Abstract

Analysis of Model Piled Raft Foundation in Sand with Emphasis on Pile-Soil, Raft-Soil Interaction

Arpita V Patel,

The Maharaja Sayajirao University of Baroda, 2024

In the developing countries like India, cities are growing fast with exponential development of infrastructure which includes multistory buildings and high-rise structures, heavy structures like bridges etc. These types of structures require foundations like, raft foundation, pile foundation, diaphragm wall foundation, caissons and piled raft foundation. Piled raft foundation is found economical compared to only pile foundation or only raft foundation however, there are certain design issues related to piled raft foundation due to complex interaction between components of piled raft foundation and soil. For the design of piled raft foundation many advanced software are used which consumes lot of computational effort and time. Poulos (2001) presented a philosophy for the analysis and design of piled raft foundations, which needs tremendous computational and numerical efforts. Hence, he emphasized the need for intensive research for the development of simplified analytical procedure. Till today, there is no such codal provision in India that can be useful for the analysis and design of piled raft foundations. Hence to develop a simplified analytical procedure, this research work has been taken. There is limited research reported on the load sharing of piled raft foundations, which incorporate various parameters from soil, pile, and raft. A limited study has been conducted for the effect of various parameters on load settlement characteristics of the piled-raft foundation and, from the study, to evaluate load sharing between the pile group and raft and the overall settlement of the system.

The present investigation highlights the analysis of experimental and numerical works on a model piled raft foundation (PRF) to understand the complex behaviour of piles and raft in their load sharing mechanism within this type of foundation system. The system was analyzed for different shape of raft, length to diameter ratio of piles (L/d), spacing between piles (S), configurations of piles (CF), soil-pile friction angle (δ) and c/s shape of piles through model experiments on different relative density of sandy formation. Further, FEM

analysis through PLAXIS 3D software was used to examine eighteen different configurations of piles in a prototype piled raft foundation for studying their carrying capacity and load sharing mechanisms.

Based on the experimental findings, an analytical equation was derived to predict the secant stiffness specifically for square and circular raft foundations. This equation takes into account the raft width and the relative density of the sand bed under design load conditions. The experiments conducted on both single piles and pile groups revealed that the initial tangent stiffness of the pile group, as determined by Fleming's equation, closely matched the experimental findings, indicating good agreement between theoretical predictions and actual results. The load-settlement characteristics of model piled raft foundations in almost all cases were found tri-linear in nature, with the first yielding denoted as the initial yield load (IYL) and the second yielding denoted as the final yield load (FYL). The analytical equations for predicting *IYL*, *FYL*, primary stiffness of PRF $\left(k_{pr}\right)_p$, and secondary stiffness of PRF $\left(k_{pr}\right)_s$ have been formulated using experimental results of only pile groups (PG), unpiled rafts (UPR), and piled rafts (PRF). The ultimate capacity of a piled raft foundation (*FYL)* exceeds that of an unpiled raft. The initial yield load (*IYL*) and final yield load (*FYL*) and the difference between the FYL and IYL of a piled raft increase with the increase in the relative density of the sand bed. The contact pressure distribution in a piled raft foundation was found to be greater in the space within the pile group compared to outside the pile group. At settlement corresponding to the initial yield load of a piled raft, the load shared by the pile group was greater in the PRF compared to the load taken by only the pile group at that settlement, whereas the load shared by the raft in the PRF was less than the load carried by an unpiled raft at the same settlement. The *FYL* of a piled raft is about 1.5 to 2.7 times the *IYL* of a piled raft in the present study. In most cases, the load shared by the pile group in the PRF at *FYL* is in the range of 1.4 to 5.7 times the ultimate load-carrying capacity of only the pile group, and the load shared by the raft in the PRF at *FYL* is in the range of 0.4 to 0.9 times the ultimate capacity of an unpiled raft foundation. In a piled raft foundation, the 50% load sharing by the pile group and 50% load sharing by the raft occur in the range of relative settlement 0.001 to 0.07 in the majority of cases. In some cases, the pile group and raft did not reach the 50%-50% load sharing. In the early stages of load application, as the relative settlement (s/B_r) increases, the piled raft coefficient (α_p) exhibits a rapid decrease from values close to 1 to ultimately falling within the range of 0.1 to 0.6. As the applied load continues to increase, α_p of most of the PRF stabilizes in the range of the relative settlement (s/B_r) = 0.02 to 0.04. Further increments in load result in either a constant value or a slight increase in α_p. Considering the effect of the configuration of the pile, the load improvement ratio of piled raft foundation is found to be maximum in PRF with all long piles and minimum with all short piles. The load improvement ratio demonstrates a direct correlation with the soil-pile friction angle across all relative densities of the sand bed, indicating that an increase in the friction angle leads to a corresponding increase in the load improvement ratio. Considering the effect of the shape of the pile, the load improvement ratio of piled raft foundation was found maximum in PRF with H pile at 40% and 60% relative density, while at 80% relative density, it was highest with hollow circular pile. The range of efficiency of PRF at *IYL* (β_1) in PRF with different shape of raft was found to be 0.9 to 1.69 and at *FYL* (β_2) it was 0.89 to 1.47. The efficiency of PRF at *FYL* (β_2) was found to be increased with increase in spacing of piles from 3d to 7d. (β_1) and (β_2) was found to be lowest at 80% relative density of sand in most of the cases, this represents that in dense sand the efficiency of PRF is less than in medium dense sand.

The study proposes a preliminary design methodology aimed at estimating the number of piles, their lengths, spacing, probable settlement of the piled raft, and the factor of safety. This design procedure serves as a foundation for conducting a detailed design methodology utilizing computer-based techniques.