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EXPERIMENTAL STUDY ON PERFORMANCE OF VERTICAL GEO DRAIN ON KAOLINITE USING LARGE SCALE MODEL CONSOLIDATION TEST

Nirav Rathod[1], Prof. A.R.Gandhi[2], Prof. (Dr.) M.V.Shah[3]

[1, 2, 3] *Applied mechanics department, L.D. College of Engineering, Ahmedabad, Gujarat, India*

Abstract — *Soft marine clay deposits exhibit low bearing capacity and high compressibility characteristics. Using sand drains or vertical Geo-drains is now well established ground improvement technique with wide theoretical base. The objective of present research work is to evaluate compressibility characteristics of kaolin clay in large sized model consolidometer having aspect ratio 1.0:0.635 (H:D) using vertical drain with 'n' (r_e/r_w) value of 10. Two materials viz. sand and LLDPE Plastic granules were used as filler for vertical drain based on their permeability characteristics. The results were compared with equal strain theory of 'Barron' with inward radial drainage based on settlement measurements. The soil used here in the present case is kaolinite procured from Bhavnagar city (Gujarat).The highlight of this study is to use large size consolidometer of size 25.4 cm diameter and 40cm height, specially designed and fabricated at Applied Mechanics department, L.D. College of Engineering using 10mm thick steel plate. The difference between conventional Oedometer test and present set-up is in their aspect ratio. In the present case aspect ratio of 1.0:0.635 is adopted. Barron's equal strain theory is more popular and widely adopted in field for inward radial flow. Referring to many theoretical models and their assumptions for evaluating consolidation characteristics it was found that this theory's hold good even for large thick samples. So this study is an attempt to validate experimental results for large size consolidation parameters by measuring settlement readings. Pre and post vane shear strength are recorded and shear strength results are compared with virgin clay.*

Keywords-*Large size model consolidation test, vertical Geo-Drain, settlement, vane shear test, Barron's equal strain theory*

I. INTRODUCTION

The consolidation settlement of soft clay subsoil creates a lot of problems in foundation engineering. Because of the very low clay permeability, the primary consolidation takes a long time to complete. To shorten this consolidation time, vertical drains are installed together with preloading by surcharge embankment or vacuum pressure. Laboratory testing with large-scale consolidation apparatus have proven useful in analysis the behavior of vertical drains installed in soft clay. Indraratna and Redana (1995) used a large scale consolidometer (450 mm × 900 mm) to investigate the effect of smear due to installation of prefabricated vertical drains and sand compactions piles. Sharma and Xiao (2000) also conducted a series of large-scale tests to study the behavior around vertical drains installed in soft clay using remoulded kaolin clay. Side wall friction, which develops along the inner wall surface of the confining cell and causes uneven compression over the specimen length, generally increases with increasing scale. The measured k values and degree of anisotropy generally increase with increasing scale.

II. EXPERIMENTAL INVESTIGATION

2.1 Testing Programme

Total three tests were performed namely

(i) Large size model Consolidation test without installing Vertical Drain (LCTWD)
(ii) Large size model Consolidation test with installing sand as vertical drain (LCTSD)
(iii) Large size model Consolidation test with installing LLDPE Granules as Vertical drain (LCTPG)

2.2 Testing Material

(i) **Soil**-The soil sample is made of Kaolinite clay with mixed de-aired distilled water, twice the liquid limit to from slurry. The properties of soft kaolinite clay are shown in Table-1.
(ii) **Sand**-The vertical drain was filled with de-aired saturated sand. The properties of sand are shown in Table-2.
(iii) **LLDPE Granules**-The vertical drain was filled with LLDPE granules. The properties of LLDPE granules are shown in Table-2.

Table-1: Index properties of Kaolinite clay

Sr. No.	Description	Indian Standard	Symbol	Determination
1	Specific-Gravity	IS:2720-3	G	2.586
2	Liquid Limit	IS:2720-5	LL	73.5%
3	Plastic Limit	IS:2720-5	PL	40.9%
4	Shrinkage Limit	IS:2720-6	SL	36.116%
5	Plasticity Index	IS:2720-5	PI	32.6%
6	Soil type	IS:1498-1970	-	CH

Table-2: Index and Engineering properties of sand and LLDPE Granules

Sr. No.	Description	Indian Standard	Symbol	Sand	LLDPE Granules
1	Specific Gravity	IS:2720-3	G	2.66	1.37
2	Permeability	IS:2720-36	k	1.2274×10^{-2} cm/sec	1.6×10^{-2} cm/sec

2.3 Large scale Consolidation Test Setup

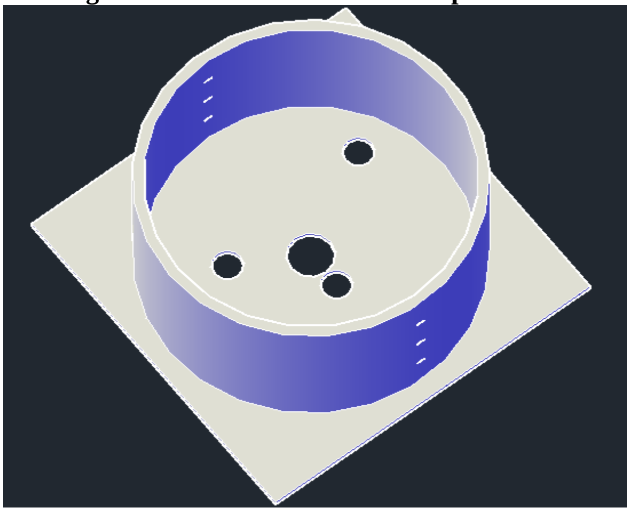

Fig 1: Large scale Consolidation Test Setup

The test set-up includes a fabricated 10 mm thick mild steel circular tank and load frame with mechanical jack with proving ring is used to measure compressive load attached to a steel rod with circular steel plate for complete transfer of axial compressive load. The internal diameter of tank is 254 mm and height 450 mm. Four drain holes of diameter 25mm are provided at the bottom of the tank to enable free drainage of the water from the bottom, if required, during the consolidation process. To measure the settlement of soil, one dial gauges having a sensitivity of 0.002 mm were used.

2.4 Preparation of test sample and test procedure

The large scale consolidation tests were carried out on kaolinite clay with and without the vertical drain. Before commencing each test, a remoulded kaolin clay test sample of 147% water content was prepared by adding water to oven dry soil. This water content is equal to twice liquid limit of kaolin clay. Than slurry transfer into cylindrical tank, before that put porous stone in drainage hole and filter paper on bottom of tank. Slurry fill into cylindrical tank up to predetermine height.Initially slurry remains for self-weight consolidation for 24 hr.The loading was done in stages to avoid pumping up of the slurry.A seating pressure of 0.1 kg/cm^2 shall be applied.at end of 0.1 kg/cm^2 stress vertical geo-drain installed in specimen with help of mandrel of 25mm external dia. With n value 10. The vertical loads were increased gradually in sequence to produce stresses of 0.2, 0.4, 0.8, 1.6 and 3.2 kg/cm^2 of time interval of 3 days each. Settlement measurements were made with help of one dial gauge was considered in calculation. At end of 3.2 kg/cm^2, vane shear test performed on consolidated specimen.

III. THEORETICAL BACKGROUND

Barron (1948) presented the most comprehensive solution to the problem of radial consolidation by drain wells. For equal strain conditions horizontal sections remain horizontal throughout consolidation process. By considering the flow into and out of an infinitesimal cylindrical element the governing equation for consolidation by radial drainage (Barron, 1948) is given by:

$$\frac{\partial u}{\partial t} = c_h \left(\frac{\partial^2 u}{\partial^2 r^2} + \frac{1}{r}\frac{\partial u}{\partial r} \right)$$

The average degree of consolidation, Uh , in the soil body is given by:

$$Uh = 1 - exp\left(\frac{-8T_h}{F(n)} \right)$$

The drain spacing factor (n) is given by,

$$F(n) = \frac{n^2}{n^2 - 1}\ln(n) - \frac{3n^2 - 1}{4n^2}$$

The time factor T_h is defined as,

$$T_h = \frac{c_h \cdot t}{4r_e^2}$$

The coefficient of radial drainage consolidation, C_h , is represented by:

$$C_h = \frac{k_h(1 + e)}{a_v \gamma_w}$$

IV. EXPERIMENTAL RESULT AND DISCUSSION

➢ The settlements observed at regular intervals of time in remoulded kaolin clay alone and with vertical sand drain and with vertical LLDPE Granules are plotted in the graphs shown in Figure. In the absence of pore water pressure measurement within the soil, time required for value of 50% degree of consolidation by using hyperbolic method.

(i) Large sized model consolidation test without installing vertical drain (LCTWD)
Using Hyperbolic Method finding time required for 50% consolidation without installing vertical drain at 20kPa, 40kPa, 80kPa, 160 kPa and 320 kPa are 2600 min., 475 min., 447 min., 421 min., and 315 min. respectively shown in figure 2.

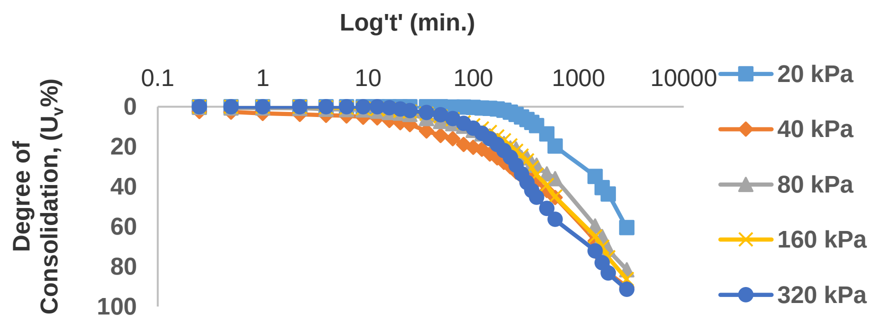

Fig 2: Degree of Consolidation (U_v) vs. Log't' for LCTWD

(ii) Large sized Model Consolidation test with installing vertical sand drain (LCTSD)
Using Hyperbolic Method, time required for 50% Consolidation using Sand as Drain material for n=10 at 20kPa, 40kPa, 80kPa,160 kPa and 320kPa are 394 min., 368 min.,368 min.,213 min. and 473 min. respectively shown in figure 3.

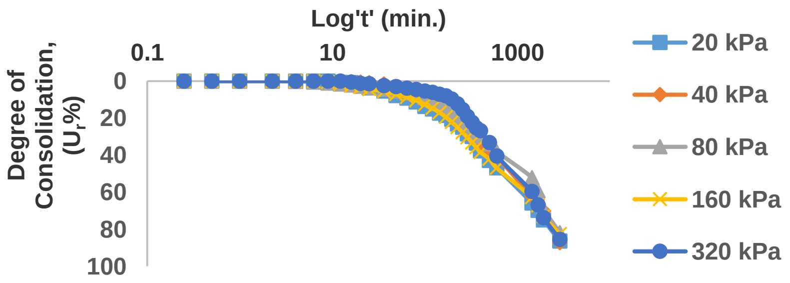

Fig 3: Degree of Consolidation (U_r) vs. Log't' for LCTSD

(iii)Large sized Model Consolidation Test with Installing Vertical LLDPE Granules (LCTPG)

Using Hyperbolic method, time required for 50% Consolidation using Plastic Granules as drain material for n=10 at 20kPa,40kPa,80kPa,160kPa and 320kPa are 1260 min.,473 min.,368 min., 342 min. and 1400 min. respectively shown in figure 4.

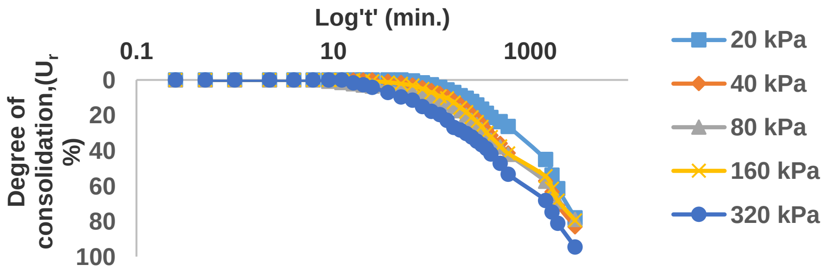

Fig 4: Degree of Consolidation (U_r) vs. Log't' for LCTPG

➢ Figure 5 depicts the degree of consolidation versus logarithm time factor recorded for large scale consolidation test with central vertical drains with 'n' value of 10.The theorectical curve given by Barron's for equal strain condition is almost similar to experimental result plot. Through large sized consolidation test the plain strain condition given by Barron can be better simulate by such large size specimen.

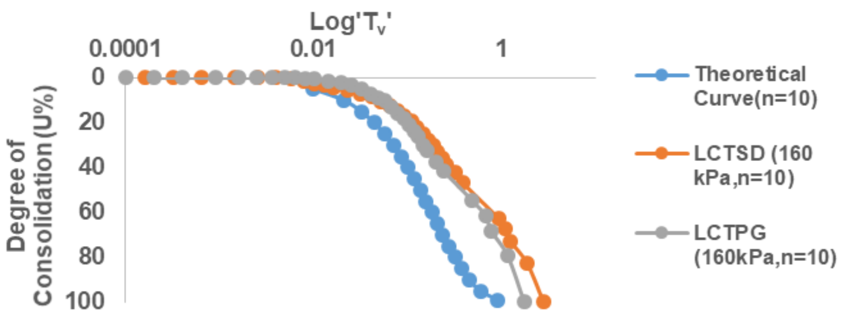

Fig 5: Degree of consolidation versus Logarithmic time factor (for n=10)

➢ Figure 6 shows the plots of settlement versus time period for various drain materials i.e. sand and LLDPE for 'n' value of 10 and of virgin soil. From the plot it is observed that at end of 15 days settlement of specimen installing with sand as vertical drain is more than other specimen due to acceleration in consolidation process by installing sand drain. Surface interaction between clay and drain plays an important role in deciding the rate of dissipation of excess pore water pressure since, the clogging rate increase due to quick dissipation of excess pore water pressure. Due to uniform size and higher permeability of LLDPE granules, dissipation of excess pore water pressure is higher at initial stage but as load increases clogging in LLDPE granules has observed between granules particles.

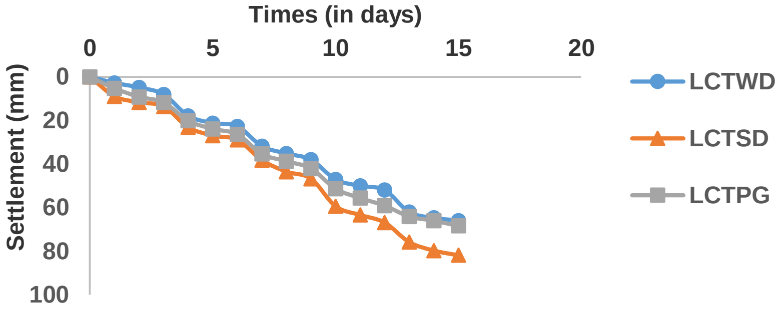

Fig 6: Settlement versus Time Period In large sized Model Consolidation Test

➢ Figure 7 shows the plots of coefficient of consolidation due to radial drainage(C_r) versus applied pressure for various drain materials i.e. Sand and LLDPE for 'n' values of 10.Here,from the plot it is very clear that the nature of C_{r50} increasing for 20,40,80,160 kPa and for 320 kpa value of C_{r50} decreasing.Value of Coefficient of Radial Consolidation finding using Barron's Equal Strain theory.

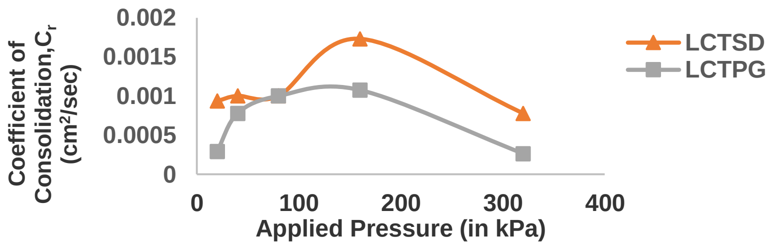

Fig 7: Coefficient of consolidation through radial drainage (C_r) versus Applied Pressure

➢ Figure 8 shows a Characteristics curve of normally consolidation soil for 'n' value equal to 10 and for with and without vertical Drain material.The value of compression index (C_c) is 0.48 for without vertical drain,0.595 for with vertical sand drain and 0.49 for with vertical LLDPE drain.

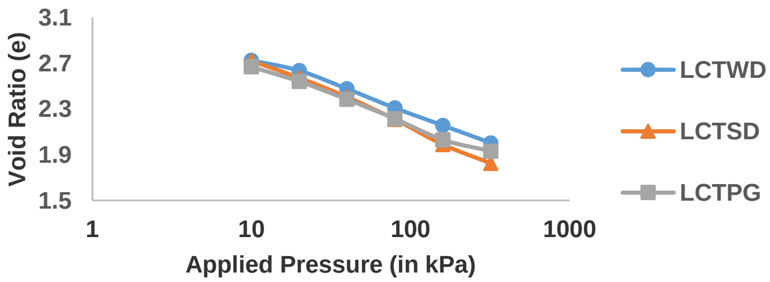

Fig 8: Comparison of drain material w.r.t. Void ratio (e) against Applied pressure for n=10

➢ Shear strength increase to some extent towards drain for any drain material. Soft clay consolidated by Sand drain gained a shear strength of 104 kPa compare to shear strength gained by LLDPE drain and without vertical drain as 74 kPa and 38 kPa respectively at end of consolidation test.

V. CONCLUSION

- Barron's equal strain theory can be used for large scale model consolidation test data for determination of various consolidation parameters.
- Time required for 50% Consolidation in Large Sized Model Consolidation test using Sand Drain as Vertical drain is more effective than plastic granules. The vertical permeability though higher of LLDPE granules but due to low strain comptability, rearrangement of particles due to same size and high effect of viscous water, overall LLDPE drain shows lower efficiency compared to sand drain of same size.
- In the field, use of sand as a vertical drain for accelerating consolidation process. The same behaviour of sand drain has also been observed in large size model consolidation test.
- Post vane shear strength results indicate higher gain in shear strength for soil treated with sand drain compared to LLDPE drain

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