Finite Element Model of Compaction Grouting

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1. INRODUCTION

Compaction grouting (CPG) is becoming popular these days as a liquefaction countermeasure in Japan. In this technique, a stiff mortar is injected under high pressure that causes increased ground density and increase in lateral earth pressure and thus checks liquefaction susceptibility of the sandy ground. However, so far, the application of the method depends mainly on the field tests, practical experience and empiricism. Although some researchers have defined the stress–strain fields using 1–D cavity expansion theory but those analyses are applicable only where the plane strain condition prevails. This study proposes a 2–D FEM model for CPG that accounts variations in stresses due for self weight of the soil and over burden pressure and depicts stress and displacement fields along depth. The soil is assumed to be isotopic, homogenous and elastic material.

2. REVIEW OF LITERATURE

In the early 1950s, grouting contractors in California began experimenting with the use of low slump mortar-type grout. They discovered that they could inject the material under high pressure to densify loose soil formations beneath distressed structures. The term they used to describe this unique process was compaction grouting (CPG). Besides the densification effects of CPG, it has been used successfully for arresting foundation settlements Warner (1977, 1978, 1982). In recent years, CPG is becoming popular more as a liquefaction remediation in Japan. Yamuguchi et al. (2000) described the design and construction method of compaction grouting as a ground-improving technique against liquefaction. Many case histories e.g. Boulenger et al. (1993), Scherer and Gay (2000), etc., prove the use of CPG to treat liquefiable soils.

3. DEVELOPMENT OF THE MODEL

For estimation of the response of CPG treated ground of large extent, the unit cell idealization is assumed to be valid. It is also important to mention that the purpose of CPG is to confine the ground and it doesn't impart in strengthening the ground. Hence its effect is taken as injection pressure only. Fig. 1 depicts the unit cell idealization and the boundary conditions employed for the FEM. The unit cell of diameter, d_s, and of depth, H_s, is free from shear stresses on its peripheral surface and undergoes no lateral displacements. This is subjected to a uniformly distributed load, q_o. The soil is assumed to be homogenous and an isotropic elastic material. The process of CPG is idealized as an expansion of a cylindrical cavity of depth, H_G and of diameter, d_G due to application of injection pressure, P_G, at depth D_G. The finite element approach used is basically the same as that adopted for solving continuum problems. In the following section, predictions are made for a set of design/input parameters (Table 1).

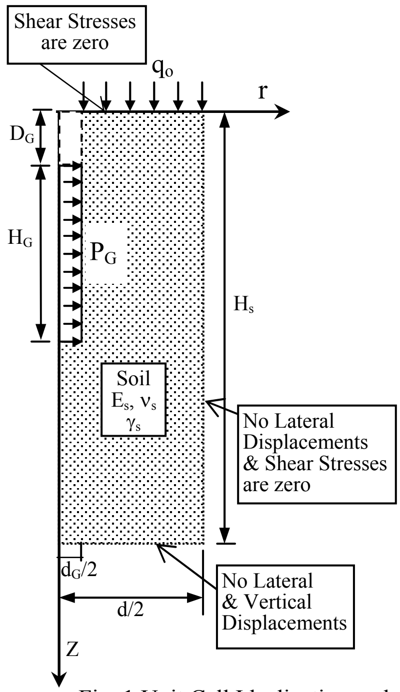

Fig. 1 Unit Cell Idealization and Boundary Conditions Employed.

4. RESULTS AND DISCUSSION

The compaction effect of CPG is defined in term of a parameter K_{II}/K_I i.e. ratio of coefficient of lateral earth pressure at application of injection pressure to before its application. Curves are plotted for five depths, 1 and 5 correspond to the bottom and top most of the cylindrical cavity (Fig. 2). At all depths, parameter K_{II}/K_I decreases rapidly with radial distance, r, upto 1/3rd of the total distance and further decreases gradually. For curve 3, the values are 15.35, 2.56 and 1.43 at r = 150, 350 and 950 respectively. At the same radial distance r, the vale of K_{II}/K_I increases from curve 1 to 4 while it decreases for curve 5. This trend is due to the impact of

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overburden pressure. Similar curves are plotted for radial displacement, u (Fig. 3). The values of u are effectively same at all the depths expect the bottom and the top most depth of cylindrical cavity. For curve 3, u is of value 22.8 at the closest point, r = 100 and it decreases sharply to value 7.08 upto r = 300 while further decreases slowly to value zero at the outer boundary. Effect of injection pressure, P_G, on the K_{II}/K_I at the mid depth of cavity cylinder for five radial locations, r, is depicted in Fig. 4. The trends of the curves are almost linear. At the radial distance, r = 350, the value of K_{II}/K_I are 1.41 and 4.26 for P_G of value 1000 and 2000 respectively.

5. CONCLUSIONS

A general finite element model has been developed to study mechanism of CPG. The compaction effect is defined in term of K_{II}/K_I, ratio of coefficient of lateral earth pressure at application of injection pressure to before its application and the radial displacement. This 2–D modeling is important as it takes into account the effect of overburden pressure and stresses due to self wt of soil. It is capable of defining stress and displacement field along depth The CPG is found to be more effective upto the 1/3rd of the total distance. The values do not change much with depth except at the top and bottom most depths of cavity cylinder. The variation of K_{II}/K_I is linear with injection pressure.

Table 1 Input values taken

Elasticity parameters, E & ν;	5000, 0.3
Unit weight of the soil	18 kPa/m^3
Depth, H_S and diameter, d/2 of unit cell	12000, 1000
Injection depth, D_G	1000
Depth, H_G and diameter, d_G/2 of grout cylinder	4000, 100
Over burden pressure, q_o	100
Injection pressure, P_G	1000

Note: All the dimensions and the stresses are in mm and kPa respectively.

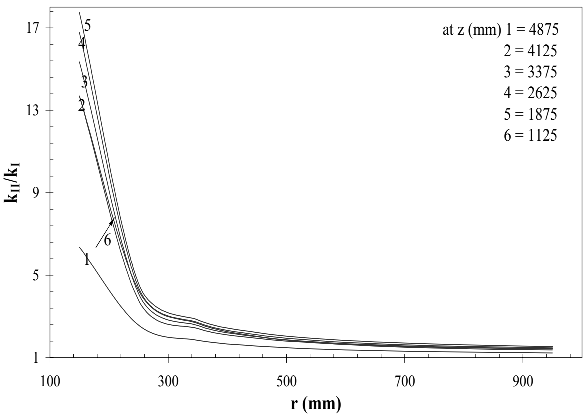

Fig. 2 Variation of parameter, K_{II}/K_I, with the radial distance.

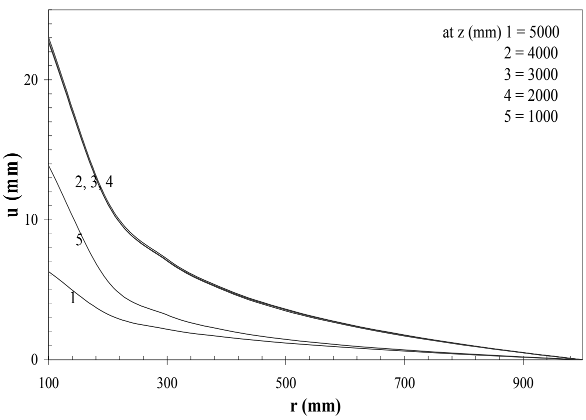

Fig. 3 Variation of u with the radial distance.

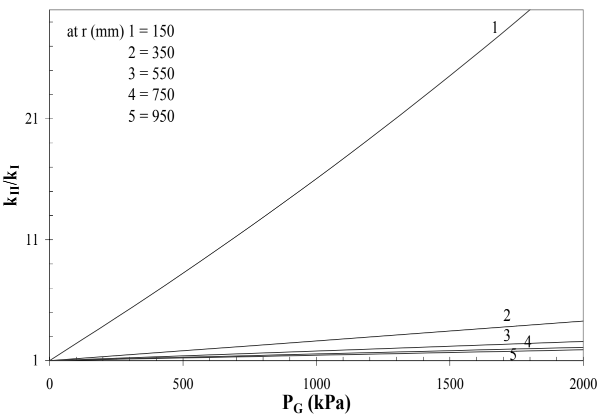

Fig. 4 Effect of injection pressure, P_G, on parameter, K_{II}/K_I.

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