Numerical investigation of T-shaped soil-cement column supported embankment over soft ground

Yi, Yaolin; Ni, Pengpeng; Liu, Songyu

2018

Yi, Y., Ni, P., & Liu, S. (2018). Numerical investigation of T-shaped soil-cement column supported embankment over soft ground. 2018 Proceedings of China-Europe Conference on Geotechnical Engineering, SSGG, 1068-1071. doi:10.1007/978-3-319-97115-5_40

https://hdl.handle.net/10356/144569

https://doi.org/10.1007/978-3-319-97115-5_40

Numerical Investigation of T-Shaped Soil-Cement Column Supported Embankment Over Soft Ground

Yaolin Yi[1](✉), Pengpeng Ni[1], and Songyu Liu[2]

[1] School of Civil and Environmental Engineering, Nanyang Technological University,
Singapore 639798, Singapore
`yiyaolin@ntu.edu.sg`
[2] Institute of Geotechnical Engineering, Southeast University, Nanjing 210096, China

Abstract. Deep mixing is a technique to stabilize soft soils *in situ* by mixing with cementitious binders to form columns. An innovative soil-cement column is proposed, with an enlarged column cap at shallow depth, and as such the column shape is analogous to a letter "T". This paper presents a numerical investigation on the performance of T-shaped soil-cement column supported embankment over soft ground. The sensitivity of differential settlement between soil and column, as well as soil and column stresses in the middle of the embankment to the diameter and the height of the enlarged column cap is systemically studied.

Keywords: T-shaped column · Embankment · Numerical modelling

1 Introduction

The surcharge load induced by highway embankments can result in excessive settlement in soft ground, and the deep cement mixing method is often used to stabilize soft soils. Liu et al. [1] originally conceived the idea of increasing the diameter of column cap at shallow depth for deep mixing soil-cement columns as illustrated in Fig. 1, and the field performance of a highway embankment section supported with T-shaped columns was encouraging compared to another section above conventional columns with a fixed diameter [1, 2]. Yi et al. [3] conducted laboratory modelling of T-shaped and conventional column-treated soft ground under embankment loading, and found that the differential settlement of T-shaped column-treated ground was significantly lower. As a further work, this study employs three-dimensional numerical model to investigate the impacts of the diameter and the height of the enlarged column cap on the performance of T-shaped soil-cement column supported embankment.

2 Numerical Modelling

~~The~~ embankment over soft soils is studied using a commercially available computer program, FLAC-3D. Due to symmetry, a half embankment model is established, and the dimensions of the model are given in Fig. 1. A fine mesh is defined near the T-shaped

I. W. Wu and H.-S. Yu (Eds.): *Proceedings of China-Europe Conference on Geotechnical Engineering*, SSGG, pp. 1–4, 2018.
https://doi.org/10.1007/978-3-319-97115-5_40

soil-cement columns and the meshes become coarser at a far distance from the embankment. The bottom boundary is fixed in all degrees of freedom, and the lateral boundaries are restrained in the normal direction. The groundwater table is assumed at the ground surface, where a fully drained boundary is adopted. The embankment fill, soft clay, bearing stratum and soil-cement columns are all characterized as Mohr Coulomb materials with parameters under the drained conditions (see Fig. 1). This is to simulate the long-term performance of the embankment. The soil-cement column has a fixed D_2 of 0.5 m and L of 12 m. All columns are arranged in a squared pattern with a spacing of S = 1.8 m. The beneficial effect of T-shaped column with three D_1 values (0.75, 1.0 and 1.25 m) and three L_1 values (2, 4 and 6 m) on the performance of embankment compared to the conventional fixed diameter column is investigated.

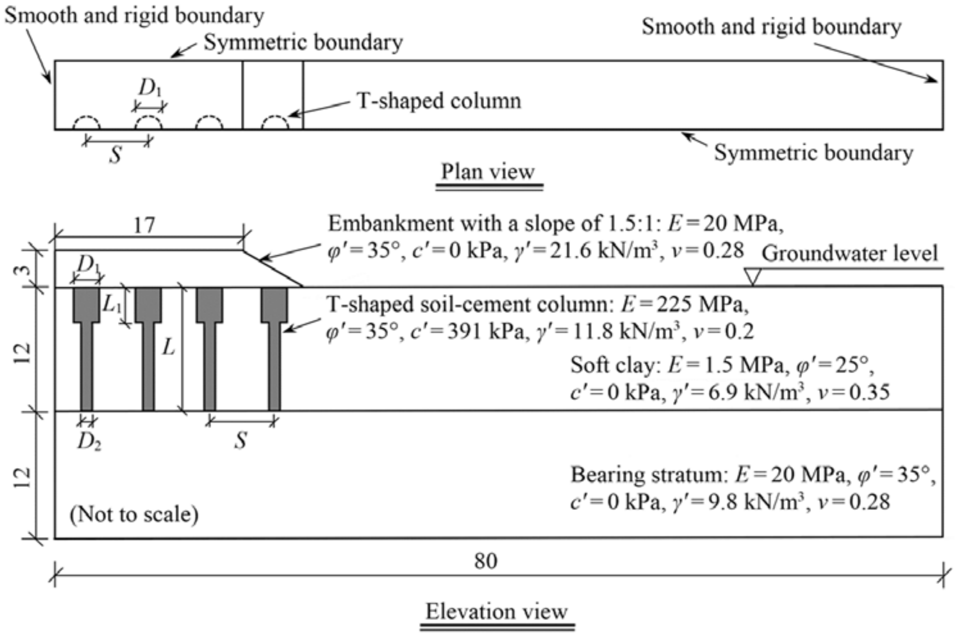

Fig. 1. Schematics of a T-shaped soil-cement column supported embankment (unit: m).

3 Numerical Results

In the middle of the embankment, the maximum settlement of soil occurs at the ground surface, and it decreases with depth as presented in Fig. 2a. For T-shaped columns, the enlarged column cap can help to reduce the maximum soil settlement significantly by approximately 50% compared to the conventional column. When the enlarged column cap has a larger diameter and a higher height, the soil settlement is smaller. All studied scenarios have the same area replacement ratio below 8 m, where the profile of soil settlement with depth becomes similar, indicating that the enlarged column cap does not influence the magnitude of soil settlement at greater depths. The variations of column settlement with depth are plotted in Fig. 2b. The magnitude of column settlement calculated for both T-shaped and conventional columns is similar. In general, a low column settlement is obtained when the column cap has a higher L_1 and a lower D_1.

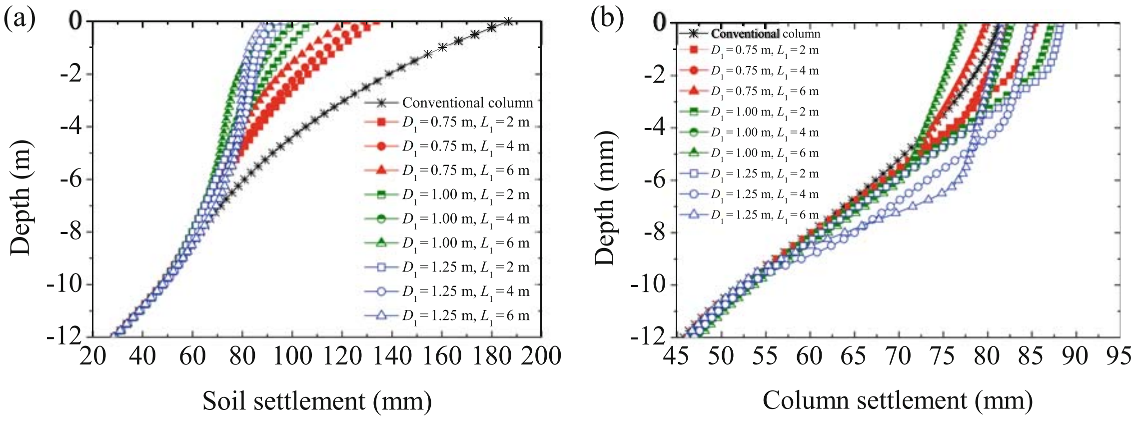

Fig. 2. Variations of settlement with depth: (a) soil, and (b) column.

The variations of differential settlement between soil and column with depth are calculated in Fig. 3a. The soil between columns settles more than the settlement of column itself at shallow depths for both T-shaped and conventional columns. It should be noted that the differential settlement is decreased significantly by introducing an enlarged column cap, which enables load redistribution and minimizes the detrimental effect of negative skin friction mobilized ~~by~~ at the soil-column interface. With the increase of depth, the differential settlement becomes positive. A higher positive settlement demonstrates that the column tip penetrates the bearing stratum. As presented in Fig. 3b, the maximum differential settlement is inversely proportional to the D_1 value. The influence of L_1 on the mobilized differential settlement is relatively negligible. In design, a higher value of D_1 should be selected, but the value of L_1 can be minimized.

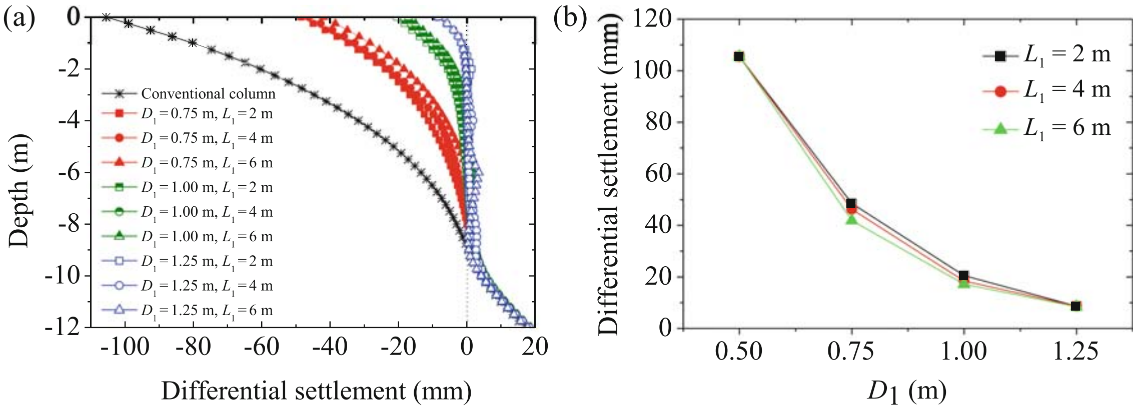

Fig. 3. Differential settlement: (a) profile with depth, and (b) influence of column dimensions.

The profiles of column stress with depth in the middle of the embankment are plotted in Fig. 4a. The equivalent unconfined compressive strength of the column is 1000 kPa. For the conventional column, the column stress increases almost linearly with depth, and the peak value is much less than the strength, indicating ~~a waste of the column in design~~. For T-shaped columns, a lower stress is mobilized in the column cap, and a sudden increase of stress can be observed below the column cap. The column cap should be designed to have a larger cap diameter, but a smaller cap height to fully utilize the strength along most of the column height. The profiles of soil stress between columns with depth in the middle of the embankment are plotted in Fig. 4b. At the ground surface, the soil stress is significantly lower than the column stress due to the arching effect occurred in the embankment. The column cap of T-shaped columns acts as a load transfer platform, which further reduces the soil stress compared to the conventional column-treated ground. This effect is mainly controlled by the value of D_1 while nearly not influenced by the value of L_1 (Fig. 4b).

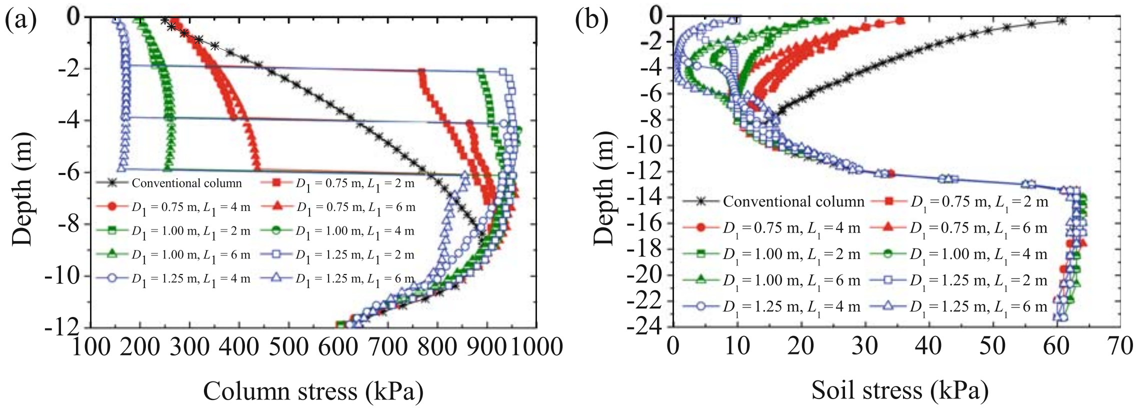

Fig. 4. Variations of (a) column stress, and (b) soil stress with depth.

4 Conclusions

The numerical study shows that the use of T-shaped column can significantly reduce the differential settlement between soil and column under embankment loading compared to the conventional column. The differential settlement is inversely proportional to the cap diameter, while the cap height has a negligible effect. Hence, a larger cap diameter and a smaller cap height are recommended for practical design.

References

1. Liu, S.Y., Du, Y.J., Yi, Y.L., Puppala, A.J.: Field investigations on performance of T-shaped deep mixed soil cement column–supported embankments over soft ground. J. Geotech. Geoenviron. Eng. **138**(6), 718–727 (2012)
2. Yi, Y., Liu, S., Puppala, A.J., Xi, P.: Vertical bearing capacity behaviour of single T-shaped soil–cement column in soft ground: laboratory modelling, field test, and calculation. Acta Geotech. **12**(5), 1077–1088 (2017)
3. Yi, Y., Liu, S., Puppala, A.J.: Laboratory modelling of T-shaped soil–cement column for soft ground treatment under embankment. Géotechnique **66**(1), 85–89 (2016)