Review Paper on to Investigate Behavior of Piles in Soil Liquefaction Condition

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Abstract- *The study focuses on investigating the settlement behavior of a piled raft on clay soils under vertical loading. The average settlement could be reduced effectively with wider spaced pile groups with the same number of piles. Furthermore, the efficiency of piles in a piled raft was maximized when the magnitude of the applied load of the piled raft was similar to the ultimate capacity of pile groups in the piled raft. It was shown that the reduction ratio was relatively smaller than that of stiff clay, although the real average settlement of soft clay was larger than that of stiff clay.Piles which support the superstructure damaged not only due to axial load as well as the inertia load while earthquake. If liquefiable soil is present in the soil strata, then it behaves like the suspension solid and exerts additional force on the pile leads to failure of pile. Past earthquakes studies revealed that, most of the structures collapsed due to liquefaction. Due to pore water pressure, saturated soil loses its shear strength and stiffness*

I. INTRODUCTION

piled-raft foundations in sandy soil through finite element modeling. They indicated that the concentrated pile arrangement method can help to considerably reduce the settlements and bending moments of the raft. However, very few parametric studies by means of numerical modeling have been reported for the large piled-raft foundation on a clay soils. Therefore, the effect of different parameters on large piled-raft foundation needs to be investigated For any pile group to raft width ratio, with increase in pile spacing to diameter ratio, average settlement ratio, differential settlement ratio, and bending moment ratio decreases up to the pile spacing of 5–6 times the pile diameter and then increases. Also, load-sharing ratio decreases and shear force ratio increases. Raft with smaller raft-soil stiffness ratio and larger pile group to raft width ratio observed to be effective in decreasing the average settlement ratio. Raft and pile group in piled- raft has carried fewer loads as that of unpiled raft and free standing pile groups.

The seismic design of pile foundations in liquefiable soils poses very difficult problems in analysis and design. The pile foundation may undergo substantial shaking, while the soil is in a fully liquefied state and soil stiffness is at a minimum. During this shaking phase, the pile is prone to suffering severe cracking or even fracture. Liquefaction may lead also to substantial increases in pile cap displacements above those for the non-liquefied case. After liquefaction, if the residual strength of the soil is less than the static shear stresses caused by a sloping site or a free surface such as a river bank, significant lateral spreading or down slope displacements may occur. The moving soil can exert damaging pressures against the piles, leading to failure.

A. Advantages

1. Pile spacing affects greatly the maximum settlement, the ultimate settlement and the load carrying capacity of the piles
2. The spacing between the piles should be within the permissible range that depends upon the loading conditions also. If the load acts at the centre of the mat structure then we have to provide lesser pile spacing.
3. Increasing the number of piles decreases the total and ultimate settlement and increases the load carrying capacity up to certain limit that depend upon the loading condition
4. The number of piles also depends upon the loading conditions. But the cost of construction will increase if the number of piles increased. So the optimum number of piles should be used.

II. STATE OF DEVELOPMENT

Elarabi Abbas 2014[1]"This technical paper discusses the Micro piles brief history, Micro piles Classification, Drilling Techniques, Grouting, Reinforcement, Design Concept, Testing procedures and Guidelines of Micro piles. The paper provides a simplified step-by-step design approach. These include geotechnical strength limit states, other structural considerations, service limit states, corrosion protection and Micro piles testing procedures. 1) Micro piles can be used as a normal foundation piles and compensation pile for remedial works, especially in area with site constraints. 2) Micro piles can be designed as either rock secreted or soil friction pile. 3) Micro pile can be used easier than other foundation types in places far away from the sources of materials. 4) Factor of safety for both geotechnical and structural designs should be at least two. 5) Buckling load should be checked in soft overburden and very soft of loose in filled cavities.

Sam Austin and SukhvarshJerath 2017[2]"Soil-foundation-structure interaction can affect the seismic response of wind turbines. This paper studies the effects of soil-foundation-structure interaction on the seismic response of 65 kW, 1 MW, and 2 MW horizontal-axis wind turbines with truncated cone steel towers. Four types of foundations with frequency-based design were analysed, including spread foundation, mono pile, pile group with cap, and anchored spread foundation. Soil is modelled both implicitly (sub grade reaction modulus) and explicitly. The finite element model developed using the ANSYS program was first validated using experimental data. Numerical models are then analysed in both frequency and time domains using the Block Lanczos and generalized HHT-formulations. Recommendations were given to simplify the soil-foundation structure interaction analysis of wind turbines subjected to seismic loading. The natural frequencies obtained from the finite element model compare well with the experimental frequencies obtained from the literature for the 65-kW turbine. Hence, numerical analysis is a valid tool for the seismic analysis of wind turbine and their foundations. 2. For the specific cases studied in this research, the natural frequencies of the soil-foundation-wind turbine systems with frequency-based design are comparable for both K-model and explicit soil model. Therefore, soil can be modeled by Model, instead of using explicit soil model which is more complicated and requires more analysis time. 3. For the specific cases studied in this research, the effect of soil foundation-structure interaction on the seismic response of wind turbines is negligibly minor. Therefore, seismic analysis of the wind turbine towers in these cases can be simplified by assuming them fixed at the base.

G.L. SivakumarBabuet.al.2004[3]"Micro piles have been used effectively in many applications of ground improvement to increase the bearing capacity and reduce the settlements particularly in strengthening the existing foundations. Frictional resistance between the surface of the pile and soil and the associated group/network effects of micro piles are considered as the possible mechanism for improvement. This paper deals with a case study in which micro piles of 100 mm diameter and 4 m long have been used to improve the bearing capacity of foundation soil and in the rehabilitation of the total building foundation system. The micro piles were inserted around the individual footings at inclination of 700 with the horizontal. The actual design for retrofitting was based on the assumption that the vertical component of the frictional force between the soil and the micro pile resists the additional load coming from the structure over and above the bearing capacity. The technique was successful and the structure did not show any signs of distress later. Detailed finite element analysis conducted validated the suggested treatment. The paper describes the case study, the method of treatment adopted in the field and the results of numerical analysis.

SandroCarbonaria et.al.2017 [4]"This paper investigates the seismic response of bridge piers founded on inclined pile groups in different soil deposits, evaluating effects of soil-structure interaction induced by different pile group geometries and piles inclinations. Analyses are performed in the frequency domain by means of the direct approach taking advantage of a numerical model developed by the authors for the analysis of inclined pile groups. Both the superstructure and piles are modeled with beam elements and the soil is schematized as a visco- elastic medium constituted by independent infinite horizontal layers. The soil-pile and the pile- soil-pile interaction are captured in the frequency domain by means of elastodynamic Green's functions that also allow including the hysteretic and radiation damping. The significance of kinematic stress resultants in piles, the foundation filtering effect and the rotational component of the input motion due to the coupled roto-translational behaviour of the soil-foundation system are also investigated; to this purpose kinematic interaction analyses are performed. These analyses revealed essential for the understanding of the general phenomena governing the dynamic response of the whole soil-foundation-superstructure systems. Results of numerical investigations highlight that conventional design approaches suggested by codes do not provide reliable predictions of the superstructure displacements and stress resultants.

The seismic response of bridge piers founded on inclined pile groups has been investigated in this paper, evaluating effects of soil structure interaction. In particular, pile groups with different layouts and piles inclinations, founded in medium stiff and soft soil deposits and supporting piers of bridges characterized by different span length, are considered. The seismic action is represented by suitably scaled real accelerograms and soil-structure interaction analyses are performed by means of a direct approach taking advantage of a numerical model developed by the authors for the dynamic analysis of inclined pile groups. Piles are modeled by means of beam elements and the soil is schematized as a visco-elastic unbounded medium constituted by independent infinite horizontal layers. The soil-pile and the pile-soil pile interaction are captured in the frequency domain by means of elasto dynamic Green's functions that also allow including the hysteretic and radiation damping. Concerning the superstructure, only the pier shaft is assumed to be deformable and is modeled as a Euler-Bernoulli beam. In order to investigate kinematic stress resultants in piles and to evaluate the significance of the soil-foundation system filtering effect, analyses of the soil-foundation systems are also performed separately (kinematic interaction analysis). By assuming a linear behaviour for both the soil and the superstructure, all the analyses are performed in the frequency domain; the soil nonlinearities are taken into account in a linear equivalent manner calibrating stiffness and damping consistently with the maximum soil shear strains

Shivanand Mali and Baleshwar Singh 2018.[5]"The piled-raft foundation is usually adopted to support the offshore structures. In the present study, a large pile draft has been simulated numerically through 3-D finite element modeling. The objective of the present study was to investigate the effect of pile spacing, pile length, pile diameter and raft-soil stiffness ratio on the settlement, load-sharing, bending moments, and shear force behavior of large piled-raft foundation. The results indicated that with increase in pile spacing up to the 5 to 6 times of the pile diameter, both average settlement ratio and differential settlement ratio decreased effectively and thereafter it increased gradually. Raft with smaller raft-soil stiffness ratio and larger pile group to raft width ratio observed to be effective in decreasing the average settlement ratio. The load-sharing ratio decreased with increase in pile spacing whereas; it increased with increase in pile length. With increase in pile spacing, bending moment ratio increased and as the length of pile increased bending moment ratio decreased up to pile group to raft width ratio of 0.6 and thereafter it increased.

JashodRoya et.al.2018.[6] "Dynamic characteristics of piled raft foundation system plays an important role in the safety of high-rise buildings subjected to seismic loadings though the analytical study considering the effect of both foundation and superstructure is very few in literature. The present study first proposes an exact analytical solution for piled raft foundation subjected to harmonic excitation and resting on an elastic Winkler foundation to obtain its natural radial frequency. After successful validation through available centrifuge test results, a series of parametric study has been carried out investigating the influence of various geometrical and geotechnical parameters of the foundation and the soils respectively. It is observed that the pile length and the pile diameter has significant effect on the natural radial frequency of the foundation system whereas soil density and spacing between piles have minimal effect. The importance of stiffness of the superstructure is also considered in the proposed methodology. It is found that the natural radial frequency of piled raft foundation including superstructure stiffness decreases by 12% to 28% when compared with the computation of the natural radial frequency excluding effect of superstructure stiffness. Hence, this study provides a new analytical methodology to obtain the dynamics characteristics of piled raft foundation considering the superstructure effect which can be used for the design. The present work develops an exact analytical solution for a harmonically vibrating piled raft foundation system. A series of parametric study is carried out after successful validation of the proposed methodology. It is observed that the natural radial frequency of the foundation decreases as the pile length increases because of a decrease in the stiffness of the piles. The natural radial frequency of a piled raft foundation including superstructure stiffness reduces from 12–28% with respect to piled raft foundation excluding the superstructure stiffness. The present study gives a new analytical procedure for obtaining the natural frequency of piled raft foundation without and with superstructure effect, hence can be considered as an improvement over existing studies.

Md.ShajibUllah et.al.2018.[7]"A simplified analytical formulation has been used to verify the superposition method of two components of soil structure interactions (SSI), namely-the kinematic interaction and the inertial interaction for estimating the dynamic response of soil-pile- structure systems (SPSS). The dynamic response analysis is conducted in the frequency domain and the soil behavior ranging from elastic-to-inelastic state is covered. The effective foundation input motion (EFIM) is obtained from shaking table model testing under 1g conditions for the kinematic interaction and the pile head impedance functions (IFs) are estimated from pile-head loading test for the inertial interaction, respectively. The EFIM and pile head IFs both have frequency and loading amplitude dependent characteristics. These experimentally recorded EFIM and pile head IFs are used as inputs in the analytical formulations to compute the dynamic response of the SPSS by superimposing the kinematic and inertial interaction. Superimposing adopts a linear interpolation method for appropriate use of the pile head IFs. The analytical (superimposed) dynamic response is then compared with experimentally measured dynamic response for verification purpose of superposition method and the comparison shows good agreement indicating that with appropriate use of EFIM and IFs, superposition method is reasonably good to produce the frequency and amplitude dependent dynamic response characteristics of SPSS. Certain discrepancies in amplification ratio and in resonant frequency particularly around the dominant vibrating modes have been observed in the comparison. The reason for such observed disagreements is possibly the difference between soil damping (hysteretic and radiation) and the difference between soil-pile stiffness. This study focuses on the verification of superposition method of kinematic interaction and inertial interaction in dynamic response analysis of soil-pile-structure systems (SPSS) in the frequency domain. Experimentally estimated effective foundation input motion (EFIM) i.e. the kinematic interaction and pile head impedance function (IFs) i.e. the inertial interaction are superimposed by means of simplified analytical formulations considering a single sway model of SPSS to estimate total dynamic response. To verify the superposition response, total dynamic response of SPSS is also estimated by shaking table model testing under 1g conditions. This experimental response shows that with the increase in the amplitude of ground excitation, the amplification of motion for both the superstructure and footing decreases, and the resonant frequencies shift towards the lower frequency region. This behavior is an expected outcome from the viewpoint of increase in the shear strain in the soil with the increase in loading amplitude. For the verification part the comparison between the experimental and the analytical (superposition) response of SPSS shows good match indicating that the superposition of kinematic and inertial interaction effects is a reasonable approximation. Certain discrepancies have been observed around the dominant vibrating modes as the analytical amplification ratio of superstructure shows lower value around the resonant frequency of superstructure, and the resonant frequency of soil shifts toward lower frequency range with an increase in amplification ratio, while compared with experimental results. The reason attributed for such disagreements in amplification ratio and in resonant frequency may be the difference between soil damping's (hysteretic and radiation) and the difference between soil-pile stiffness's, which occurred during soil-pile model testing with pile head loading and total SPSS model testing with ground excitation. Apart from such inconsistencies, the superposition method of kinematic interaction and inertial interaction with appropriate use of EFIM and IFs is reasonably good to produce the frequency and amplitude dependent dynamic response characteristics of SPSS.

ZhiguoZhanga et.al.2018.[8]"The current design practice for predicting the interaction mechanics for tunnel-soil-pile is generally based on Winkler's foundation, which is subject to some important limitation, such as ignoring the continuity of the soil foundation. Furthermore, the current analytical studies are mostly employed the plane strain analyses and do not consider the influences of lateral soil displacements on pile behaviour. To improve the accuracy for the pile behaviour prediction induced by tunnelling, the analytical method should account for the effects of a number of parameters, such as the ground shearing displacements, and the influence of lateral soil displacements next to the pile. This paper focuses on a simplified solution based on Pasternak's foundation model to predict the lateral displacements and internal forces of a single- pile and group-piles induced by tunneling considering the effects of lateral soil displacements. First, the simplified solution of tunnel-soil-pile interaction, which reflects the influence of shearing displacements of foundation, is established on Pasternak's foundation model. Second, the equivalent concentrated forces are supplied to the pile through the shear layer to consider the influence of lateral soils beside the pile. The validity of the solutions is verified by the boundary element program results, centrifuge test data, and field measurements. The calculated results are also compared with and without considering the effects of tunnel-soil-pile interaction. When the influences of lateral soil displacements are considered, the results are shown to be closer to the monitored in-situ data and the centrifuge test data. In addition, the influencing factors of a single- pile and group-piles displacements are also investigated, including the shear layer modulus, pile diameter, ground-loss ratio, pile-tunnel distance, and pile spacing.

The influence of soil shear displacements on pile response cannot be ignored, and an error may occur when Winkler's foundation model is used to solve this problem. To avoid the drawbacks of the plane strain analyses and Winkler's foundation, this paper addresses the influence problem of tunnel-soil pile interaction, and a simplified method is proposed based on Pasternak's foundation model. The analyses aim to provide an efficient means to assess the effects of tunneling on the lateral displacements and bending moments of an adjacent single-pile and group-piles. The pile response induced by tunneling is presented firstly based on Pasternak's foundation model considering the shearing displacements of foundation. To obtain more accurate results, the simplified solution is derived secondly considering the effect of lateral soil displacements. The response of a single-pile is determined by imposing the free-field soil movement profile estimated by Loganathan-Poulos' analytical expression to the passive pile based on Pasternak's foundation model. The shielding effect of passive group-piles due to pile- soil-pile interaction is then considered, and Mandolin's solution for the lateral response is adopted to simulate the pile-pile interaction. The responses of group piles due to tunneling are finally obtained by the superposition principle. The proposed method is verified through comparisons with published solutions by the boundary element program GEPAN, centrifuge test data and field measurements. The displacements and bending moments of a single-pile and group-piles induced by tunneling are calculated through the presented method considering the effects of lateral soil displacements. The presented method can consider the impacts of lateral soil displacements on pile response and reflect the effects of tunnel-soil-pile interaction. The proposed method considering the effects of lateral soil displacements provides reliable estimates for the response of a passive single-pile and group-piles induced by tunneling. The method is based on Pasternak's foundation model and two parameters, k and G, to account for the shearing interaction between surrounding soils. The results show that parameter G has a certain impact on the pile response. Therefore, the influence of soil shear displacements on pile response cannot be ignored for higher precision.

George Anoyatis and Anne Lemnitzer 2017.[9]"Beam-on-dynamic-Winkler-foundation models are widely used to study kinematic soil-pile interaction. Winkler models consider the pile as a flexural beam and simulate the restraining and dissipative action of soil through independent springs and dashpots along its axis.Their performance is related to the proper selection of the spring stiffness and dashpot coefficient which depends on parameters such aspile geometry, pile- soil stiffness ratio and boundary conditions. Expressions for static and dynamic Winkler moduli from literature wereimplemented in a Winkler model to assess its ability to predict the curvature ratio and kinematic response factors for various pile boundary conditions. Based on an existing static expression, a frequency-dependent, logarithmic-based Winkler modulus is proposed. This modulus offers an attractive and versatile alternative to existing mathematically complex formulations as it is capable of capturing resonant effects and can be used for both inertial and kinematic analyses, while all other frequency-independent expressions from literature are limited by their unique application to kinematic problems. A comprehensive graphical comparison is given between the results from the Winkler model, using existing and proposed moduli,

w d l finn et.al [10] "Seismic response analyses were conducted on pile groups in liquefiable soils which were subjected to earthquake excitation on the large centrifuge at the University of California at Davis. The analyses were done using a simplified 3-D effective stress finite element program. Tests and analyses of a single pile and a 2×2 pile group subjected to an input acceleration record with a peak acceleration of 0.49 g are presented. There is good agreement between computed and measured free field porewater pressures, pile cap accelerations, time histories of moments and the distributions of maximum moments with depth

W. D. L. Finn and N. Fujita 2004.[11] "A general picture of the current state of the art and the emerging technology for dealing effectively with the seismic design and analysis of pile foundations in liquefiable soils is presented. Two distinct design cases are considered and illustrated by case histories. One is the static response of pile foundations to the pressures and displacements caused by lateral spreading of liquefied ground. The other is the seismic response of piles to strong shaking accompanied by the development of high pore water pressures or liquefaction. Design for lateral spreading is examined in the context of developments in design practice and the findings from shake table and centrifuge tests. Response of piles to earthquake shaking in liquefiable soils is examined in the context of 1.5m cast in place reinforced concrete piles supporting a 14 storey apartment building.

Vaibhav Bhende1 and R. S. Londhe 2015.[12]"In seismic prone areas where water table is at low level from the ground level, piles support the structure. Due to pore water pressure, soil gets saturated and behaves as a suspension solid which is unable to bear the load. Many pile supported structures collapsed in major earthquakes due to liquefaction as the liquefiable soil gets saturated and lose their stiffness and shear strength. Soil behaves like a fluid which moves laterally due to the inertia load results in continuous movement of liquefiable soil. Research shows that, liquefaction should be considered while designing the pile; however this work is not significantly done. Building on the work of other researchers, linear time history analysis is carried out by finite element software SAP2000 considering liquefiable and non-liquefiable soils. Modeling consists of building model (G+9, G+12, and G+ 15) which are supported on pile foundation surrounded by soil. The provision of soil is fulfilled by assigning the particular stiffness properties to pile in lateral direction. An earthquake ground motion record for Northridge and El Centro is applied to the structure. Based on the comparison of the liquefied and non-liquefied soil structures considering the parameters like pile length and loading on superstructure, the structural response of piles such as moments in piles, joint displacement and shear induced in lateral direction of pile is studied. Ultimately, it can be seen that the effect of liquefiable soil is a great concern and it affects the interacting parameters as compared to non-liquefiable soils. The analytical results indicate that the results obtained due to liquefiable soil on piles are quite different than that of non-liquefiable soil.

Jaeyeon Cho et.al 2012.[13]"The settlemenbehavior of asquarepiledraftin clay soil was investigat educing numerical analysis. The emphasis was on quantifying there duction of the average and differential settlements in soft and stiff clay soils.To obtain the detailed information on the pile draft, a nonlinear three-dimensional finite element analys is with pile soil slip interface model was performed for various pile positions ,pile numbers ,pile length under the raft and different loading types.Based on the results obtained, the settlement aspects for an efficient design of pile drafts subjected to vertical loading are discussed for soft and stiff clay soils.It is found that the variation of reduction ratio(sPR,avg/sUR,avg) of soft clay was relatively greater than that of stiff clay,where as the reduction ratio of soft clay was relatively smaller than that of stiff clays. It is also found that the required pile group-raft arearatio(Ag/Ar) for minimizing differential settlement in soft clay was slightly larger than that of stiff clay in the same pile array.

Dj.AmarBouzid et.al 2013.[14] "Practice, analysis of laterally loaded piles is carried out using beams on non-linear Winkler springs model (often known as p-y method) due to its simplicity, low computational cost and the ability to model layered soils. In this approach, soil-pile interaction along the depth is characterized by a set of discrete non-linear springs represented by p-y curves where p is the pressure on the soil that causes a relative deformation of y. p-y curves are usually constructed based on semi-empirical correlations. In order to construct API/DNV proposed p-y curve for clay, one needs two values from the monotonic stress-strain test results i.e., undrained strength (su) and the strain at 50% yield stress (ε50). This approach may ignore various features for a particular soil which may lead to un-conservative or over-conservative design as not all the data points in the stress-strain relation are used. However, with the increasing ability to simulate soil-structure interaction problems using highly developed computers, the trend has shifted towards a more theoretically sound basis. In this paper, principles of Mobilized Strength Design (MSD) concept is used to construct a continuous p-y curves from experimentally obtained stress-strain relationship of the soil. In the method, the stress-strain graph is scaled by two coefficient NC (for stress) and MC (for strain) to obtain the p- y curves. MC and NC are derived based on Semi-Analytical Finite Element approach exploiting the axial symmetry where a pile is modelled as a series of embedded discs. An example is considered to show the application of the methodology.

C. Prabha et.al 2014.[15] "Pile foundations are extensively used to support various structures built on loose/soft soils, where shallow foundations would undergo excessive settlements or have low bearing capacity. Piles are usually slender, having high length to width ratio, and are mainly designed to resist axial loads. However, some structures such as high rise buildings, offshore structure (Quay, harbors), earth retaining walls are also subjected to horizontal or lateral pressure caused by wind force, wave force, traffic movement, water pressure and earth quake. Lateral soil movements mostly have a negative effect on the behaviour of axially loaded piles. Many different methods of analysis have been proposed to solve the problem of a laterally loaded pile, where the problem can be generally defined as computing pile deflection and bending moment as a function of depth below the ground surface. In this thesis work a laterally loaded pile in cohesion less soil whose field test data's available is taken. The pile is modelled in finite element software Plaxis, both in 2D and 3D and the results obtained are compared with the published test results. Also, the analysis is done with Brom's method and Characteristic load method, and the results are compared for validating the program. Then we adopt piles with different characteristics and different soil conditions in-order to investigate the effect of variation of pile and soil properties on behaviour of laterally loaded piles.

III. CONCLUSION

This paper focuses only on the literature review of previously published studies. The findings of this paper areseismic analysis of the wind turbine towers in these cases can be simplified by assuming them fixed at the base.The parameter G has a certain impact on the pile response. Therefore, the influence of soil shear displacements on pile response cannot be ignored for higher precision.The general phenomena governing the dynamic response of the whole soil-foundation-superstructure systems. numerical investigations highlight that conventional design approaches suggested by codes do not provide reliable predictions of the superstructure displacements and stress resultants.

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