Geosynthetics - 7th ICG - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

Stress strain behavior of soft soils reinforced by flexible piles

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ABSTRACT: A parametric analysis was conducted to examine the distribution of shear stresses with depth and radial distances in the soil, basal reinforcement, pile cap and flexible pile, to obtain the resultant settlement of the system and influence of various design parameters. The interactive shear stresses between basal reinforcement, pile cap, and soil are considered responsible for soil structure interaction between them and their stress transfer. Compatibility condition between soil column displacements for each element of soil pile system is imposed to obtain the solution. A predictive methodology is proposed to predict the stress-strain behavior of inclusion reinforced soil under various varying parameters. The proposed tool is verified with finite element analysis and is found to be reliable and valid for wide range of parameters.

1 INTRODUCTION

Several empirical and theoretical approaches are available considering different failure modes and load sharing mechanisms and homogenization techniques (Greenwood, 1970, Baumen and Bauer, 1974, Hughes and Wither, 1974, Priebe, 1976, Madhav and Vitkar, 1978, Goughnor and Bayuk, 1979, Balaam and Booker, 1981, Schweiger and Pande, 1986, Canetta and Nova, 1989).

All existing design approaches are based on “equal strain theory” (Hansbo, 1994) in which load sharing between column and surrounding soil is calculated on assumption that horizontal section in ground remain same during settlement. However, this may not be true in flexible loading through basal reinforcement as deformation of soil and flexible pile will be different (Leung and Tan, 1993) thus “equal strain “ assumption may not be suitable. Though Balaam et al. (1977) presented a finite element solution to determine the settlement of granular column reinforced ground subjected to uniform vertical pressure imposed by a flexible raft foundation or embankment. However, a simple analytical method to obtain the solution of flexible piling is required this is basically the theme of this paper.

2 DESCRIPTION OF PROBLEM

Flexible piling system: this piling system comprises of flexible piles comprised of precast micro reinforced concrete filed in side woven geotextile encased with half split PVC tubes. The uniformly distributed load of embankment is transferred by basal reinforcement comprising of geotextile and polymeric (friction ties) partially to pile cap and ground between inclusion and rest by frictional mobilization in the horizontal direction.

3 DESIGN APPROACH

The embankment and basal reinforcement is designed based on standard guidelines mentioned in British Standard BS-8006. The test embankment was to be used for approach road of road-over bridge (ROB) comprising of reinforced soil wall. This test embankment consisted of 240 m long section with heights varying from 0-12 m. the partial factors for live and loads were taken as 1.3 and 1.5 mm respectively. The traffic surcharge intensity was taken as 20 kN/m^2. The pile loads were calculated as equivalent concentrated load for load distribution area (neglecting sharing table of load by intermediate soil). This works out to be on conservative side.

The basal reinforcement assist in uniform distribution of load and lowering the load intensity at pile caps as part of the load is shard by friction and part by intermediate ground.

4 FORMULATION OF PROBLEM

A soft ground reinforced by flexible piles is subjected to uniform loading transferred by basal reinforcement. Flexible piles rest on fairly firm ground with cone penetration test (CPT) value being greater than 7 and load is applied through flexible material. Unit cell concept is used as it fairly well represents the behavior pile reinforced ground (Barksdale and Bachn, 1983, Balaam and Booker, 1985 and Poorooshasb et al., 1991, Van and Madhav, 1992). The pile is a cylinder of length H = 18 m and Diameter, d_c = 150 mm. The unit cell of diameter d_e is loaded with uniform load 60. Balaam and Booker, 1981 relate diameter, d_e with spacing of column, s_c (take 1 m), as $d_e = C_g + S_g$, where C_g is geometric constant equal to 1.05, 1.13, 1.29 and 1.35 for triangular, square, hexagonal and circular arrangements respectively. Thus value of d_e comes out to be 1.35 m. the soil is assumed to be a linearly deformable layer of homogeneous material defined by a constant modulus of deformation E_s = 25 MPa and a constant Posisson’s Ratio, ν_s = 0.2 that are not influenced by the presence of pile and remains constant through out the loading process. The pile material is assumed to be linearly deformable homogeneous material defined by a modulus of deformation, E_c = 9000 MPa after 31 days. And a constant Poisson’s Ratio = 0.15. The displacement of pile and soil at interface shall be equal as column soil interface is assumed to remain elastic without any step. The shear stress outside the boundary shall be 0 due to symmetry of load and geometry. Thus vertical deformations are being considered as radial deformations are assumed to be negligible.

Methodology adopted for analysis:

1. discretization of pile soil system
2. equation for assumed deformation pattern for the heterogeneous system
3. developing equation for evaluation of interaction shear stresses and stress on pile and soil by stress transfer mechanism.
4. to obtain pile/soil displacement under elastic behavior.
5. imposing compatibility condition for pile soil displacements.
6. determining settlement composite grounds, displacement field, stresses on pile and soil.

5 COMPARISON OF RESULT BETWEEN FINITE ELEMENT ANALYSIS (FEM) AND PROPOSED METHOD

The problem selected for FEM is that of basal reinforced uniformly loaded typical flexible pile reinforced ground having $H/d_c = 20$, $n = 4.0$, $\sigma_0 / E_s = 0.10$, $E_c / E_s = 10$, $\nu_c = 0.20$ and $\nu_c = 0.40$, STAADPRO is used for FEM analysis. the modelling is done using 152 eight-noded linear strain quadrilateral elemnts. Each element has 9 integration points at which stresses and strain are calculated. The load is applied as uniform presure atr the top. The boundary condition for themess are the same as those conhsidered for the propoesed method that is te outer bounadry is restrained in the horizontal direction and is assumed to be smooth i.e., free to move in th evertical direction. The base of the layer id assumed to be rigid and smooth and hence is restrained in vertical direction but free to move in the horizontal direction.

It can be seen that the proposecd approach underpredict the settlement compared from FEM fron centre of pile upto theradial distance $r / a = 2.50$, while after that it over predict upto the outer boundary ($r /a = n$) of the unit cell. Thus it is observed that predicted deformatin patterns of the reinforced ground obtained by theproposed method and the finite elemnt analysis are quite similar. It is observed there is good correlation between the proposed method and those of the finite elemnt analysis except that the proposed approach under predict slightly at the top. In both prediction, the stress concentration increases rapidly with depth and after certain depth it become constant. At top, result are same, but there overprediction than FEM result.

From these observations, the proposed method is having good reliability ansd validity and solution can be obtained easily by using the particular dispalcement function in proposed analysis.

6 CONCLUSION

Attempt has been made to evolve simple theoretical approach to predict the deformation behavior of uniformly loaded soft ground reinforced by basal reinforcement and flexible pile inclusions. This approach takes into account the free strain condition distribution of shear stresses strain condition and the load sharing between pile and soil. A simple deformation mode of the pile soil system is assumed and the compatibility of the displacements between the pile and the soil is considered. Results are presented for uniformly loaded, pile reinforced ground fro varying spacing, modular ratio and Poisson's ration of soil. It is observed that effects of these factors are prominent except Poisson's Ratio. These results are compared with FEM results and very high similarity in magnitude and pattern exists for settlement profiles, shear stress distributions. This demonstrates the usefulness of proposed method, which is simple in concept, and requires minimal computational efforts.

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