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A REVIEW ON SOIL-PILE INTERACTION UNDER SEISMIC LOAD FOR DIFFERENT GROUND CONDITION

Rashmika K. Barot[1],Grishma Thaker[2], Kosha Pachchigar[3]

[1]*Civil Engineering Department, ChhotubhaiGopalbhai Patel Institute of Technology,*
[2]*Civil Engineering Department, ChhotubhaiGopalbhai Patel Institute of Technology,*
[3]*Civil Engineering Department, ChhotubhaiGopalbhai Patel Institute of Technology,*

Abstract *—Pile foundations are commonly adopted for various types of multi storied and industrial structures, bridges and offshore structures. Their seismic design is very important to ensure efficient functioning of various structures even under severe seismic loading conditions. In the design process, ground conditions (soil type) play an important role in terms of seismic loads transferred to foundation and foundation capacity. This paper presents seismic design of pile foundations for different ground conditions. Estimation of seismic loads, for a typical multi-storied building considered being located in different seismic zones, for different ground conditions according to Indian standard are presented. Design considerations based on various theories evolved on pile foundation performance concepts under seismic conditions are discussed. Three different ground conditions are selected as exemplary cases in demonstrating the evaluation of seismic loads and seismic design of pile foundations as per codes of practice.*

Keywords*-Seismic Design, Pile Foundations, Ground Condition, Soil-pile-structure interaction.*

I. INTRODUCTION

Piles are the most commonly adopted deep foundations to support massive superstructures like multi-storey buildings, bridges, towers, dams, etc., when the founding soil is weak and result bearing capacity and settlement problems. In addition to carrying the vertical compressive loads, piles must also resist the uplift loads (loads due to wind or hydrostatic pressure) and the dynamic lateral loads which are common in the offshore structures, retaining walls and the structures in the earthquake prone regions. With increasing infrastructure growth and seismic activities, and the devastation witnessed, designing pile foundations for seismic conditions is of considerable importance. Several studies were conducted by various researchers on the seismic analysis and the design of pile foundations and evolved different theories on the same. Codes of practice available in suggest some procedures for seismic design of pile foundations. In the design process, ground condition plays an important role in selecting the design parameters and also to consider various failure mechanisms. The estimation of the loads that act on a structure during an earthquake depends on the seismicity of its location (zone) and the subsurface conditions of the site. Different codes of practice around the world have suggested different methods to estimate the seismic action on a structure. Indian standard (IS 1893: Criteria for Earthquake Resistant Design of Structures (2002)) recommend different ground conditions based on the nature of the engineering hard stratum in selecting design acceleration level.

II. LITERATURE REVIEW

A. Seismic Design of Pile Foundations for Different Ground Condition, 15 WCEE 2012, LISBOA2012

A.Murali Krishna, A. PhaniTeja,S. Bhattacharya, Barnali Ghosh;

1. The frictional resistance offered by the soil in the liquefiable layer must be neglected. This leads to increase in the pile length for the same factor of safety.
2. Due to change in fixity point after liquefaction and loss of lateral confinement to the pile in the liquefied layer, the pile is essentially designed as a column against buckling. Bhattacharya and Bolton (2004) suggested the minimum pile diameters needed to be adopted based on thickness of the liquefiable layer.

3. The natural period of the system will change due to liquefaction because of the reduction in strength of the soil and the change in fixity point.
4. When the layer is liquefied, the soil layers above the liquefied zone move according to the liquefied zone movement, resulting in passive pressures on the pile. These additional passive pressures rise the moments at the fixity point and thus the moment capacity of pile has to be increased. This can be achieved by the increasing the reinforcement in the originally adopted section or by increasing the pile section to meet the requirement.

Considering the above points, the design of the pile for the estimated seismic loads is again done assuming the cohesion less soil layer in the soil profile is liquefiable. Variations of the pile capacity versus and the resulting Factor of safety values with the pile diameter and the cases with and without liquefaction. The results show that a driven cast in-situ, free headed pile of length 18 m and diameter 0.95 m must be adopted for the liquefiable case to get the factor of safety of 3.5.

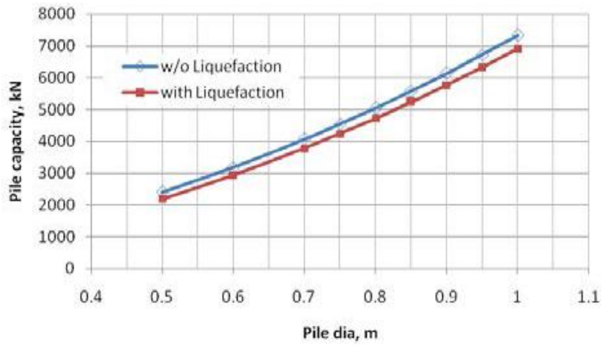

Figure.1 Variation of Pile Capacity (kN) with the Pile diameter (m) with and without Liquefaction

With the increasing seismic activities in the recent times an efficient design of the pile foundations to resist the estimated earthquake loads is a major concerned issue. In this interest, this study deals with the estimation of the seismic loads on a super structure as per the two international codes selected, IS 1893 and EN 1998. Different cases are considered assuming the location of the structure to be in different seismic zones of India and on different ground types (Type C and Type D). The estimated seismic loads are applied to the SAP2000 model of the structure and analyzed to find the maximum (design) foundation loads. Liquefaction potential was evaluated, before proceeding to the pile design, for the selected soil profiles in the Guwahati region. Then the pile is designed for a selected case of seismic zone V and the ground type C. The pile is first designed for using the Indian Standard IS 2911. Then the design was checked against lateral deflection and limiting moment capacity of pile for the estimated lateral loads and moments under seismic condition using commonly used method called the Characteristic Load Method. Further the seismic design is revised for both the cases considering the soil profile to be liquefiable. It is to conclude that ground conditions should be considered much prior in the analysis of any structure to evaluate the seismic loads acting on the structure which will further influence the foundation design loads and foundation capacity.

B. Non-Linear Analysis Of Soil-Pile-Structure Interaction Under Seismic Loads;The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China

Yingcai Han and Shin-Tower Wang; "An examination of the computation results for the seismic response of the vacuum tower structure, supported with different foundation conditions, suggests the following conclusions:

1. The nonlinear behavior of the soil-pile system can be simulated using the model of boundary zone.
   The validity of the model has been verified by dynamic experiments on full-scale pile foundations for both linear and nonlinear vibrations.
2. The soil – pile interaction is an important factor which affects the stiffness and damping of foundation. The liquefaction of a layer of saturated fine sand can reduce the horizontal stiffness significantly, and further damage is possible.
3. The soil-pile-structure interaction should be considered in a seismic analysis. The theoretical prediction for a structure fixed on a rigid base without the interaction does not represent the real seismic response, since the stiffness is overestimated and the damping is underestimated.

4. The problem of soil-pile-structure interaction is complex in a seismic environment. The approximate and practical method described in this study is workable with the help of two computer programs (DYNAN 2.0 and SAP2000)."

C. Numerical Study of Piles Group under Seismic Loading in Frictinal Soil—Inclination Effect; Open Journal of Earthquake Research, 2014, 3, 15-21

FadiHageChehade, Marwan Sadek, DouaaBachir; "In this paper, we present a three-dimensional numerical modeling of the soil-pile-structure interaction under seismic loading. The effect of the plasticity has been investigated in the case of a frictional soil as well as the effect of the dilancy angle. The numerical modeling has been carried by using harmonic excitation and real seismic loading recorded during the Kocaeli earthquake (Turkey, 1999). The effect of the pile inclination has been also analyzed. For simplicity, we consider the case that the piles are embedded in a homogeneous soil. The case of heterogeneous soil could be treated in the future.

The harmonic loading leads to high values of the internal forces (Bending moment, shear) especially when the frequency of the load is near to the proper frequency of the soil. For the example treated here, the plasticity of the soil has a minor effect on the results. For frictional soil, the plasticity spreads from the surface due to the low confinement of the soil in this area. Plasticization of the soil around the piles head makes them more vulnerable, and the post seismic observations of damaged piles show the formation of a vacuum around the head of the piles. The inclination of piles leads to a reduction in the lateral amplification of the superstructure resulting from an increase in the rigidity of the system. The inclination of piles can be beneficial for both the dynamic behavior and the behavior of the superstructure. It depends on the interaction of the frequency of the seismic load with the frequencies of the soil-pile-structure. The inclination increases the lateral stiffness of the foundation which, unfortunately, can cause a significant increase in the load transmitted to the foundation of the superstructure. Despite the improved performance of inclined piles, the bending forces at the top of piles are still very significant."

D.Effect of Liquefaction on Soil Pile Interaction under Seismic Loading;Proceedings of International Conference on Architecture, Structure and Civil Engineering (ICASCE'15) Antalya (Turkey) Sept. 7-8, 2015 pp. 1-10

Jamal Ali, Syed Muhammad Jamil, Ph.D., Hamza Masud, SandeerahChoudhary and Kamran Jilani; "In this study, aspects of the behavior of sandy soils towards seismic loading are discussed. A base shaking analysis was conducted for a singular circular pile in various formations of soil strata with major emphasis on the depth and relative position of a liquefiable layer under seismic loading.
This research study gives a general view of the minor features of soil and ground inclination that must be considered while designing the pile foundations. Even mild slopes and small lens of liquefiable layers can be very damaging in case of earthquakes.

A small lens of liquefiable layer sandwiched between the non-liquefiable strata can also cause great deflections and failure in pile. Similarly, pile displacement is a function of time and pile deflection is significantly more in liquefiable soil strata. The depth of liquefiable layer also dictates the total lateral displacement of pile. As the depth is more, the magnitude of acceleration is higher and the pile experiences higher lateral load. The effect of spacing and diameter of stone column have direct relation to end pile deflection. The effect of diameter of stone column is more important than varying the spacing between columns. Hence for design purposes, hit and trail method by varying the diameter of column can be employed to optimize the design."

E. Pile Design in Liquefying Soil;The 14th World Conference on Earthquake EngineeringOctober 12-17, 2008, Beijing, China;14 WCEE

Vijay K. Puri and Shamsher Prakash; "The design of pile foundations in liquefying soil needs an understanding of soil liquefaction, behavior of soils following liquefaction and the soil-pile interaction. The practice of pile design in liquefying soil has progressed considerably in the last decade based on observations during the past earthquakes and experimental studies on centrifuge and large shake table. However, there are several parameters and questions which eed to be examined further in detail."

III. CONCLUSION

From the above literature we conclude that

1) The soil – pile interaction is an important factor which affects the stiffness and damping of foundation.
2) The problem of soil-pile-structure interaction is complex in a seismic environment. The approximate and practical method described in this study is workable with the help of onecomputer programs (SAP2000).
3) It is to conclude that ground conditions should be considered much prior in the analysis of any structure to evaluate the seismic loads acting on the structure which will further influence the foundation design loads and foundation capacity.

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