Study of the Behaviour of Pervious Concrete Pile Under Vertical and Lateral Loading

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***Abstract*- Granular column ground-improvement methods are widely used to improve bearing capacity and provide a drainage path. However, the behaviour of granular columns depends on the confinement provided by the surrounding soil, which limits their use in poor soils. A new ground-improvement method is proposed using pervious concrete piles to provide high permeability while also providing higher stiffness and strength, which are independent of surrounding soil confinement. This paper investigates the behaviour of Pervious concrete piles under Vertical and Lateral loading and the effects of installation on their response.**

Keywords: Pervious Concrete pile, Granular column, Axial loading, Lateral loadin

I. INTRODUCTION

Permeable ground-improvement columns made of granular materials (i.e., stone columns, sand compaction piles, and rammed aggregate piers) are commonly used to improve the load-carrying capacity and to provide a drainage path for soft cohesive and loose cohesionless soils. Combined high stiffness and permeability allows the use of permeable ground-improvement granular columns in applications to reduce liquefaction potential, increase consolidation rate, improve bearing capacity, reduce settlement, improve embankment stability, and stabilize slopes (Barksdale and Bachus 1983; Mitchell 1981; Aboshi and Suematsu 1985; Bergado et al. 1994; Baez 1995; Terashi and Juran 2000; Okamura et al. 2006; Elgamal et al. 2009; Stuedlein and Holtz 2013). When subjected to lateral loading, such as to stabilize slopes or during an earthquake, permeable granular columns fail in direct shear at the location of loading or along the slope failure surface.

Developing a ground-improvement alternative that combines the high permeability (drainage) of granular columns with the high strength and stiffness of concrete piles (independent of soil confinement) will be attractive and may lead to increased use of permeable ground-improvement piles for soft soils and loading conditions not considered before.

II. MATERIAL AND TEST PROCEDURE

A. Sand

The soil used in the two lateral load tests was classified as poorly graded sand (SP) using the Unified Soil Classification System.

Table.1: Sieve analysis results

Sieve size(mm)	Cum. Wt of sample retained (g)	% of sample retained	% finer
4.75	14.820	2.964	97.036
2.36	33.44	6.688	93.312
1.18	303.44	60.688	39.312
0.6	422.15	84.430	15.570
0.425	468.38	93.676	6.324
0.3	483.69	96.738	3.262
0.075	500.00	100.000	0.000

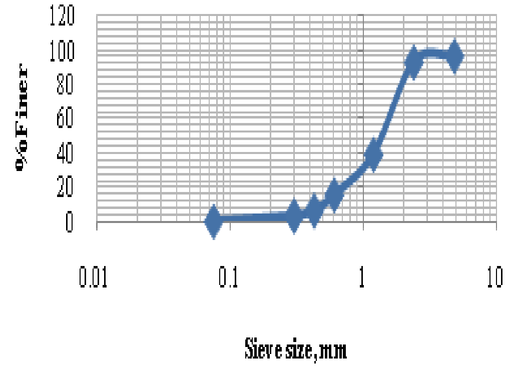

Fig 1: Particle size distribution of sand sample

Table 2: Physical property of sand used

Soil	G	D60 (mm)	D30 (mm)	D10 (mm)	Cu	Cc	Type
Sand	2.615	1.44	0.94	0.48	3	1.278	SP

The minimum and maximum unit weights of sand at oven-dry condition obtained from minimum and maximum relative density tests [ASTM D4253 (ASTM 2009a) and ASTM D4254 (ASTM 2009f)] were 15.10 and 18.20 kN/m^3. The Density index of Sand was found to be 0.188. The specific gravity test of the Sand obtained from testing is found to be 2.615.

B. Pervious Concrete

The mixture with 0.26 water/cement ratio, 0.07 sand/aggregate ratio, 343 kg/m3 cement, and 1,510 kg/m3 coarse aggregate, 0.49 kg/m^3 Air Entraining Admixture and 0.96 kg/m^3 High Range Water Reducers was used for casting the test piles. The Aggregate used for pile casting

was washed and sieved, and the portion passing the 9.5 mm sieve and retained on the 4.75 mm sieve was used.
This mixture was selected because it has a high permeability (1.41 to 1.47 cm/s) comparable to the permeability of granular columns [ranging from 0.05 to 2.0 cm/s according to Baez (1995) and Barksdale and Bachus (1983)].

C. Tests on Pervious Concrete

Pervious Concrete samples are tested for the compressive strength. The results thereby obtained showed that the value of Compressive strength ranges from 21.9 to 23.5 MPa, which is within the range of normal concrete compressive strength. Samples cut from the test piles were used to measure the porosity and permeability of the two piles. The permeability and porosity for the precast pile were 1.33 cm/s and 10.4%, respectively. For the cast-in-place pile, the permeability and porosity were 1.51 cm/s and 11.3%, respectively.

D. Axial and Lateral Load setup

A test tank of 30 cm Φ and 30 cm height is used to determine Axial load carrying capacity of Granular column. The dimension of the tank is chosen based on following criteria:

$$\frac{Em\, Im}{Ep\, Ip} = \frac{1}{10^n}$$

Where
E_m = Modulus of elasticity of model pile
E_p = Modulus of elasticity of prototype pile
I_m = Moment of inertia of model pile
I_p = Moment of inertia of prototype pile
1/n = Scale factor for length
(n=4.5 for Sand; n=5 for Clay)

For Lateral Loading, A Rectangular tank of dimension (1.2 x 0.6 x 0.8) m equipped with Lateral Loading arrangement and Strain gauges to record the strain produced along the length of pile is used. The setup used for Axial testing is shown in the figure below.

Fig 2. Setup used for Axial Loading

III. DETERMINATION OF LAOD CAPACITY OF PILE

The test tanks used for the testing are filled with the Soil or sand and the Pile is installed with the help of PVC pipe of respective diameter. For the installation of the pile, following techniques can be used.

1. Sand Compaction Piles
2. Stone Columns
3. Rammed aggregate piers

The general method adopted is as follows. Initially sand is filled into the tank using Sand raining technique. This method is adopted to obtain uniform density of soil. After the tank is filled with the sand, the pile installation is accomplished using a PVC pipe of diameter required. The PVC pipe is driven into the soil and Concrete mixture is poured in layers of 5cm and followed by proper tamping. Then the PVC pipe is lifted with a minimum overlap of 2cm and this process is repeated. The test tank used for Lateral loading is shown in figure below.

Fig 3. Test tank used for Lateral Loading

For lateral loading, the test tank is equipped with pulley arrangement for application of lateral load. The Strain gauges are attached on the surface of the Pile and a Data Acquisition System is used to obtain the variation of strain along the length of the pile.

IV. RESULTS AND DISCUSSION

From the Permeability test conducted, it can be inferred that the permeability of the Pervious Concrete pile is within the range of 1.5 – 2.0 cm/sec, well within the range of Granular column.

The Axial Load Capacity test conducted on the Granular pile and Pervious Concrete pile clearly showed that the load carrying capacity of Pervious Concrete pile is nearly 4 times that of Granular pile.

V. CONCLUSIONS

Based on the results obtained from the tests conducted it can be concluded that the Pervious Concrete Pile can be used as a densification technique along with the provision for Drainage. Also the installation method results in lateral compression and densification of surrounding sand, as well as increasing lateral stress.

VI. REFERENCES

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