ABSTRACT

In the present thesis, analytical, numerical and experimental studies have been conducted on stone column-improved ground under various loading conditions. Mathematical model is developed for prediction of settlement, stress and rate of radial consolidation for stone column-improved ground under axi-symmetric loading condition (i.e. circular embankment) by converting the stone columns to equivalent rings of stone keeping the area ratio constant. Mathematical models are also developed to study the soil-foundation interaction behavior of stone column-improved ground under uniformly loaded circular raft and cylindrical storage tank considering separation between the bottom raft and the ground under lift-off condition (i.e. tensionless foundation) which can occur in the bottom raft at certain loading conditions. In the developed models, the stone column, soft soil and granular fill are idealized as stiff non-linear spring, spring-dashpot system and Pasternak shear layer, respectively. The circular embankment is also idealized as Pasternak shear layer, whereas the raft is assumed to follow the theory of thin plate. In case of cylindrical storage tank, the raft is loaded with line load and moment along the periphery in addition to uniformly distributed load over the raft. The governing differential equations are derived and appropriate boundary conditions are applied for each loading condition. The solution is obtained using finite difference method. The developed models are simple and take less time for the analysis. However, the stone column-reinforced ground is actually a 3D problem. Therefore, some conversion techniques are used to convert the 3D problems to axi-symmetric (or plane strain) problem. To study the real 3D problem and check the effectiveness of the developed mathematical models, laboratory experiments and 3D numerical modeling (in *FLAC*^{3D}) are done on stone column-supported embankment. In the laboratory model test, nine stone columns arranged in square pattern are loaded with sand embankment. Model experiments are conducted for different spacing to diameter ratio of stone columns, surcharge load and embankment material with or without fine content in it. In the numerical simulation, square unit cell and strip models (strip of stone columns) are developed considering modified Cam clay model for soft soil and Mohr-Coulomb failure criteria for both embankment and stone aggregates. It is observed that the use of modular ratio up to 40 and spacing to diameter ratio in between three and four is suitable for effective design of stone columns. Tensionless foundation idealization for elastic foundation is essential for appropriate design under lift-off condition. Proper choices of density of granular fill, thickness or grade of concrete of the raft can avoid the lift-off as well as it can make the design economical by means of reduction of moments and shear force in the raft. Charts are provided for maximum stress concentration ratio at different height of embankment, geometry of stone columns and modular ratio. Arching ratio increases and stress concentration ratio decreases with the increase of fine content in the embankment material. Change in settlement is insignificant beyond 20% fine content in the embankment soil. No differential settlement can be observed on the embankment surface if the embankment height (i.e. critical height) is more than 2 times the clear spacing between the stone columns for embankment soil without any fines and the value is increased to 2.6 when fine is present in the embankment soil. It is further observed that the developed mathematical models predict the response of the improved ground properly with a maximum 10% variation as compared to the results obtained from the actual 3D numerical analysis.

Keywords: Stone column, elastic model, tensionless foundation, embankment, raft, storage tank, axi-symmetric, laboratory model test, *FLAC*^{3D}.