A MODEL STUDY ON THE BEHAVIOUR OF PERVIOUS CONCRETE PILES IN POORLY GRADED SAND

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Abstract – *Pervious concrete piles are special kind of piles made with coarse aggregate, cement and water. Since fine aggregate is not used, they show enough permeability. They will increase the bearing capacity of soil such as clay, silt, poorly graded fine sand etc. They have properties comparable to stone columns and do not have bulging failure like stone columns. So here, a model study was done to find the working of pervious concrete pile in poorly graded fine sand. The test was done on both precast and cast in-place pervious concrete piles with same length and diameter. Test result shows that cast in-place pervious concrete piles have more load carrying capacity than precast pervious concrete piles. Both the two types of piles have comparable permeability with stone columns and can be used as an alternate method to stone columns in poorly graded sand.*

***Key Words*: Precast pervious concrete pile, Cast in-place pervious concrete pile, Stone column, Poorly graded sand, Model study.**

1. INTRODUCTION

There are different ground improvement techniques are there to improve bearing capacity of soil. Stone columns are such kind of a technique provided to increase bearing capacity of loose sand, silt, clay etc. They have good permeability as well. So they can act as vertical drain and hence time rate of consolidation of soil can be increased. Their working depends mainly on the confining soil. If the soil does not have enough confinement they will fail by bulging. This is one of the major drawbacks of stone column. So the need of a method to avoid this problem is very essential. Pervious concrete is a special kind of concrete which is prepared by mixing coarse aggregate, cement, water etc. and fine aggregates are usually avoided. Because of this, they show good permeability. The void paces get increases in the absence fine aggregate and thereby increasing permeability. So pile prepared by using pervious concrete can be used as an alternate method to stone columns. Comparing with the stone columns they have more stiffness and hence do not fail by bulging.

The present study aims at finding the behaviour of pervious concrete piles in poorly graded fine sand under vertical loading. Tests were done on both precast and cast in-place pervious concrete piles. Piles were prepared with same length and diameter and with different coarse aggregate sizes (10mm, 16mm and 20mm).

2. LITERATURE REVIEW

Hai Lin, Muhannad T. Suleiman, Hanna M. Jabbour [1] Explains the response of biogrouted pervious concrete pile in poorly graded sand. The result shows that axial compression responses of pervious concrete pile were improved using biogrouting. Compression loading was applied on pervious concrete pile, one without biogrouting and another with biogrouting. By analysing mechanical responses of the pile along the pile length, pile capacity was found to be improved by using biogrouting.

Lusu Ni, Muhannad T. Suleiman, Anne Raich [2] Lateral loading response of pervious concrete pile was explained. The test was done on both precast and cast-in-place piles. Cast-in-place pile had good responses than precast pile. When applying lateral load they behaves like flexible pile and also provide good permeability.

Mahmoud Ghazavi, Javad Nazari Afshar [3] The working of unreinforced and reinforced stone columns were explained. Reinforcements were provided by using geo-textiles. The tests were done on a model tank with clay bed. The load carrying capacity of both reinforced and unreinforced stone columns were done by changing the diameter and keeping length to diameter ratio same. They also had done the load carrying capacity of clay by providing it with stone column group. FEA was also done in PLAXIS soft ware.

P.Mohanthy, M.Samanta [4] Effect of providing stone column in layered soil was studied. Both laboratory model study and numerical studies were done. Two layers are providing such that soft clay overlying stiff clay and vice versa. The test was done on a 88mm diameter stone column. Unit cell concept was used to evaluate the stress vs. settlement characteristics. Parametric study was also done in PLAXIS software with elastic-perfectly plastic Mohr-Coulomb failure criterion. By analysing the results they arrived at a conclusion that top layer soil has influence on axial stress of the stone column.

Jian-Feng Chen, Liang-Yong Li, Jian-Feng Xue, Shou-Zhong Feng [5] Explains the behaviour of geosynthetic encased stone column in soft soil under embankment loading. Physical model was prepared in the laboratory and three dimensional and two dimensional finite element analyses were also done. By analysing experimental and numerical study, it was clear that the failure of geosynthetic encased stone column was by bending, not by shear. Through the three dimensional finite element analysis, it was clear that distribution of unbalanced lateral loading acting on the stone column was symmetric about a hinge point above plastic hinge. Based on the distribution of this load an equivalent shear resistance model of geosynthetic encased stone column was developed. Two dimensional finite element analysis was done to find the stability of embankment.

3. MATERIALS

Poorly graded sand was used as confining soil in this study. For preparing pervious concrete piles 3 types of coarse aggregates (10mm, 16mm and 20mm), OPC 53 grade cement and an admixture for increasing workability was used.

3.1 Properties of sand

Properties of collected sand is tabulated in table 1.

Table -1: Properties of sand

properties	values	specification
Specific gravity	2.5	-
Uniformity coefficient	2.05	Poorly graded sand.
Coefficient of curvature	0.85	-
Cohesion	0	-
Permeability coefficient(cm/s)	4.478×10^{-3}	Fine sand, loose silt.

Particle size distribution curve of sand is shown in chart 1.

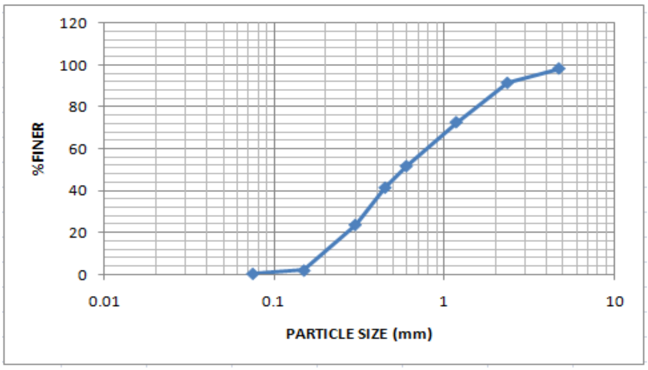

Chart -1: Particle size distribution curve of sand

3.2 Properties of cement and coarse aggregate

Coarse aggregate of specific gravity of 2.7 and with sizes 10mm, 16mm and 20mm were used. Cement used was ordinary Portland cement of 53 grade with specific gravity 3.1.

3.3 Properties of pervious concrete

Mix design of pervious concrete was done as per IS 10262-2009. Mix with water-cement ratio of 0.3 and cement-aggregate ratio 1:4.2 was found to be economic for 10mm coarse aggregate. For 16mm and 20mm aggregates water cement ratio and cement-aggregate ratio were 0.32, 0.35 and 1:4.2, 1:4.1 respectively. To find the properties of pervious concrete, cubes of size 15cm×15cm×15cm were casted. Properties of pervious concrete is shown in table 2. Compressive strength testing was done as per ASTMC39. Void ratio testing was done as per ASTMC1688 and coefficient of permeability as per ACI522R-06.

Table -2: Properties of pervious concrete

Aggregate size (mm)	Void ratio (%)	Compressive strength (MPa)	Coefficient of permeability (cm/s)
10	18.63	15.83	0.53
16	24.30	10.6	0.86
20	28.80	8.8	0.90

4. METHODOLOGY

A model tank of size 0.9m×0.9m×0.6m was used for the present study. The dimension of tank was taken by considering stress zone. Poorly graded sand was filled in it as confining soil. Mix design of pervious concrete was done as per IS 10262-2009. Precast pervious concrete was prepared with a diameter of 7.5cm and length 30cm. They were cured for about 7 days. Cast in-place pervious concrete piles were also prepared with the same length and diameter as precast pervious concrete piles, but they were casted at the tank itself, testing was done after 7 days of casting. Vertical load test was done to both precast and cast in-pace pervious concrete piles. The model tank prepared for vertical load test is shown in figure1.

Fig-1: Model tank

5. MODEL STUDY

Model tank of size 0.9m×0.9m×0.6m with loading arrangement is shown in figure 2. Loading frame was mounted on the tank and load was applied by rotating a loading arm which was connected to a proving ring and load was applied vertically at the top of pile through a load transfer unit. Settlement of pile was measured from dial gauges and corresponding load from proving ring. The loading arrangement is shown in figure 2.

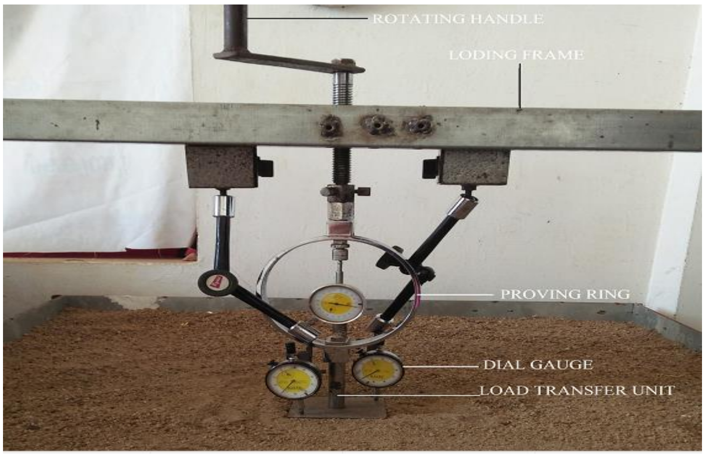

Fig-2: Loading setup

Settlement of single pervious concrete pile under vertical loading was tested here. Load-settlement graph was plotted with the values obtained from proving ring and dial gauges under vertical loading.

6. RESULT AND DISCUSSION

Load settlement analysis of both precast pervious concrete pile and cast in-place pervious concrete pile was done. The chart showing load-settlement behaviour of piles with 10mm, 16mm and 20mm aggregates are given below.

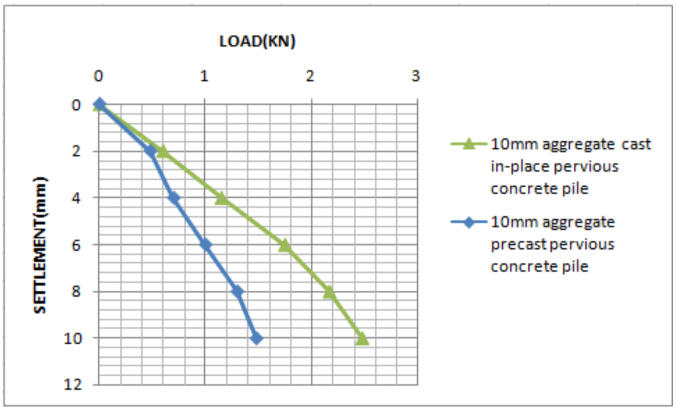

Chart-2: Load-settlement curve of 10mm aggregate piles.

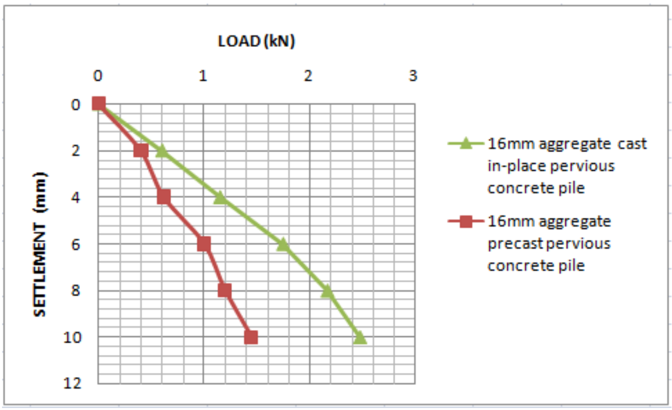

Chart-3: Load-settlement curve of 16mm aggregate piles.

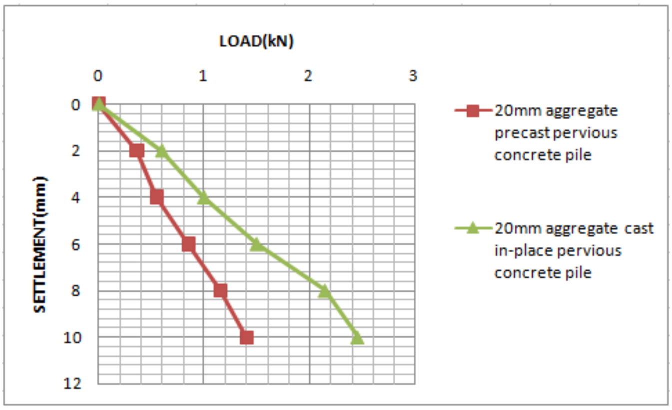

Chart-4: Load-settlement curve of 20mm aggregate piles.

The variation of load-settlement behaviour of 3 types of precast pervious concrete pile alone is plotted in chart-5 and cast in-place piles alone in chart-6.

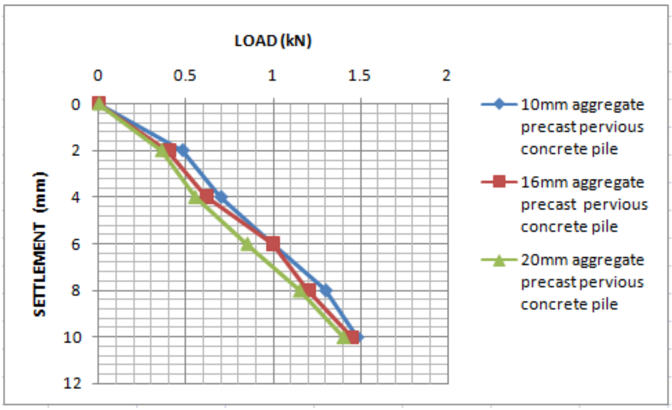

Chart-5: Behaviour of precast pervious concrete piles

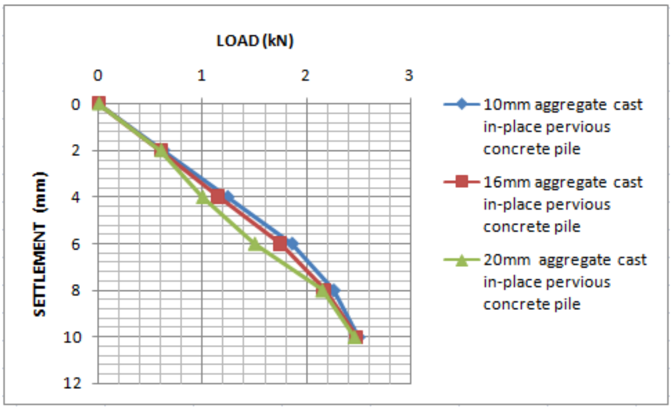

Chart-6: Behaviour of cast in-place pervious concrete piles.

There is only slight variation in maximum load between the piles with three different aggregate sizes. The variation of maximum load with aggregate size is plotted in chart-7.

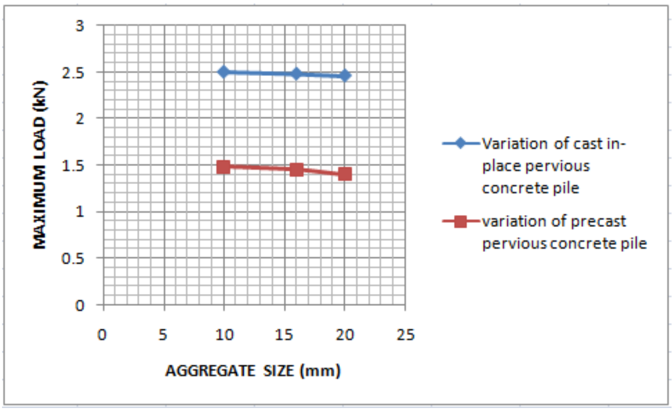

Chart-7: variation of maximum load with aggregate size.

Falling head permeability test was done as per ACI522R-06 to find the coefficient of permeability of pervious concrete. The variation of coefficient of permeability with changing aggregate size is plotted in chart-8.

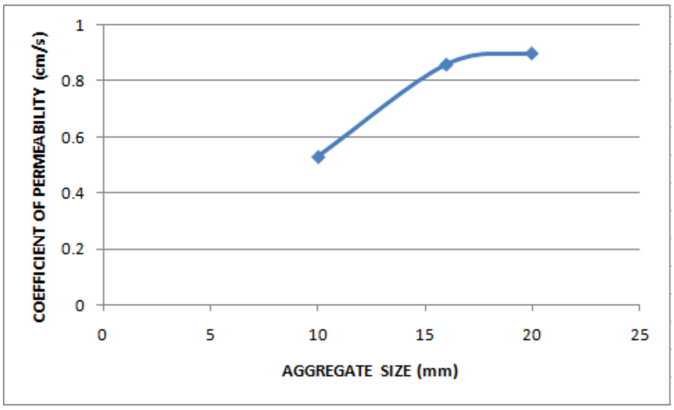

Chart-8: Variation of permeability with aggregate size.

Variation of compressive strength with changing aggregate size is plotted in chart-9.

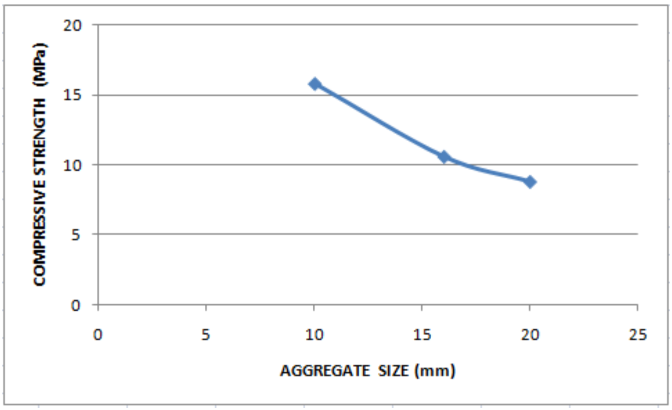

Chart-9: Variation of compressive strength with aggregate.

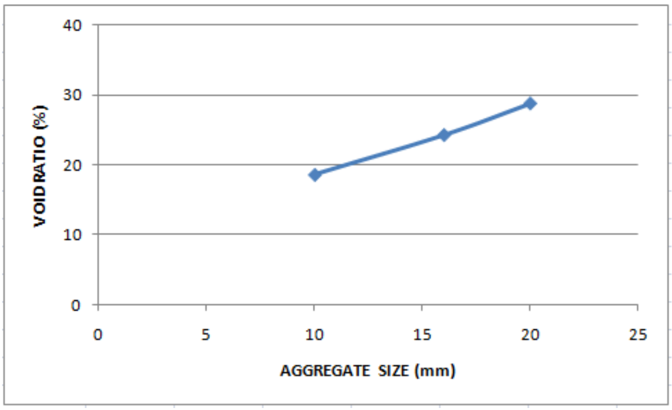

Chart-10: Variation of void ratio with aggregate size.

7. CONCLUSION

- Compressive strength of pervious concrete pile reduces and coefficient of permeability increases as size of aggregate increases, this is because void ratio increases as size of aggregate increases.
- Cast in-place pervious concrete piles have more load carrying capacity than precast pervious concrete pile, because more frictional resistance creates between pile shaft and confining soil in case of cast in-place piles.
- Geotechnical performance of pervious concrete piles made with 3 different sizes of aggregate was almost same. This is because the length and diameter of pile was same so they show almost same performance, slight variation is because of changing surface roughness of pile.
- Pervious concrete piles have comparable permeability with stone column and better load carrying capacity than stone column. Hence can be used as an alternate method to stone column.

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