

MEMBRANE-CONFINED STEM-GROUTED PILES

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ABSTRACT:

Conventional deep foundations with high uplift resistance, such as enlarged base/belled/under-reamed piles, often pose significant challenges in terms of quality control and assurance. The concerns arise from uncertainties regarding the stability of the cavity and the proper bulb formation during the construction process. Specifically, the collapse of enlarged/reamed zones during reaming operations is inevitable in sands and saturated fine-grained soils, and the associated stress relief from the surrounding soil leads to lower axial capacity for such piles. This research introduces “membrane-confined stem-grouted pile” as an effective alternative foundation system to overcome collapse and stress relaxation issues and offer significant uplift as well as compression resistance. The stem-grouted pile is essentially a bored cast-in-situ pile with a nearly spherical grout bulb formed by membrane-confined pressure grouting. The constructability and suitability of the membrane-confined stem-grouted pile under the uplift and compression loading scenarios were investigated through experimental and numerical investigations. The experimental studies revealed an enhanced soil stress state around the grout bulb, as well as improved skin and bearing resistances due to stem grouting. The finite element modelling of the stem-grouted pile was performed using a three-dimensional finite element software, PLAXIS 3D. The numerical investigation aimed to visualize the failure pattern during uplift loading and understand the variation in the soil stress state during grouting and pull-out load testing. Based on the failure mechanism observed from the finite element modelling, an analytical method for predicting the uplift resistance of stem-grouted piles was developed. The study affirms that the stem-grouted pile can overcome the collapse and stress relaxation issues inherent in the aforesaid piles and offers significant uplift resistance. Moreover, pressure grouting with membrane confinement is possible at any depth, even in unfavourable soil conditions (problematic soil, high water table, etc.), unlike the limitations associated with the reaming operation. Recognising that deep foundations often encounter combined loading conditions, this study was extended to investigate the behaviour of stem-grouted piles under coupled axial (uplift/compressive) and lateral load to assess their suitability for practical field applications.

The influence of axial loads (both compression and uplift) on the lateral response and vice versa of stem-grouted piles installed in sand was investigated using three-dimensional numerical analysis; their performance was compared with that of similar-sized underreamed piles. A detailed parametric analysis was conducted by varying the number of bulbs and bulb configuration (i.e., bulb position and bulb spacing) to understand their influence on the combined load response. The results concluded that stem-grouted piles outperformed underreamed piles, with certain bulb configurations providing a balanced enhancement in both axial and lateral resistance. Overall, the findings of this research offer valuable practical insights into the application of stem-grouted piles under complex loading conditions, underscoring their effectiveness in overcoming limitations associated with conventional piles while providing enhanced load resistance for reliable field performance.

Keywords: bored cast-in-situ pile, cavity expansion solution, cohesionless soil, residual soil, finite element modelling, stem-grouted pile, uplift resistance, grouting effectiveness, combined loading, underreamed pile, soil-pile interaction.