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Internal Forces in a Pile During Seismic Event in Cohesive Soil

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Abstract

During the event of earthquake the pile foundation is subjected to time dependent stresses, displacements and strain which is dependent on the underlying soil strata. For such events the study needs to be properly carried out to estimate the internal forces in the pile that is likely to be developed during such events. This paper presents the study of maximum bending moment and shear stress developed in pile foundation during such events with comparison between different pile diameter and spacing for fine grained soil. PLAXIS 2D is used to model and analyse the internal forces generated in the pile during such event. The results from the analysis shows that there is increment in the bending moment and shear force in the pile with increase in the pile diameter and pile spacing.

Keywords

PLAXIS-2D, earthquake, pile, fine grained soil, bending moment, shear force

1. Introduction

Many of the pile foundation in the past has experienced damage during seismic events in many parts of the world. During seismic events in addition to the stresses in pile due to inertial effect additional stresses are built due to the kinematic stresses in soil due to the soil-pile interaction developed during such events. Thus, consideration of kinematic stresses due to the seismic events is must in design of foundation. This objective of the study is to give an overview of the stresses in the pile foundation during the seismic events. The stresses in the pile varies with the variation in the pile diameter and pile spacing. The comparison of such parameter with the stresses built in the pile are presented here.

1.1 Earthquake forces and pile response to earthquake forces

1.1.1 Earthquake forces

During the event of earthquake soil element are subjected to time dependent displacement and strain which is dependent on the location of the foundation and underlying soil strata. The earthquake loads can be considered using three methods [1].

1. Equivalent static load at surface, earthquake load as certain percent of the vertical static load or as the base shear
2. Equivalent dynamic load at surface
3. One component of the earthquake acceleration applied at bed rock, usually applied in the form of prescribed displacement

1.1.2 Pile response to earthquake force

The study of the pile response to the earthquake can be studied under two parts [2].

1. Determination of the dynamic response of the soil medium along when excited through its lower boundary by a prescribed horizontal seismic motion
2. Determination of the entire structural system with the moving soil medium

2. Modelling

Although modelling and analysis of the piles during earthquake loads are 3D problem, general overview on the 2D modelling of the pile is given by Sluis [3]. According to Sluis [3], the application of the 2D analysis of pile foundation for lateral and dynamic loading is limited to the low pile spacing, as the spacing between the pile increases the result seems to deviate from the results from volume piles. Another such study done by Kwaak [4], the normalized pile displacement and bending moment calculated from PLAXIS 2D are shown to be similar to that of volume piles for low pile spacing (spacing/diameter <4). For this range the embedded pile row gives similar results to that from other method available such as node to node anchor and plate elements.Comparison of the bending moment and shear forces in pile for different configuration are compared by Finn [5]. The results from the study were compared to that for the full analysis done in 3D which showed good agreement. According to Finn [5] the group effect in the pile group does not appear to be the significant factor as far as bending moment and shear forces are concerned.

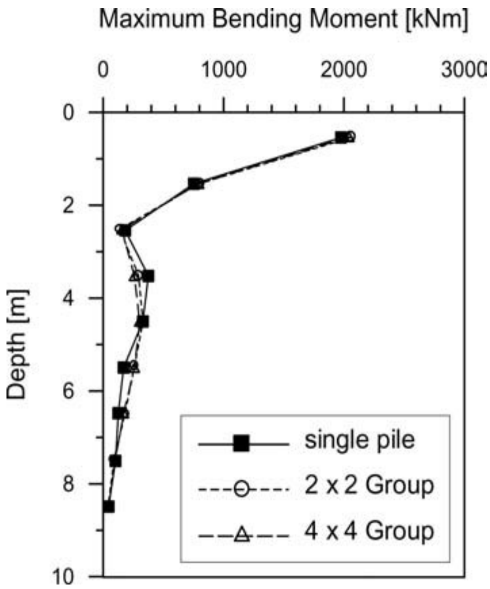

Figure 1: Comparison to maximum bending moment to depth [5]

Modeling using PLAXIS 2D For this study purpose PLAXIS 2D was used for the modelling and analysis. Three layers of soil was used for the analysis with depth of 4m, 5m and 6m with corrected SPT value 15,22 and 37 respectively. Soil mass was modelled using Mohr-Coulomb constitutive model with quadratic 15 node triangular elements for the mesh generation. Circular concrete pile of 10m length was used and modelled using plate elements. Both standard fixities and standard earthquake boundaries are used for the analysis. The earthquake loads are applied as prescribed displacement applied at the lower boundary of the model. On application of the standard earthquake boundary the program generated left- and right-hand vertical boundaries are applied

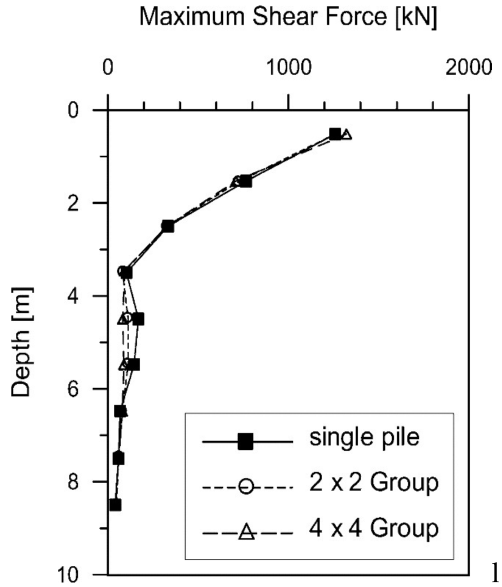

Figure 2: Comparison to maximum shear force to depth [5]

with a prescribed displacement at the base of the model. For the earthquake loading the data from 2015 Gorkha earthquake recorded at Department of Mine and Geology(DMG), Lainchaur in ASCII file format was used. Only the first 70s of the earthquake acceleration was applied to the model as earthquake load.For the scaling of the applied load an prescribed displacement (ux=0.01 m) was applied., Pile of different diameter 0.4m, 0.5m and 0.6m were modelled at spacing of 2D, 3D and 3.5D for each pile diameter. The positive maximum bending moment and shear force for the pile were further analysed and compared to get the final result for the study.

Validation of the result For the verification a different model was prepared with two pile elements in single layer of cohesive homogeneous soil model. The maximum bending moment and shear force was then compared with the results from Finn [5] as shown in figure 3 and 4.

For the comparison result obtained from the model was normalized to range [0,1] using min-max normalization method which was then compared to the normalized results from study of Finn [5].

3. Results and Discussion

Different charts for the comparison of the maximum bending moment and shear force to depth for different diameter of pile and for different spacing are presented.Figure 5 and 6 shows the comparison of

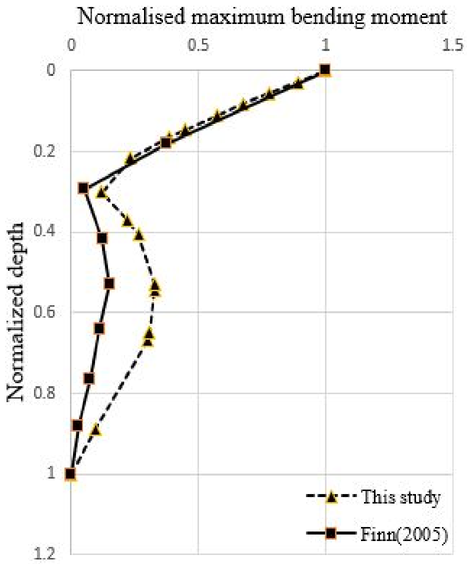

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Figure 3: Comparison of normalized maximum bending moment to depth

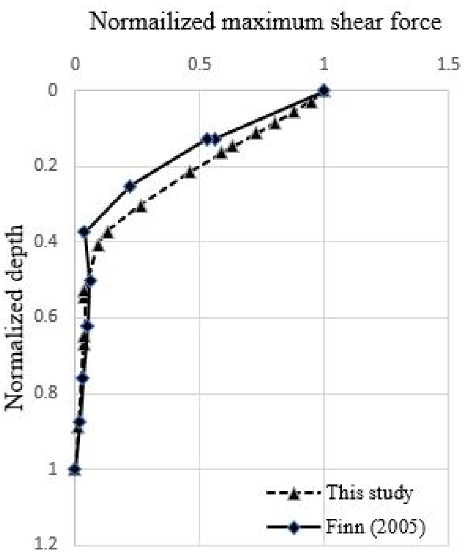

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Figure 4: Comparison of normalized maximum shear force to depth

maximum bending moment and maximum shear force for different pile location for same diameter of pile in a pile row.

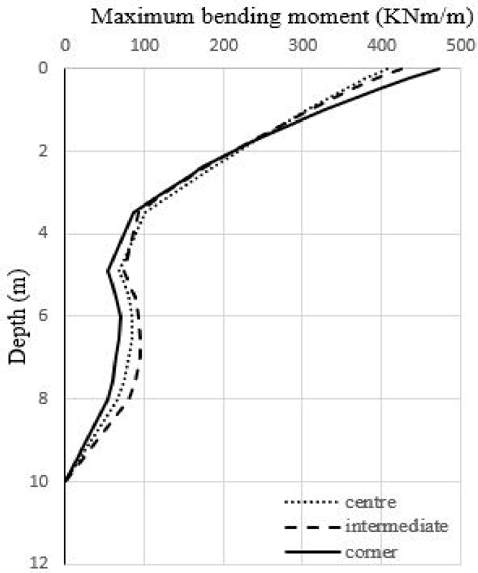

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Figure 5: Comparison of maximum bending moment to depth for different location of pile for 400mm pile diameter

When bending moment and shear for different pile locations are compared with that of corner piles in a pile row,for bending moment it shows an increment of 10% and 14% for intermediate pile and centre pile respectively whereas for the shear force an decrement of 15% and 31% is seen in intermediate pile and centre pile respectively.

Figure 7 and 8 shows the comparison of maximum bending moment for different spacing of pile for pile diameter of 400mm, for this comparison only the pile at corner is considered since maximum forces are generated at the corner piles. An increase of 8% and 10% is seen for bending moment an increase of 15% and 23% is seen for shear force pile at spacing 3D and 3.5D respectively.
Figure 9 and 10 shows the comparison of maximum bending moment for different spacing of pile for pile diameter of 500mm, for this comparison only the pile at corner is considered since maximum forces are generated at the corner piles. An increase of 6% and 9% is seen for bending moment an increase of 16% and 24% is seen for shear force pile at spacing 3D and 3.5D respectively.
Figure 11 and 12 shows the comparison between maximum bending moment and shear force for different diameter of piles. When compared to the

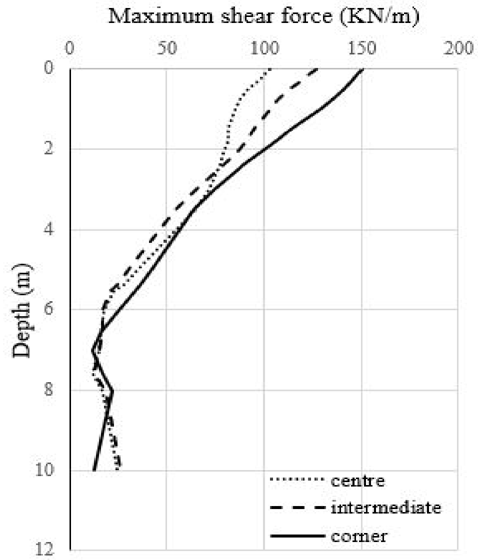

Figure 6: Comparison of maximum shear force to depth for different location of pile for 400mm pile diameter

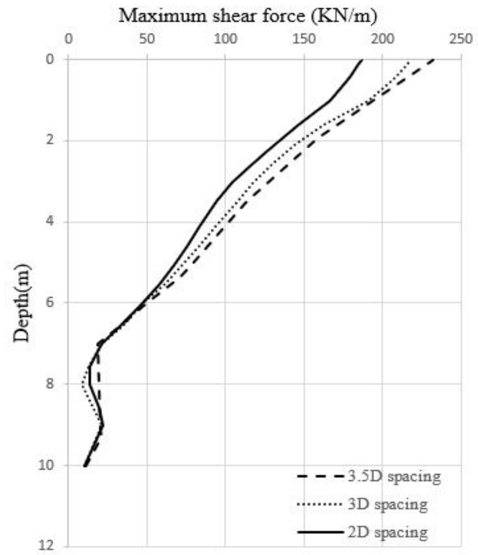

Figure 8: Comparison of maximum shear force to depth for different spacing of pile for 400mm pile diameter

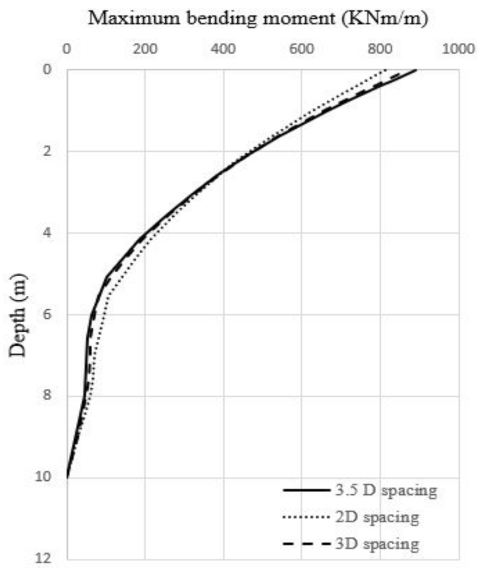

Figure 7: Comparison of maximum bending moment to depth for different spacing of pile for 400mm pile diameter

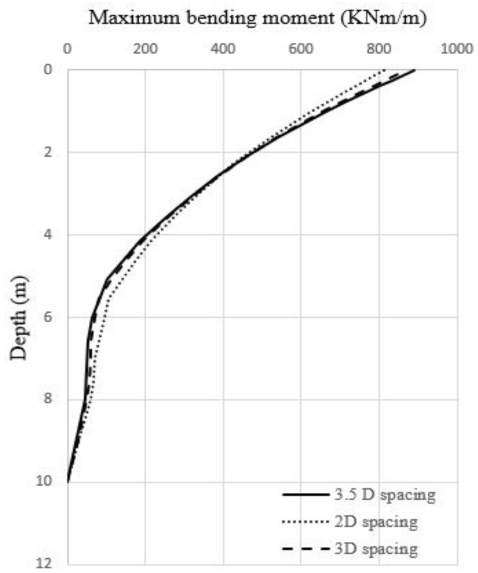

Figure 9: Comparison of maximum bending moment to depth for different spacing of pile for 500mm pile diameter

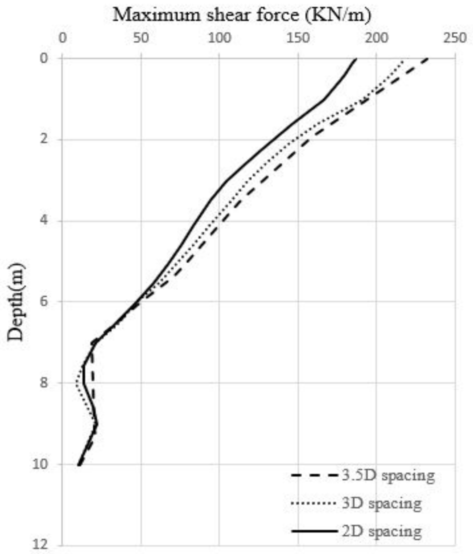

Figure 10: Comparison of maximum shear force to depth for different spacing of pile for 500mm pile diameter

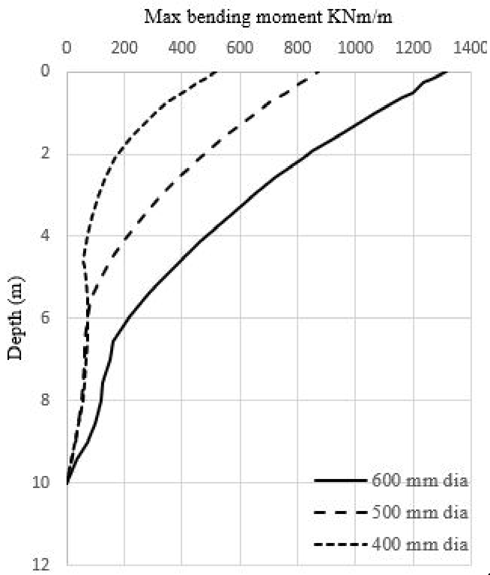

Figure 11: Comparison of maximum bending moment to depth for different diameter of pile

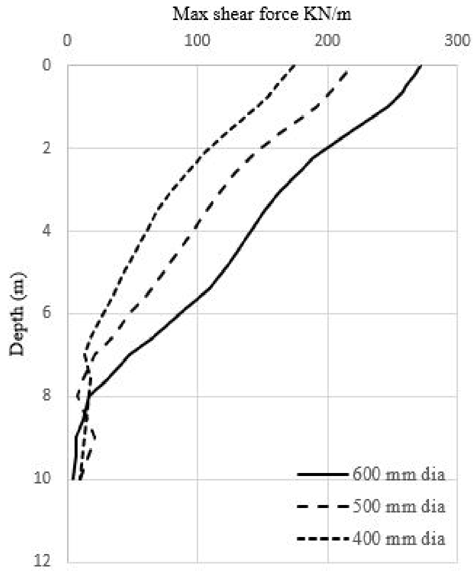

Figure 12: Comparison of maximum shear force to depth for different diameter of pile

bending moment and shear of 600mm diameter pile the bending moment and shear force decreases in both 400mm diameter pile and 500mm diameter pile by 60% and 36% and 33& and 20% respectively.

4. Conclusion

This paper presented the comparison of the maximum bending moment and shear force generate in piles due to seismic load for different pile location in a pile row as well as comparison of those for different pile spacing as well as for different pile diameter.In all cases, it is seen that the maximum bending moment and shear force are generated at the pile head. Further, the maximum bending moment and shear for the corner piles are larger when compared to the piles at centre and those in between.The bending moment and shear forces in the pile shows increment when the diameter of the pile and the spacing between the pile increases. The increment in the above mentioned forces is significantly larger for increase in the diameter of the pile. Whereas, for the increase in the spacing between the piles the difference between the maximum value is less when compared to the difference while the pile diameter is increased. So, in order to properly evaluate the effectiveness of pile foundation the kinematic interaction is to be considered in addition to the inertial interaction. Moreover, the kinematic interaction needs to be studied together with inertial interaction so that the kinematic interaction is not underestimated.

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