

Experimental Study on Permeability Behaviour in Cement Treated Marine Clay



Engineering

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ABSTRACT

Construction activities on soft soils of marine environment have proven to be a challenging task for engineers. The marine clay deposits are very soft and it possess very high natural moisture content. This clay soil is characterized by its low permeability and high compressibility. Many important onshore and offshore structures are to be supported on this soil. A study to improve the shear strength of the marine clay has become imperative. In the previous studies as cement stabilization was considered effective in improving the strength parameter. The focus was mainly on shear strength of the marine clay. The permeability characteristics of cement treated marine clay and its effect on shear strength was not addressed. The present study is focused on permeability and strength behavior of cement treated marine clay at varying cement contents. The remoulded marine clay collected from the shores of Bay of Bengal, Akkaraipettai, Nagapattinam, Tamilnadu are used. Oedometer tests are conducted on marine clay specimens to study the variation of permeability and strength (vertical and horizontal) characteristics. In addition, curing periods on the flow characteristics are also studied.

INTRODUCTION

Marine clays cover large areas of earth including many low-land and coastal regions, where many urban and industrial hubs are located, and are frequently encountered in civil engineering projects. One of the major problems related to construction activities on marine clay is High liquidity index is a notable characteristic of such soil, resulting in high compressibility and low shear strength. The presence of soft soil can be problematic in many different ways. If proper engineering measures are not taken, structure built on soft clay could undergo excessive settlements or even failure. Soil subsidence due to the withdrawal of ground water is another issue in soft clays. In addition, marine clay undergoes large deformation even on relatively small loads.

Two approaches for tackling the problems associated with the presence of soft or sensitive clays are considered. The first one is to pre-consolidate clay using vertical drains under surcharge to accelerate consolidation and improve its mechanical properties. Due to longer duration of time involved in this approach, an alternative, in which soft clays can be solidified by artificial production of cementitious bonding is considered. Modification of soils to enhance their engineering behaviour using cementing agents is well established and extensively practiced. Early methods of surface stabilization for compacted soils, in particular for sub-base construction of roads, were developed to improve the mechanical behaviour and reduce the total thickness of the base course. For instance, with growing environmental concerns, artificial cementation has been employed for solidification and isolation of contaminated sediments.

Deep mixing and jet grouting techniques have been developed during the past twenty years to produce cemented columns in soft ground for the stabilization of roads, excavations, and lightly loaded foundations. Unlike shallow mixing, which transforms the entire volume into cemented material, these deep mixing techniques only produce discrete cemented columns, leaving a large portion of the soft clay untouched. In most of these methods, the cementing agent is introduced deep into the ground by either mechanical or high pressure grout mixing.

Several techniques have been developed in the recent past to stabilize soft clay. However their permeable properties of cement treated marine clay was not rigorously addressed. In this study the effect of cement stabilization on permeability of soil both in vertical and horizontal direction is analyzed. In addition due to admixing of cement and varying curing periods on soil structure is also studied.

PROPERTIES OF THE MATERIALS

The sample of marine clay sample for the study was collected at latitude 10°45'5.63" N and longitude 79°50'45.86" E (Akkaraipettai, Nagapattinam, Tamilnadu). The properties of marine clay are shown in Table 1.

S.No	PROPERTIES	RESULTS
1	Natural Moisture Content	82.00%
2	Specific Gravity (G)	2.78
3	Free Swell Index	40.00%
4	pH	8.10
5	Gravel	00.00%
6	Sand	03.00%
7	Silt	33.00%
8	Clay	64.00%
9	Liquid Limit	55.30%
10	Plastic Limit	35.45%
11	Shrinkage Limit	11.00%
12	Soil classification	CH
13	Optimum Moisture Content	23.00%
14	Maximum Dry density	1.5801 g/cc
15	Unconfined Compressive Strength (q_u)	151 kN/m ²
16	Cohesion (c_u)	75.5 kN/m ²

Table 1 Properties of Marine clay

EXPERIMENTAL STUDY

Specimen Preparation

Cement content in various proportions such as 2.5%, 5%, 7.5% and 10% in the form of slurry was gradually added to the remoulded base clay and thoroughly mixed using a stirrer for 10min at a speed of 61rpm. The water content to be calculated for the preparation of slurry is obtained from Equation (1).

$$C_w = w^* + (w/c)A_c \quad \text{-- (1)}$$

where, C_w is the final water content of the clay-cement mix(%), w^* is the water content of the base clay, w/c is the water-cement ratio by weight of the cement slurry and A_c is the cement

content as the percentage by weight of the dry base clay. In the present study the water-cement ratio was generally maintained as 0.8. The water content of the base clay was 92.25%. It is noted that the effect of water content is significant on the properties of cement treated soil.

The cement admixed clay was filled in the PVC sampling tube of 60mm inner diameter in three stages. The entire process of filling in the sampling tubes was done in less than 10 minutes ensuring that no air is entrapped. A detachable porous stone is mounted at the top and bottom of sampling tube for drainage. Porous stones are boiled after each and every single use to ensure the free drainage. A minimum height of 10mm water level is maintained above the top cap for proper curing. After the curing period, the specimen was ejected and trimmed to obtain the required specimen of height 20mm.

Test Setup (Vertical)

The one-dimensional consolidation testing procedure was first suggested by Terzaghi(1925). This test is performed in oedometer. The schematic diagram of oedometer is shown in Fig 2 .The soil specimen is placed inside a metal ring with two porous stones, one at the top of the specimen and another at the bottom. The specimens are 60 mm in diameter and 20 mm thick. The load on the specimen is applied through a lever arm, and compression is measured by a micrometer dial gauge. The specimen is kept under water during the test. Each load is usually kept for 24 hours. After that, the load is usually doubled, thus doubling the pressure on the specimen, and the compression measurement is continued. At the end of the test, the dry weight of the test specimen is determined. Three trials were performed. Oedometer test is shown in Fig 1

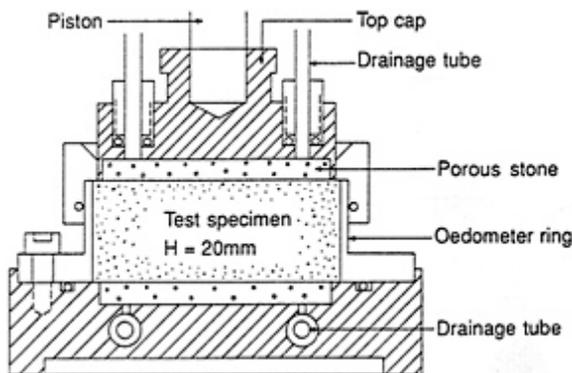


Fig 1 Schematic Diagram of Oedometer

Test Setup (Horizontal)

The test setup is similar to vertical flow but a sand drain is introduced at the center of the specimen having diameter of 6mm for finding the horizontal flow by taking the value of drain spacing ratio (n) is 10. The schematic diagram of the horizontal flow is shown in Fig.2

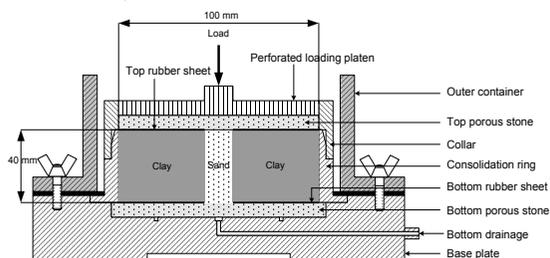


Fig 2 schematic diagram of the horizontal flow

Horizontal consolidation test was then conducted on the sample by applying loads in steps with load increment ratio which is very similar to the one-dimensional vertical consolidation tests. From the time-settlement data, the values of c_v were determined using Barron's theory (1948) for the equal strain consolidation by the log t method (Sridhar and Robinson, 2011).

RESULTS AND DISCUSSIONS

The Coefficient of permeability for various cement content is shown in Table 2. Coefficient of consolidation for 10% of cement content is shown in Table3.The UCC strength for various cement proportions and various curing days are shown in Table 4

Sl. No	Cement Content	K_v cm/sec	K_h cm/sec
1	0%	4.11×10^{-10}	5.76×10^{-9}
2	2.5%	3.631×10^{-10}	5.034×10^{-9}
3	5%	3.152×10^{-10}	4.29×10^{-9}
4	7.5%	2.474×10^{-10}	3.21×10^{-9}
5	10%	2.01×10^{-10}	2.564×10^{-9}

Table 2 Coefficient of permeability for various cement content - 28 days of curing

Sl. No	PROPERTIES	7 Days	14 Days	28 Days
1	Coefficient of consolidation (c_v)	2.3056×10^{-4} cm ² /sec	2.8472×10^{-4} cm ² /sec	4.3673×10^{-4} cm ² /sec
2	Coefficient of consolidation (c_h)	1.2868×10^{-4} cm ² /sec	1.1035×10^{-4} cm ² /sec	0.7043×10^{-4} cm ² /sec

Table 3 Coefficient of Consolidation for 10% of cement content

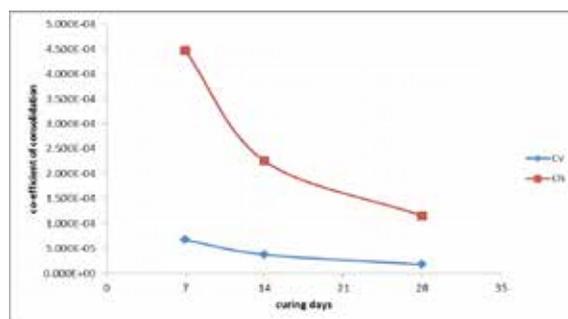
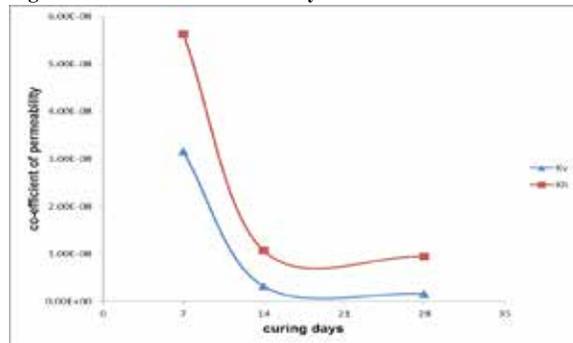


Fig 3 Coefficient of Consolidation in Horizontal and Vertical Flow For 10% Cement for Various Curing Days

Fig 4 Coefficient of Permeability In Horizontal And Vertical



Flow For 10% Cement At 28 Days Curing

DISCUSSIONS

- It is observed that there is significant increase in strength

on addition upto 10% cement.

- It is observed from the results of effective pressure that at the vertical stress level of 0.8 kg/cm^2 , C_h is almost 9.3 times the C_v value.
- It is observed from results based on curing period that the coefficient of consolidation ratio C_h/C_v is about 6.3
- The permeability gets decreased significantly on addition of cement content from 7.5% to 10%. This could be due to pozzolonic cement substances in the pores of soil.

CONCLUSIONS

- Laboratory horizontal consolidation tests subjected to drainage and surcharge loading using a modified one dimensional consolidation were conducted to determine permeability characteristics in radial direction.
- The strength of soil gets increased significantly upto the addition of 10% cement content beyond which strength does not increase significantly due to the inert zone effect.
- The secondary compression is less significant when the soil is subjected to horizontal drainage.
- Water in base clay helps in hydration process when cement is added it helps in the formation of cementitious bond in voids.
- The value of C_h is higher than C_v is due to the change in the orientation of soil settle down from slurry.

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