Effect of Stone Column- Pile Combination on Settlement and Evaluation of Factors Affecting Bearing Capacity

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ABSTRACT

Improving difficult and soft soils by means of stone columns is a favored technique to strengthen their ability to support loads. Yet, when loads are high or the subsoil is extremely soft, stone columns by themselves may not perform as they should. However, piles support heavy loads well, but they do not allow for drainage and are easily liquefied. We hope to understand how a compound system of stone and piles performs better than each part on its own, by using PLAXIS 3D software to model the system. The results of a raft at 10×10 meters on soft clay were compared against a system with no reinforcement, ground treated only with stone columns and ground treated only with piles. The way changes in diameter, length and the spacing of several stone columns impact their ability to support loads was also looked into parametrically. The data revealed that together, the reinforcements and raft material cause a big rise in bearing capacity and improved safety by decreasing settlement. It was found that a higher number of stone columns were the best solution for the raft foundation. The parametric study revealed that the bearing capacity of the stone column is mainly affected by its diameter.

Keywords:

Stone Column, Pile, Settlement, Bearing Capacity, Combined Ground Improvement

1. INTRODUCTION

Today, because more construction is needed and good land is limited, improving difficult and problematic soil is a significant challenge in geotechnical engineering. A number of suggestions have been made to better the engineering performance of soils, including their strength, ability to hold up loads and how much they compact. One of the ways architects solve this problem is by using columnar elements. Since the 1950s, engineers have used compacted rock granules in Europe to raise the strength of soft soil using stone columns. In addition, these columns raise the load capacity and help prevent settlement, reduce liquefaction risk and encourage fast consolidation because they are so permeable [1] . Other frames, particularly those with concrete piles, are described as durably transferring loads to the stronger underlying strata. Many papers have investigated the efficiency of stone columns and piles independently [1], [3], [4], [5].

2. NUMERICAL SIMULATIONS

Experts believe that stone columns used in combination with piles on a (rigid) raft can help achieve the best cost and performance for foundations in soft soil. In order to check the performance of these cases geotechnically, PLAXIS 3D, a 3D finite element software, was used [6]. By testing various ideas, we designed the model's geometry to prevent stresses acting in only the horizontal or vertical directions. The entire 3D model, starting from the base to the peak, measured 100 m in both directions and 60 m high. This 3D model has the bottom supported by a fixed stand and it is believed that there are roller supports along the vertical boundaries, each visible in Figure 1. The entire surface received uniform pressure from a 10 meter by 10 meter rigid raft (Figure 1).

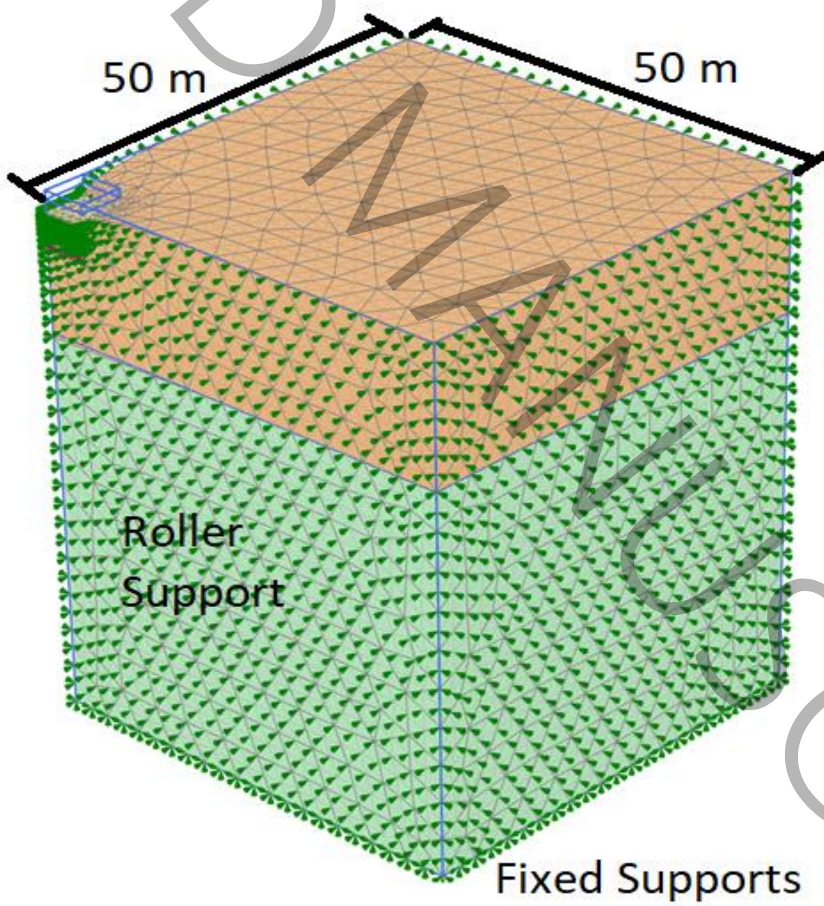

Fig.1. Plaxis 3D model with boundary conditions.

The success of any finite element analysis relies heavily on the mesh size. Results using a finely meshed model are very similar to the real behavior, but the analysis probably takes longer. In the reported study, interface elements of suitable strength (R_{inter} = 0.67) were added between the pile, column, raft and clay soil as a link. Arrangement of the mesh included 15-noded components, while the critical areas had especially fine element plots [6]. Initial in-situ stresses were examined, followed by excavation, setting the reinforcement elements, constructing the raft and applying loads, either controlled by settlement or by its collapse.

3. RESULTS AND DISCUSSION

Simulations were carried out for raft foundations (10x10m) placed on layers of soft clay (CL7) and (CL30) (material properties given in Table 1).

The CAD model was built in 3D using symmetry, with only a single quarter of the system actually built. Some cases were improved by modeling piles or stone columns (specific shape: diameter of 0.7 m and length of 20 m) beneath the 10 by 10 meter raft in different configurations.

The conclusions based on stone columns here corresponded to those made in [1], so the results can be trusted.

Table 1. Material properties for the stone column, piles, and rigid raft.

Properties	CL7	CL30	Stone column	Pile	Raft
Unit weight, γ(kN/m^3)	13.36	15.56	16	-	-
Young's modulus, E_s(MPa)	2.15	5.5	55	23.5×10^3	23.5×10^3
Drainage Type, D_T	Undrained A	Undrained A	Drained	-	-
Poisson's ratio, ν'	0.33	0.33	0.3	0.15	0.15
Angle of friction, ϕ' (°)	27	27	43	-	-
Cohesion, c' (kN/m^2)	7	30	23	-	-
Diameter (m)	-	-	0.5, 0.7, 0.9	0.7	-
Length (m)	-	-	10, 15, 20	20	-
distance (m)	-	-	3.15, 3.65, 4.15	3.65	-

4. CONCLUSION

To investigate the performance, numerical research was carried out on the use of a pile-stone column system in soft clay soil, with the aid of PLAXIS 3D software. The most important findings are summarized as follows:

1. Once piles and stone columns are incorporated into a foundation system, there is an increase in bearing strength, the soil becomes improved and geotechnical works become much cheaper.

2. This arrangement which combines piles and stone columns, causes less settlement and provides stronger support than piles or stone columns used alone in other plans (in some scenarios).

3. A better system design is to place more stone columns to reduce settlement.

4. The diameter of a stone column plays the biggest role in raising its bearing capacity. Almost doubling the diameter from 70 to 90cm resulted in much improved bearing capacity, while increasing the length from 15 to 20 meters had a minor effect. About five times the diameter of each column was determined to be the right spacing.

5. Adding more piles to the composite system makes the foundation base able to handle higher loads.

6. PLAXIS 3D software can be used to assess and compare various soil improvement systems and make sure their designs are right.

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