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ORIGINAL PAPER

Integrated Experimental-Numerical Assessment of Piled Raft Foundation on Granular Soils Using Varying Configurations

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Abstract

Piled-Raft Foundations (PRFs) are increasingly recognized for their effectiveness in enhancing load-bearing performance, particularly in granular soils where differential settlements pose a significant challenge. By integrating the benefits of both piles and rafts, PRFs promote more efficient load distribution and reduce total settlements. Despite their widespread use, the behavior of various PRF configurations, especially those incorporating inclined piles, remains insufficiently explored. This study undertakes a comprehensive experimental and numerical evaluation of PRFs in granular soils, focusing on four configurations: Unpiled Raft (UPR), Disconnected Piled-Raft (DPR), Vertical Piled-Raft (VPR), and Inclined Piled-Raft (IPR). Laboratory-scale models were subjected to controlled axial loading across varying relative densities to assess load-bearing performance and settlement behavior. These experiments were supported by 3D finite element simulations in Plaxis-3D, which were used to analyze internal responses such as axial forces, shear forces, bending moments, and displacements. Findings revealed that the VPR system improved load-bearing capacity by 32% over UPR, while the IPR configuration achieved an additional 34% enhancement relative to VPR. This superior performance of IPR was attributed to its broader load dispersion and increased passive soil resistance. Furthermore, IPR reduced settlement by up to 25%, performing consistently well in both dense and loose sand. Numerical results closely mirrored experimental trends, with Plaxis-3D predictions aligning within a 5–10% margin. Inclined piles offered more effective lateral restraint and higher settlement efficiency ratios than vertical piles, establishing the IPR system as the most favorable configuration for mitigating differential settlements and improving foundational stability.

Keywords Piled-Raft Foundations (PRFs) · Granular soils · Differential settlements · Inclined piles · Load-bearing capacity · Settlement · Finite element simulation (Plaxis-3D)

Introduction

Recent progress in civil engineering has enabled the construction of large-scale infrastructure systems that impose considerable stresses on the underlying foundation. While shallow foundations may be suitable in certain conditions, their effectiveness is significantly constrained in soils with low strength or high compressibility. In such cases, piled raft foundations (PRFs) have emerged as a reliable and efficient alternative, as they integrate the bearing capacities of both piles and rafts along with the support provided by the surrounding soil [18, 20, 24]. PRFs function as composite systems where the raft contributes to load distribution, and the piles primarily reduce total and differential settlements, thereby enhancing the overall load-bearing capacity. This dual function makes PRFs particularly beneficial under challenging loading scenarios, including eccentric and dynamic conditions [1, 13, 18]. The role of piles in controlling settlement in weak soils has been extensively emphasized in past studies (J.D. Patil et al. 30) [19].

Numerous experimental and numerical investigations have been carried out to study the behavior of PRFs under varied loading conditions and soil types. Finite element modeling and parametric analyses by researchers such as

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