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Dynamic Analysis of Laterally Loaded Piles (Effect of Spacing & Diameters)

Junaid Maste, P. J. Salunke, N. G. Gore

Abstract: In this study the finite element model (FEM) analysis of group of piles in cohesionless soil with the diameter from 0.5m to 2m and spacing between the piles varied from 2D to 3D by means of the FB-multipier software. Hence by developing a finite element model soil structure interaction study is carried out considering nonlinear soil behavior in time domain analysis with the help of Newmark's beta method.

Keywords: Laterally loaded piles, Dynamic analysis, p-y curves, Newmark's beta method, FB-multipier.

I. INTRODUCTION

The soil–structure interaction (SSI) has increasingly attracted the interest of researchers and engineers in the fields of wave mechanics and soil dynamics. Piles are generally used to carry the vertical loads from the super structure but sometimes to withstand the effect of lateral load e.g. offshore structure, retaining structure etc.

There are various methods available to carry out the analysis of laterally loaded piles like finite difference, elastic continuum approach, subgrade reaction & finite element etc. Amongst all these nowadays the most realistic and accurate method is finite element method. Hence finite element method is adopted for the present work. While dealing with very high excitation like wind gusters, one must have to take into consideration the effect of non linearity. In order to consider soil non-linear behavior, the springs can have a varying stiffness given through a non-linear load-deflection relationship that depends on the type of soil and type of pile therefore nonlinear curves are used called p-y curves, where p is pressure and y is corresponding deflection.

Design engineers often prefer to use the Beam-on-Dynamic-Winkler-Foundation (BDWF) model for design purposes rather than the Finite difference method or elastic continuum solutions. BDWF methods use traditional semi empirical *p-y* curves such as those developed by Matlock (1970) and Reese et al. (1974). These curves represent the nonlinear soil behavior by a series of nonlinear springs.

The entire analysis is carried out in FB-multipier software. The pile is idealized as a beam element, the pile cap as two dimensional plate elements using Mindlin theory and the soil as non-linear elastic springs using the p-y curves . Further the two different arrangements i.e. parallel and series arrangements of pile groups are considered. The results show that pile behavior is severely affected by various soil and pile properties and as spacing increases lateral resistance of the pile also increases.

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Junaid Maste, P.G student, MGMCET, New Panvel, India.
Prof. P. J. Salunke, Assistant Professor, MGMCET Navi Mumbai, India.
Prof. N. G. Gore, Assistant Professor, MGMCET Navi Mumbai, India.

p-y curve:

The p-y curve is developed for cohesionless soil with the help of p-y curve proposed by Reese et al. (1974). The characteristic shape of the *p-y* curve is composed of 3 straight lines and a parabolic curve (Figure (a)). In this approach, the initial modulus of subgrade reaction and ultimate soil resistance are needed to develop *p-y* curves. Reese et al. (1974) suggested suitable values for the initial modulus of subgrade reaction for different relative density of sands.

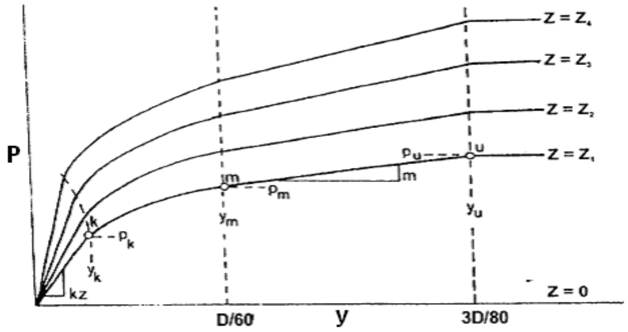

Fig (a): Characteristic shape of *p-y* curves for sand (Reese et al. 1974).

Numerical Techniques for Dynamic response:

Solution of the equation of motion for a single-degree-of-freedom system is usually not possible if the excitation applied force P(t)or ground acceleration Üg(t)--varies arbitrarily with time or if the system is nonlinear. Such problems can be tackled by numerical time-stepping methods for integration of differential equations, for this work taking into consideration reliability and accuracy Newmark's Beta method is adopted. The Newmark Beta integration method is also based on the assumption that the acceleration varies linearly between two instants of time. Two parameters α and β are used in this method, which can be changed to suit the requirements of a particular problem. The parameters α and β indicate how much the acceleration enters into the velocity and displacement equations at the end of the interval Δt. Therefore, α and β are chosen to obtain the desired integration accuracy and stability. The parameter β is typically between 0 and ¼, and α is often taken to be ½. The advantages of using Newmark's method over the central difference method are that Newmark's method can be made unconditionally stable (if β= ¼ and α= ½) and that larger time steps can be used with better results.

Soil structure interaction finite element model using FB-multipier software:

For the analysis purpose FB-multipier software is used. Soil-pile modeling is done with finite element in FB-multipier to investigate the lateral deformation, positive - negative moments and soil reaction. The pile is modelled as two nodded beam element while the pile cap is modelled as plate element based on mindlin formulation.

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The sketch of the typical model used for the analysis is shown in fig (b) below.

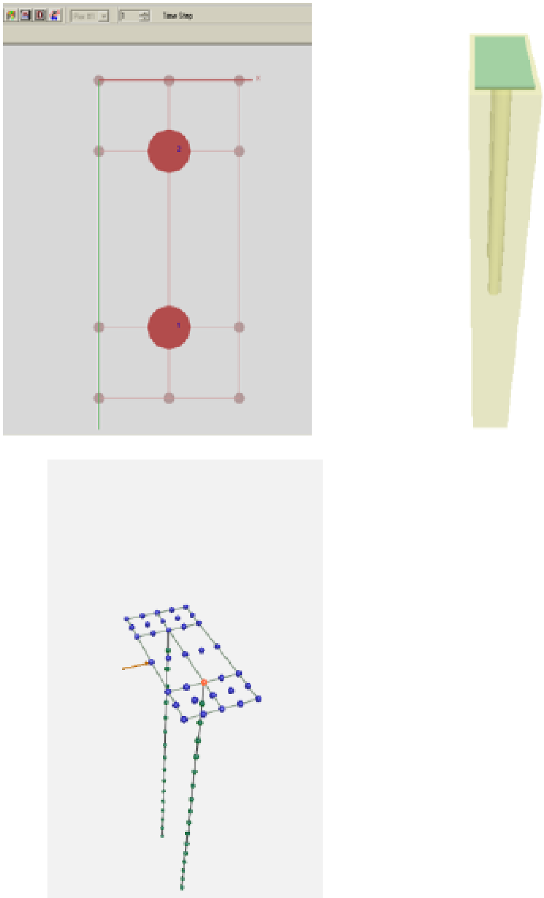


Fig: (b) Plan and finite element representationof model

Parametric study:

A parametric study is carried out for the pile group considering the parallel arrangement i.e. the application of loading is perpendicular to the length of the pile cap. A dynamic load of 1000KN is applied as lateral load. The pile is modeled as beam element, soil as non-linear springs and the cap as plate element. Both the effect of diameter as well as spacing is studied by varying diameter i.e. 0.5m to 2m and by varying spacing between the two piles i.e. 2D to 5D where D is the diameter of the pile. The various parameters used for pile, soil and cap are described below in table (a).

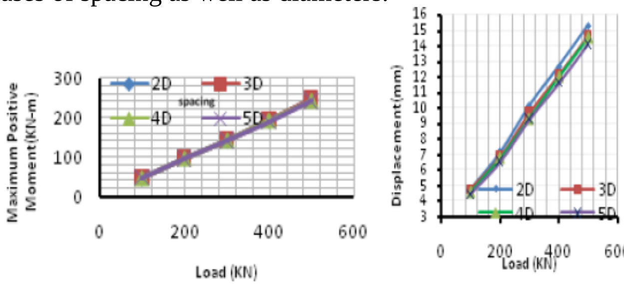
Table (a): Parameters used for Pile, Soil and Pile-cap

Pile diameter	0.5m
Length	10m
Concrete grade used for pile and pile cap	M45
Young's modulus of pile	$31.52*10^6$ KN/m^2
Shear modulus of pile	$19.7*10^6$ KN/m^2
Pile cap thickness	0.1m
Soil Type	Cohesionless
Poison's ration	0.3
Internal friction angle ϕ	30
Modulus of subgrade (KN/m^3)	10000
Unit weight(KN/m^3)	17

The entire analysis is carried out in FB-multipier software and the results are obtained for displacement, max-positive and negative bending moments.

Results and discussion:

After analysis in FB-multipier software the results are obtained and are shown graphically in fig(c) for both the cases of spacing as well as diameters.



Fig(c): load vs. displacement, max- negative moment (effect of spacing)

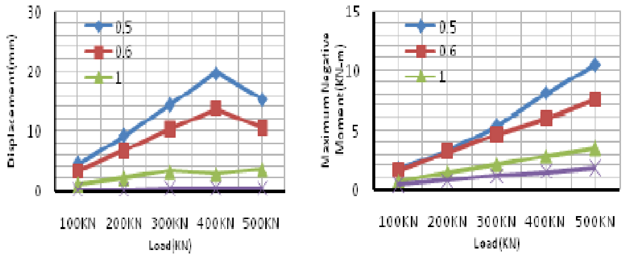


Fig (d): load vs. displacement, max. negative moment (effect of diameter)

The output from the program is used to develop the load–pile displacement, positive and negative moment curves. The horizontal displacements computed at the top of the pile group or pile cap are found to decrease with the increase in spacing. The reduction in displacements with the increase in spacing may be attributed to the overlapping of the stressed zones for the case with closer spacing. This further indicates the increase in resistance to lateral loads. It is observed that the capacity of the pile group increases with spacing. The positive moments are found to decrease while negative moments are found to increase with effect of spacing for the pile group with the parallel arrangement of piles. In another way with the effect of diameter the moments are found to decrease while negative moments are found to increase. For the purpose of accuracy of FB-multipier model in the present work is validated with sawant et al.(2012) and the results are found to be in good agreement.

II. CONCLUSION

From this study the following results are concluded.

1. As the spacing increases the lateral resistance of the pile also increases.
2. The soil non-linearity, spacing, soil and pile properties and diameter severely affects the behavior of pile group.
3. As the diameter increases the lateral resistance of the pile group also increases.
4. With the increase in spacing, the positive moment decreases while negative moment increases.
5. But as the diameter size increases the positive moment increases while negative moment decreases.

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