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INFLUENCE OF SOIL STRENGTH PARAMETERS ON THE LATERAL PILE RESPONSE

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ABSTRACT:- A three-dimensional finite element technique has been used to analyze the single pile lateral under pure lateral load. The main objective of this study is to assess the influence of soil strength parameters (c, ϕ) on the lateral behavior of single pile. The lateral single pile response in this assessment considered both lateral pile displacement and lateral soil resistance. As a result, modified p-y curves for lateral single pile response has been improved when taking into account the influence of lateral load magnitudes and soil strength parameters. The finite element method includes linear elastic, Mohr-Coulomb and 16-nodes interface models to represent the pile behavior, soil performance, and interface element, respectively. It can be concluded that the lateral pile deformation and lateral soil resistance due the lateral load are always influenced by lateral load intensity as well as soil strength parameters.

***Keywords*:-** piles, lateral response, soil strength parameter, 3D FE analysis.

INTRODUCTION

In the design of pile subjected to lateral load, the lateral displacement at working loads should be within the permissible limit (Poulos & Davis, 1980, and Patra & Pise, 2001). In addition, the second main key element in the design of laterally loaded piles is the determination of ultimate lateral resistance that can be exerted by soil against the pile (Zhang et.al. 2005) particularly the ultimate soil pressure which occurred in the middle of the pile.

It is generally accepted that the finite element method is the major technique used in numerical analysis of geotechnical problems particularly piles and soil consolidation. As reported by Poulos & Davis (1980), the first attempt to study lateral behavior of piles includes a two-dimensional (2-D) finite element model in horizontal plane. Anagnostopoulos

& Georgiadis (1992) attempted to explain the lateral pile response through an experimental model supported by a 2D finite element analysis. Other investigations have attempted to study the lateral response of pile under pure lateral load using the finite element approach (Muqtadir & Desai 1986, Trochanis 1991, Yang & Jeremic 2005, Johnson et. al. 2006 and Kahyaoglu 2009). In addition, the influence the lateral pile response in 3D finite element approach when the pile carried both axial and lateral loads which studied by Karthigeyan et al. (2006 & 2007).

Therefore, in this Study, the importance for conducting a fundamental study is discussed. A fundamental study of the lateral pile response under pure lateral load was conducted by varying soil properties (i.e. cohesionless soil and cohesive soil).

ANALYSIS METHODOLOGY AND LAYOUT

Finite element analyses were performed using the software PLAXIS 3D Foundation. In the finite element method a continuum is divided into a number of (volume) elements.

Each element consists of a number of nodes. Each node has a number of degrees of freedom that correspond to discrete values of the unknowns in the boundary value problem to be solved. The finite element mesh used in the simulation of single pile analysis (shown in Figure 1) consists of (1134) 15-nodes wedge element, including (1099) soil element and (35) pile element. The lateral load is applied at the tip of the pile that is found at the ground surface in the x-direction and at y-direction when axial loads are applied. Plan and 3D view for the finite element mesh of single pile and surrounded soil mass is illustrated in Figure 1.

The outer boundaries of soil body of cubic shape are extended to 10D on the sides and 5D at the bottom of pile base.

Analyses were performed with several trial meshes with increasing mesh refinement until the displacement changes to very minimal with more refinement. The aspect ratio of elements used in the mesh is small and close to the pile body near to the pile top and base. All the nodes of the lateral boundaries (right and bottom) are restrained from moving in the normal direction to the respective surface.

The finite element simulation includes the following constitutive relationships for pile, surrounded soil and interface element. The finite element includes linear elastic model to simulate structural part of problem (e.g. pile), Mohr-Coulomb model to represent the surrounded soil and 16-node interface elements to represent interface element.

RESULTS AND DISCUSSION

The study includes the lateral pile response (i.e. lateral pile displacement and lateral soil pressure) under pure lateral load. Two types of soil are used (i.e. cohesionless and cohesive soil). Lateral load intensity ranged *H* = (5-45) $\{\gamma_w D^3\}$. Slenderness ratio, *L/D* = 10. Pile shape is circular, soil types are cohesionless soil and cohesive soil. The baseline soil parameters used for the analysis of laterally loaded pile group are illustrated in Table 1.

The soil parameter is one of the important factors affecting the behavior of laterally loaded pile as any other geotechnical issues. The major well-known parameters are angle of internal friction (*ø*) for cohesionless soil and Cohesion Intercept (*c*) for cohesive soil. In this section, the influence of these two factors on the lateral pile response (lateral pile displacement and lateral soil pressure) will be discussed in the case of pure laterally loaded pile.

INFLUENCE OF ANGLE OF INTERNAL FRICTION (Ø)

The influence of the frictional angle of the cohesionless soil (*ø*) on the pile response is studied by trying number of values. Four different friction angles (i.e. 5^0, 15^0, 30^0, and 45^0) are used in this study. These values are tested separately and drawn together for the three load magnitudes to show its effect under low, intermediate and high load intensities, respectively.

The response of lateral pile tip displacement vs. pile depth for four friction angles is shown in Figure 2a for cohesionless soil. Higher friction angles employ higher resistance in the soil. It can seem that the lateral displacement values are much closed in case of (30^0 and 45^0) friction angle, this event on all loads intensities. The large lateral displacement occurred at the friction angle of 5^0 and also can see non-uniform performance when the pile carry different amount of loads.

Figure 2b shows the distributions of the lateral soil resistance along the depth for four different angle of internal friction for cohesionless soil. The soil resistance response is insensitive to the friction angle at low load level (e.g. 50kN). However, at high load level, the soil resistance distribution tends to move down the pile length. Figure 4a present *p-y* curves predicted under the effect of friction angle (*ø*) at depths of (z=0, D, and L/5D) that represent near to surface and deep under ground level. It can seen that the angle of friction is large affect the lateral pile response with time. The highest value of lateral soil pressure is observed when *ø* is equal to 45^0, while very small pile resistance is obtained when *ø* is 5^0.

INFLUENCE OF COHESION INTERCEPT (C)

The influence of the cohesion intercept of the cohesive soil (*c*) on the pile response is studied by trying number of values. Four different cohesion intercept (i.e. 5, 10, 15, and 25) are used in this study. These values are tested separately and drawn together for the three load magnitude to show its effect under low, intermediate and high load intensities, respectively.

Figure (3a) shows the affect of the cohesion intercept on the variation of lateral displacement with pile depth. It can seem that the cohesion intercept affected the lateral pile response. In case of low load level, gradual increase in the lateral pile displacement occurred when (*c*=5) which represent very weak soil. While there is very little difference event during the load level of all other magnitude of the cohesion intercept.

Figure (3b) shows the lateral soil pressure distribution with depth. In case of low load, very little change occurred with time when the magnitude of cohesion intercept was changed and generally lateral soil pressure started from the lowest value near to the surface and increased with depth. When increasing the load to the intermediate load level, the lateral soil pressure increased in the region of upper part of the pile and significant increase in the lateral soil pressure with load level can be noticed. Finally, the lateral soil pressure is affected when change cohesion intercept and the maximum values occurred between (1D – 2D) from the surface.

Finally, the *p*-*y* curves predicted when take into account the effect of the values of cohesion intercept (*c*) at three depths (i.e. z=0, D, and z=L/5D) are detailed in Figure 4b. It can be observed that the cohesion intercept value was largely influenced on the lateral pile response at z=0 (near to surface) because of the early failure of the soil surface . Less effect of (*c*) when calculate the *p*-*y* curve at depth of D, while very little effect of cohesion intercept on the *p*-*y* curve at depth 2D.

CONCLUSIONS

The lateral pile deformation and lateral soil resistance due the lateral load is always influenced by lateral load intensity and soil type as well as soil strength parameters. Higher friction angles employ higher resistance in the soil. The lateral displacement values much closed in case of (30^0 and 45^0). Highest value of lateral soil pressure observed when takes ø of 45^0.

On the other hand, cohesion intercept affected the lateral pile response. The lateral pile displacement and soil pressure values are much closer in case of (ø = 30^0 and 45^0) and (c

= 20 and 25) for cohesionless and cohesive soil, respectively. The lateral soil pressure is affected when the cohesion intercept is changed and the maximum values occurred between (1D – 2D) from the surface. Less effect of (c) occurs when calculating the p-y curve at depth of D, while very little effect of cohesion intercept on the p-y curve at depth 2D.

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Table (1): Soil parameters for analysis of pile group.

Parameter	Unit	Cohesionless	Cohesive
Unit weight, *γ'*	kN/m^3	20.0	18.0
Young's modulus, *E'*	kN/m^3	1.3 x10^4	1.0x10^4
Poisson's ratio, *v'*	-	0.3	0.35
Cohesion intercept, *c'*	kN/m^2	0.1	5.0
Angle of internal friction, *ø'*	-	30	25

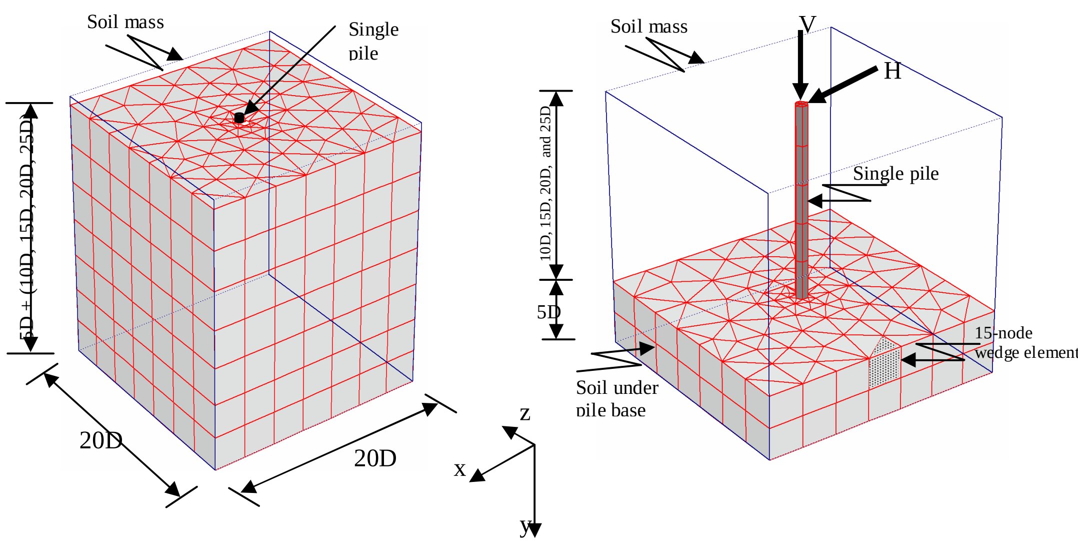
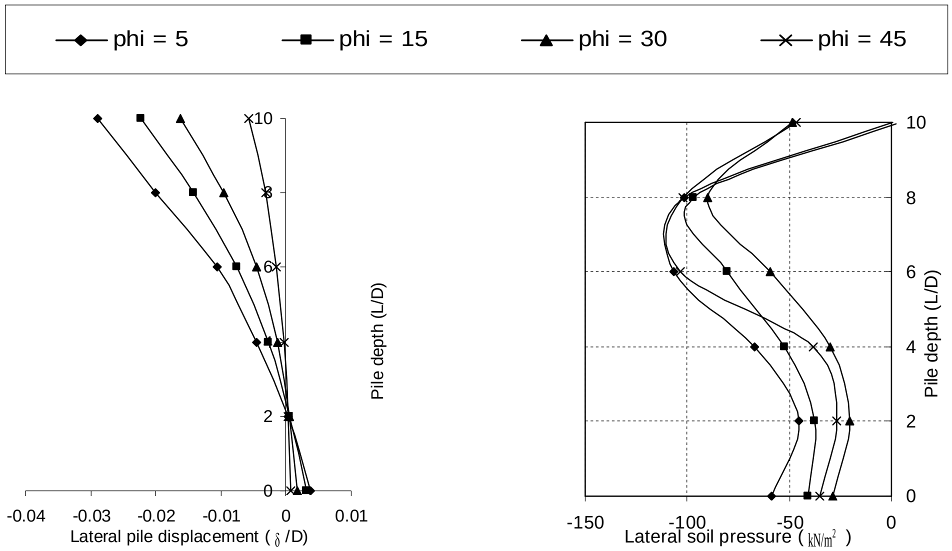
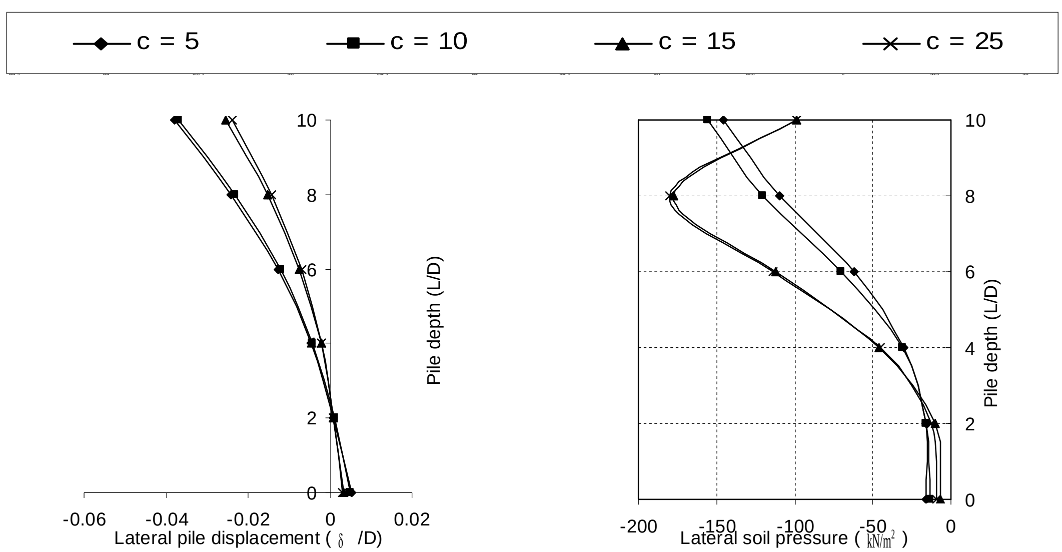


Fig.(1): Three dimension finite element mash for single pile and surrounded soil mass.



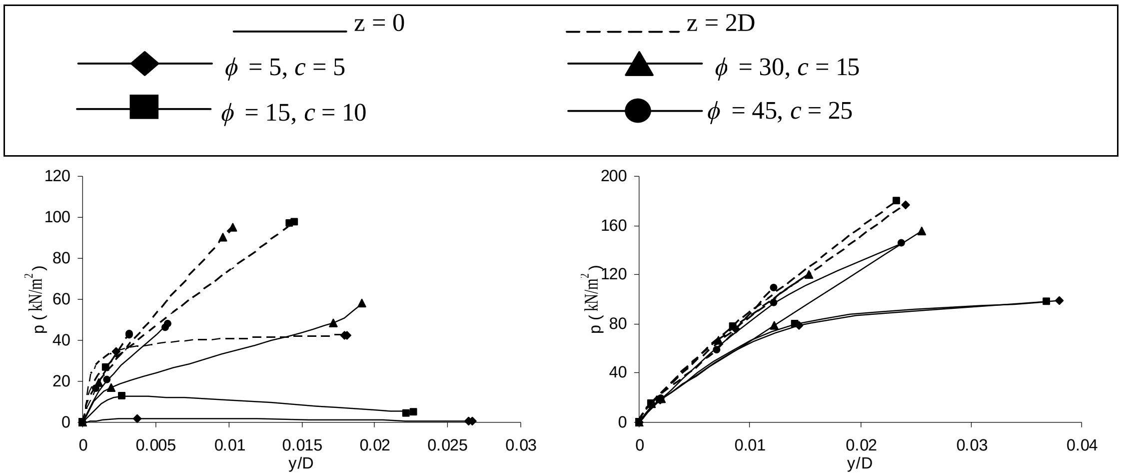
(a) (b)

Fig.(2): Influence of the value of angle of internal friction on the lateral pile response, (a) lateral pile displacement and (b) Lateral soil pressure.



(a) (b)

Fig. (3): Influence of the value of cohesion intercept values on the lateral pile response, (a) lateral pile displacement and (b) Lateral soil pressure.



(a) (b)

Fig.(4): p-y curves predicted under the effect of soil properties, (a) cohesionless soil and (b) cohesive soil.

تأثير خواص مقاومة التربة على التصرف الجانبي للركيزة

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الخلاصة

استخدمت طريقة العناصر المحددة لتحليل قابلية تحمل ركيزة منفردة معرضة لحمل جانبي. ان الهدف الرئيسي من هذه الدراسة لتحليل تأثير عوامل القوة للتربة على التصرف الجانبي للركيزة. في هذه الحالة يكون التصرف الجانبي للركيزة يتضمن كل من الإزاحة الجانبية للركيزة بالإضافة إلى مقاومة التربة الجانبية. كنتيجة نهائية تصرف إجهاد-إزاحة المطور للتصرف الجانبي طور عندما تأخذ بنضر الاعتبار تأثير كل من كمية الحمل الجانبي و خواص التربة. طريقة العناصر المحددة تتضمن كل من تصرف خطي للركيزة و مور-كولومب للتربة و 16 عقدة للتماس بين التربة و الركيزة. كاستنتاج لذلك إن التصرف الجانبي للركيزة يتأثر بشكل ملحوظ بكمية الحمل الجانبي المسلط وخواص التربة.

كلمات الدلالة : الركائز, التصرف الجانبي, خواص المقاومة للتربة, طريقة العناصر المحددة.