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Behavior of Pervious Concrete Pile based on Vertical Loading

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Abstract: Permeable granular piles are used to increase the time rate of consolidation, reduce liquefaction potential, improve bearing capacity, and reduce settlement. However, the behaviour of granular piles depends on the confinement provided by surrounding soil, which limits their use in very soft clays and silts, and organic and peat soils. This research effort aims to develop a new ground-improvement method using pervious concrete piles. Pervious concrete piles provide higher stiffness and strength, which are independent of surrounding soil confinement, while offering permeability comparable to granular piles. This proposed ground-improvement method can improve the performance of different structures supported on poor soils. To achieve the goal of the research project, a series of pervious concrete sample mixing has been conducted to investigate the pervious concrete material properties. Laboratory tests are carried out on a pervious concrete pile of 100 mm diameter and variation at different lengths (500mm,400mm,300mm) surrounded by sand of different density. The tests are carried out either with an entire equivalent area loaded to estimate the stiffness of improved ground or only a column loaded to estimate the limiting axial capacity. Pervious concrete is a special concrete product made primarily of a single-sized aggregate. Pervious concrete has been used in pavements to reduce storm-water-runoff quantities and perform initial water-quality treatment by allowing water to penetrate through the surface. In the United States, pervious concrete is mainly used in pavement applications, including sidewalks, parking lots, tennis courts, pervious base layers under heavy-duty pavements, and low traffic-density areas. The vertical load responses of pervious concrete are the variation of soil stresses and displacement are discussed. Nine tests are conducted on pervious concrete pile further investigate the behaviour of the pervious concrete pile and surrounding soil under vertical load condition. Therefore, Pervious Concrete Piles is particularly suitable for reinforcing subsoil that has low strength and poor permeability.
Keywords: Consolidation; Settlement; Stiffness; Permeability; Confinement. etc.

I. INTRODUCTION

Ground improvement methods are widely used to enhance soil strength, allow for drainage path, mitigate total and differential settlements, and to reduce construction time. Based on different conditions, various ground improvement methods are available (i.e., prefabricated vertical drains, vacuum consolidation, deep soil mixing, grouting, and vibro-compaction). As one of the most commonly used ground improvement methods, granular piles have been used extensively in several geotechnical engineering applications (Mitchell 1981; Barksdale and Bachus 1983; Aboshi and Suematsu 1985; Bergado et al. 1994; Baez 1995; Terashi and Juran 2000; Okamura et al. 2006). The sections below will discuss different types of granular piles and their installation, properties and failure mechanisms. In addition, this chapter presents the properties of pervious concrete.

The construction of granular piles will change the soil stresses and accelerate pore water pressure dissipation, resulting in consolidation, which leads to the improvement of surrounding soil. Granular piles have been used to increase the time rate of consolidation, increase the bearing capacity, reduce liquefaction potential, and reduce settlement (Mitchell 1981; Barksdale and Bachus 1983; Aboshi and Suematsu 1985; Bergado et al. 1994; Baez 1995; Terashi and Juran 2000; Okamura et al. 2006).

A. Pervious Concrete

Pervious concrete also referred to as "No-fine Concrete" or "Porous Concrete" is material comprised of narrowly graded coarse aggregates, cementations materials, water and admixture and in some cases fibres. Pervious concrete is a special concrete made primarily of single-size aggregate (Figure 1.). Pervious concrete has been used in pavements to reduce the quantity of storm water runoff and perform initial treatment of water quality by allowing water to penetrate through the porous surface. The pervious concrete is mainly used in pavement application, including sidewalks, parking lots, tennis courts, and low traffic density areas (Tennis et al. 2004; and Suleiman et al. 2011).

Fig. 1 Pervious Concrete

B. Experimental Investigation

Pervious concrete is a special concrete made primarily of single-size Aggregate & no fines are used.

C. Preparation of Pervious Concrete

Table No. 1

Sr.No	Properties	Value
1	Compressive strength	17.3 to 26.5 mpa
2	Porosity	15 to 33%
3	Permeability	0.01 to 1.50 cm/sec
4	Modulus Of Elasticity	15×10^6 kPa
5	Unit weight	20kN/m3
6	Poisson Ratio	0.2

The size of pervious concrete cube was taken as 15cmx15cmx15cm & the size of aggregate Passing 12.5mm and Retained from 10mm.The different water cement ratio are 0.30, 0.25, 0.22 (9 cube cast).

Fig. Preparation of Pervious Concrete Cubes

D. Result of Pervious Concrete Cube (28 days)

Sr. No.	W/C Ratio	Cube No.	Compressive strength	Average Compressive Strength
1	0.30	1	36.7	35.6mpa
		2	34.6	
		3	35.5	
2	0.25	1	31.9	30.1mpa
		2	28.6	
		3	29.7	
3	0.22	3	-	-

E. Preparation of Pervious Concrete Pile

II. LABORATORY TESTING

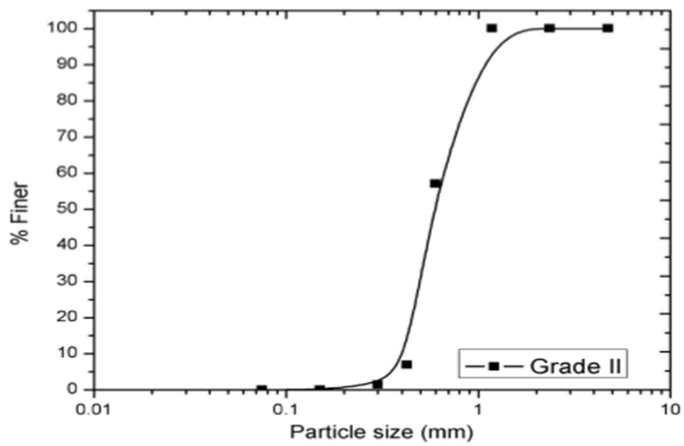
A. Soil Properties

The soil used in vertical load test was classified as poorly-graded sand (SP) according to the Unified Soil Classification System. The sand was rained into the soil box to produce a homogeneous soil profile along the total depth of the pile. The minimum and maximum unit weight of the sand were 14.18 and 17.04 kN/m3, respectively (i.e., maximum void ratio of 0.813 and minimum void ratio of 0.508). The rained sand had different relative density such as 40% and 80% respectively.

Table No. 3 Properties of Sand

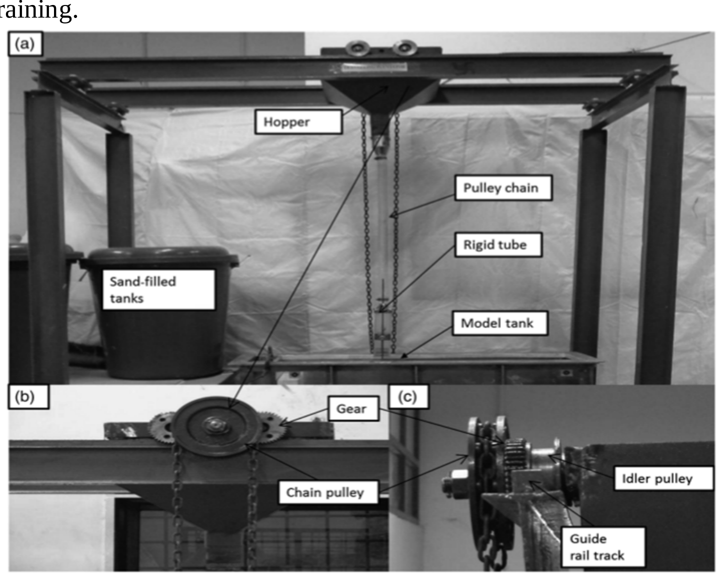
Sr.No	Properties Of Sand	Values
1	Specific Gravity	2.62
2	Max. Dry Unit Weight	17.04 kN/m^3
3	Min. Dry Unit Weight	14.18 kN/m^3
4	e_{max}	0.813
5	e_{min}	0.508
6	e_o	0.569
7	D_{10}	0.35
8	D_{30}	0.40
9	D_{50}	0.57
10	Coeff. of Uniformity (Cu)	1.36
11	Coeff. of Curvature (Cc)	0.95

Grain size distribution curve



B. *Preparation of Soft Sand Bed*

Tests have been conducted in a Sand bed prepared at two different relative density 40% & 80% respectively. Relative density achieved with the help of sand draining.



Preparation of uniform and repeatable reconstituted sand specimens of required density is a prerequisite for obtaining reliable results from laboratory tests. An air pluviation technique is widely used to achieve uniform and repeatable sand specimens. Many of the previously developed air pluviation setups were stationary in nature, and these setups have inherent limitations, which do not allow the preparation of large, uniform sand beds. In this study, a mechanized traveling pluviator (MTP) is developed, which has two main features, including a freely movable hopper and rigid tube made up of Plexiglas to observe the sand flow during pluviation. This study aims at understanding the effect of the number of diffuser sieves, deposition intensity (DI), and height fall (HF) on the relative density (RD) and uniformity of sand specimens. The uniformity of a sand bed is verified by conducting cone penetration tests (CPTs) using a miniature cone. Using the developed MTP setup, large uniform sand specimens with a wide range of relative densities (viz, 38%–100%) can be prepared. For the sand used in the present study, the height of the fall and the depositional intensity significantly influence the RD of sand beds, whereas diffuser sieves control the uniformity of sand beds.

C. Testing Program

All experiments were carried out on a 100 mm diameter Pervious Concrete Pile surrounded by sand in cylindrical tanks of 520 mm high and a diameter of 330 mm.Pervious concrete pile same diameter but varying length such as 500mm, 400mm and 300mm. Tests with column area alone loaded were used to find the limiting axial stress and tests with entire area loaded were used to study the stiffness of improved ground. A typical test arrangement for a single column test is shown in Fig. The pervious concrete pile has placed in center of the tank. Vertical stress has applied either only over the pervious concrete pile. The load was applied through a proving ring at a constant displacement rate of 1.2 mm/min.

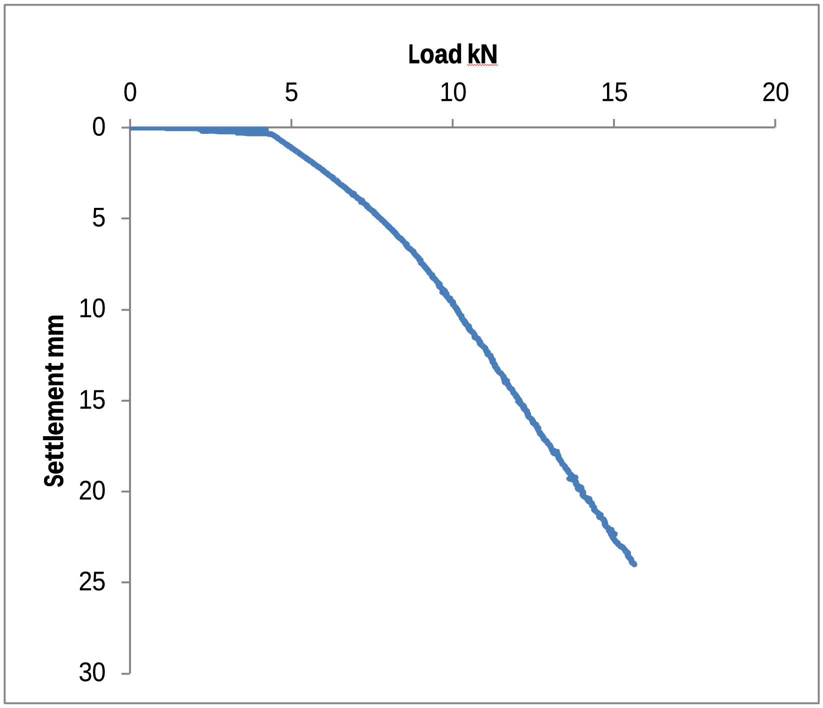
III. RESULTS AND DISCUSSIONS

The results of various tests carried out during the experimental investigation have been presented in this chapter. Tests have been conducted in a Sand bed prepared at two different relative density 40% & 80% respectively. All experiments were carried out on a 100 mm diameter Pervious Concrete Pile. Cylindrical tanks of 520 mm high and a diameter of 330 mm. Pervious concrete pile has same diameter but varying length such as 500mm, 400mm and 300mm.Tests with column area alone loaded were used to find the load and settlement at different density. Strain Controlled Loading at a Strain Rate 1.2mm/min

A. Relative Density- 40% And Length of Pile 300mm

Max.Load = 15.62kN

Settlement = 23.98mm

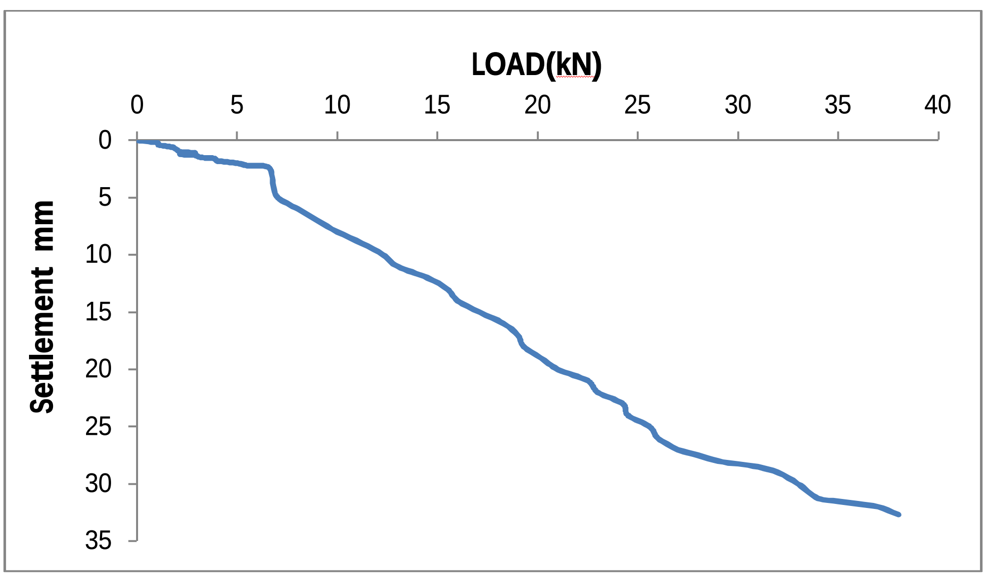


PCP has tested Friction pile the Cylindrical tank first filled 200mm Sand layer with respective relative density then applied vertical load at strain rate 1.2mm/min.

B. Relative Density- 40% and Length of Pile 400mm

Max.Load = 38.62kN

Settlement = 32.67mm



PCP has tested Friction pile the Cylindrical tank first filled 100mm Sand layer with respective relative density then applied vertical load at strain rate 1.2mm/min

A. Test Results

Sr. No.	Relative Density (RD)	Slenderness Ratio (l/d)	Max. Load (kN)	Settlement (mm)
1	40%	3.0	15.60	24.50
		4.0	38.62	32.00
		5.0	48.60	24.35
2	80%	3.0	22.65	40.20
		4.0	57.30	21.60
		5.0	52.40	28.00

IV. CONCLUSIONS

Based on the experimental work carried out in the present study, the following conclusions are drawn:

A. Slenderness ratio l/d=4of the PCP is increase then ultimate load carrying capacity increased by 2.5times than l/d=3
B. When the Relative density of sand 80% then the load carrying capacity is maximum and settlement lower. Relative density of the sand 40% then the load carrying capacity minimum and settlement maximum.
C. For end bearing pile higher load carrying capacity and lower settlement.
D. Pervious concrete piles have a compressive strength that is more than 10 times that of granular piles..
E. The pervious concrete pile, which has the same dimensions, aggregate, has ultimate load that was 4.4 times greater than the ultimate load of the granular piles.
F. The pervious concrete pile failed by vertically punching into the soil at the pile tip, whereas the granular column failed by bulging outward into the surrounding soil.
G. Pervious concrete piles provide higher stiffness and strength as compared the stone column.
H. Pervious concrete pile reduces liquefaction potential during earthquakes, improve bearing capacity of soil, and reduce settlement of structures.

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