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Bearing capacity of piled rafts

Capacité portante des fondations mixtes semelle-pieux

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1 INTRODUCTION

Piled rafts subjected to vertical loads provide an economical foundation option for circumstances where the performance of an unpiled raft does not satisfy the design requirements. Under these circumstances, the addition of a limited number of piles may improve the ultimate load capacity and the settlement performance.

While in the last decades the research has been aimed to the use of piles as settlement reducers, less attention has been dedicated to the bearing capacity of piled rafts. In view of innovative design approaches, it is believed that the development of a general approach to evaluate their bearing capacity is mandatory.

At the present time, the evaluation of the vertical bearing capacity Q_{PR} of piled rafts is made by taking the smaller of the following values: (a) the ultimate capacity Q_{BF} of the block containing the piles, plus that of the portion of the raft outside the periphery of the pile group; (b) the sum of the ultimate loads of the raft Q_R and of all the piles Q_P. The installation of the piles, however, may affect the soil properties beneath the raft and consequently modify its performance in comparison with that of the unpiled raft. Moreover, the behaviour of the piles may be affected not only by the interaction among piles but also by the surcharge exerted by the raft. From all above the following general expression:

$$Q_{PR} = \alpha_{UR} \times Q_R + \alpha_P \times Q_P \qquad (1)$$

can be considered (α_{UR}, α_P = coefficients affecting the failure load of raft and piles when combined in a piled raft.

Traditional design approach, being based on neglecting the contribution of the raft, assumes $\alpha_{UR} = 0$ and $\alpha_P = 1$ in eq. (1). On the other hand, suggestion (b) yields to $\alpha_{UR} = \alpha_P = 1$.

The present Panel has been aimed to contribute to this field of research; particular emphasis has been placed on piled rafts resting on clayey soils where the problem of the bearing capacity is of particular concern.

2 RE-USE OF THE AVAILABLE KNOWLEDGE

Summing up the available experimental evidence in clayey soils at full and lab scale (see Mandolini *et al.*, 2005), a critical value for the spacing ratio s/d could be established for a group made by n piles uniformly spread underneath raft and having a bearing capacity Q_S:

- for $s/d > (s/d)_{crit}$ the piles would fail as ‘individual’ (Q_P = E x n x Q_S; E = pile group efficiency = 1) and the raft is allowed to contribute to transfer load at failure ($\alpha_{UR} > 0$);
- for $s/d < (s/d)_{crit}$, the piles would fail as ‘block’ (E < 1; $Q_P = Q_{BF}$ < n x Q_S) and the raft contribution at failure is inhibited by the“shadow” effect generated by the piles ($\alpha_{UR} = 0$).

3 RECENT DEVELOPMENTS

A number of piled raft layouts were investigated by means of 3D FE analyses (de Sanctis & Mandolini, 2005). The main numerical results are well summarized in figure 1, where A_G = area occupied by piles and A = area occupied by the raft.

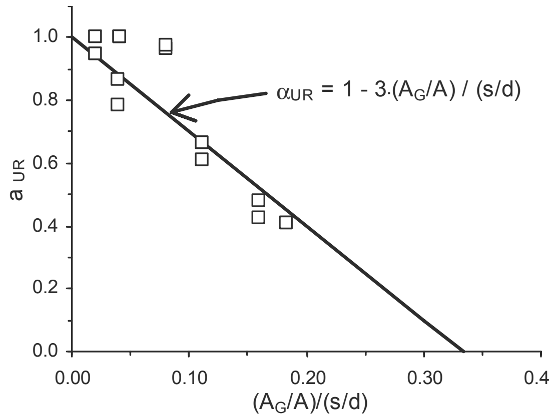

Figure 1. Relationship between α_{UR} and filling factor FF = $(A_G/A_R)/(s/d)$

For the case of an unpiled raft ($A_G/A = 0$), the equation in the figure yields to $\alpha_{UR} = 1$, as expected; on the other side, for the case of piles uniformly spread underneath raft ($A_G/A \sim 1$) at relatively small spacing ($s/d \sim 3$), $\alpha_{UR} \sim 0$. It follows that FF = 1/3 may be viewed as a critical value corresponding to the transition from a pile group (no contribution of the raft, $\alpha_{UR} = 0$) to a piled raft (the raft supplies a fraction $\alpha_{UR} > 0$ of its bearing capacity when unpiled). Such result is similar to that for a traditional piled foundation ($A_G/A = 1$): the value $s/d \sim 3$ represents an average critical value corresponding to the transition from ‘block’ mode of failure to individual pile failure.

These findings could be considered very useful in practice in view of an optimum design. Piles uniformly spread underneath the raft ($A_G/A = 1$) at s/d = 6 make available 50% of the theoretical bearing capacity of an unpiled raft ($\alpha_{UR} = 0.5$); the same applies if more closely piles (s/d = 3) are concentrated in the central part of the raft with $A_G/A = 0.5$. An optimum solution may be selected to satisfy other design requirements (reduction of displacements and/or stress level in the raft).

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