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Study of Strength Parameter for Different Drain Material using PVD for Consolidation of Soft Clay by Radial Flow

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Abstract:- **The rapid development and associated urbanization have compelled Engineers to construct earth structures, including major highways, over soft clay deposits of low bearing capacity coupled with excessive settlement characteristics. Consolidation due to radial drainage using PVD is one of the ground improvement techniques in which the consolidation is accelerated by reducing drainage path. Soil improvement is required to provide adequate bearing capacity and improve shear strength of the soft cohesive soils to satisfy the need for various type of construction on sites underlain by such soft soils. Amongst various ground improvement techniques the technique of preloading or pre-compression used in combination with vertical drains is one of the oldest and most widely used techniques to preconsolidate and strengthen weak compressible soils. Present research work focuses experimental model of various drain materials like Saw dust wrapped with Filter paper (SD), Saw dust wrapped with Geotextile (SDW), Sand drain and Jute wrapped with Polyamide Polyster Geosynthetics (JPPG) to expedite the in situ settlement due to excess pore water pressure dissipation under preloading by radial drainage taking advantage of having more horizontal permeability than vertical. The hydraulically pressurized Rowe-type oedometer was developed in the Applied Mechanics Department of M.S. University of Baroda, India. The present research work focuses on finding the most optimum drain in terms of materials (both natural and synthetic type), size (diameter of drain) and geometry to accelerate the consolidation of soft clays with a complete set-up of hydraulically pressurized modified oedometer with conventional bishop pore pressure measuring system and measuring settlement using a dial gauge. The effect of PVD of 'n' value (ratio of zone of influence to the diameter of drain) of 10, 12.09, and 14.76 on the consolidation characteristics of Kaolinitic clay was investigated to study the dissipation characteristics using isochrones & settlement characteristics. Time-pore pressure dissipation and time-settlement observations were recorded for different applied stresses under long duration testing. Average Degree of consolidation was computed using iso-chrones. The shear strength of the Kaolinitic clay was found out before and after the consolidation test by Vane shear test.**

The shear strength of different drain material is compared and also consolidation and compressibility of circular and cross shape drain is compared for good shear strength. Present work shows the Comparison of Experimental Results of shear strength for all the drain materials

Keywords—Vane shear test, shear strength, cross and circulr shape , Effective shear strengt, n value

1. INTRODUCTION

Beginning with the classical work of Terzaghi on three dimensional consolidation process and thereafter Barron's theory on consolidation due to radial flow which was further extended by Hansbo, number of research workers carried out research and focused the attention on various influencing factors of vertical geodrain on consolidation characteristics of clayey soil due to radial flow either by laboratory model or in the field. Most of the soil deposits have greater permeability in horizontal direction which can be utilized efficiently by the use of prefabricated vertical drains. After the use of sand drains, several new types of geo-drain has come on the horizon, with different shapes and material namely Sand wick Drain, Jute Drain, Polypropylene Drain, Card board drain, Rope Drain etc.

At first three dimensional consolidations problem was given by Terzaghi (1923). Prior to this three dimensional consolidation problems were solved using one dimensional approximation to three dimensional problems using Terzaghi`s famous consolidation theories. Further modified in Terzaghi (1943) and Barron (1948) reported simplified expression for the design of vertical drains. The theory after Tan (1961) includes stress strain relationship for clays during radial flow as a function of time, which he approximately solved using linear, integrated equation. The fourth theory was propagated and enhanced by workers namely Hansbo (1960), Henrich and Desoyer (1961), Escario et al (1961), Tan et al (1971) and Hansbo (1981). They have extended the scope of the theory, considering with respect to variable nature of loads, permeability, compressibility and structural viscosity. The equations of Barron were also used by Rowe (1969) in analyzing the consolidation of lacustrine, laminated Clays. This work was subsequently developed by Horne (1964), which includes and gives for laminated or layered clays having sequence of identical layers.

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2. VANE SHEAR TEST

The Vans shear test is used to measure **THE** shear strength of cohesive soils and for the soils of shear strength less than 0.3 kg/cm2 for which unconfined tests cannot be performed. This test gives the undrained strength of the cohesive soil. This test can be done in laboratory or in the field directly on the ground.

FIG. 1VANE SHEAR APPARATUS WITH SOIL SAMPLE

3. SCOPE AND OBJECTIVE

The hydraulically pressurized Oedometer (Rowe Type) with central geodrain is employed in present investigation and Cvr value is determined for both settlement and pore pressure readings. Measurements of pore pressures are planned to carry out by conventional Bishop's pore pressure setup and extensometer.

It is intended to conduct a series of Consolidation tests with radial drainage through vertical geodrain centrally placed and measurement of Settlement and pore water pressure at 3 radial distances will be taken so as to prove efficacy against various physical factors namely type of drain material, shape, aspect ratio , various shapes of drain , 'n' value (ie. Different diameters of drain related to influence zone)

In present investigation it is intended to use Sand, Saw dust, Saw dust wick, Jute, Polyamide Polyster Geosynthetics to fabricate the vertical geodrains of different diameters in relation to diameter of hydraulically pressurized oedometer (Rowe Type) is used which has special facility for measuring pore pressure and settlement during consolidation due to radial flow of water. The present investigation will simulate the theoretical values of Degree of Consolidation with experimental values for all n values where n = Radius of Oedometer to Radius of the drain

3 LABOTATORY INVESTIGATIONS

3.1 MATERIALS USED

The soil used for this investigation was clay mineral Kaolinite obtained commeially in the form of powder. To ensure full saturation of the sample the clay was mixed to form slurry with twice the liquid limit using de-aired distilled water.

TABLE 2 PROPERTY OF KAOLINITE SOIL

Type of clay	Kaolinite
Specific Gravity	2.456
Liquid Limit (LL)	59.6%
Plastic limit (PL)	33.33 %
Plasticity Index (PI)	26.27 %
Classification by A-line Casagrande Chart	CH
Co-efficient of Permeability	0.6 x 10-6 cm/sec

3.2. Properties of PVD drain material:

In present investigation, Saw dust wrapped with Whatman filter paper (SD), Saw dust wrapped with Geosynthetics (SDW), Sand Drain and Jute wrapped with polyamide polyster (JPPG) is used for investigation. The properties of the drain material are shown in Table.2, Table.3, Table.4 and table.5. The Saw Dust is treated chemically and then used as a drain by encasing it with Whatman filter paper

TABLE 2 PROPERTY OF SAW DUST WRAPPED WITH WHATMAN FILTER PAPER

Sr. No.	Properties of saw dust	Value
1	D10mm	0.29
2	D30mm	0.52
3	D60mm	1.05
4	Co-efficient of uniformity, cu	3.620
5	Co-efficient of curvature, cc	0.888
6	Maximum compressive stress, kg/cm2	0.138
7	Coefficient of permeability, cm/sec	1.502×10-3

TABLE 3. PROPERTIES OF GEOTEXTILE USED IN SAWDUST WICK DRAIN

Sr. No	Description	Value
1	Type of Geotextile	Non-woven
2	Mass per unit area	250gm/m2
3	Tensile strength	14 KN/m
4	Permeability by falling head	3.6x 10-3cm/sec
5	Opening size	85 microns

TABLE.4. PROPERTIES OF SAND USED IN SAND DRAIN

1	Specific Gravity	2.645
2	Co-efficient of Permeability	8.45 x 10-3 cm/sec
3	Co-efficient of uniformity, cu	2.023
4	Co-efficient of curvature, cc	1.295
5	Fineness Moduli	2.2-2.3
6	Sand classified	SW

TABLE.5 PROPERTIES OF PREFABRICATED VERTICAL CIRCULAR JUTE WRAPPED WITH POLYAMIDE POLYSTER GEOSYNTHETICS

Sr. No	Properties of newly developed jute wrapped with Polyamide Polyster drain	unit	value
1	Weight	gms	5
2	Diameter	Cm	2.1
3	Height	Cm	5.1
4	Peak unconfined stress for flexibility measurement	Kg/cm2	0.8
5	A.O.S. (095) – Filter	µm	<75
6	Permeability – Filter	Cm/sec	1.1x10-1

TABLE.6 PROPERTIES OF JUTE USED IN JPPG DRAIN

Sr. No	Description	Value
1	Mass per unit area	388gm/m2
2	Tensile strength	250-350 N
3	Permeability by falling head	3 x 10-2cm/sec
4	Jute thickness single layer and double layer	1.08mm & 2.06
5	Grab tensile strength	800-900 N
6	Length of fibers in mm	10-200(highly variable)
7	Elongation percentage at break	5%

3.4 Method of Soil Preparation

The soil used for this investigation was clay mineral Kaolinite obtained commercially in the form of powder. To ensure full maturation of the sample the clay was mixed to form slurry with twice the liquid limit using de-aired distilled water. Density was sufficiently low to allow the removal of entrapped air when the sample in the consolidation cell was vibrated. The slurry was transferred into the Oedometer after the cell body had been lightly coated with a thin layer of silicon grease to minimize side friction; the Oedometer was then placed on a handle operated vibrator and vibrated for approximately one hour after which only occasional air bubbles could be seen on the surface. The clay was then scribed level. And a filter paper followed by a porous stone was placed at the top.

The sample was then preconsolidated under gradually applied static dead load of 8 Kpa, with Δp/p = 1, (1kPa, 2kPa, 4kPa, 8kPa) so that the consolidation occurring is normal. These increments are given by means of dead load with porous stone on the top of the clay sample topped by filter paper so that sample during consolidation water gets removed through porous stone. These increments of static loads are to be kept for a longer period of time (at least 48 hours).

Increments are calculated as shown below:

$$\text{Area of Oedometer} = \frac{\pi}{4} \times 25.4^2 = 506.708\ cm^2$$

$$\text{For 8 kPa Load} = 506.708 \times 8 = 40.53\ KN$$

Representative sample for determination of water content was taken and measured. Initial strength was measured by Vane shear in separate crucible of vane shear apparatus by dead loading in same fashion by small weights. To avoid the soil structure disturbance of soil cake prepared.

Initial Height was measured with pointer arrangement with stand and the extra soil was trimmed.

Filter paper is kept on the surface of the trimmed soil and rigid Perspex plate was laid on it to create the equal strain condition while loading.

Installation of drain:

The axial hole was formed with a thin walled mandrel, having area ratio of 0.8 to 1.6 attached with template and guide frame. Circular Filter paper of size PVD is lowered in the bore hole. A drain hole was then flooded with water from the central connection to the reservoir.

The drain was filled with de-aired saturated PVD drain material with the aid of small diameter flexible tubing by syphoning action without any smear and without any intrusion of clay in PVD to avoid blockage. The top cover is then seated into position.

FIG. 2 INSTALLATION OF VERTICAL DRAIN

3.6Test Procedure

After the cell is sealed, settlement dial gauge and Bishop Pore pressure measuring apparatus were connected at their respective location. The first pressure increment is applied through the flexible convoluted jacket after closing the drainage control valve and settlement gauge reading is recorded. After completion of consolidation process drainage control valve was closed then the next increment of load is applied and the same process is repeated for a series of

various pressure increments, with P/P = 1.0. The loading was done in the increment of 20, 40, 80, 160 and 320 kPa keeping ΔP/P = 1.After the completion of the test, vane shear test was performed at 3 locations to determine the gain in strength due to dissipation of water.
The value of settlement and pore water pressure is measured with respect to time and co-efficient of radial consolidation is calculated.

Shear Strength Variation Radially:
Initial shear strength was measured using Vane shear apparatus. A soil sample in separate crucible of vane shear was prepared and was preconsolidated by dead loading in same fashion by small weights. This was done to avoid the soil structure disturbance of soil cake prepared. The final shear strength was also measured for all 4 drain materials
The final strength variation was calculated using vane shear test apparatus after each experiment at radial distance for all drain material. The shear strength was measured at the top surface of the cake at a distance r1, r2, r3 from the central drain.

4. Tests and Result Analysis:

1) The shear strength for SD, SDW, Sand drain and JPPG drain are 98 KPa, 114 KPa, 100.6 KPa and 126 KPa respectively.
2) It is observed that the gain in strength of the consolidated mass is better in JPPG Drain in comparison to SDW, Sand, and SD.
3) The effective shear strength was calculated for all drain materials. Comparing the effect of various drain materials, the effective shear strength (SE) achieved at end of consolidation is observed that JPPG (101 kPa) and SDW (103 kPa) exhibit more strength as compared to sand and SD.
4) The Sand drain and saw dust exhibit almost same effective strength of 82 kPa while SDW and JPPG exhibit same order of 102 kPa

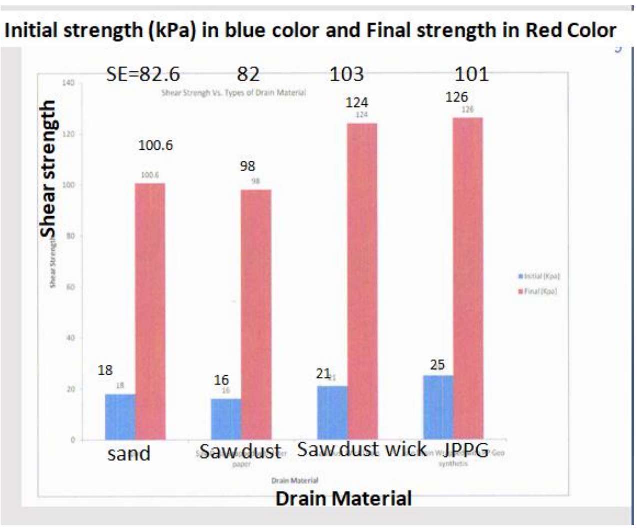

FIG. 3 COMPARISON OF SHEAR STRENGTH

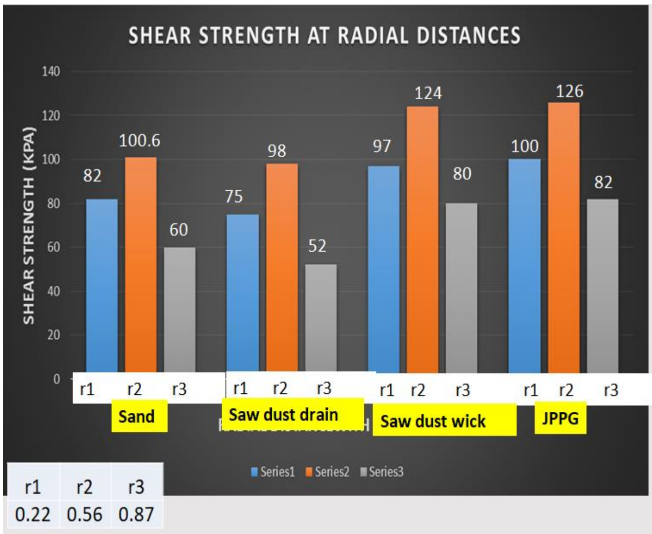

FIG. 4 SHEAR STRENGTH AT RADIAL DISTANCES

5. CONCLUSION:

It is observed that mid plane strength in every material is higher compared to near the Drain and at farthest radial point. Average percentage increase of shear strength from near the drain to mid plane is 46% while decrease of strength from mid plane to farthest point is 66%.

6. REFERENCES:

[1] Abid, M.M., and Pyrah, I.C., 1990, "Consolidation behavior of finely laminated clays", Computers and Geotechnics, 10 (4), 307-323

[2] Balasubramanian A. S, 1995, "Experiences with sand drains and prefabricated vertical drains in ground improvement of soft clays", Seminar on Eng. for Coastal Development, Singapore, 29–40

[3] Barron, R. A. 1948, "Consolidation of Fine-Grained Soils by Drain Wells", Transactions, ASCE, 113, 718-754.

[4] Bergado D. T, Brenner R. R, Balasubramaniam AS, Chotivittayathanin R. and Pananookooln R 1990 ;Improvement of soft Bangkok clay using vertical geotextile band drains compared with granular piles ;Geotextiles and Geomembranes, 9 (3), pp. 203–231

[5] Bergado D.T., Cheung, YK, Lee, PKK, and Xie, KH., 1991, "Smear effects of vertical drains on soft Bangkok clay". Journal of Geotechnical Engineering 117 (10), 1509–1529.

[6] Bergado D. T, 1993a, "Improvement of soft Bangkok clay using vertical drains "Geotextiles and Geomembranes 12 (7), 615–663

[7] Bergado D. T., Mukherjee K., Alfaro M. C. and Balasubramaniam A. S.., 1993b, "Prediction of vertical-band-drain performance by the finite-element method"; Geotextiles and Geomembranes, 12 (6), 567–586

[8] Bergado, D.T, Balasubramaniam, A.S, Fannin. R.J and Holtz, R.D., 2002; "Prefabricated vertical drains (PVDs) in soft Bangkok clay: a case study of the New Bangkok International Airport project" Canadian Geotechnical Journal, 39, 304–315

[9] Chu J, Bo M.W, Choa V., 2004 "Practical Considerations for using Vertical Drains in Soil Improvement Projects", Geotextiles and Geomembranes, 22, 101-117

[10] Dhar A. S, Siddique A and Syed A. F., 2000, "Investigation of smear zone around vertical drain", Proceedings of the Third International Conference on Ground Improvement Techniques, Singapore, 109–114.

[11] Hansbo, 1997, "Aspects of vertical drain design: Darcian or non-Darcian flow". Geotechnique 47, 983–992.

[12] Holtz, R. D., Jamiolkowski, M., Lancellotta, R. and Pedroni, S., 1987, "Performance of Prefabricated Band-Shaped Drains", Construction Industry Research and Information Association (CIRIA), London, England; Report RPS 364.

[13] *Madhav M. R. & Khan Ayub P. 2011, "Consolidation of soft ground with drains with no (PVDs) and finite stiffness (granular piles)" Proceedings of Indian Geotechnical Conference, December 15-17,*

[14] *Naga A. H. M and Bouazza, 2009; "Equivalent diameter of a prefabricated vertical drain", Geotextiles and Geomembranes*

[15] *Shah M. and Shroff A.V., 2009, "Consolidation of soft clay through Radial drainage using vertical sand Drains of various diameter and geometry" Proceedings of ASCGE, Vol-1*

[16] *Shah M. and Shroff A.V., 2006, "Non-linear theory of consolidation through radial Drainage for soft soils using vertical drains" Proceedings of XIII-Danube-European Conference on Geotechnical Engineering, Vol-I, pp-349-354*