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THE SUCCESS OF ROUND IMPROVEMENT OF VERY SOFT CLAY WITH VERTICAL DRAINS

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ABSTRACT

The construction of oil storage tanks and embankments over very soft clays are being managed by adopting ground improvement with vertical drains under preloading of soft clays, the structures are being supported with stone columns. The success of round improvement of very soft clay with vertical drains using preloading depends on the accguracy of design parameters and planning of proposed stage wise loading.In the present study, an investigation is done into failure of ground improvement of very soft marine clay with PVDs to support a railway embankment adjacent to Meghadri canal at HPCL white oil terminal, Visakhapatnam. The details of the failure and design particulars of PVD system installed are gathered. A revised design of PVD system is done along with various other measures required for stability of embankment, such as strengthening of soft clay beyond toe of embankment and lateral confinement of soil for better supporting strength of marine clay has been suggested for the consideration.

Keywords: PVD System, Marine Clay, Preloading and Lateral Confinement.

I INTRODUCTION

Marine clays are highly compressive with low bearing capacity and normally available in soft consistency. To improve the performance of the soft clays it is important to remove the water from clay soil, for removing the water from the clay soil we have various techniques like sand drains, stone columns, wick drains, vacuum dewatering and electro osmosis.

The most important property that is to be focused on clay soils is its mineralogical composition. Clay minerals have the property of sorbing certain anions and cations and retaining them in an exchangeable state. Index properties give rough assessment of the engineering properties. The important index properties are natural water content, grain size distribution, Atterberg limits, initial void ratio and specific gravity.

The Atterberg limits along with the natural water content give useful indication of the consistency of a clayey soil. Natural water content close to the liquid limit indicates a soft compressible soil while natural water content close to the plastic limit is characteristic of stiff and less compressible clay. Water content is intermediate indicates the soil is somewhat over consolidated and the water content is greater than liquid limit indicates soils on verge of being a viscous liquid. The structures constructed on the soft clays will lead to many problems like larger differential settlements, heaving at plinth level and also chance of developing negative skin friction in pile foundation etc. This may be due to the low bearing capacity and high compressibility of soft clays. They also produce large amount of lateral earth pressure behind the retaining walls and bridge abutments.

In addition to these, heaving and cracking of the pavements or road ways and ground supported floor slabs can occur due to existence of marine clay immediately below the pavements and floor slabs. Various methods that are adopted for improving the performance of soft clays are Pre-Loading, Sand Columns, Wick Drains, Vacuum Dewatering, Electro Osmosis, Stone Columns etc.

II OBJECTIVE

The aim of the work is to investigate in to shear failure of marine clay which is treated with vertical drains at white oil terminal and to suggest improved design. To achieve the above aim the following objectives are to be worked

1. To collect the design data of vertical drains adopted at the site.
2. To determine the CV and Ch of marine clay using Oedometer method.
3. To verify the adequacy of adopted design in light of established engineering properties.
4. To propose the revised spacing for drains based on the values of CV and Ch keeping in view of time constrained and to propose other methods for stability of proposed embankment supporting railway track.

III METHODOLOGY

3.1 Description of Failure

The railway embankment under construction on the bank of meghadri canal at HPCL white oil terminal, Visakhapatnam has failed during construction. To support the main embankment a berm is provided on the canal side. The bottom of the berm is layered with moorum filling over sand drainage layer and the berm is planned to construct in layers. When the height of the berm reached 2.6m in 25 days failure has been occurred.

Embankment has very soft marine clay as foundation soil. It has been observed that, overstressing of the ground due to the construction activities and placement of fill at faster

rate led to the lateral movement of the soft soil and forming an upheaval in the canal bed. To prevent further movement of the slip and additional damage to the embankment, placements of the fill and construction activities are ceased in the vicinity of site boundary.

3.2 Gathering Design Data of Pvd's & Soil Parameters

Considered In Design:

Based on the earlier site investigation, depth of weak soil having a cohesion 5t/m^{2}is upto 16m below the ground level and standard penetration test value is recorded from 0-3. The liquid limit and plastic limit for the clay soil is 76 and 41. Coefficient of consolidation in vertical (C_v) and radial (C_h) direction is considered as 2.80 and 3.50 from laboratory tests. In cohesive fine soils, the consolidation settlements are of major concern.

It is observed that the time required for 90% consolidation settlement without PVD's treatment is 12.80yrs. Hence the time taken for consolidation is very high and it is necessary to provide brand drains to minimize the total time of consolidation. By considering the above soil parameters the height of surcharge load is 4.85m from ground level with embankment soil having a density 1.80t/m^3. Surcharge loading is done in two stages with initial height of 3m and remaining height is achieved in next stage of consolidation is 0.232yrs. loading. Spacing provided for the band drains is 1.1 m c/c and time taken for 90% consolidation is 0.232yrs.

IV EXPERIMENTAL WORK

The procedure for determination of coefficient of consolidation (Ch) in horizontal direction using modified oedometer is described in detail. The properties of PVD's used for ground improvement of marine clay established from laboratory tests are summarized.

4.1 Engineering Properties of Marine Clay

4.1.1. Specific Gravity

Specific gravity of marine clay was determined by using density bottle method. Marine clays are generally expansive in nature. So, kerosene is used instead of water due to its non-polar nature. The specific gravity so obtained is multiplied with specific gravity of kerosene.

$$G = [(M_2 – M_1) / (M_2 – M_1) – (M_3 – M_4)] * G_k$$, Where

M_1 = Mass of empty density bottle

M_2 = Mass of density bottle + soil

M_3 = Mass of density bottle + soil + water

M_4 = Mass of density bottle + water

G_k = Specific gravity of kerosene

4.1.2. Atterberg limits

The consistency limits are used to define the different ranges of states in which a cohesive soil can exist from liquid to solid. Liquid limit, plastic limit and percent clay fraction characterize any fine grained soil to a great extent.

4.1.3. Vane shear test

The vane shear test is another method of obtaining the undrained shear strength of cohesive soils. The common shear vane usually consists of fourth in steel plates of equal size welded to a steel torque rod. The test is performed by pushing the vane into the soil and torque is applied at the top of the torque rod. The torque is gradually increased until the cylindrical soil specimen fails.

$$S = T / \pi (D^2 H/2 + D^3/6)$$

4.1.4. Consolidation

Consolidation characteristics (particularly 'C_v' is required in design of PVD system).The time rate of consolidation is represented by coefficient of consolidation both in vertical and horizontal direction. The test is performed by using specimen of 6 cm diameter and 2 cm thickness. The coefficient of consolidation in vertical direction is performed according to IS 2720.

$$T_v = (C_v t) / d^2$$

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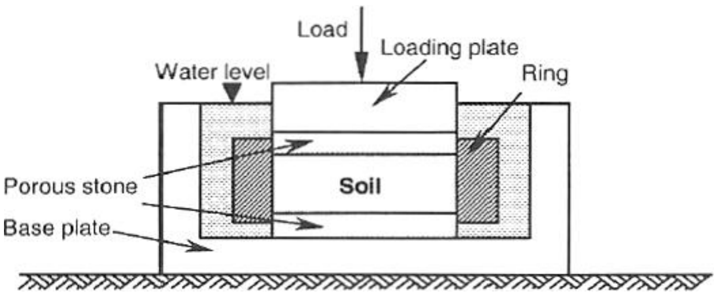

Figure 4.1: Diagram Showing Consolidation Test in Vertical Direction

4.2. Determination Of Coefficient Of Consolidation In Radial Direction

To determine the Coefficient of consolidation in radial direction, modified oedometer test is performed based on Rowe's method of radial consolidation. The test procedure is as follows.

- Soil sample is prepared in the oedometer as in regular consolidation test.
- A small diameter plastic pipe is pressed into clay specimen at Centre and then it is carefully removed to make a cavity into the specimen.
- The cavity (cylindrical hole) is filled by pouring clean graded sand up to the surface of the specimen.
- Rubber sheets of 6 cm diameter with central holes of diameter equal to diameter of central sand drain are placed at top and bottom of the soil specimen.

A symmetric line diagram and prototype of modified oedometer test is shown in figure 4.2.

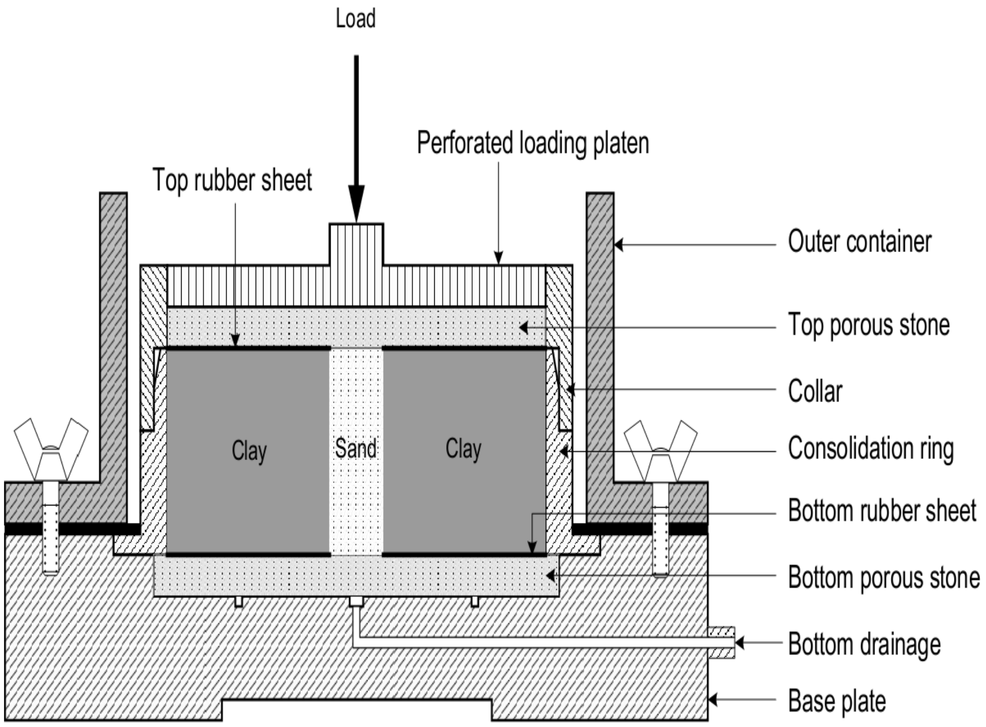

Figure 4.2. Line Diagram of Modified Oedometer Test

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The results of the tests conducted above are tabulated in the Table 4.1.

Table 4.1: Engineering Properties of Marine Clay

S.No	Property	Value
1.	Specific Gravity	2.5
2.	Grain Size Analysis a) Sand Size (%) b) % Fines c) Silt (%) d) Clay (%)	 14 86 27 59
3.	Plasticity characteristics a) Liquid Limit (%) b) Plastic Limit (%)	 61 38
4.	IS Classification	OH
5.	Bulk Density (t/m^3)	1.65
6.	Natural Water Content (%)	74
7.	Initial void ratio, e_o	1.75
8.	Undrained Cohesion, C (kN/m^2)	3.8
9.	Differential Free Swell (%)	60
10.	Coefficient of Permeability (m/yr)	0.00676
11.	Consolidation characteristics a) Coefficient of Consolidation C_v (m^2/yr) b) Coefficient of Consolidation C_h(m^2/yr) c) Ratio of Coefficient of Consolidation in Horizontal to Vertical (C_h / C_v)	 0.4 1.25 3.12

V SUMMARY AND CONCLUSIONS

The summary of experimental work carried out on soft marine clay at case study area and properties of PVDs evaluated from laboratory tests are summarized below. The engineering properties of marine clay are presented in Table 4.1 reveals that marine clay is containing more number of fines (88.8%) and has natural water content above its liquid limit (61%). By comparing the properties of marine clay adopted in design differed much from the actual properties of marine clay prevailing at the site (Table.4.1).

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Design of PVD system will be effective only if it is based on proper soil investigation. By calculating co-efficient of consolidation in vertical and horizontal direction. Estimation of co-efficient of consolidation in horizontal direction (C_h) significantly affects the efficiency of vertical drains. Embankment construction over soft clay shall be planned with counter berms on either side to act as surcharge over the foundation soil and to increase load capacity of soil between berms area. Vertical drains are to be extended beyond to as the soil extending 0.707B from edge of loading contributes to bearing capacity. Whenever water bodies are present without proper bunds it is essential to provide additional lateral consignment system by lime soil columns and sheet piles.

Martine clay is highly fine-grained material with high natural moisture content (NMC> Liquid Limit) and poses very low shear strength (Un-drained shear strength 3.8kN/m^2) in the present study. The (C_h)in horizontal direction for marine clay under study is 3.1times the value of C_v in vertical direction. Hence, provision of vertical drains under pre loading will have accelerated consolidation due to faster rate of consolidation in horizontal direction.

VI SCOPE FOR FURTHER STUDY

In the present study, ground improvement of marine clay is done by using prefabricated vertical drains. Ground improvement of soft clay may also be done by using other type of vertical drains. Introducing pile foundation that extends up to hard strata and laying a raft on the piles. The embankment may be constructed on the pile raft. Construction of sheet piles at canal boundary may obstruct the lateral displacement of foundation soil may also be studied.

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