Numerical Modeling of Piled Raft Foundations on Improved Soft Clay

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Abstract

The soil layers in south west of Iran are mostly soft and fine. Raft foundations undergo excessive settlement on these soils. In these cases, using piled raft foundations can decrease the settlements to some extent. But because of low stiffness of soft clay, settlement is still more than expected. An appropriate solution is soil improvement. In this paper, a 3D nonlinear continuum FEM numerical model is adopted to investigate the possibility of increasing the efficiency of the pile-raft systems through top soft soil layer improvement. The improvement of the top soil layer is possible by for example, backfilling on the soft ground surface, removing and replacing the top layer with compacted granular material, and mixing the top layer with cement or lime. The improved top layer thickness could be in the range of 1 through 4 m, in practical applications. Average settlement, maximum settlement, differential settlement, piled raft coefficient and load distribution in center pile for soft clay and improved clay are compared. It was observed that soil improvement caused settlement reduction significantly.

Keywords: piled raft, soft clay, finite element method, soil improvement.

1. INTRODUCTION

Increasing the number of constructed structures on soft soils is a reasonable reason for studying piled raft behavior on such soils. Piled raft foundations (PRF) are thought to be an appropriate solution when the raft foundation has adequate bearing capacity, but the total and/or differential settlements exceed the allowable amounts. Nonetheless the settlement of PRF on soft clay is noticeable. Using combination of piled raft foundations with soil improvement technics seems to be an appropriate solution in such cases. In this paper, compacted backfilling on the ground surface, removal and backfilling or soil mixing of the upper 1 through 4 m of the soft layer is considered.

Piled raft foundation is a composite concept consisting of three bearing elements including piles, raft and soil. Due to complicated interactions between raft, pile and soil, design of piled rafts are different than traditional foundation design, as the load is shared between piles and raft. In traditional method, the contribution of the raft for the transmission of the load directly to the supporting soils is usually neglected. This issue causes non-economical design. In new method, the total bearing capacity of piles is mobilized. This method leads to use of less number of piles for decreasing settlement. Furthermore, the piles reduce the loads supported by raft. Also the amount of moments in raft reduces significantly. Based on studies which have been done by Horikoshi & Randolph (1998), three steps for optimizing the design are suggested as follows:

1. Piles should be distributed at 16-25% of center region of raft.
2. It is better that bearing capacity of piles is limited to the range of 40 to 70% of the total load, regarding the soil properties and piles and raft effective areas.
3. The maximum mobilized bearing capacity of piles should not exceed 80% for preventing increased non-uniform settlements.

The PRF system analyses are complicated because of interaction effects between: (1) pile-soil, (2) pile-pile, (3) raft-soil and (4) pile-raft (Hemsley, 2000). The simplified closed-form solutions, therefore, are not so effective for proper analysis of such a system. Numerical methods such as FEM have been used within the past two decades for 3D linear and non-linear analysis of the PRF systems, such as Zhuang (1991),

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