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A Simplified Approach of Design Pile Foundation on Liquefiable Soil in India

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ABSTRACT

In India, piles are designed as per IS 2911:2010 (Part 1) for different soil conditions considering all the load criteria. But there is no such provision in Indian Standard Codes for designing piles in potentially liquefiable soils. In this paper, the design of pile foundation in liquefiable soil is discussed. The provisions for design of pile foundations in liquefiable soil from different codes of practice from different countries are studied, and the design approaches for the same are discussed based on those studies. The load bearing capacity of a pile in liquefied soil and non-liquefied soil is made based on the force equilibrium approach. A standardize graph which may be useful for practicing engineers has been plotted. Further, a comparative study is made based on the force equilibrium approach in Indian conditions.

KEYWORDS

Codal Provisions, Force-Equilibrium, IS 2911:(2010)Liquefaction, Load Bearing Capacity, SAP2000

INTRODUCTION

Deep foundations are adopted to support structural loads where the foundation soil is weak in a smaller depth and results bearing capacity failure and settlement problems. Piles are the popularly used deep foundations to support huge structural loads. In addition, piles must be resistive to the uplift loads due to hydrostatic or wind pressure. Piles are designed as per provisions of Indian Standard code (IS 2911:2010) for different soil conditions considering all the load criteria. But there is no such provision in Indian Standard Codes for designing piles in potentially liquefiable soils. Liquefaction is an earthquake induced phenomenon in soil strata with fine sand and silt. During potential earthquakes, soil behaves like liquefied one with lesser shear strength and starts flowing laterally. This phenomenon is called spreading of soil. Due to spreading a lateral load is applied on the piles. This lateral load produces bending and lateral deflection of piles (Unjoh et al, 2012). Besides, as there is lesser or no lateral support due to liquefaction, piles become critically susceptible to buckling. For these, well-designed structures with pile foundation collapse during different earthquakes despite being well designed considering high factor of safety. With increasing infrastructure growth and increasing earthquake activities researchers are giving more importance on this problem. Several researches were conducted by various researchers on the analysis and the design of pile foundations in liquefied soil

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and established different theories on this behalf (Ashour et al, 2011). Codes of practices available in other countries suggest some procedure for seismic design of pile foundations also (Ghosh et al, 2012).

In this paper, the behaviour of pile foundation in liquefied soil and the design of pile foundation in liquefiable soil are discussed. The provisions for design of pile foundations in liquefiable soil from different codes of practice are studied and the design approaches for the same are discussed based on those studies (Puri et al, 2008). Further, a comparison between the load bearing capacity of a pile in liquefied soil and non-liquefied soil is made based on the force equilibrium approach in Indian condition.

CODAL PROVISIONS FOR DESIGN OF PILES IN LIQUEFIABLE SOILS

Design codes from different countries adopted high values of partial factor of safety against plastic hinge formation. Those provisions suggested to design and construct the piles such a way that piles remain elastic to avoid subsurface repairment. But it is economical to allow a limited amount of yielding in the pile while designing. Details on specified codal provisions is presented below to access this design view.

Euro Code 8 (EN 1998-5:2004) Provisions

Euro code 8 prescribed that piles and piers should be designed to resist the action of two types of forces, one is Inertia forces from superstructure and second one is the kinematic forces. Kinematic forces are generated due to the deformation of surrounding soil during passing of shear waves. Bending moments are considered to be produced when there are consecutive soil layers with sharp change of soil stiffness in some high or moderately high seismic zone. Although the side resistance of soil layers that are susceptible to liquefaction or to substantial strength degradation is ignored. EN1998:5 suggested that pile designing should be done with a principle to remain elastic but may under certain conditions be allowed to develop a plastic hinge at their heads. According to Clause 5.8.4 the region of formation of potential plastic hinging is:

- A region of twice of pile diameters from the pile cap.
- A region of $\pm$ twice of pile diameters from any interface between two layers with excessive difference in shear stiffness (where ratio of shear modulus > 6).

JRA Provisions

The Japanese Highway Specification, JRA (2002) has suggested a new concept of "top-down" and "bottom-up" effects. The code has prescribed that "the design of piles against bending moment should be done considering that the non-liquefied crust layer exerts passive earth pressure on the pile and assuming the liquefied soil exerts 30% of total overburden pressure." This statement interprets that the lateral earth pressure coming from the non-liquefied crust layer is equals to passive earth pressure. In this case the coefficient of earth pressure will be same as the coefficient of passive earth pressure. On the other hand, the coefficient of earth pressure that is considered for the liquefied soil layer is 0.3. Based on the shear parameters of soil, pressure diagrams and the total lateral load acting on the pile is estimated and the effect of that lateral load on pile is analysed. This estimation of pressure is based on back calculation of case histories of performance of pile foundations during the Kobe earthquake. The Japanese Code of Practice (JRA 1996) has incorporated this understanding of pile failure and is shown in Figure 1. This code also specify that the maximum bending moment is assumed to occur at interface between the liquefied and non-liquefied soil layer and suggested designers to check factor of safety against failure due to inertial force, bending moment and kinematic forces separately, not due to the combination of loads.