Effects of unreinforced /reinforced sand layers coupled with / without sand columns on bearing capacity – settlement of soft clay

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Received: 15 Oct. 2019 Accepted: 26 Jul. 2020
(Paper pages 437-454)

Abstract

In current paper the effects of surface unreinforced / reinforced sand layers coupled with and without single and group sand columns on the bearing capacity – settlement behavior of soft clays has been investigated. In this regard behavior of soft clay, clay + unreinforced / reinforced sand layer, clay + single / group sand piles and clay + unreinforced / reinforced sand layer + single / group piles samples has been assessed. Geogrid was adopted as the reinforcement, a circular plate 5cm in diameter as the loading surface and C.B.R. apparatus as the loading system. Results show that employing unreinforced / reinforced sand layers at a settlement ratio of 5% improves bearing capacity by 4 t0 7 times the soft clay. Coupling the surface unreinforced / reinforced sand layers with single / group sand piles further increases the bearing capacity by 7 to 9 times that of soft clay.

Keywords: Bearing capacity, soft clay, sand column, reinforcement, geogrid.

Extended Abstract

Introduction

Natural soft clay soils due to the lack of sufficient bearing capacity and the high deformation potential require to be improved using either chemical stabilization methods or physical methods such as soil reinforcement or pre-compression. The method used is greatly influenced by technical and the economic considerations as well as the physical characteristics required (Abdi and Zandieh, 2014, Ibrahim, 2014, Ramadan and Hussien, 2015). Chemical stabilization generally results in increasing the strength and the

bearing capacity and reduces the swelling – shrinkage potential of the clayey soil. On the other hand from ancient times humans have used natural fibers to alleviate the weakness of soil in resisting tensile stresses (Abu-Farsakh et al., 2008). Now-a-days due to the technical progress made, synthetic materials such as geo-synthetics are used for soil improvement. Use of geo-synthetics such as geogrids and geotextiles have grown rapidly in the construction of soil structures such as embankment dams for reducing the volume of materials needed as well as drainage purposes, increasing bearing capacity and reducing the settlement of soft clays and foundations etc. These materials are easy to use and environmentally friendly. Coarse grained materials are also employed in construction of reinforced soil structures due to high drainage and shear strength characteristics as well as volume stability due to moisture variations and time (Alawaji, 2001). In current research the effects of unreinforced /reinforced sand layers together with / without single / group piles on the bearing capacity – settlement behavior of soft clays has been assessed using CBR apparatus as the loading system.

Methodology

In this study the effects of unreinforced and geogrid reinforced sand surface layer coupled with / without single / group sand piles on bearing capacity and settlement of soft clay has been evaluated experimentally using CBR equipment as the loading system. In this regard sand has been used as the coarse surface layer, geogrid as the reinforcement together with sand piles with diameters of 4, 6 and 8cm. Box with the dimensions of 320×320×350mm was used for the preparation of the soft clay samples and geogrid samples were cut 290 × 290mm and positioned in the middle of the sand layer. A circular metal plate 50mm in diameter and 25mm in thickness was used as the loading surface. The clay with liquid limit, plastic limit and plasticity index of 32, 19 and 13% respectively was classified as CL according to Unified Soil Classification System (USCS). It was prepared with a moisture content of 25% o be considered as soft clay and kept in plastic containers for 48 hours to reach moisture uniformity. The sand used as the surface layer as well as the sand columns was classified as SP according to USCS. After preparation of the samples, the box was placed on the CBR apparatus, baring plate and gauges with set and loading was applied at a rate of 1.27mm/min. Loading was applied up to a maximum settlement of 1B. Figure 1 shows the picture of the test set up and the various combinations tested.

Results and discussion

Results of tests conducted on the soft clay and the sand samples which were used as a basis for comparison are shown in Fig. 2. As can be seen bearing capacity gradually increases with settlement ratio for the soft clay whereas for the sand it increases sharply up to a settlement ratio of approximately 10% and then reduces with further settlement. Using unreinforced / reinforced sand layers on soft clay has significantly improved the bearing capacity and reduced the settlement ratio as depicted in Figure 3. The concurrent reinforcement of the surface sand layer and inclusion of single and group piles has dramatically improved the bearing capacity and settlement behavior of the samples such that even after settlement ratio of 50%, the bearing capacities are still increasing.

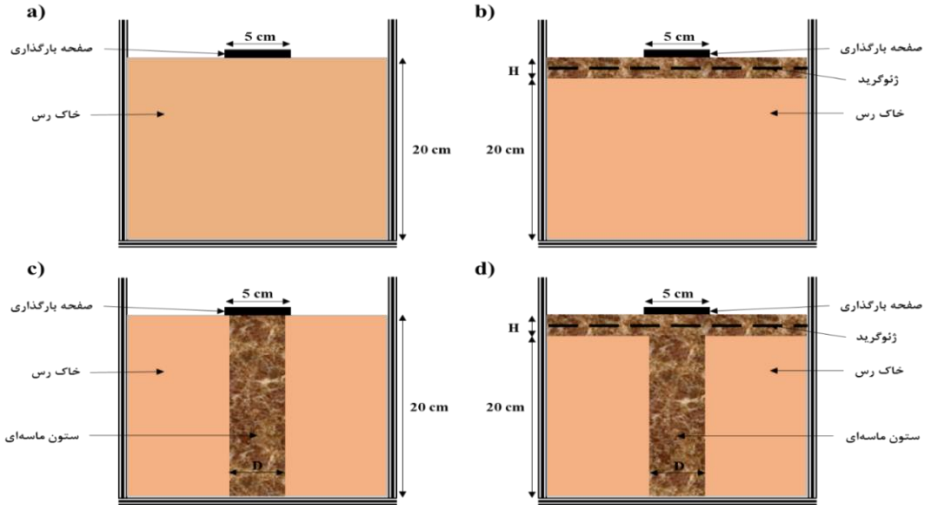

Figure 1: Various combinations tested

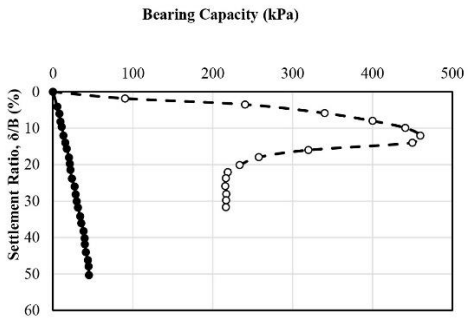

Figure 2: Variations of settlement ratio – bearing capacity for soft clay and sand

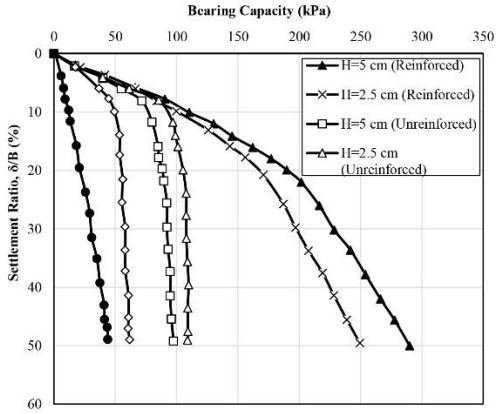

Figure 3: Variations of settlement ratio – bearing capacity for soft clay and soft clay + unreinforced / reinforced sand layer

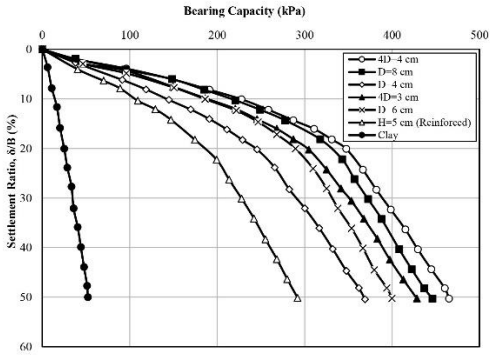

Figure 4: Variation of settlement ratio – bearing capacity for soft clay + reinforced sand + single / group piles

Conclusions

Using unreinforced / geogrid reinforced sand surface layer enhances the bearing capacity – settlement behavior of soft clays. Reinforcing the surface sand layer alters the shear failure mechanism of the soft clay sample. Using thin sand layers with thicknesses of 0.1 to 1B unreinforced or reinforced with one geogrid layer , increases the bearing capacity by 9 times at a settlement ratio of 10%. The inclusion of single / group piles in the soft clay has also enhances the bearing capacity / settlement behavior of the soft clay. Results show that sand surface layer thickness has significant influence on bearing capacity – settlement behavior at low settlement ratios whereas sand pile diameter becomes a significant factor at larger settlements.

References

Abdi, M.R. and Zandieh, .R.,"Experimental and numerical analysis of large scale pull out tests conducted on clays reinforced with geogrids encapsulated with coarse material", Geotextiles and Geomembranes, 2014, 42, pp. 494-504.

Ibrahim, K.M.H.I. (2014). Bearing capacity of circular footing resting on granular soil overlying soft clay. *Housing and Building Research Center*. 12, 71-77. https://doi.org/10.1016/j.hbrcj.2014.07.004

Ramadan, M. I., & Hussein, M. H. (2015). Bearing capacity of sand overlying clay strip footing. *International Journal of Science and Research (IJSR)*, 4(11), 1852-1859.

Abu-Farsakh, M., Chen, Q., Sharma, R. and Zhang, X, (2008). "Large scale model footing tests on geogrid-reinforced foundations and marginal embankment soils", Geotechnical Testing Journal, ASTM 31 (5), pp. 413-423.

Alawaji, H.A. (2001). "Settlement and bearing capacity of geogrid-reinforced sand over collapsible soil", Geotextiles and Geomembranes, No. 19, pp. 75-88.

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