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THE INFLUENCE OF THE FIBER REINFORCED SOIL CEMENT MATERIAL AROUND PILES IN LIQUEFIABLE SOIL

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ABSTRACT

The research is carried out to analyze and give treatment around piles with fiber reinforced soil cement material in liquefable soil. The buckling behavior of pile is examined in Plaxis-2d in which numerical modelling is done to study liquefaction under earthquake loading. The different labotaory performed for the input parameters for numerical modelling. The different models are made to examine without treatment and with treatment of fiber reinforced soil cement material to fetch the behavior of the pile in liquefable soil. By obtaining the results from numerical modelling, the buckling phenomenon of piles are reduced fifty percent proving treatment by 3m, 2.5m, 2m, 1.5m, 1m, and 0.5m. In a nutshell, the buckling of piles has reduced to 50% and fiber reinforced materials is helpful to reduce the maximum settlement.

Keywords: Liquefaction, Plaxis-2d, UBC3D-PLM, Dynamic Analysis.

I. INTRODUCTION

Liquefaction is a phenomenon that occurs in saturated or partially saturated soils, mainly in sands, by the loss of the shear strength against the augmenting of the pore water pressure, when the loading condition accidentally occurs in the form of static and dynamic. After that, the soil loses its stiffness and strength. There are far-reaching implications due to liquefaction which will eventually lead to serious and impeccable casualties and loss of humans. It has had implications widely on the building in the alliance of the settlement, and changes in the volumetric and shear strain. A lot of destruction can be happened by this phenomenon. This could be as differential settlement, boiling of sand, lateral spreading, and loss of bearing strength below the existing structure as of liquefaction. All in all, in the seismic-activated zone, liquefaction in the soils is very much vital for the shallow and pile foundation. During the last five to six decades of research and analysis, reliable and standard procedures are to be applied to triumph against liquefaction. Several mitigations for the liquefaction have to be adopted as removal of excessive groundwater, improvement techniques applied as stone column and soil densification, and removing of the lowered-density soil. These methods and techniques will lower the implications and not only resist the triggered ramifications, but sustain the structure and its safety. The liquefaction can happen in the deep as well as the shallow and pile foundation, but it had a greater extent in the deep foundation. As for the shallow and pile foundation, the design and construction of the bridges, buildings, and other heavy structures are also to be carried out for their safe use. Deep pile foundations could have a reduction in lateral capacity and stress towards soil which causes lateral displacement and flows liquid failures. The buckling factor occurred in mainly deep piles concerning surrounding soils, pile properties, and seismic areas.

II. LITERATURE REVIEW

Ziotopoulou &Montgomery [1]examined the loss of bearing capacity when dynamic loading was applied. Besides, he shifts the paradigm from historical old approaches of charts to predict the liquefaction and bantam number of case histories studied in the past in that scenario which was a limited approach. He worked over the post liquefaction reconsolidation settlements as evaluated in the numerical as well as the constitutive model for the shallow foundation in which he considers the other factors such as bearing capacity, soil features, and crust layer thickness in numerical (FLAC) and centrifuge modeling. Kumar et al. [2] used Biot's basic theory of porous media for modeling and predicting shallow foundation behavior. They examined using the FEM in FORTAN 90 to predict the behavior of the liquefiable soil and applied the sinusoidal motion to the ground. Sharma et al. [3] observed northern areas of the Indian Himalayas where liquefaction was the most common factor in the region in presence of sandy soil layers up to 40 m. Ruan et al. [5] studied numerical modeling on shallow bays which were the earthquake area for years. The work was to be carried out in 2D finite-element refined nonlinear modeling in which spatial peak ground acceleration factor and ground motion function were to be analyzed. The results which were observed are closely related to the local soil conditions of the bay. Ghulam Fatima Saba

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Shahwani et al. [13] made models with soilcrete fiber reinforced physical model to study the behavior of the soil around liquefiable soil with loose and dense sand layers. The cyclic loading is applied in the model to learn the buckling behavior of the soil by using the soil parameters from the shaking table tests. In this study, the authors evaluated the whole model and calibrated it with a 1-g environment, and also study the way-forwards to tackle the buckling in piles. By authors' study, successfully led to stamping out the settlement with permissible limits. In the end, there would not be any kind of structural damage that occurred to the Piles.

III. METHODOLOGY

In the creation of the monopole in the liquefiable soil layer, a pile with 0.1m dia is to be created along the given condition. The modulus of elasticity is given as 10,000MPa with Poisson's ratio of 0.3 and has a density of the pile as 7859 Kgm^{-3} . moreover, there will be no interface provided in the pile foundation in it because of the dynamic analysis. Furthermore, the soil properties are to be inserted into the soil parameters. The different soil test is to be carried out as direct shear box test, field density test, shaking table test, particle size distribution test, and supportive literature is supported.. In the first stage, simply pile self-weight loaded in the initial stage. And in the second stage, the pile will be loaded at 2000 kpa and then in the third stage, 10,000 kpa is applied for the calibration purpose. Finally, the earthquake profile loading test is to be applied for the dynamic analysis last which will give the results till the final analysis. The soil parameters are given after the boring hole by the geometric analysis. In that condition, a layer of around 30m is tested with liquefiable loose layer by using the Mohr-Coulomb model and UBC3PLM model with an undrained-A test. Furthermore, the dry and saturated density is given as 18 and 22 with cohesion 2 and peak friction angle as. The mesh generation is performed at medium mesh condition which will reduce the time for the number of nodes that perform the calculation. The nodes are used for the equation which works behind the FEM for minimum refinement degree. It will not produce fine and connected nodes if the soil parameters and borehole conditions are not satisfied for the condition. For the calculation of the stresses at different stages, different phases are to be created for the simplicity of the program running in FEM, Plaxis-2D. AT the initial stage only the construction of the pile is initiated and the self-weight of the pile is calculated with the water table at the ground level. Then all the stresses and different parameters are calculated. For the second phase, the loading is increasing such that 2000kpa and all the system is running through calculation has done. In this phase, the loading is applied so it will take plenty of time to calculate different parameters. In the third stage, the loading is increased by 10000kpa and the dynamic profile of the earthquake is applied for the dynamic analysis.

IV. MODELING AND ANALYSIS

The results of the model are presented and discussed. Model parameters have been obtained by the laboratory tests and the numerical modeling software Plaxis-2D. The main momentous object of this analysis is to model the buckling of piles as a result of liquefaction or softening caused by the earthquake loading. The given model is to analyze the seismic analysis and liquefaction behavior around piles. Besides, Fiber reinforced soil cement treatment is also provided to resist the settlement in the vertical direction and horizontal displacement of the piles when the piles buckle or laterally defects. Moreover, the behavior is also obtained to model the liquefaction with the UBC3D-PLM soil model.

Figure 1: Pile without treatment

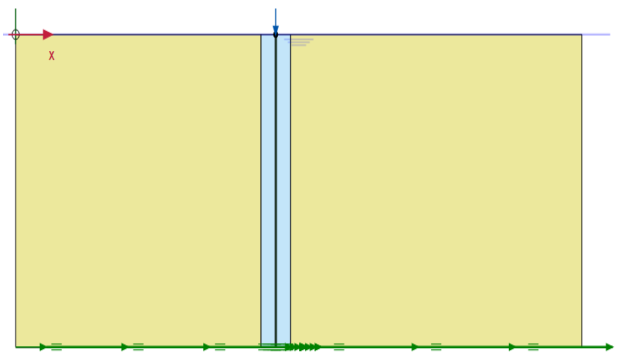

Figure 2: Pile with Treatment

Figure 1: 3D view of building.

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V. RESULTS AND DISCUSSION

The Model description: a Single pile of 0.25m dia is applied in a liquefiable layer of 50m thick layer. The vertical load on the pile was applied as 10000 kN with some accidental eccentric due to the construction. In this base case, the length to diameter ratio of the pile is 200 which is higher than the maximum limiting to length to diameter is 50 for the buckling of the piles. A typical earthquake loading in the form of the history of the earthquake was applied at the base of the model.

The UBC3D-PLM parameters are found by the following formulae:In this model,

The soil parameters for the UBC3D-PLM model is calculated through Beaty and Byne et al. (2011) which is based on the correlations:

First and foremost, the SPT corrected value is taken from the book as Braja M. Das,$(N1)_{60} = 10$.

Elastic shear Modulus $K^e_G = 21.7 \times 20 \times ((N1)_{60})^{0.3333}$

So the calculated elastic shear modulus is $K^e_g = 934$

Elastic Bulk modulus $K^e_B = K^e_G \times 0$

$K^e_B = 654$

Plastic Shear modulus k $K^P_G = K^e_g \times ((N1)_{60})^2 \times 0.003 + 100$

$K^P_G = 380$

Peak friction angle

$\Phi_{pi} = \Phi_{CV} + ((N1)_{60}) / 10$

$\Phi_{pi} = 34$

Constant volume friction angle

$\Phi_p = \Phi_{pi} + \max(0.0, ((N1)_{60} - 15) / 5$

$\Phi_p = 32$

Failure Ratio

$R_f = 1.1 \times ((N1)_{60})^{-0.15}$

$R_f = 0.70$

The elastic shear modulus index, elastic bulk modulus index, and plastic shear modulus index are taken as 0.5

The model is set out at UBC3PLM model with the undrained condition.

Table 1: Observation and calculation of Pile model

Parameters	Symbol	Unit	Calculated Values
Depth	-	m	50 [7]
Type of soil	-	-	loose sand
Young modulus	Eref	kN/m2	500e3 [13]
Poisson's ratio	v	-	0.3
Unit weight	γunsat	kN /m3	15
Saturated unit weight	γsat	kN /m3	16
Void ratio	eint	-	0.7400
Constant volume friction angle	φcv	(o)	32 [12]
Peak friction angle	φp	(o)	34
Cohesion	C	kpa	10
Elastic shear modulus	keG	-	934
Elastic bulk	keB	-	654

modulus			
Plastic shear modulus	kpG	-	380
Elastic shear modulus index	ne	-	0.50 [11]
Elastic bulk modulus Index	me	-	0.50 [11]
Plastic shear modulus index	np	-	0.50 [11]
Failure ratio	Rf	-	0.7 [11]
Atmospheric pressure	PA	-	100 [11]
Tension cut-off	σt	kpa	0.00 [11]
Densification factor	Fachard	-	0.45 [11]
Corrected SPT value	(N1)60	-	10
Post liquefaction Factor	Facpost	-	0.20 [11]
Permeability	K	m/day	0.01728 [11]

The pile parameters are

Table 2: Observation and calculation of Pile Parameters

Parameters	Symbol	Unit	Calculated Values
Material model			Linear elastic
Drainage type			Non- Porous
Unit weight	Γunsat	kN /m3	25 [05]
Void ratio	eint	-	0.5 [05]
Modulus of Elasticity	E	kN/m2	10e6
Poisson's ratio	v	-	0.15 [03]

Treatment is provided: Jet grouted fiber reinforced soil cement column. 3m treatment.

In this model, a jet grouted fiber reinforced soil cement column is provided on both sides with 3m dia of the treated column around the pile. The jet grouted fiber reinforced soil cement column which was followed by the Mohr Columb and has the following parameters:

Table 3: Observation and calculation of Soil Parameters with treatment along the piles

Parameters	symbol	Unit	Calculated Values
Material model	M	-	Mohr-Coulomb
Drainage type	D	-	Non- Porous
Unit weight	γunsat	kN /m3	15
Void ratio	eint	-	0.5
Modulus of Elasticity	E	kN/m2	500e3

Poisson's ratio	v	-	0.2
Cohesion	c		4000

Ghulam Fatima Saba Shahwani et al. [13], the modulus of elasticity of fiber reinforced soil cement column has taken from the mentioned author as E=500x10^3 kN/m2. The cohesion at 30% cement content and highest strength achieved at 0.5% of fiber content was 17000 kN/m2 which is taken as 4000

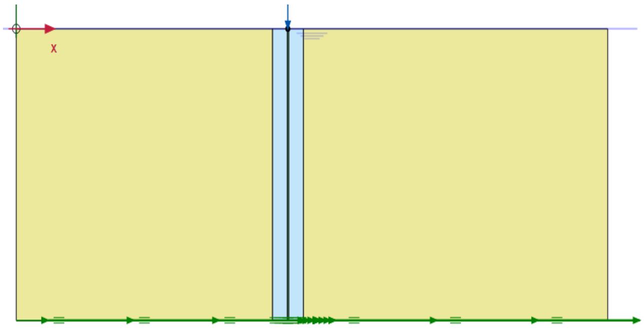

Figure 3: Pile with Treatment

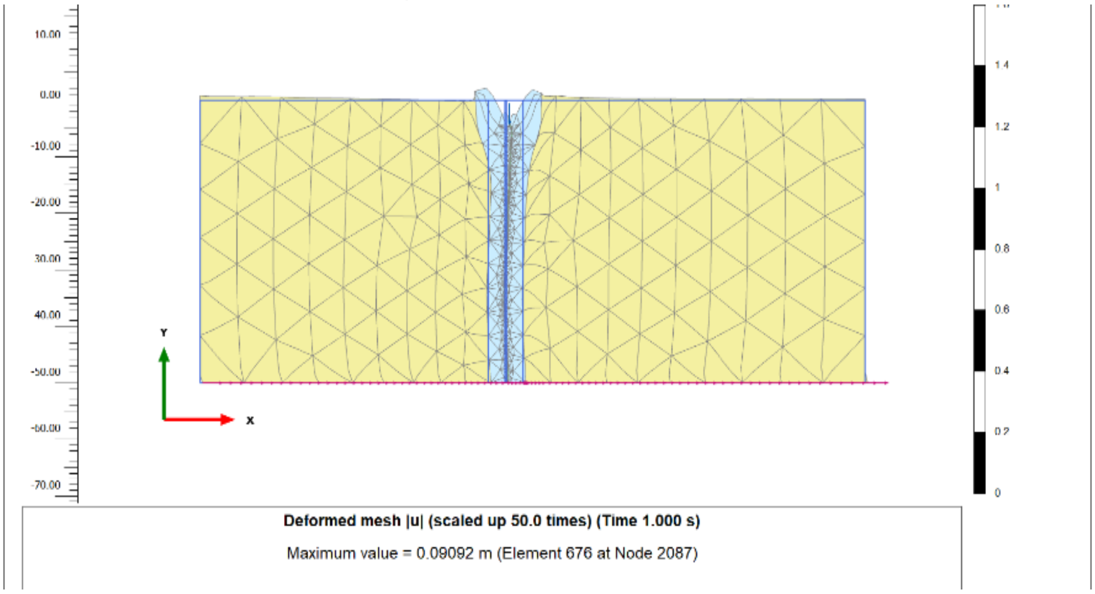

Figure 4: Pile Calculation

Final Discussion:

Pile Diameter			
	Maximum settlement in the whole model (cm)	Settlement (Displacement in Y-direction) (cm)	Horiozpntal displacement Settlement in X-axis (10^{-3} m)
Untreated Pile 0.25 m	20.41	-22.1	-0.033
3m	0.09092	-11.2	-2.536
2.5	0.09114	-11.2	-1.238
2	0.1106	-13.5	-1.430
1.5	0.1250	-15.2	-0.621
1	0.1425	-17	-4.155
0.5	0.1661	-19.5	-5.695

In the above table, it is clearly shower that on comparison with [13], the untreated pile in liquefable soil layer in plaxis 2D gives maximum settlement under the axial load is 20.41cm and in physical modelling it is 6.6cm which is lower. It means that in percentage 300% more. But when the fiber reinforced soil cement jet grouted

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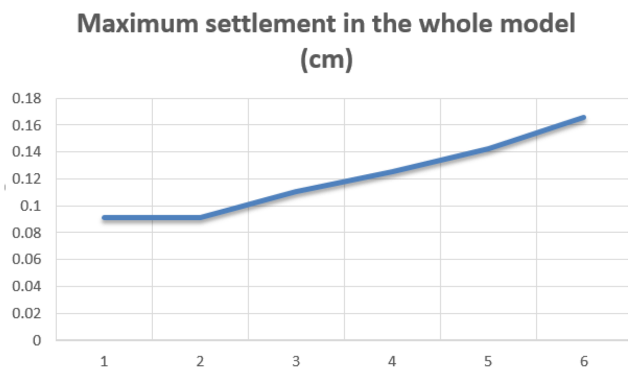
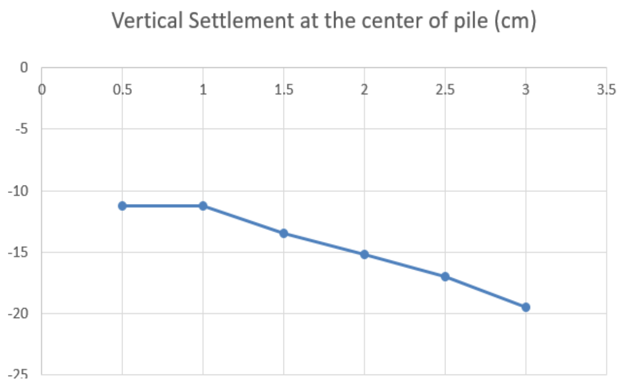
column provided for stablising the condition under dynamic analysis. In the physical modelling, the result after the jet grouted fiber reinforced jet grouted column was as 0.56cm. on the other hand, the numerical analysis, plaxis-2d gave under the liquefiable soil as 11.2cm.In terms of percentage it is 200% more in the modelling. It clearly shows that the result after the treatment is 50% decrease in the plaxis-2D numerical modelling which is the main concerned of the topic.





VI. CONCLUSION

As in 2D modeling, the problem was modeled as a plane strain 2D model which simulates the width of the pile in lateral dimension infinite. To get more insight into the problem in 3D plaxis modeling is required to model the real 3D model. Conclusion: Following conclusions were drawn from the above objects. Plaxis 2D model with UBC3PLM was successfully able to model the liquefaction of soil and resulting buckling of the piles in a very clear way. The slender pile with a large slenderness ratio under the axial load in liquefiable silty sand layer subjected to earthquake loading and resulting liquefaction, bucKles to large extend as the soil liquefies The fiber-reinforced jet grouted column treatment around the piles was very much effective to reduce the vertical settlement and horizontal displacement caused by the bucKling to limiting value. The parametric studies were performed with different widths of treatment which showed that treatment of 2.5m was the optimum treatment to control and reduce the buckling.

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