STRESS TRANSFER FROM GRANULAR COLUMN TO SOIL CONSIDERING SLIP AT THE INTERFACE

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1. INTRODUCTION

Granular columns (usually referred to as stone columns or granular piles) are becoming popular ground improvement technique to increase the bearing capacity, reduce settlement, improve slope stability and resistance to liquefaction in soft clays or loose granular deposits. Several empirical and analytical approaches are available to evaluate the performance of granular column reinforced ground. But still the real behaviour of reinforced granular column can not be predicted effectively. Hughes et al. (1975) observed that the prediction is excellent if allowance is made for transfer of load from column to clay through the side shear and correct column size. Recently, authors(1993) proposed an elastic approach to estimate the interaction shear stresses at the column soil interface. Since the real soils have a finite shear strength and the column-soil interface has a finite adhesive strength, slip or local yield will occur when the shear stress reaches at the adhesive (or yield) strength. In this paper, the aforementioned elastic analysis is modified to take acount the slip at the interface of granular column and soil. It is found that interface shear stresses, stresses on column and soil are different at the top region but at the lower part the results are almost same for elastic and slip cases. It is also found that the settlements are almost same for the both cases.

2. PROPOSED ANALYSIS

In this analysis, the 'unit cell' concept, which consists of a granular column and surrounding soil within a column zone of influence (Fig.1) is considered. The platform supported by the column-soil system and the supporting base are assumed to be rigid and smooth. The radial deformations are small and neglected. The applied stress are shared by the column and the soil on the basis of their stiffness, geometry and the mobilized shear stress. From symetry of load and geometry the shear stresses at the out side boundaries of the unit cell are zero. The column materials and the soils is assumed to have constant soil parameters before and after installation of column. Since the load is applied through a rigid platform, the settlements at the top of unit cell are the same. In this analysis, the unit cell is divided into ten equal elements and

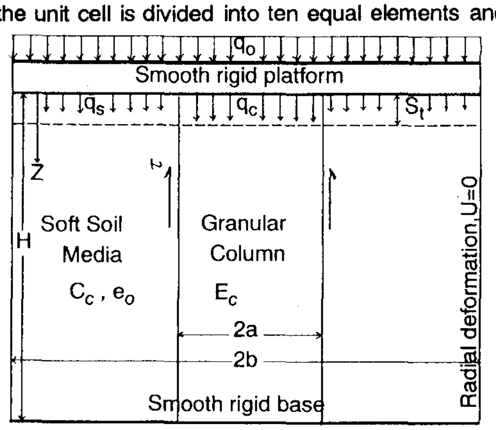

Fig.1 Definition sketch

it is assumed that the displacements of column and soil at the top and middle of any element are also the same. The equilibrium of vertical forces for the ith element is expressed as

$$q_o = \frac{1}{n^2}q_{ci} + (1-\frac{1}{n^2})q_{si} \tag{1}$$

where q_o=stress on unit cell; q_{ci},q_{si}=stresses on column and soil respectively; n=b/a, a and b are the radii of column and unit cell respectively. The deformation of granular column and soil are evaluated from the linear stress-deformation and void ratio versus log effected stress relation respectively. Satisfying the compatibility of deformations at the top and middle of the ith element of granular column and soil, the following two equations are obtained respectively in dimensionless form to evaluate sharing of stresses (Alamgir et al. 1993).

$$q_{ci}^* = \frac{H^*\tau_i^*}{N} + \mu_{cs}\ln[1+\frac{Nq_{si}^* + \frac{H^*\tau_i^*}{(n^2-1)}}{(2i-1)}] \tag{2}$$

$$q_{ci}^* = \frac{3H^*\tau_i^*}{2N} + \mu_{cs}\ln[1+\frac{Nq_{si}^* + \frac{3H^*\tau_i}{2(n^2-1)}}{(2i-.5)}] \tag{3}$$

where $q_o^*=q_o/p_o$; $q_{ci}^*=q_{ci}/p_o$; $q_{si}^*=q_{si}/p_o$; $\tau_i^*=\tau_i/p_o$; $\mu_{cs}=.434E_cC_c/(1+e_o)/p_o$; $p_o=.5\gamma' H$ and $H^*=H/a$. τ_i= shear stress at the interface; H=length of column; N=no. of elements; i=1 to N; E_c=deformation modulus of granular material; C_c=compression index; e_o=initial void ratio of soil. Eqns.1 to 3 are solved for q_{c1}, q_{s1} and τ_1 on the assumption that all the elements are elastic. This shear stress is then compared with the specific limiting stress (τ_a). If $\tau_1<\tau_a$, all the elements are in elastic condition and the solution is the same as Alamgir et al.(1993). If $\tau_1>\tau_a$, the displacement compatibility equation for that element is replaced by the following equation, taking the shear stress at that element equal to τ_a. Then q_{c1} and q_{s1} are evaluated by the Eqns.1 and 4. The shear stress for the next element is evaluated assuming all other elements are in elastic. Then Compared the value of τ_2 with τ_a, if $\tau_2<\tau_a$, the evaluations are the same as elastic. If $\tau_2>\tau_a$, the displacement compatibility equation for the slipped elements are replaced by Eqn.4.

$$q^*_{ci}=\frac{iH^*\tau^*_a}{N}+\frac{\mu_{cs}}{i}\sum_{i=1}^{i=N}\ln\left[1+\frac{Nq^*_{si}+\frac{H^*\tau^*_a}{(n^2-1)}}{(2i-1)}\right] \quad (4)$$

In this way, by comparing the value of τ_i with τ_a for every elements the mobilized shear stresses are obtained. Once the shear stress and stresses on column and soil are known the settlement at any level are evaluated by adding the deformations of all the elements considered below that level.

3. EVALUATION OF RESULTS

Some evaluations are made considering a typical granular column to depict the applicability of the proposed method. These results are compared with that of elastic analysis and are presented in Figs.2-4. It is observed from Figs.2&3 that the distribution of shear stresses and stress concentration factor (ratio of stress on column to stress on soil) along the depth differs at the top region of granular column for elastic and slip analysis. At the bottom part of column they become the same.Fig.4 reveals that the settlement ratios (ratio of settlement of treated ground to the settlement of untreated ground) are almost the same for the both cases.

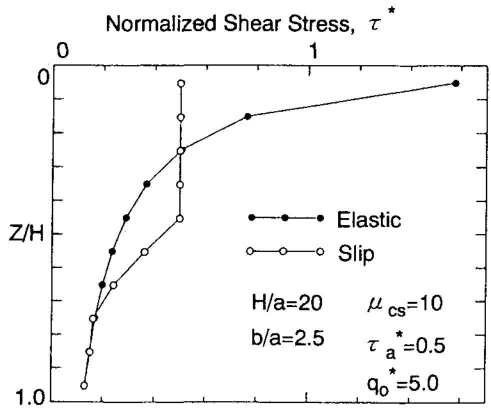

Fig.2 Variation of shear stress with depth

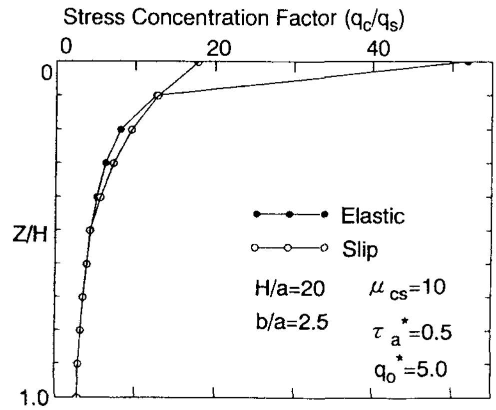

Fig.3 Variation of stress concentration factor along the depth of unit cell

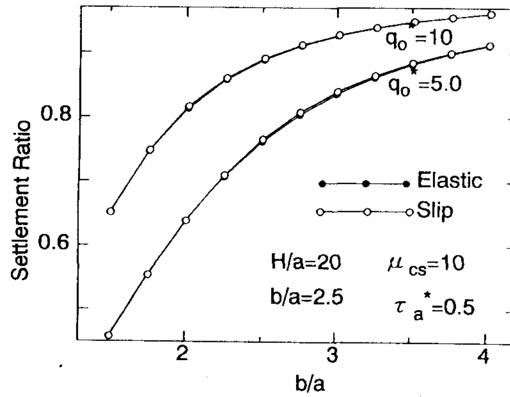

Fig.4 Variation of settlement ratio with spacing

4. CONCLUSIONS

The proposed approach can be used to predict the overall behaviour of granular column considering slip at the column-soil interface. The evaluations reveal that elastic solutions can be used to predict settlement response of granular column effectively.

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