EFFECT OF DILATANCY ON RESPONSE OF GRANULAR COLUMN IN SOFT CLAY

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1. INTRODUCTION

In this paper a study has been undertaken to demonstrate the effect of dilatancy of granular material on settlement response of granular column in soft clay. To perform this exercise the design method of granular column proposed by Alamgir & Kabir (1992) is used. The work of Bolton (1986) on strength and dilatancy of sands is considered to evaluate the rate of dilation. The findings appear to be very encouraging as found by Van Impe & Madhav (1992). The result shows that the settlement of the improved ground is reduced with the dilatancy effect included compared to the case in which the column is supposed to yield at constant volume.

2. ANALYSIS

A single granular column surrounded by a semi-infinite soft clay media resting on a smooth rigid base is taken into consideration. The surrounding clay media is assumed to be soft, saturated and normally consolidated having undrained shear strength linearly increasing with depth. The quasi-static vertical load is applied on the top of the column through a smooth rigid platform in undrained condition. It is assumed that the mode of failure of column is bulging. The mechanical behaviour of the constituent materials is expressed by two parameters a and b, where 1/a is the initial tangent modulus and 1/b is the ultimate strength. For the analysis of granular column the nonlinear design method proposed by Alamgir & Kabir (1992) is used. In this method compatibility of deformation amongst the constituent materials in plain strain condition is considered. The lateral resistance given by the surrounding clay media is evaluated based on the cavity expansion theory and the skin friction developed along the column and clay interface is also included in the analysis. In this method it is assumed that the column will yield at constant volume. As the densified granular column material will dilate due to applied stress, the volume of the granular column will not remain constant throughout the loading process. Hence there is a strong need to revise the above analysis and introduce the effect of dilatancy. The following equations were given by Bolton (1986), can be used to evaluate volumetric strain for granular material based on relevant parameters.

$$\varepsilon_{vd} = 0.30\ (\ I_D\ (10 - \ln p'\ ) - 1\ )\ \varepsilon_p \qquad (1)$$

$$\varepsilon_{vd} = 0.06\ (\ \phi_{max} - \phi_{crit}\ )\ \varepsilon_p \qquad (2)$$

where, ε_{vd} = volumetric strain due to dilatancy, I_D = relative density, p' = mean effective stress, ε_p = axial strain corresponding to peak strength, ϕ_{crit} = critical angle of shearing resistance, ϕ_{max} = maximum angle of shearing resistance. As the volumetric strain due to dilatancy is considered in the present analysis, the relationship between axial strain (ε_v) and lateral strain (ε_h) will be the following (Eqn. 3). Considering the behaviour of granular material to dilate, the analysis process is revised and it is found that there is a reduction of settlement with dilation at the same load as calculated earlier considering no volume change condition. As the volumetric strain increases the axial strain decreases, as a result the settlement decreased for the same vertical load.

$$\varepsilon_v = 1 - (\ 1 + \varepsilon_{vd}\ )\ (\ 1 + \varepsilon_h\ )^{-2} \qquad (3)$$

3. ILLUSTRATIVE EXAMPLE

To depict the effect of dilatancy of granular column an illustrative example is presented here. The granular material is stone aggregate 9mm to 12mm, having an angle of shearing resistance of 47^{o} and the parameters a_a and ba of 0.00225 and 0.1375 respectively. A 5.5m thick homogeneous clay media having undrained shear strength of 14 kPa, undrained shear modulus of 933 kPa, unit weight of 16.50 kN/cum, Poisson's ratio of 0.50 and the parameters a_s and b_s as 0.095 and 1.667, respectively is considered. The column is 4m long, 0.50m diameter and founded at a depth of 1.5m below the ground surface. The predicted stress- settlement relationships are shown in Fig.1, for the dilations of 0 %, 0.50% and 1%. The settlements corresponding to the stress of 200 kPa are 55mm, 44.73mm and 36.37mm, respectively. This result is also expressed in terms of settlement ratio (settlement considering dilatancy to the settlement not considering dilatancy) versus load intensity in Fig.2. It is found that the settlement ratio increases with the increase of vertical load and the rate of increase decreases gradually with the increase of vertical stress in the same manner irrespective of the rate of dilation. For 0%, 0.50% and 1.0% dilations the settlement ratios are found to be 1, 0.81 and 0.66, respectively corresponding to the vertical stress of 200 kPa.

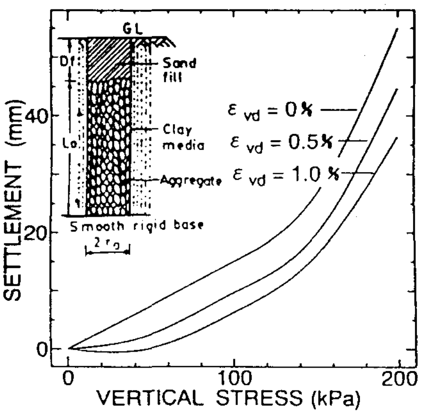

Fig.1 Stress vs. Settlement

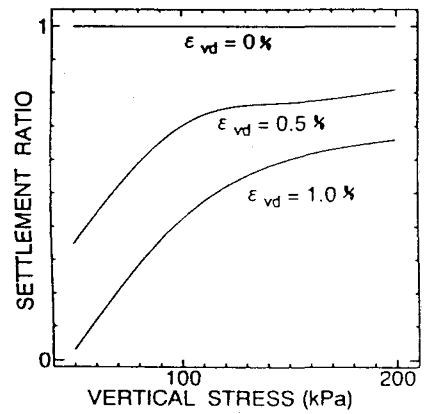

Fig.2 Stress vs. Settlement ratio

4. CONCLUDING REMARKS

The study presented here leads to the following conclusions. (i) The settlement of the granular column reduces as the rate of dilation increases and the reduction of settlement depends on load intensity. (ii) The behaviour of granular column evaluated in this study considering the effect of dilatancy is similar to the results presented by Van Impe & Madhav (1992). (iii) There is a strong need to determine the rate of dilation of granular material to evaluate the load carrying capacity of granular column. Bolton's (1986) equations can be used for a preliminary design.

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