CHAPTER 7

SUMMARY AND CONCLUSIONS

7.1 Summary of the thesis

The objective of the present study was to investigate the effect of various parameters such as the effect of the shape of the footing, the relative density of subgrade sand, the geometry of the geocell reinforcement, and the relative density of infill sand (in the geocells) on the performance improvement of geocell-reinforced sand. Three types of footing such as square, rectangular, and strip footings were used to investigate the effect of the shape of footing on unreinforced and geocell-reinforced sand foundations with geocell with d/B = 0.5, h/B = 0.66, u/B = 0.1, b/B = 3 & $D_{r,}$ = 70%. Thereafter, a series of laboratory model load tests were carried out to investigate the effect of various parameters such as relative density of subgrade sand (D_r), placement depth of geocell reinforcement from the base of the footing (u), the equivalent diameter of geocell pocket (d), the height of geocell reinforcement (h), the width of geocell reinforcement (b) and relative density of infill sand in the geocells ($D_{r,\text{ infill}}$) on the behaviour of geocell-reinforced sand under static and repeated loading.

The test results obtained from two different loading conditions, static load, and repeated load, are presented and discussed in two chapters, for both unreinforced and geocell-reinforced sand beds. The results are presented in terms of bearing pressure-settlement and surface deformation profiles. Besides, different bearing pressure ratios are introduced to compare the foundation behavior and reinforcement contributions. In the subsequent chapter, the regression analysis carried out on the experimental data obtained from the model load tests is presented. Statistical analysis was conducted to develop an empirical equation to estimate the bearing capacity of the reinforced foundation as a function of various test parameters such as footing settlement (s), depth of placement of reinforcement layer (u), pocket size of geocells (d), the height of geocell layer (h), friction angle of soil (φ) and soil-geotextile interfacial friction angle (δ_s). A multiple regression approach was adopted to develop the models wherein the bearing pressure of reinforced bed (q_R) is taken as the dependent variable while the rest of the parameters were considered independent variables. The regression model developed in this study can be used in actual field conditions for making a preliminary design of a square foundation supported by the sand-geocell system.

7.2 Conclusions

Based on the experiments and parametric study carried out in this investigation, the following major conclusions can be made on behaviour of geocell-reinforced sand beds under static and repeated loads.

Unreinforced and geocell-reinforced sand under static loads

- The model tests performed on the unreinforced sand beds depicted a local shear failure in square and rectangular footing and a general shear failure in strip footing. Contrarily, in geocell-reinforced sand beds no clear failure modes were observed for all three types of footings even up to a large settlement of s/B = 22%. Further, a higher bearing capacity improvement factor (*IF*) was observed for square and rectangular footing as compared to strip footing.

- The performance improvement of geocell-reinforced sand bed was found to have increased with a decrease in the denseness of subgrade sand bed i.e. the contribution in improving the load carrying capacity of geocell reinforcement was more significant at low-density subgrade sand than the high-density subgrade sand bed. Furthermore, the geocell reinforcement almost arrested the surface heaving of soil irrespective of which relative density of sand bed the footing was rested.

- The critical placement depth of the geocell reinforcement layer (u) that gave maximum performance improvement was about $0.1B$ from the base of the footing.

- The performance improvement in bearing capacity increased with a reduction in the geocells pocket size (d). However, when the footing size was larger than the geocell pocket size, the performance improvement was substantially high. Further, the heaving of the soil surface was more predominant for a geocell pocket size higher than the footing size. Thus, for all practical applications, the geocell reinforcement layer and footing should be designed such that the footing completely covers at least one geocell pocket opening.

- The performance improvement of the geocell-reinforced sand bed increased with an increase in height of the geocell layer. However, the efficacy of improvement was marginal beyond h/B =0.66. Besides, the surface heaving of the soil surface reduced with the increase in height of geocell reinforcement.

- The bearing capacity improvement factor increased with an increase in the geocell reinforcement width. However, when reinforcement width reached an optimum value ($3B$), the effects of improvements became marginal. Further, surface heaving on the soil surface is reduced with an increase in the width of geocell reinforcement.

- The performance improvement of the geocell-reinforced sand bed increased with an increase in the relative density of infill soil. Therefore, to achieve the optimum performance of geocell reinforcement soil, the infill soil should be compacted at the highest possible state.

Unreinforced and geocell-reinforced sand under repeated loads

- In cases where structures are very sensitive to settlement, geocell reinforcement can be effectively used to obtain the same allowable load-carrying capacity at a much lower settlement for the same soil density.

- For the same initial static load intensity and the number of load cycles, the magnitude of total settlement due to repeated loading decreased with the use of the geocell layer.

- For the same number of load cycles, the total settlement due to repeated load increased with increasing initial static load level.

- The total settlement was found to have increased with the number of load cycles at a gradually decreasing rate. For all the tests, most of the total settlement was observed to have occurred due to the first ten cycles, and thereafter, the rate became slower until the number of cycles reach 30 cycles.

- The optimum embedded depth of the geocell layer beneath the footing under repeated loads was approximately $0.1B$.

- The total settlement of footing under repeated load increased with an increase in the equivalent diameter of geocell pocket size. This happened because of increase in geocell pocket size decreased the confinement effect of soil and frictional resistance of the soil-geocell interface.

- Increasing the height of the geocell layer resulted in better performance of geocell-reinforced sand beds due to the better load spreading of the composite system. However, the beneficial effect became marginal after a certain height ($h/B = 0.66$).

- For a given value of the magnitude of repeated load, with an increase in the width of geocell reinforcement, the cumulative footing settlement decreased. However, the efficacy decreased with an increase in the width of reinforcement after a certain value ($b/B = 3$).

- With the increase in the relative density of subgrade sand, the total settlement decreased due to an increase in the stiffness of the foundation bed. Further, the benefit of reinforcement was more evident at the higher magnitude of repeated load due to the active participation of soil and reinforcement as a composite material.

Regression model

- The proposed regression model was found to be reasonably good in predicting the bearing capacity of the reinforced foundation bed under square loading.

- The model can be useful for making a preliminary design of a square foundation supported on a sand-geocell system.
- The regression model developed in this study is applicable to square footings resting on geocell-reinforced sand, with the following conditions for the parameters: $35\% \leq D_r \leq 90\%$, $0 \leq s/B \leq 0.14$, $0 \leq u/B \leq 0.25$, $0.33 \leq d/B \leq 1.5$, $0.33 \leq h/B \leq 1.25$, $2 \leq d/B \leq 5$.

7.3 Scope for future research

- Instrumentation facilities can be installed to measure the deformations in the geocell wall to estimate the membrane and interfacial resistance. Further, it will be helpful in the formulation of theoretical models.

- Numerical models can be developed and validated with experimental observations. In the future, these models can be used to analyze the behaviour of prototype foundations.

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