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Study on Various Properties On Pervious Concrete and its Behaviour on Pile Model

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Abstract: Stone column is a good technique to support structures in weak soil. It increases the bearing capacity, rate of consolidation and decreases the liquefaction potential of the soil. But stone columns strength depends upon the confining soil. It tends to fail by bulging when used in weak deposits like very soft clays and in organic peat soil. So an alternative should be found out for stone column in weak deposits. Pervious concrete when used as vertical piles does not fail by bulging when the surrounding soil is weak. So this study aims at finding out the properties of pervious concrete so that a good alternative for stone column can be found out. The study is further extended to find out a mix which having good strength and comparable permeability to that of a stone column and to analyse the behaviour of pervious concrete group pile model. For finding out a proper mix design pervious concrete properties like Compressive strength , Permeability , Elastic modulus were found out for different aggregate sizes. Comparing all these values a design mix was finalised for making the pervious concrete piles. Load carrying capacity of pervious concrete pile groups and their combination with stone column were found out and compared for prescribed settlement both by experimentally and FEM models.
Index Terms: pervious concrete; pile; mix design; Stone Column

I. INTRODUCTION

Population on the earth is increasing rapidly. So the need for roads and buildings and other infrastructures are increasing. This also increases the importance of ground improvement, as most of the land do not have the natural strength to achieve our needs like roads, buildings etc. Ground improvement techniques like sand compaction piles and stone columns are some good techniques as it increases the bearing capacity of the soil and also increases the rate of consolidation. In low permeable soils like clay use of this permeable columns allows water to percolate faster and it reduces the time of treatment. This reduces the runoff and thereby increases ground water table. Permeable granular columns have a disadvantage that its strength depends greatly upon the surrounding soil. If the confining pressure is low they have a tendency to fail by bulging. This keeps away this method from using in very weak deposits of soil. The importance of material which do not fail by bulging when used in weak deposit was important to overcome this situation. So the importance of a material like pervious concrete which do not depend upon the confining soil has increased. Pervious concrete is a open-graded material consisting of hydraulic cement, coarse aggregate, admixtures and water. Cement and water are mixed to forms a paste that binds the coarse aggregate together in a hardened product with pores that allow water to pass through easily. The pores can range from 2 to 8 mm, and the void content usually ranges from 18% to 35%. The density and flow rate depends on the properties and proportions of the materials used. Therefore, mix designs must take into account the aggregates of various types used in each locality .Pervious concrete is used for flatwork application like low volume pavements, footpath, parking areas, tennis courts, residential areas, and other light traffic areas.

II. OBJECTIVE

The main aim of this study is to prepare a mix design for the pervious concrete having good mechanical and hydraulic properties. Based on suggested mix design, model test of full length pervious concrete piles are to be compared with pervious and stone column combinations and full stone column piles in terms of load for prescribed settlements.

III. LITERATURE REVIEW

An experimental study was conducted by [1] on pervious concrete mechanical and hydrological properties. A linear regression relation between density and porosity, compressive strength and permeability was discussed in this study. [2] conducted a laboratory investigation to improve the strength properties of pervious concrete through the addition of latex polymer and focused on the balance between permeability and strength properties of polymer-modified pervious concrete. Based on the assumption that the cement paste only plays a role of coating, it does not fulfill the void among the grains of gravel an analytical method has been developed by [3] to facilitate the concrete producers. In the study conducted by [4] three lightweight aggregates were used to make pervious concrete.The study mainly focused on mechanical properties, water permeability, thermal conductivity and optimum mix design was determined. [5] conducted a study on material properties of pervious concrete. The study also included the installation method for pervious concrete piles and a comparative study based on the response of pervious concrete and aggregate piles. Effect of rice husk ash (RHA) to strengthen pozzolanic cement paste and the effect of 0%, 2%, 4%, 6%, 8%, 10% and 12% weight percentages as a cement replacement in concrete mixtures on the permeability was studied by [6].[7] describes about application of Recycled Aggregate Porous concrete Pile (RAPP) to improve soft ground in his study. The main investigation areas were acomparative analysis on the vertical displacement, pore water pressure, vertical stress increment of the RAPP-reinforced system. In this study [8] pervious geopolymer concrete were made from Recycled aggregates. Mechanical properties, total void ratio, and water permeability were tested. It was concluded that Recycled aggregates could be used as coarse aggregates to produce pervious geopolymer concrete with acceptable properties.[9] Washed municipal solid waste incinerator bottom ash (MSWIBA)was used as the main experimental aggregate. A wide range of values of the water–cement ratio and the pore filling paste ratio was used to fabricate pervious concrete samples for testing. The mix proportions of the concrete mixes with the best test results were selected and MSWIBA with a maximum aggregate size of 9.5 mm. Tests were then performed to investigate the differences in the properties of the concretes made using washed MSWIBA and natural aggregate The study includes [10] Vertical permeability distribution calculated from vertical porosity distribution and a revised form of porosity–permeability relationship. An effective permeability calculated from vertical permeability distribution.

IV. MATERIAL PROPERTIES

Experimental Investigations were done to study the mechanical properties of materials used so as to find out the best design mix. Ordinary Portland cement of grade 53 was used for the present study. Coarse aggregate of sizes 4.75-9mm, 12.5mm and 20mm were used. Cubes were casted for size 15 x 15 x 15 cm with aggregate cement ratio 4.5: 1 and water cement ratio of 0.33. Table 1 shows 7 days compressive strength of cube.

Table 1: 7 Days Compressive Strength values

Age(days)	Aggregate size(mm)	Max load (KN)	Compressive Strength(Mpa)
7 days	16	87.67	3.89
7 days	12.5	102.33	4.54
7 days	4.75-9.5	220	9.77

Fig. 1: 16 mm aggregate cube

Falling head permeability apparatus was made using PVC pipe to find out coefficient of permeability as shown in Fig.2.

Fig. 2: Falling head permeability apparatus

Fig. 3: Sample placing inside apparatus

Coefficient Permeability (k) = $$\frac{2.303(al)\log 10\left(h1/h2\right)}{At}$$ Eq.(1)

Where'a' refers to the cross sectional area of stand pipe, cross sectional area of soil sample is represented by 'A' and height of specimen 'L' and 't' is the time required for the height drop h1 to h2. Table 2 shows the coefficient of permeability value for different sizes of aggregate.

Table 2: Coefficient of permeability values for different sizes of aggregate

Size of aggregate (mm)	Coefficient of permeability(cm/s)
9.5	0.283
12	0.548
16	0.760

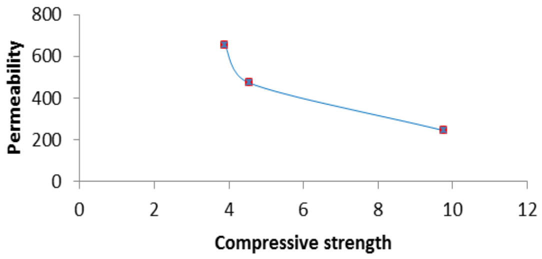


Fig. 4: Permeability v/s Compressive strength

Fig.4 clearly indicates that as compressive strength increases permeability decreases. Pervious concrete if used as pervious column instead of stone column it should have good compressive strength as well as comparable permeability. So aggregate size of 4.75- 9.5 mm can be used for this purpose. Fig.5 shows the particle size distribution graph of the aggregate and Fig.7shows stress v/s strain graph and Modulus Of Elasticity was found to be 7169 N/mm^2.

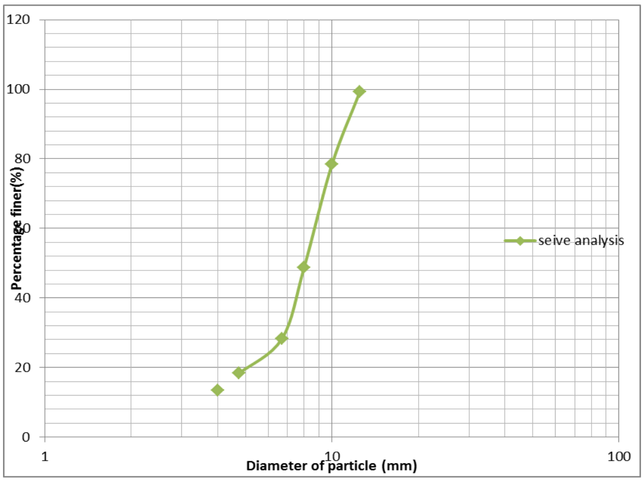


Fig. 5: Particle Size Distribution

Fig. 6: Setup to find out Modulus Of Elasticity

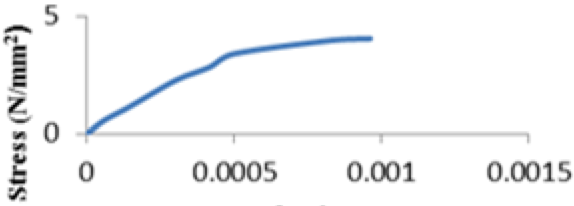


Fig. 7: Stress v/s Strain

V. EXPERIMENTAL SETUP

Load test on group column were conducted on pervious concrete group column and ordinary group stone column to compare their relative performance. First set of tests were performed on the sand bed by 75 mm diameter full pervious concrete group columns. Second set of tests were performed on the sand bed by 75mm diameter piles of 75% length pervious concrete and 25 % length stone column. Third series of tests were performed on the sand bed by 75 mm diameter full stone column piles After construction of pervious concrete columns axial load was applied at constant rate of 1.2mm/minute through a square plate of dimension 32 cm x 32 cm. The centre to centre distance between each column is 21.5 cm. The loads corresponding to different displacement were measured using a load cell .The deformation was measured using a L V D T (Linear Variable Displacement Transducer) .Test was conducted for 10 mm displacement. Fig.8 and Fig.9 shows the model of group piles and its test setup respectively.

Fig. 8: Filling of sand inside the tank containing pervious concrete piles

Fig. 9: Test set up for testing group pile

VI. FINITE ELEMENT MODELLING

The numerical analysis was carried out using an available package PLAXIS 3D to compare the load deformation behaviour with model test. For these purpose three dimensional finite element models of exactly the same size as the laboratory models were prepared and analysed. Parameters used for modelling pervious concrete and stone column in Plaxis model are defined in Table 3 and Table 4. Fig.10 and Fig.11 shows the modelling done in PlAXIS.

Table 3:Parameters for pervious concrete in Plaxis Model

Parameters	**Pervious concrete**
Model	Linear elastic
Behaviour	Drained
Unsaturated unit weight (kN/m^3)	19
Saturated unit weight (kN/m^3)	21
Elastic modulus (kPa)	71×10^5
Permeability (m/day)	250

Table 4 : Parameters for stone column in Plaxis model

Parameters	**Stone column**
Model	Mohr-coulomb
Behaviour	Drained
Unsaturated unit weight (kN/m^3)	18
Saturated unit weight (kN/m^3)	20
Cohesion (kPa)	2
Angle of internal friction (degrees)	40
Elastic modulus (kPa)	40000
Poisson ratio	0.3
Dilatancy angle (degrees)	10
Permeability (m/day)	900

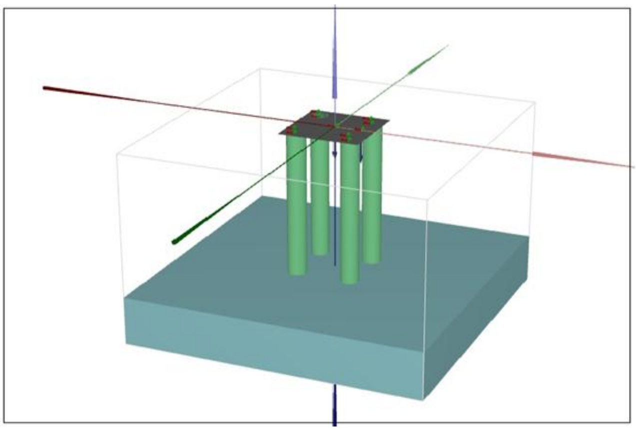
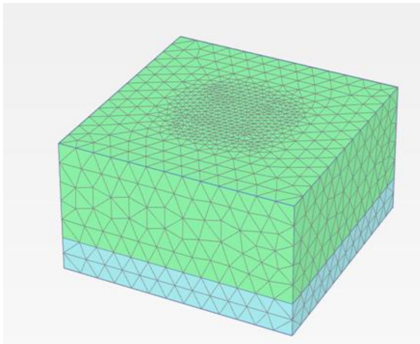


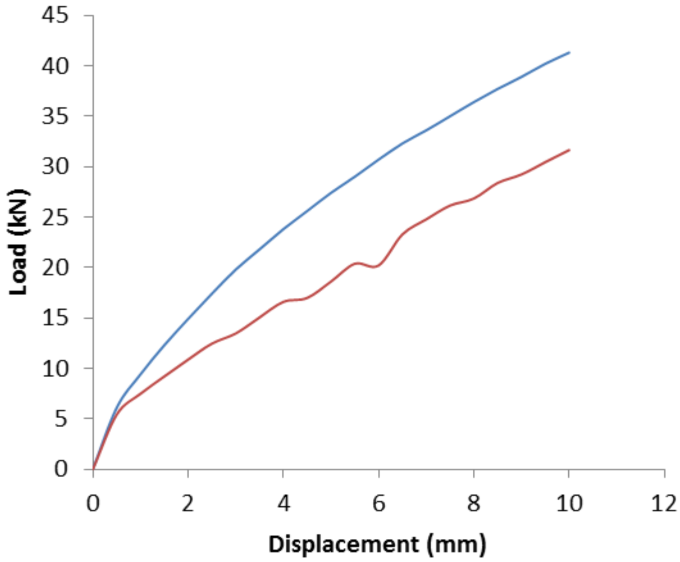
Fig. 10: Pervious concrete group model in PLAXIS

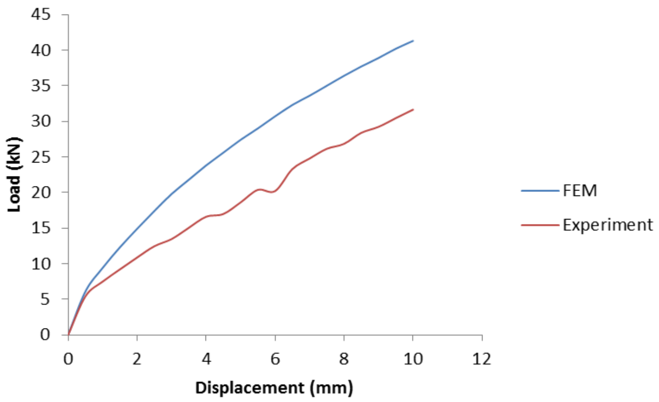


Fig, 11: Mesh generated in PLAXIS

VII. RESULTS AND DISCUSSIONS

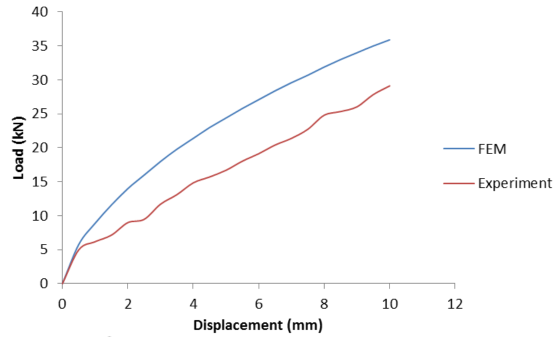
The PLAXIS results of 75 mm group pile with full pervious concrete , 75 % pervious concrete , full stone column are compared with model test results. It is followed by PLAXIS result of 75 mm pile groups with 50% and25% pervious concrete.





Fig, 12: Load displacement graph of 75 mm full pervious pile group

From Fig.12 a variation of about 20 percentages has been seen in the results as compared to FEM model and Experimental model. Piles used in experiments were precasted. If piles were casted using cast-in-situ method then the results would have been more closer. As compared to Fig.12 load taken by 100 % PC is 1.2 times greater than 75 % PC as in Fig.13. From Fig. 14 it is seen that stone column group piles fails by bulging within 2 mm to 4 mm settlement for a load of 6 kN to 8 kN.
By comparing to Fig.12and Fig.15 load carrying capacity of 100 % Pervious Concrete is almost 1.6 times greater than 50 % Pervious Concrete.



Fig,13 Load displacement graph of 75 mm 75 % PC pile group

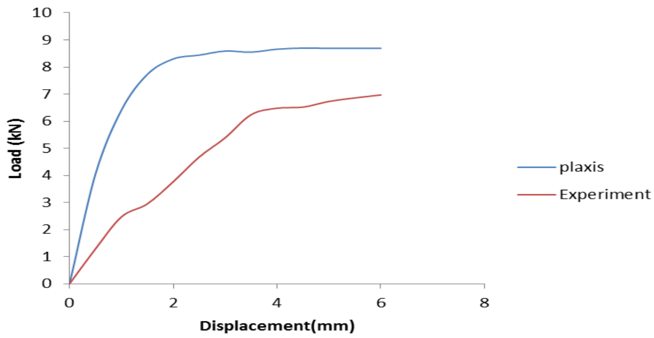


Fig. 14: Load displacement graph of 75 mm full SC pile group

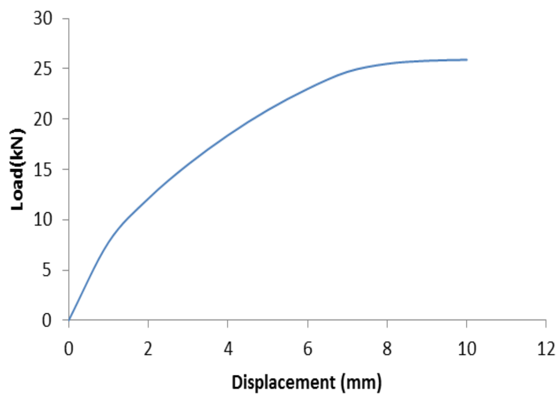


Fig. 15: Load displacement graph of 75 mm 50 % Pervious concrete in FEM

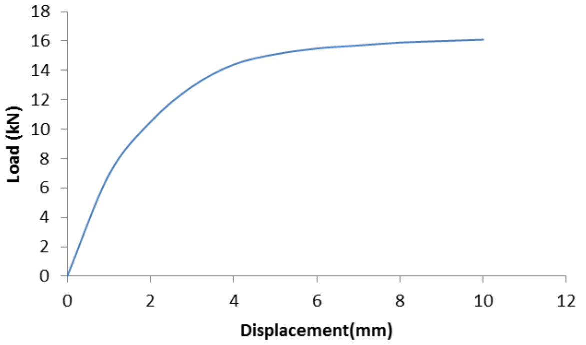


Fig. 16: Load displacement graph of 75 mm 25 % Pervious concrete in FEM

Fig.17 represents a comparative study using different percentages of pervious concrete with varying diameter of piles by FEM models.

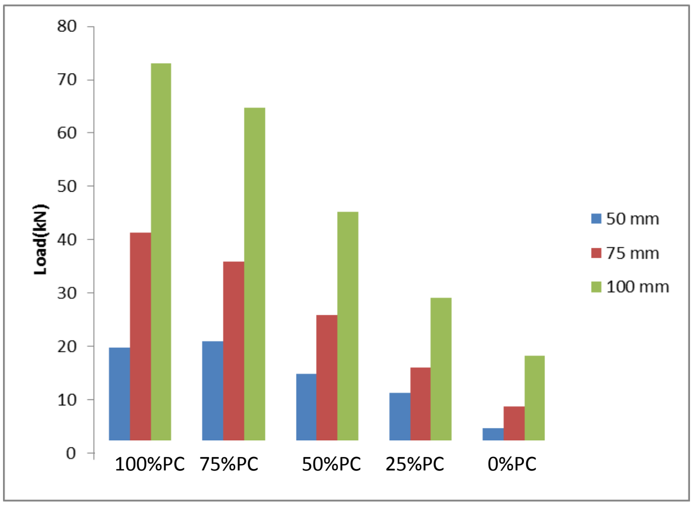


Fig. 17: Settlement load for different FEM models having different diameter and different PC content

VIII. CONCLUSIONS

A design mix of aggregate cement ratio 4.5:1 and water cement ratio 0.33 had given proper bond between particles. Aggregate of range 4.75 – 9.5 mm have good compressive strength of 9.45 Mpa (7 days) and permeability of 244 m / day which will give better results than stone column. It was found out that pervious concrete pile does not fail by bulging as that of stone column. Load taken by FEM model was almost 1.2 times that of Model test piles for 10 mm settlement. Load taken by 100 % Pervious concrete piles is almost 1.2 – 2.5 times greater than Pervious concrete stone column combination piles. Load taken by 100 % pervious concrete is almost 5 times greater than full stone column pile for 10 mm settlement.

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