behavior of a single pile or symmetrical pile group in sandy soil under cyclic axial loading. The analysis allows consideration of the effect of degradation of skin friction, base resistance and soil modulus, the influence of load rate, and the accumulation of permanent displacements. Laboratory data for skin friction degradation are presented and it is shown that the amount of degradation due to cyclic loading depends on the cyclic displacement. The number of cyclic loading depends on the cyclic displacement, number of cycles, soil type , and type of pile. Theoretical solutions for a hypothetical pile and a previous field test emphasize the importance of determining whether the degradation of skin friction depends on the absolute cyclic displacement or the cyclic displacement related to the diameter.

2-3 Finite Element Analysis Review:

Kuhlemeyer, in 1979 [14] formulated approximation to obtain an efficient modeling to the dynamic transversely loaded piles. Dynamic solution was obtained for the case of transversely loaded piles embedded into homogenous, isotropic, and elastic half space. The fundamental solution was presented in the from of flexibility coefficients equal to the static case values multiplied by frequency-dependent complex numbers, which were approximated by polynomial expression, such that closed form solution was obtained valid for the practical range of the pile to soil elastic modulus ratio.

Krishnan, Gazetas and Veles, in 1983 [15], did a systematic parameter investigation for the static and dynamic response of a single free head pile embedded in soil stratum, the modulus of which increases linearly with depth. The study was conducted by means of a dynamic finite-element formulation which accounts for the three-dimensionality of soil deformation while properly reproducing the radiation damping characteristics of the system. The soil is modeled as a linear hysteretic continuum and the excitation consists of a sinusoidally time-varying horizontal force or moment applied at the pile head. It has been shown that the ratio of pile Young's modulus to soil modulus at a one-diameter depth is the most significant parameter which controls the response. The slenderness ratio is of secondary importance.

Essa & Al-Janabi, in 1992 [16], studied the dynamic behavior of plane frames resting on or partially embedded in winkler elastic foundation to obtain the dynamic response frame, considering the foundation-structure interaction. A beam element is used with axial force supported by elastic foundation of winkler type having normal and tangential modulus of subgrade reaction linearly varying with the length of the element. The end bearing resistance of the elastic foundation is also included in the analysis. This problem was solved using the mode super position and the newmark-β method. They concluded that the accuracy of newmark integration scheme depends on the size of time step. In general, the scheme gives an accurate solution for multi-degree of freedom system when the time step to smallest period is less than (0.1) otherwise the method exhibit an amplitude decay period elongation.

Sa'eed, in 2002 [17], studied the dynamic behavior of foundations supporting vibrating machinery. The finite element procedure was used in simulation of the machine foundation which is discretized using plate elements having the capability of undergoing the forces in three dimensions as well as the bending ability. The piles are discretized using space frame elements. The soil structure interaction was modeling using Winkler type foundation which have coefficients in three dimensions.

Barros, in 2003 [18] studied the response of piles with circular section embedded in transversely isotropic half spaces loaded by time harmonic axial loads. The pile was modeled as a series of bar elements. The soil is modeled by an indirect formulation of boundary elements. The boundary element formulation uses influence functions which are displacements and stresses due to loads distributed along circular and cylindrical surfaces inside a transversely isotropic elastic half space. He found that this method is effective when dealing with the problem of vertical pile embedded in transversely isotropic soil. The numerical results show that the isotropic soil has a marked influence on the pile response.

2-4 Soil-Structure Interaction review:

Nogami and Konagai, in 1987 [19], considered nonlinear conditions in the time domain formulation for the dynamic response of pile foundation. Both single piles and group of piles subjected to vertical dynamic load are considered in their study. The nonlinear effects in the vertical response are assumed to result from slippage of the pile from the soil. In order to demonstrate the capacity of the formulation and to see the effect of nonlinearity on the dynamic response of pile foundations, the response of pile foundations are computed for both harmonic and transient loads.

Other pile diameters [43].

In place of y_{50}, use y_c.

[redacted]

$y_c = 2.5\varepsilon_{50}$ $\overline{\;12.75''\;}$ $12.75 = 8.9\varepsilon_{50} d^{0.5}$ (Inches)

A-1-2 "p-y" Curves for Stiff Clay

A-1-2-1-In presence of Free Water

Derivation of curves is depended on works of Reese et al. (1975) which is base on 6 inch and 24 inch diameter piles in stiff clay[42].

General shape of curve:

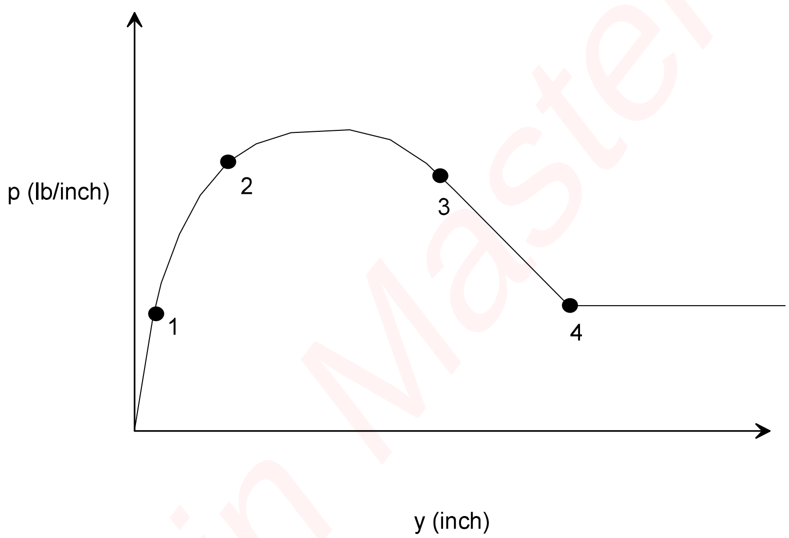

Fig. (A-3): Characteristic shape of p-y curve for stiff clay.

1. Slope of 0-1 = E_{si}

$$E_{si} = kz$$

Table (A-2) : Recommended values of k for stiff clay.

	c_u (tsf)				
	<0.25	0.25-0.5	0.5-1	1-2	2-4
k (static) – pci	30	100	500	1000	2000
k (cyclic) - pci	-	-	200	400	800

where:

c_u is average value from z = 0 to 5d

2. Evaluate ultimate soil resistance at depth x, p_u

$$p_{u,1} = 2c_{avg}d + \gamma dz + 2.83c_{avg}z$$ (near ground surface, based on wedge theory) .

$$p_{u,2} = 11c_z d$$ (at depth, based on theory of soil flow around pile) .

Theoretical ultimate resistance, $p_{u,th}$, is taken as the smaller of $p_{u,1}$ and $p_{u,2}$.

Actual p_u values are found from experiments to be smaller than $p_{u,th}$.

$$A = \frac{(p_u)_{static}}{p_{u,th}} \qquad B = \frac{(p_u)_{cyclic}}{p_{u,th}}$$

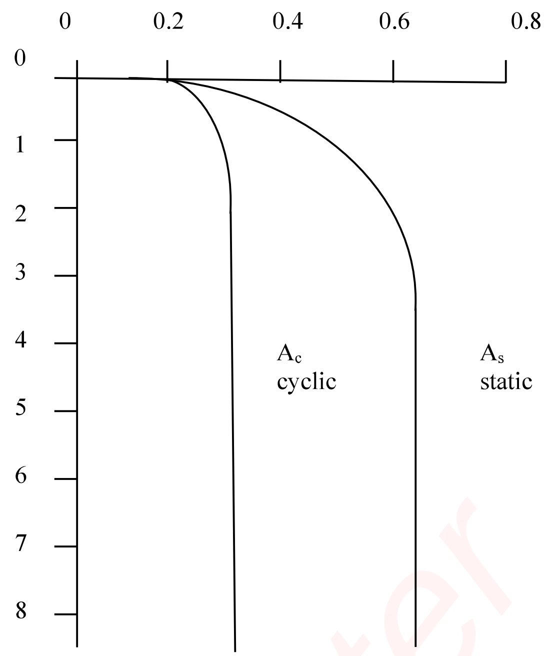

Fig. (A-4): Values of constants A_c and A_S .

3. Parabolic section 1-2

$y_{50}=\varepsilon_{50}\ D \quad y_{p}=4.1\ A_c\ y_{50}$

$$\frac{p}{p_{u,th}} = 0.5\sqrt{\frac{y}{y_{50}}}$$ for static loading

$p = A_c\ p_c\ (1-|\ (y-0.45y_p)/0.45y_p|^{\ 2.5}$ for cyclic loading

ε_{50} from triaxial laboratory test, or: table (A-3)

Table (A-3): Values ε_{50} of for stiff clay.

c_u (kN/m^2)	24-48	48-96	96-190
ε_{50}	0.007	0.005	0.004

Point 1 on the curve is defined by intersection of the parabola with the straight line segment, if no intersection, extend the parabola to origin.

Point 2 at $y = Asy_{50}$ for static load

$y = 0.6y_p$ for cycle load

4. Parabolic section 2-3

Offset applied to parabola from (3):

$$\frac{p}{p_{u,th}} = 0.5\sqrt{\frac{y}{y_{50}}} - 0.055\left(\frac{y - Ay_{50}}{Ay_{50}}\right)^{1.25} \quad \text{for static loading}$$

Point 3 $y = 6Ay_{50}$

$P = 0.936\ A_c\, p_c - (0.085/y_{50})\, p_c\, (y - 0.6y_p)$ for cyclic loading

Point 3 $y = 1.8y_p$

5. Straight line section 3-4

Slope $E_{ss} = -\dfrac{0.0625\, p_{u,th}}{y_{50}}$ for static loading

Point 4 $y = 18Ay_{50}$

Slope $E_{ss} = -\dfrac{0.085\, p_c}{y_{50}}$ for cyclic loading

Point 4 $y = 1.8y_p$

6. Horizontal line at $y > 18Ay_{50}$ for static loading

$y > 1.8y_p$ for cyclic loading

A-1-2-2- Without Free Water

Derivation of curves is depended on works of Reese et al. and Welch (1972) [42].

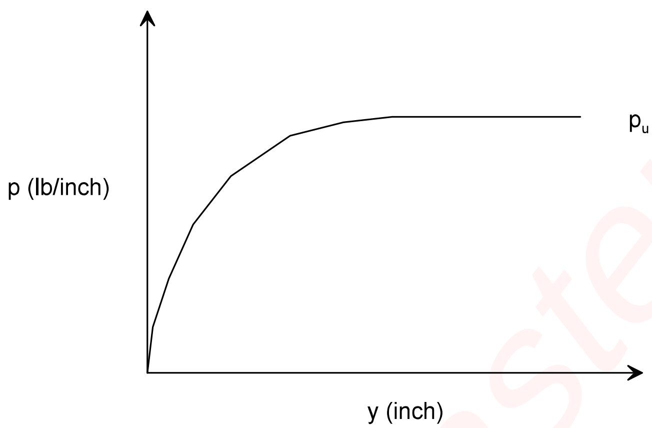

Fig. (A-5): "p-y" for Stiff Clay (without free water).

$$\frac{p}{p_u} = 0.5\sqrt[4]{\frac{y}{y_{50}}} \qquad y < 16y_{50}$$

$$p = p_u \qquad y > 16y_{50}$$

A-1-3"p-y" Curves for Sand

Derivation of curves is depended on works of Reese et al. (1974) which is base on field testing of two 24 inch diameter piles in soils ranging from clean fine sand to silty fine sand [42].

General shape of curve:

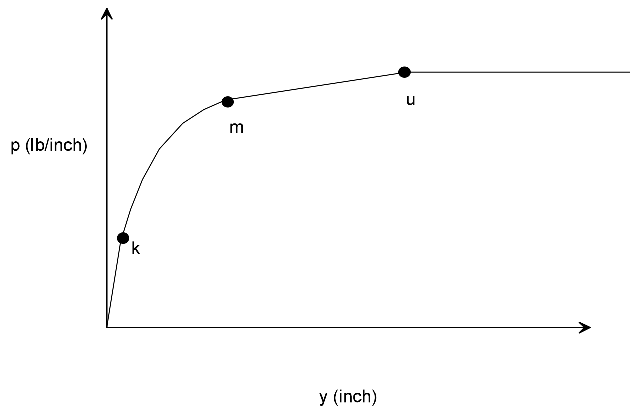

Fig. (A-6): General shape of p-y curve for sand

Table (A-4): The initial slope "E_{si}".

$E_{si} = kz$	Loose	Medium	Dense	
k (lb/in^3)	20	60	125	← submerged
k (lb/in^3)	25	90	225	← above gwt

Values apply for static + cyclic

1. Ultimate resistance, p_u

   (a) Near ground surface, derive from strain wedge theory

   Using the following geometry and Mohr-Coulomb theory,

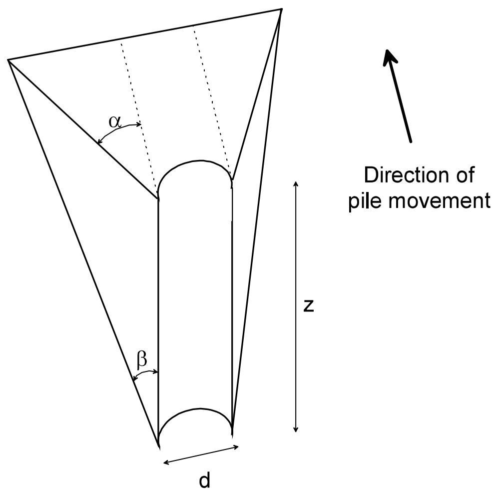

Fig. (A-7): Wedge type failure of surface soil.

$$p_{u,1} = \gamma z \; \frac{K_o z \tan\phi \sin\beta}{\tan(\beta-\phi)\cos\alpha} + \frac{\tan\beta}{\tan(\beta-\phi)}\left(d + z\tan\beta\tan\alpha\right) + K_0 z \tan\beta\left(\tan\phi s \sin\beta - \tan\alpha\right) - K_a d$$

in equation, best to use $K_0 \approx 0.4$ (this was used for interpretation of field data)[45].

$$K_a = \tan^2\left(45 + \phi/2\right)$$

(b) At depth z_r.

Soil assumed to flow laterally around pile

$$p_{u,2} = z\gamma d\left[K_a\left(\tan^8\beta - 1\right) + K_0 \tan\phi \tan^4\beta\right]$$

Take $p_{u,th}$ as the smaller of $p_{u,1}$ and $p_{u,2}$.

Actual p_u values are found from experiment to be smaller than $p_{u,th}$.

$$A = \frac{(p_u)_{static}}{p_{u,th}} \qquad B = \frac{(p_u)_{cyclic}}{p_{u,th}}$$

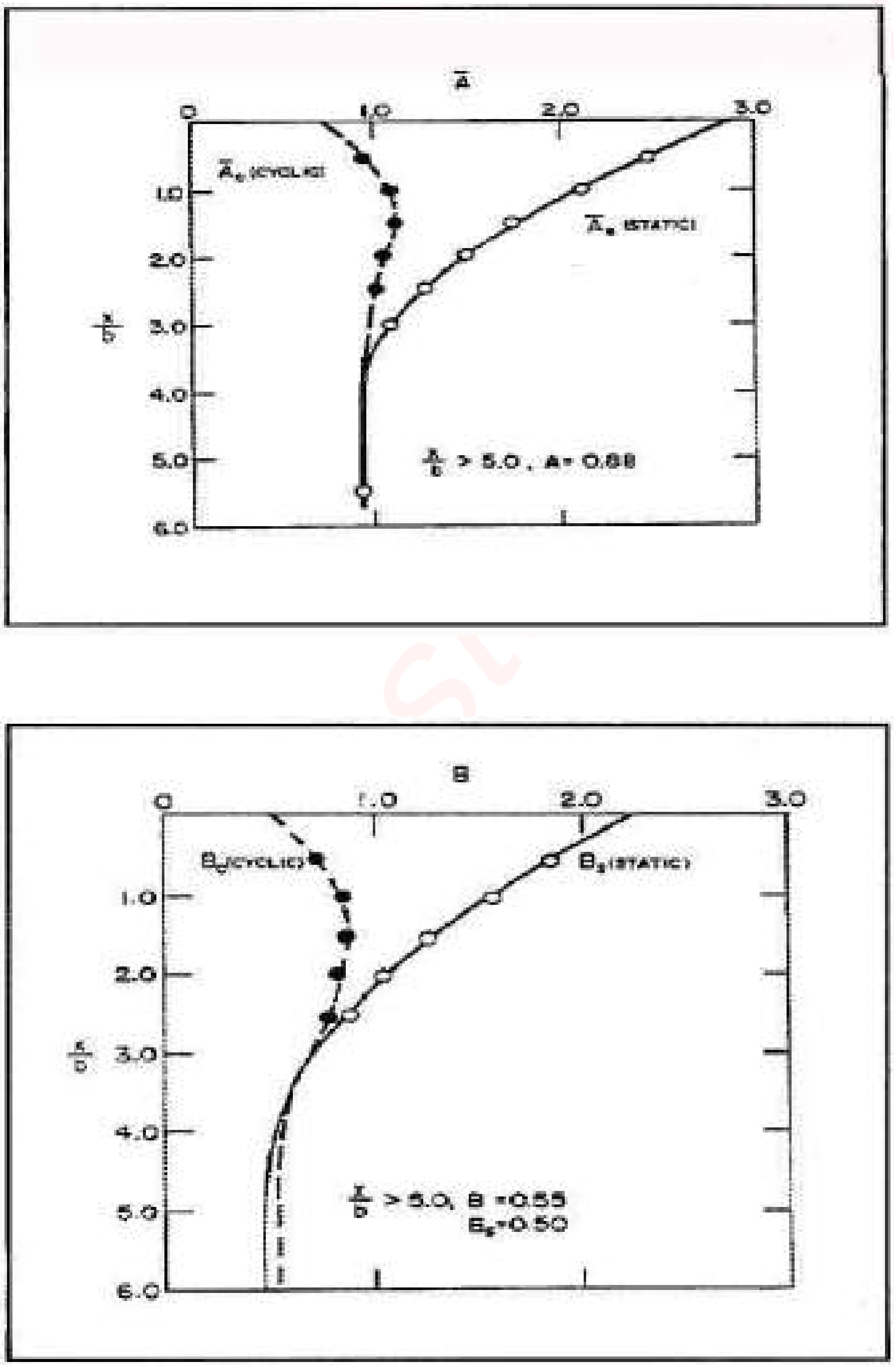

Fig (A-8): Nondimentional coefficients (A and B) for sand.

2. Deflection at Points m and u

$y_m = d/60$ $y_u = 3d/80$

3. Evaluate p at Point m

$p_m = (A' \text{ or } B')p_{u,\,th}$

4. Fit parabola between Points k and m

$$p = Cy^{1/n}$$

slope @ m, $s_m = \dfrac{p_u - p_m}{y_u - y_m}$

$$n = \frac{p_m}{s_m y_m}$$

$$C = \frac{p_m}{y_m^{1/n}}$$

displacement at k, $y_k = \left(\dfrac{C}{kz}\right)^{n/(n-1)}$

A-2: Response of Piles to Vertical Loads: "t-z" and "q-z" Approaches :

A-2-1: "t-z" And "q-z" Curves for Clay:

The evaluation of "t-z" and "q-z" curves for clay required the following steps [8]:

1- The unit ultimate of skin friction f_u and bearing q_u for the soil are evaluated by:

$f_u = \alpha C$

$q_u = N_c C$

α and N_c are dimensionless coefficient given in table (A-5)

Table (A-5) typical (α and N_c) values

C in KPa	α	N_c
0≤c≤24	1.0	For all clays $N_c = 9$
24≤c≤72	1.25 – 0.01c	
c>72	0.5	

2- The depth Z_c is determined by:

i- for end bearing Z_c= 0.04D to 0.06D, depending on the soil strength.

b- for skin resistance Z_c= 1.75mm.

3- The first portion (ab) of the "q-z" curve can be determined from

$$\frac{q}{q_u} = \left(\frac{z}{z_c}\right)^{1/3}$$

A-2-2 "t-z" and "q-z" Curves for Sand

"t-z" and "q-z" curves for sand can be derived using the following steps [8]:

1-the unit ultimate skin friction and q_u for the soil is evaluated as follows:

$$f_u = k\gamma' x \tan\delta$$

$$q_u = N_q \gamma L$$

the values of δ (angel of friction between pile and soil), k and N_q depend on the values of φ (angel of internal friction for sand). Table (A-7) gives the values of φ, δ, N_q and k for different soil types.

Table (A-7) gives the values of φ, δ, N_q and k

Soil type	φ	δ	N_q	k
Clean sand	35	30	40	0.5-0.1
Silty sand	30	25	20	
Sand silt	25	20	12	usually taken 0.7
Silt	20	15	8	

The depth Z_c is calculated as:

ii- a- for skin friction $Z_{c=}2.5$

b- for end bearing Z_c=0.05

iii- the curves may then be constructed as shown in figure (A-10-a)

b- the first portion of "t-z" curve (ab) may be determined from table (A-6)

Table (A-6): Values of points on "t-z" curve for clay.

Zmm	0.25	0.5	0.75	1	1.25	1.5	1.75
f/f_u	0.2	0.4	0.6.	0.75	0.9	0.97	0.1

iv- the portion (bc) for both curves can then be constructed (a horizontal straight line).

Figure (10-9): shows a typical “t-z” and “q-z” curves for clay.

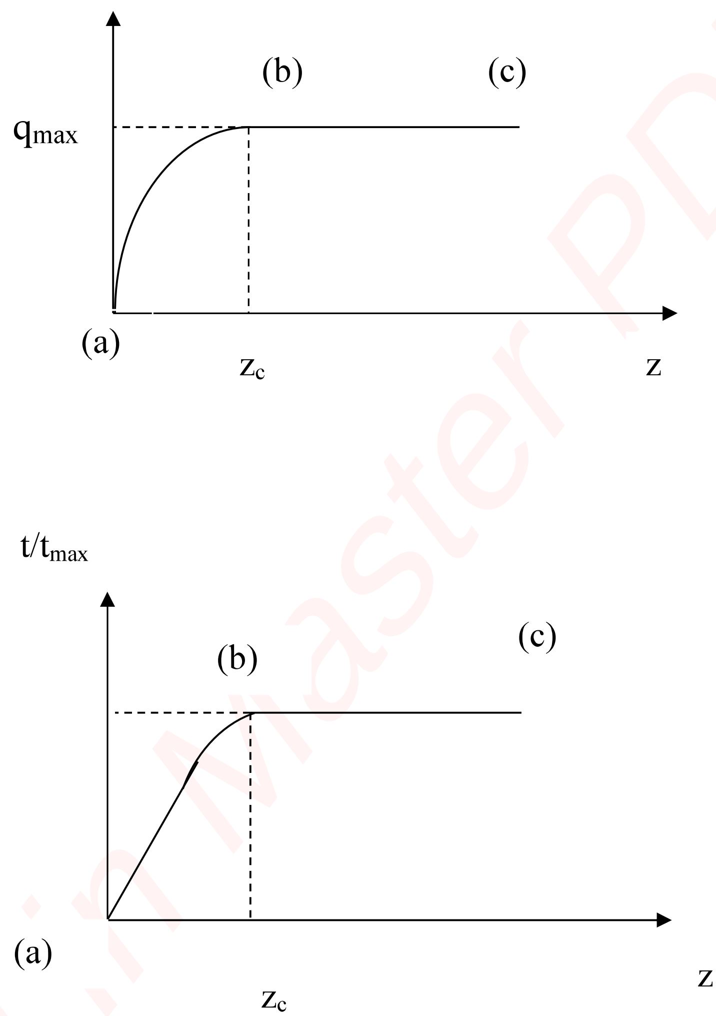

Fig. (A-9): Typical "q-z" and "t-z" curves for clay.

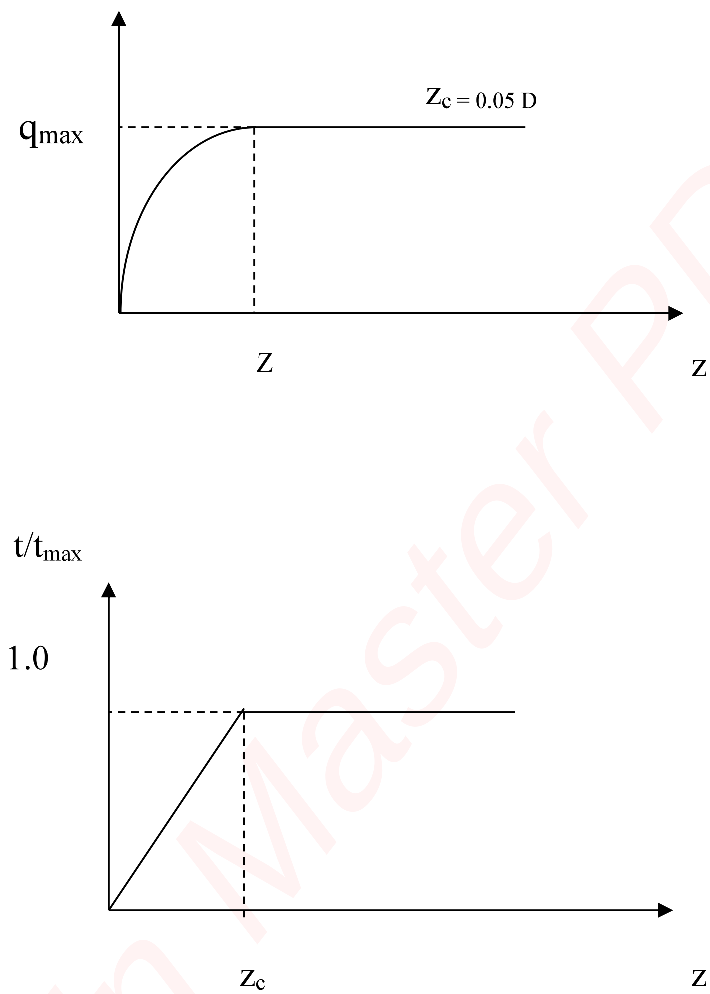

Fig. (A-10): Typical "q-z" and "t-z" curves for sand.

ألخلاصه

تم في هذا البحث استخدام طريقه العناصر ألمحدده لدراسة السلوك الحركي لركائز دائرية المقطع في تربه طينيه متجانسة الخواص تحت تأثير أحمال حركيه. تم تمثيل الركيزة بواسطة تقسيمها لسلسله من العناصر المرتبطة مع بعض , أما العلاقة بين الركيزة و ألتربه ألمحيطه بها فقد تم تمثيلها باستخدام نموذج وينكر (Winker type model) باستخدام سلسله من النوابض الحلزونية لتمثيل ألتربه في نقاط التثبيت ذات جسائه باتجاهين; الأول مماسي لعمود الركيزة و الآخر عمودي عليه. و خصائص هذه النوابض تم حسابها من خلال استخدام طريقه المنحنيات (t-z),(p-y) و(q-z) المعتمدة من قبل معهد بحوث النفط الأمريكي, هذه المنحنيات تم تحويرها في حاله مجاميع الركائز اخذين بنظر الاعتبار تأثير التداخل المرن للتربة و الركائز.

تم استخدام برنامج (Fortran power station) لحساب منحنيات ألـ (t-z),(p-y) و(q-z) بالإضافة إلى الاستخدام الواسع لبرنامج أل (ANSYS 5.4) لنمذجه و تحليل موضوع البحث.

تم اخذ مثالين كتطبيقين على طريقه التحليل المعتمدة; الأول لركيزة دائرية مفرده تحت تأثير حمل حركي اخذين بنظر الاعتبار تأثير جسائه الركيزة و نوع الحمل و نوع تقييد راس الركيزة . أما المثال الأخر فقد اختص بدراسة مجموعه من الركائز باختلاف عددها و المسافات بين ركيزه و أخرى بالاضافه لنوع الحمل الحركي المسلط. بشكل واضح وُجِدَ إن الازاحات تحت تأثير أحمال موجيه هي بقدر 0,61 منها في حاله كون الحمل الحركي فجائي كما تبين إن نوعَ الحملِ الحركي لَهُ تأثيرُ مؤثر ليس فقط على الازاحات ولكن أيضاً على الاستجابة الحركية للركيزة،كما تبين أن درجه تأثر الركيزة ألمفرده ألمعرضه لحمل حركي بالنمط الأفقي أو العمودي مختلفةُ باختلاف جساه الركيزة وتشير النتائج بشكل واضح لتأثيرِ المسافات بين الركائز في مجموعه الركائزِ وحجمِ المجموعةِ على التشوه و الاستجابة الحركية للمجموعة مع الحمل المسلط.

التحليل

باستخدام طريقه العناصر ألمحددة لركائز

دائرية المقطع

تحت تأثير أحمال حركية

رسالة مقدمة إلى

كلية الهندسة- جامعة البصرة

كجزء من متطلبات نيل شهادة الماجستير

في الهندسة المدنية

من قبل

سعد فهد رسن

بكالوريوس في الهندسة المدنية

2005 م