

## Critical Study on Piled raft foundation

Poulos et al. (1997) described some of the methods for studying piled rafts that have been developed. The less simplified numerical analysis methods tend to fall into the following categories:

- (a) Techniques based on a strip-on-springs approach, in which the raft is represented by a sequence of strip footings and the piles by appropriate stiffness springs (e.g. Poulos, 1991).
- (b) Techniques based on a 'plate on springs' approach, in which the raft is represented by a plate and the piles by springs (e.g. Clancy & Randolph, 1993; Poulos, 1994a; Russo & Viggiani, 1998; Yamashita et al., 1998; and Poulos & Georgiadis, 1998).
- (c) Boundary element approaches, in which both the raft and the piles within the system are discretized and elastic theory is used (e.g., Butterfield & Banerjee, 1971; Kuwabara, 1989; and Sinha, 1997)
- (d) Approaches that combine boundary element analysis for piles and finite element analysis for rafts (e.g., Hain & Lee, 1978; Ta & Small, 1996; and Franke et al., 1994).
- (e) Simplified finite element analyses, which often involve the foundation system being represented as a planar strain problem (Desai, 1974) or an axisymmetric problem (Hooper, 1974).

### Burland's Approach

**Burland (1995)** developed the following simplified design approach for piles designed to act as settlement reducers and to achieve their full geotechnical capacity at the design load:

In the absence of piles, determine the total long-term load-settlement relationship for the raft (see Figure 2-29). The design load  $P_0$  yields the total settlement  $S_0$ . Determine an acceptable design settlement  $S_d$ , including a margin of safety.

Choose a design settlement  $S_d$  that is acceptable and includes a safety factor.

$P_l$  is the raft's load, which corresponds to  $S_d$ .

## Critical Study on Piled raft foundation

It was believed that settlement-reducing piles support the extra load  $P_0 - P_1$ . No safety factor was used because the shaft resistance of these piles would be fully mobilized. Burland, on the other hand, suggested multiplying the "conservative best estimate" of ultimate shaft capacity,  $P_{su}$ , by a "mobilization factor" of roughly 0.9.

$$Q_r = Q - 0.9P_{su} \quad (2-43)$$

After that, the bending moments in the raft could be estimated by examining the piled raft as if it were a raft subjected to lower loads,  $Q_r$ . Burland did not specifically explain the method for predicting the piled raft's settlement, although it looks possible to utilize **Randolph's (1994)** approximate methodology, which states:

$$S_{pr} = S_r \frac{k_r}{k_{pr}} \quad (2-44)$$

where,  $S_{pr}$  = settlement of piled raft

$S_r$  = settlement of raft without piles subjected to the total applied loading

$k_r$  = stiffness of raft

$k_{pr}$  = stiffness of piled raft.

Equation (2-28) can be used to estimate  $k_{pr}$ .

## Critical Study on Piled raft foundation

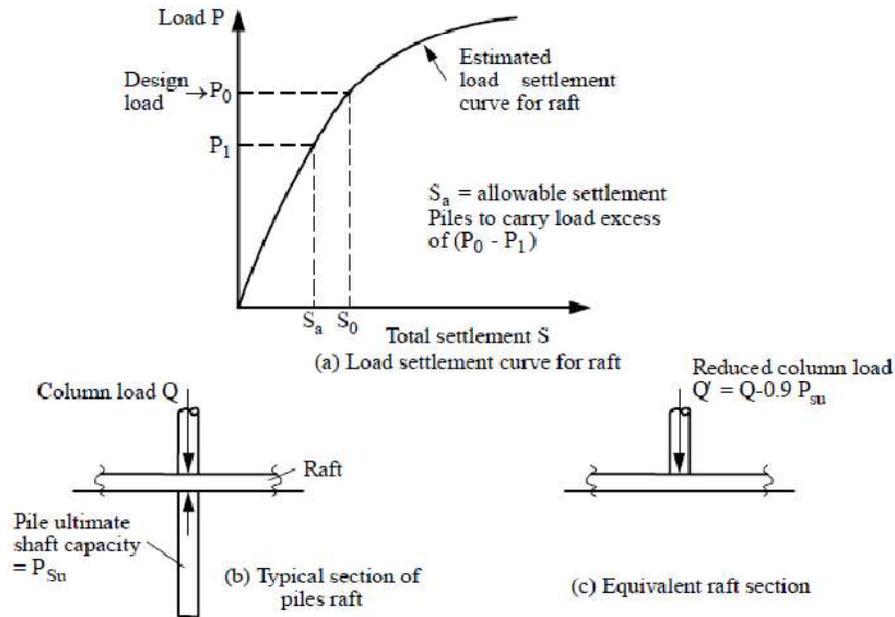


Figure 2-29 : Burland's simplified design concept (after Burland, 1995)

**Omeman et al. (2012)** created a simple model for predicting raft-pile settlement and load sharing for piled-raft foundations. This model can help foundation engineers formulate piled-raft foundations, especially in the early stages of the design process, as well as conduct feasibility studies to assess various alternatives. Engineers can save a lot of time and effort by employing this model instead of a complicated numerical analysis that requires special tools. Because piled-raft foundations are a combination of raft and pile foundations, the stiffness of piled-raft foundations,  $k_{pr}$  was considered to be a combination of the stiffness of the raft,  $k_r$  and the stiffness of the piles,  $k_p$  as provided by the equation (2-45).

$$k_{pr} = k_r + k_p \quad (2-45)$$

As a result, equation (2-45) cannot adequately represent the stiffness of the piled-raft foundations' system. As a result, equation (2-45) had been changed to equation (2-46) to account for the influence of the raft-pile interaction. New factors called raft stiffness and pile stiffness efficiency factors had been proposed in this equation.

## Critical Study on Piled raft foundation

$$k_{pr} = \alpha_r k_r + \alpha_p k_p \quad (2-46)$$

Equations (2-47) and (2-48) can be used to calculate the load sharing between the raft and the piles:

$$\text{Raft load \%} = 100 * \left( \frac{\alpha_r k_r}{k_{pr}} \right) \quad (2-47)$$

$$\text{Pile load \%} = 100 - \text{Raft load \%} \quad (2-48)$$

where  $\alpha_r$  is the efficiency factor for modifying the stiffness of the raft due to the influence of the pile, and  $\alpha_p$  is the efficiency factor for modifying the stiffness of the piles due to the effect of the raft.  $k_r$  and  $k_p$  can be estimated using standard methods from the literature. The constructed model PLAXIS 2-D was used to determine the value of the interaction factor,  $\alpha_r$  and the number of examples of piled-rafts supported by a single pile with varying pile-raft stiffness ratios. For each scenario, the raft load,  $k_p$ ,  $k_r$ , and  $k_{pr}$  were calculated. Then, for each scenario,  $\alpha_r$  was computed using equation (2-47). The value of  $\alpha_p$  was then calculated by replacing the value of  $\alpha_r$  in equation (2-46). As demonstrated in Figure 2-30 and Figure 2-31, the interaction factors  $\alpha_r$  and  $\alpha_p$  varied with the stiffness ratio of the piles to the raft,  $k_p/k_r$ . The interaction factors  $\alpha_r$  and  $\alpha_p$  were estimated graphically using equations (2-49) and (2-50).

The load sharing between the raft and the piles can be determined using the ratio of the raft's load to the piled-raft's load at the same amount of settlement as given by equation (2-47) Equation (2-48) can be used to calculate the load carried by the piles.

## Critical Study on Piled raft foundation

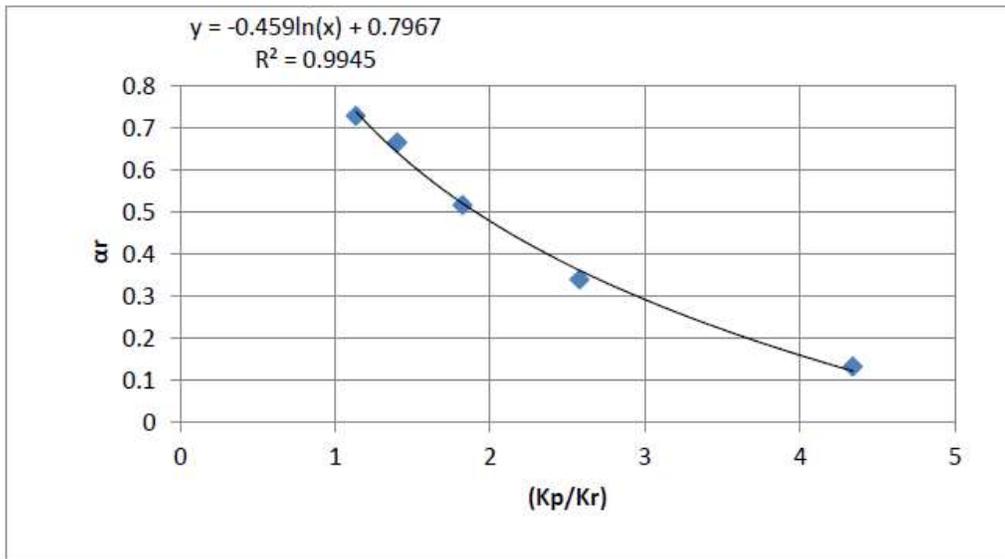


Figure 2-30 : Effect of pile-raft stiffness ratio on the raft efficiency factor,  $\alpha_r$ , (after Omeman et al., 2012)

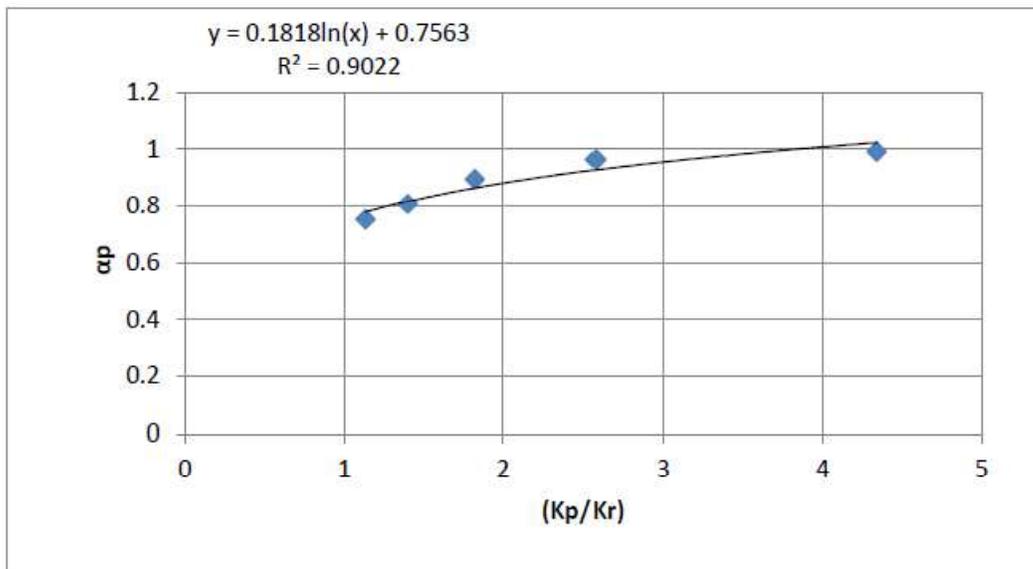


Figure 2-31: Effect of pile-raft stiffness ratio on the pile efficiency factor,  $\alpha_p$ , (after Omeman et al., 2012)

## Critical Study on Piled raft foundation

$$\alpha_r = -0.459 * \ln\left(\frac{k_p}{k_r}\right) + 0.7967 \quad (2-49)$$

$$\alpha_p = -0.1818 * \ln\left(\frac{k_p}{k_r}\right) + 0.7563 \quad (2-50)$$

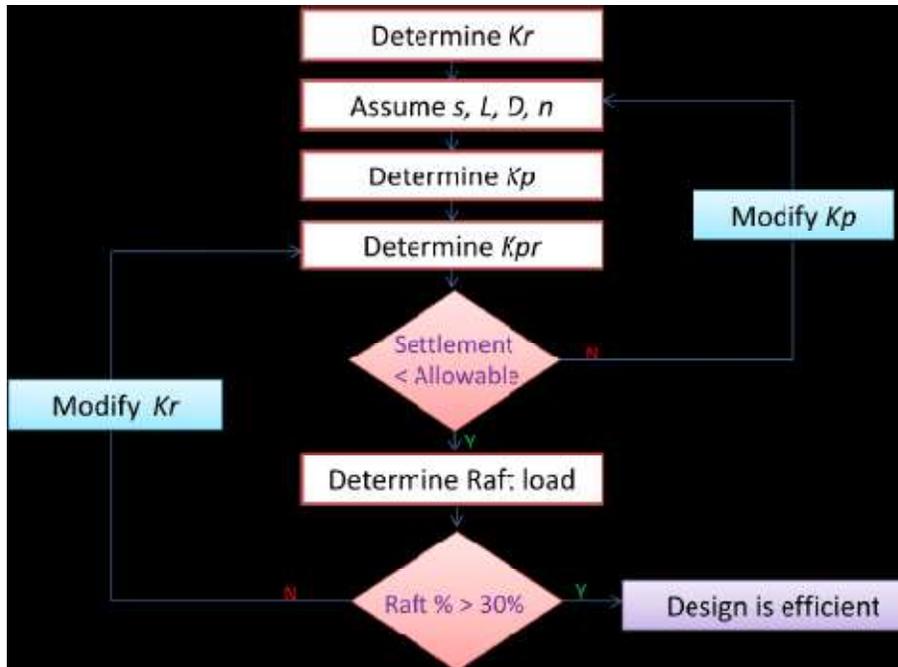


Figure 2-32 : Procedure for preliminary design of piled-raft foundations (after Omeman et al., 2012)

Figure 2-32 depicts a flow chart of this procedure:

- 1) Calculate the stiffness of the raft foundation alone,  $k_r$ .
- 2) To reduce raft settlement, examine a variety of pile groups with varying numbers of piles, pile length, pile diameter, and pile spacing.
- 3) For each scenario, calculate the stiffness of the pile group without the raft,  $k_p$ .