Soil foundation behavior under the action of rigid footing-reinforcement system

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INTRODUCTION

The use of rigid footing with vertical piles is common in areas with soft soil deposits. The structural loads are supposed to carry partly by the footing and the rest by the friction piles. The analysis of the behavior of such a piled footing is very complicated due to the variety of influencing factors. In this research we investigate the soil foundation behavior under the action footing-reinforcement system using the soil-water coupled finite deformation analysis. The action of pile is taken as 'reinforcement' in the soil under the plane strain condition.

METHOD OF ANALYSIS

The soil-water coupled finite consolidation deformation analysis using the finite element method was employed in the investigation. In order to simulate the rigid reinforcement/footing effect, assuming that reinforcement/footing moves together with the soil, some linear constraint conditions on the velocity field of soil skeleton, in particular the "no length change condition and no angle change condition" were introduced to the finite element model (plane strain). (details can be found in reference. 2). In fact, the reinforcement is a zero thickness wall like in this plane strain model. The homogeneous, lightly overconsolidated (OCR=2) foundation soil was assumed to follow the subloading surface (Hashiguchi, 1989) Cam-clay model (Asaoka et al, 1997). Analytical half domain was 25m in height and 30m in width and the loading was applied gradually at a rate of 1kN/m^2/day until total load reached 100kN/m^2. The rigid footing was supported by three vertical reinforcements. The initial vertical effective stress distribution was triangular. The material parameters used are shown in Table 1.

EXCESS PORE PRESSURE DISTRIBUTION

Fig. 1a and 1b show the excess pore pressure distribution at 100kN/m^2 load level for the cases of rigid footing only and rigid footing, reinforcement combination respectively. The reinforcement was 10m in length. The reinforcement-footing connection was assumed fixed. As shown in the figure, in the case of footing reinforcement combination the peak excess pore pressure occurs below the reinforcement tip. This implies that most of the load is taken by the reinforcements and transferred to deeper levels. When the load is transferred only through the footing (Fig. 1a) the peak excess pore pressure occurs at the top center portion.

Fig. 2 shows the excess pore pressure distribution when the reinforcement-footing connection is assumed pinned. In this case somewhat lower excess pore pressure magnitudes were generated.

SHEAR STRESS VARIATION

Figs. 3a and 3b illustrate the shear stress variation along the depth for some elements for reinforcement only and footing, reinforcement combination respectively. The referenced elements in these figures are shown in Fig. 4. The footing-reinforcement combination gives almost uniform distribution of shear stress with depth at the end of loading (at 100kN/m^2). With the subsequent consolidation process, shear stress in the vicinity of reinforcement tip increases significantly. This behavior is justifiable due to the generated high excess pore pressure in this area (Fig. 1b). The top portion (up to about 6m) exhibits some reduction in shear stress at the end of consolidation. This is due to the unloading character of the elements in this area. There is no significant difference in shear behavior when the pinned reinforcement-footing connection is assumed. When only the reinforcement case is considered, significant increase in shear stress at the end of consolidation can be seen in the top portion. During load application also higher stresses are developed in this area.

Fig. 5a and 5b show the bending moment distribution along the footing and the reinforcements at the end of loading and end of consolidation respectively. This result is for fixed footing-reinforcement connection. As shown here the consolidation process reduces the bending moment significantly. It should be noted here that due to very high stiffness (under linear constraint conditions) there exist very high bending moments at the end of loading. When the axial force distribution is concerned the magnitudes increase with consolidation for the reinforcements. For the footing it decreases. Further, footing-reinforcement combination makes the final settlement to decrease significantly.

CONCLUSION

Rigid footing-reinforcement combination effectively transfers the load to deeper layers by shear, reducing final settlements. The forces acting on rigid footing and reinforcement changes with consolidation process.

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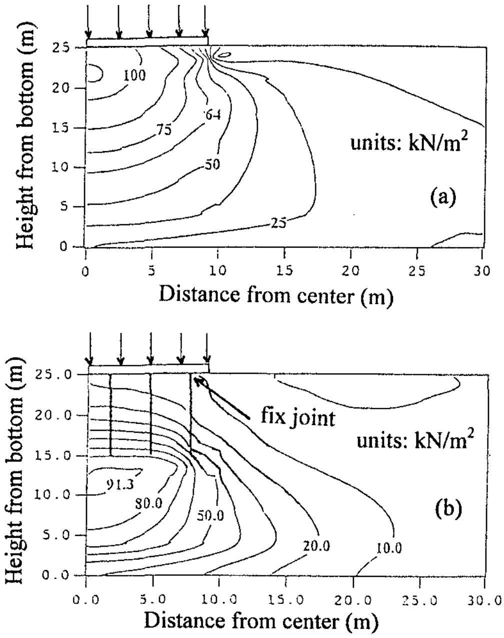


Fig. 1 Excess pore pressure distribution

Table 1 MATERIAL PARAMETERS

Compression index	0.02
Swelling index	0.04
Critical state parameter	1.53
Permeability constant	1×10^{-7}cm/s
Poisson's ratio	0.30
OCR	2.0
Voids ratio on NCL at unit pressure	3.0
Subloading model constant (v_2)	10.0
Earth pressure at rest (K_0)	0.7
Saturated density	18.5kN/m^3

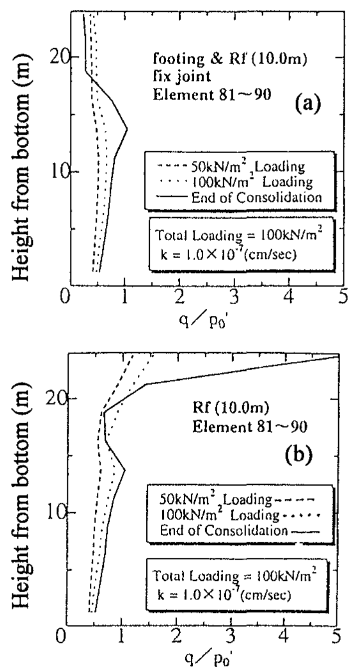


Fig. 3 Shear stress distribution

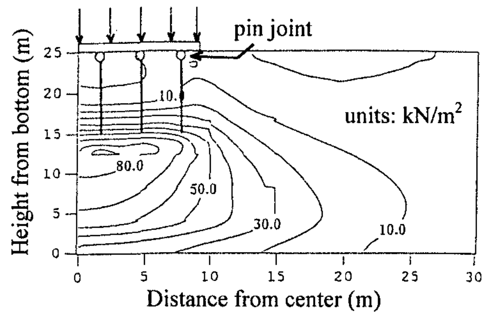
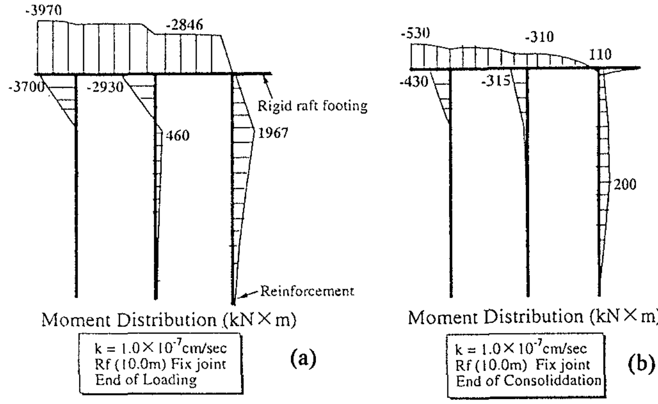


Fig. 2 Excess pore pressure distribution



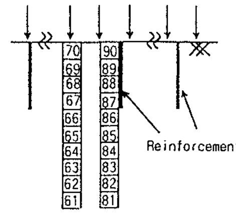


Fig. 4 Elements for fig. 3

Fig. 5 Bending moment distribution