International Journal of Civil and Structural Engineering– IJCSE
Volume 3 : Issue 1 [ISSN : 2372-3971]
Publication Date: 18 April, 2016

THREE DIMENSIONAL NUMERICAL STUDY FOR PILE GROUP BEHAVIOR UNDER TORSION EFFECT

A. F. Zidan

Abstract

The objective of this research is investigating the piled foundation behavior under torsional load effect through a series of 3D numerical model. This paper presented a complicated three dimensional model to simulate the pile soil structure interaction problem. 2X2 pile group subjected to torsion was conducted in this study to draw a conclusion about the torsional resistance of pile group. Based on the Drucker-Prager behavior low the soil layer has been modelled. The concrete pile cap and cylindrical piles were modelled as elastic materials. The interface elements were attached between piles and surrounding soil to model the soil. The influences of pile length, group size and pile cap rigidity on the pile group resistance were presented.

Keywords

Torsional load, Pile-soil structure interaction, pile foundation, three-dimensional analysis.

1.Introduction

The behavior of piled foundation under torsional loading is extremely complicated topics and an important issue that widely affects the performance of structures. After construction the piles loaded axially due to gravity loads of the superstructure. The lateral loads can be transmitted to the pile foundation due to wind, earthquake, ship impact, wave actions and other sources of loading. This lateral loads can transmit significant torsional loads to the structures such as tall buildings, bridges foundations, offshore platforms.
Numerical and testing models were performed by some previous researchers to study the behavior of single pile subjected to torsion[1-14]
In the current study, the behavior of pile group in homogenous soil is investigated under the torsional loads effect. In this study the three dimensional finite element study has been established by the well known finite element program ANSYS. This code is employed to introduce three dimensional model of pile group soil interaction and to introduce the elasto-plastic soil constitutive mode. The influence of pile length, group size and pile cap thickness on the torsional resistance of pile group is presented in this paper.

Faculty of engineering- Beni-Suef University
Egypt

2. Numerical Modelling

The numerical study is going to be carried out by means of the finite element method as it allows for modelling complicated soil structure interaction.
ANSYS code is used here to perform the three dimensional analysis. The parametric study of this work dealt with the behavior of piled cap under torsional loads. The dimensions of model are presented in Fig.1. The model dimensions were selected such that the magnitude of failure load remains unchanged even increased beyond the chosen value. The vertical boundaries of the model were constrained horizontally, and the bottom boundary was constrained in both horizontal and vertical directions.

The soil is assumed to be homogeneous isotropic and elastic-perfectly plastic based on the Drucker-Prager behavior low. Solid 45 brick element which has 8 nodes element is used to simulate the soil media. This element has 3 degree of freedom to move in X, Y and Z directions and considers nonlinearities of plasticity, creep, nonlinear elasticity, swelling, large displacements and strains (ANSYS Manual). The soil parameters that assumed in this study are illustrated in Table1.

The concrete material of the cylindrical pile and pile cap is modelled as elastic materials using the 3D Solid 65 brick element which has 8 nodes, translation in X, Y, Z directions.

This element is capable of plastic deformation, cracking in three orthogonal directions, and crushing. The pile cap contains four piles and the characteristics of piles and cap are given by: pile diameter d (constant in this study d=0.5m, pile length L, pile cap thickness T and pile spacing s. The concrete elements are modelled with weight γ=25kN/m^3, Young's modulus E=2×107 kN/m^2, and Poisson's ratio ν = 0.2.

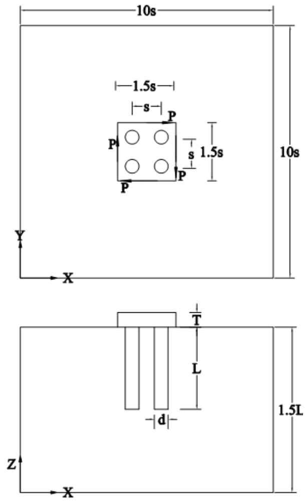

Fig.1 Model geometry.

Table 1: soil and interface parameter

Parameter	Value
Modulus of elasticity (Es), kN/m^2	7000
Poison's ratio (ν)	0.3
Unite weight (γ), kN/m^2	17
Cohesion (C), kN/m^2	10
Angle of internal fiction (ϕ), deg	1
Dilation angle (Ψ), deg	0
Friction angel at interface (d), deg	0.5
Adhesion (Ca) kN/m^2	6.66

In order to make the simulation of soil structure interaction problem more universal representation and more realistic a thin layer of interface element is modelled between cylindrical piles and soil. The presence of interface element allows the relative movement takes place between piles and surrounding soil under tortional loading. The interaction at the soil pile surface is modelled using the Targe170 and conta173 contact element. Conta 173 is used to simulate the weaker materials (soil) and targe170 is used to represent the stronger materials (piles). This target surface is discretized by a set of target segment elements (TARGE170) and is paired with its associated contact surface (CONTAC174) via a shared real constant set [15].

The torsional load is modelled as 4 horizontal loads distributed on the four edges of the pile cap. To investigate the behavior of piled cap system and the group capacity the torsional load was applied in increments until failure occurs.

The parametric study included changing of pile length (L), the pile spacing (s) and pile cap thickness (T). These Parameters are normalized (non dimensional) to pile diameter (d) L/d, s/d and T/d to describe the general behavior of model. Table 2 shows the deferent cases in the current study. Figure 2 shows an example of deformed pile cap under torsional loading effect.

3. Results and discussion

In this section the relationship between the applied torque and the twist angle of pile cap is presented due to the variation of pile spacing, pile length and thickness of pile cap. Fig. 3 shows the torque rotation angle curve

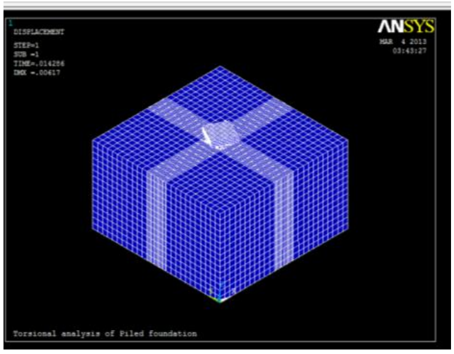

Fig. 2 An Example of the model deformation under torsional load.

for piled foundation versus pile spacing. It can be noted that the torsional resistance increases with pile spacing or group size.

At the twist angle 8^o the torsional resistance of S/d=5 is 1.2 times that of S/d=4 and 3 times that of S/d=3. Fig. 4 shows the effect of pile length in pile group on the resistance of piled foundation. It shows that the torsional resistance increases with the increase of pile length. It can be noticed that the torsional resistance influenced by the pile length when 3^o is achieved. At the twist angle 8^o the torsional resistance for case of L/d=20 is 1.1 times that of L/d=15 and 1.18 times of L/d=10. Fig. 5 shows the variation of torsional resistance with the change of pile cap thickness. It can be observed that the torsional resistance of piled foundation slightly affected by the thickness of pile cap whereas the torsional resistance at 8^o when T/d changes from 1 to 2 ranges from 5400 to 6090 kN.m. This change is about 12.7 % when we double the pile cap thickness for our studied cases.

Fig.6 summarized the resistance of piled group exposed to torsional load where, the ultimate torsional moment versus pile spacing, pile length and pile cap thickness is presented. It shows that the efficiency of pile group increases with the increase of pile spacing and pile length and slightly increases with the pile cap thickness. It can be seen that the pile spacing is the most influential factor of the increases pile group resistance due to torsion.

Table 2: Parameters investigated in the numerical study.

Group	Constant parameters	Variable parameters	Remarks
1	L/d=20, T/d=2	s/d=3, 4, 5	Influence of pile spacing (3 cases)
2	s/d= 3, T/d=2	L/d= 10, 15, 20	Influence pile length (3 cases)
3	s/d=3, L/d=20	T/d= 1, 1.5, 2	Influence pile cap thickness (3 cases)

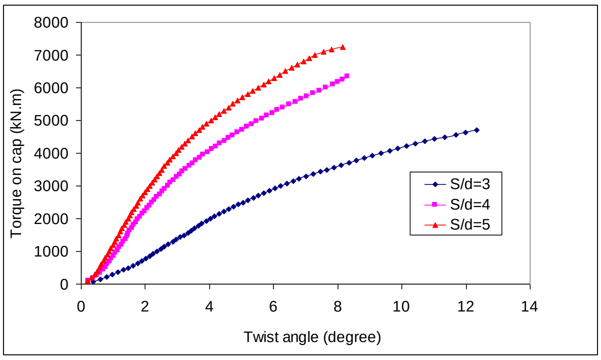

Fig. 3 Effect of pile spacing on torsional resistance of pile group.

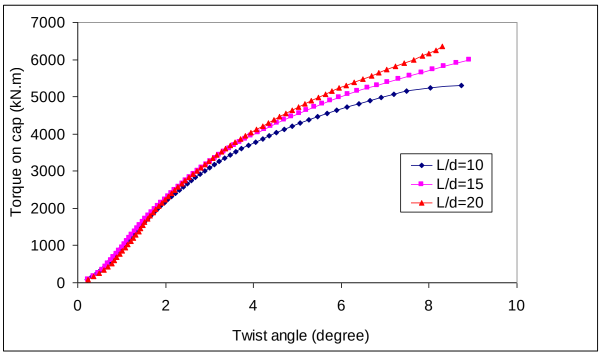

Fig. 4 Effect of pile length on torsional resistance of pile group.

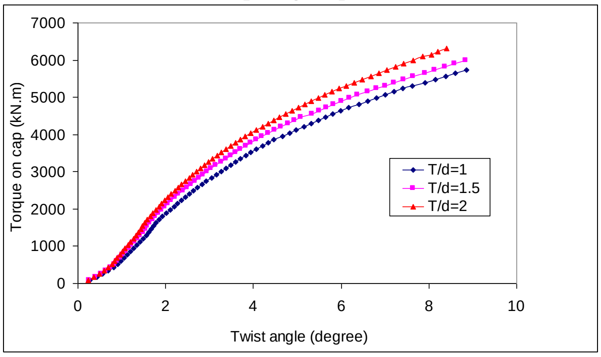

Fig. 5 Effect of pile cap thickness on torsional resistance of pile group.

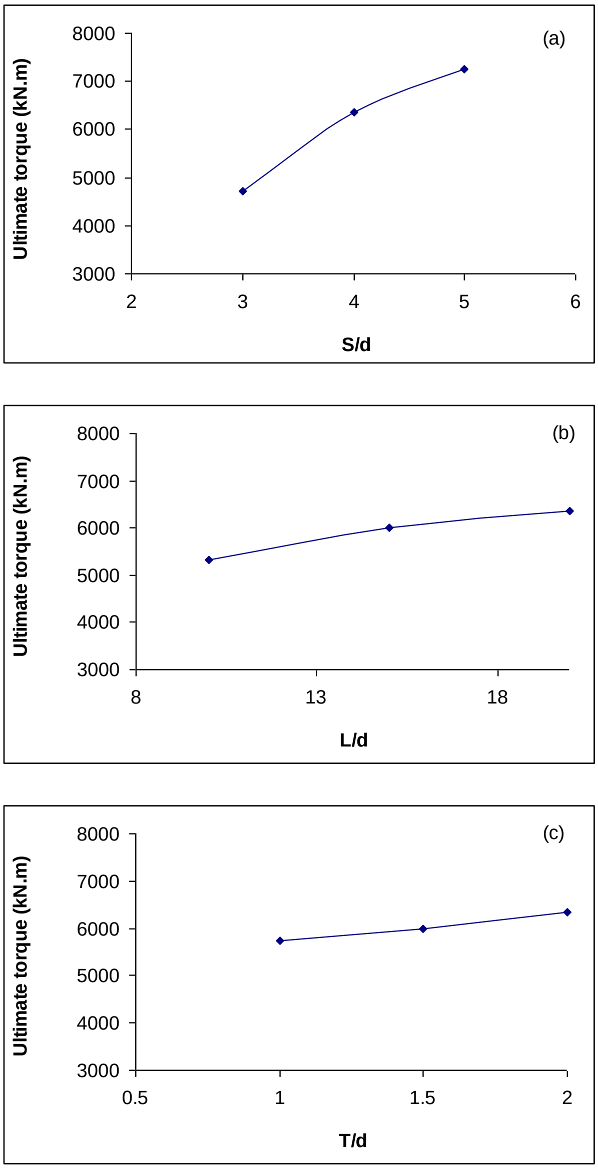

Fig. 6 Ultimate torsional capacity due to the variation of; (a) pile spacing, (b)pile length, (c) pile cap thickness

Conclusion

This paper investigates the performance of pile group exposed to torsional load in clayey soil. The pile cap, piles, soil and interface element between soil and piles are modelled through a series of 3D numerical model. Based on numerical results, the efficiency of pile group increases with the increase of pile spacing and pile length and slightly increases with the pile cap thickness. It can be said that the pile spacing is the most influential factor of the increases pile group resistance due to torsional effect.

References

1. Matlock, H., Correlations for Design of Laterally Loaded Piles in Soft Clay., 2nd Annual Offshore Tech. Conf., Houston, 1 1970 577-594.
2. Idriss, I.M., Singh, R.D. and Dobry, R., Non-Linear Behaviour of Soft Clay During Cyclic Load, Journal of Geotechnical Engineering, ASCE, No. 12, (104) 1978 427-447.
3. Poulos, H.G, Behaviour of Laterally Loaded Piles: I - Single Piles, Journal of Soil Mechanics and Foundation Division, ASCE, No. 5, (97)1971 711-731.
4. Vucetic, M. and Dobry, R., Degradation of Marine Clays under Cyclic Loading, Journal of Geotechnical Engineering, No. 2, 114 1988 133-149.
5. Basak, S., Behaviour of Pile under Lateral Cyclic Load in Marine Clay., Ph.D. Thesis, Jadavpur University, Kolkata, India, 1999.
6. Stoll, U. W.,Torque shear test of cylindrical friction piles, Civ. Eng.,42 1972 (4), 63–64.
7. Poulos, H. G. “Torsional response of piles.” J. Geotech. Engrg. ASCE, 1981. 1019–1035.
8. Dutt, R. N., and O’Neill, M. W., Torsional behavior of model piles in sand, Geotechnical practices in offshore engineering, ASCE, New York 1983, 315–334.
9. Randolph, M. F., Piles subjected to torsion, J. Geotech. Engrg., 107 (8) 1981, 1095–1111.
10. Bizaliele, M. M., Torsional cyclic loading response of a single pile in sand, Dissertation, Schriftenreihe des Instituts fur Grundbau, Ruhr Univ., Bohum, Germany 1992.
11. Guo, W. D., and Randolph, Torsional piles in non-homogenous media, Comput. Geotech.,19 (4) 1996, 265–287.
12. Laue, J., and Sonntag, T., Pile subjected to torsion, Proc., Centrifuge ’98, Balkema, Rotterdam, The Netherlands,1998 187–192.
13. Zhang, L. M., and Kong, L. G., Centrifuge modeling of torsional response of piles in sand, Can. Geotech. J.,43 2006 (5), 500–515.
14. L. G. Kong and L. M. Zhang , Centrifuge Modeling of Torsionally Loaded Pile Groups, GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING, ASCE, 133 2007 (11) 1374–1384.
15. Ansys manual, user manual ansys 11. (2), 499-510 (2012)