

# Improvement of Coir Reinforced Clay Soil by Natural and Synthetic Prefabricated Vertical Drains

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**Abstract—** Soft Clay soil when subjected to large Overburden pressures and traffic loads, settlement may occur during constructions and differential settlements at later stages. The use of natural fibers such as coir as soil reinforcement is expected to accelerate the process of consolidation by permitting pore water pressures to dissipate easily when subjected to overburden pressures. The use of vertical drains will shorten the length of the horizontal drainage paths and thus reduces post construction settlement. A system of vertical drains combined with surcharge preloading has become an attractive ground improvement alternative in terms of both cost and effectiveness. This study focus on the improvement of clay soil by using coir reinforcement and vertical drains. Vertical drains used in study are a prefabricated vertical synthetic drain (SPVD) and a prefabricated vertical jute drain (PVJD). Model tests are conducted in a cylindrical mould made of mild steel with unreinforced and reinforced soil samples with and without vertical drains. From the results it was found that Coir reinforced clay with vertical drains are much better than unreinforced soil with drains. The results obtained from the tests are very encouraging for JPVD and are closely comparable with the performance of SPVD.

**Keywords—** SPVD, JPVD, Clay, Coir reinforcement, Eco-friendly Biodegradable, Accelerated Consolidation

## I. INTRODUCTION

Extensive urbanization and industrialization in low land and coastal regions of many countries have required to improving very soft ground in its shear strength and compressibility as to handle its stability and settlement problems. The shortage of good sites required for construction purposes often necessitates the use of sites, which were characterized by low bearing capacity. Therefore clay soil has to be improved before any engineering work to prevent settlement failure.

Simply, Ground improvement is the alteration of any property of soil to improve its engineering performance. Preloading is one of the ground improvement technique, which can be effectively used for improving soft cohesive ground as it increases the bearing capacity and reduces the compressibility of weak ground. Preloading is done by placing temporary surcharge on the ground. Surcharge will be generally more than the expected bearing capacity. The main drawback of this method is that Surcharge must remain in place for months or years, thus delays construction activities

which results in transport of large quantities of soil. Also if the ground consists of uniform thick low permeable soil, preloading technique alone may not work. Because of its low permeability, consolidation settlements took more time to complete. In such cases, the presence of a vertical drain can greatly reduce the pre-loading period. Vertical drain installation reduces the length of drainage path and accelerates the rate of consolidation by promoting rapid radial flow which decreases the excess pore pressure while increasing the effective stress and allows the clay to achieve rapid strength, finally results in the improvement of bearing capacity. The period of loading required to achieve stabilization in soft soil can be considerably reduced.

Sand drains are basically boreholes filled with sand. The installation causes disturbances, especially in soft and sensitive clays, which reduces the shear strength and horizontal permeability. Prefabricated Vertical Drain is a prefabricated material consisting of a plastic core covered by synthetic geotextile filter jacket. Core serves as a longitudinal flow path along the drain and Filter jacket allows water to pass into the core while restricting intrusion of soil particles. Nowadays, Biodegradable natural materials such as jute geotextiles, coir strands and coir mats are utilized in making PVDs as an alternative to polymers wherever applicable and feasible.

Coir fiber is strong and degrades slowly compared to other natural fibers due to high lignin content. In this connection, the use of natural fibers such as coir, in providing soil-reinforcement, is will accelerate the process of consolidation by dissipating pore-water pressures easily when subjected to overburden pressure.

## II. LITERATURE REVIEW

### A. Studies on Natural Fibers for Soil Reinforcement

Nithin S and Sayida M K (2012) studied the improvement of bearing capacity of lateritic subgrade using coir geotextiles. The test results indicates the behavioral changes acquired by using the coir geotextile as reinforcing agent and reveals the potential to provide excellent and economical medium for stabilizing subgrade for rural roads. R.R Singh, Shelly Mittal (2014) reported that addition of coconut coir fiber results in less thickness of pavement due to increase in CBR of mix and reduce the cost of construction and hence economy of the construction of highway will be achieved.

Mandel (1989) and Charan (1995) observed that natural fibers could be effectively used in temporary stabilization of embankments for highways and railways. The studies also tested the use of natural fibers in fabricating vertical drains. Dilrukshi A.L and Kumara G.H (2010) studied the advantages of using coir dust in vertical drains for the improvement of soft clay.

**B. Studies on effect of coir reinforcement and vertical drains**

The work of DurgaPrashanth and Santosh G (2012) deals with accelerated consolidation of un-reinforced and coir-reinforced lateritic soils, provided with three vertical sand drains. The relative increase in consolidation (Cr) for un-reinforced soil with vertical drains was quite higher than that of un-reinforced soil without vertical drains, with values above 40.61%.

Radhakrishnan G and Kumar M Anjan (2010) conducted Study of Consolidation Accelerated by Sand Drains. In this paper the results of the testing and also the variation of percentage of consolidation with construction time by providing and without providing sand drains is studied.

Ramakrishna Hedge and Varghese George (2011) studied the effect of coir reinforcement and vertical drains on the settlement properties of Laterite soil. Investigations were performed on unreinforced and reinforced soil samples with and without vertical drains reinforced with coir. Results indicate that settlements in the soil sample on applying a preload pressure of 350 kg was the highest. For the reinforced samples with vertical drains it took only 11 hours whereas 37.16 hours for unreinforced sample with vertical drains for their final settlement.

G. VenkatappaRao (2009) focused improvement of pond ash with prefabricated vertical drain. This paper presents the application of prefabricated vertical drains to accelerate the consolidation process of pond ash deposits. Model tests under simulated conditions have been carried out on two samples of pond ash collected from an ash pond. The changes in the total settlement and moisture contents at different depths of the tank have been studied, with and without the installation of prefabricated vertical drain.

R.Kugan and T.A.Peiris (2003) studied peaty clay improvement with prefabricated vertical drains in large scale model test setup under axisymmetric conditions. Investigations were done with and without PVD. Comparative studies on soft clay soils of Bangkok by Bergado revealed the use of compacted granular piles (CGP), and prefabricated vertical drains (PVD). The studies indicated that in the case of soils improved with PVDs, the settlement rates were higher by 30% - 35% when compared to soils improved using CGPs.

**III. OBJECTIVES OF THE STUDY**

- To measure the time-settlement properties of un-reinforced clay Soil with and without the use of vertical drains
- To measure the time-settlement properties of coir reinforced clay Soil with and without the use of vertical drains.

**IV. MATERIALS USED**

**A. Clay soil**

Clay collected from Thonnackal; Thiruvananthapuram district from a depth of 2 m from ground surface. The basic properties of the collected soil samples are determined through laboratory tests as per the standard procedures recommended by the ASTM codes. Table 1 below represents the soil properties.

TABLE I. SOIL PROPERTIES

PROPERTY	VALUE
Specific Gravity	2.35
% of sand	4%
% of clay	56%
% of silt	40%
Liquid Limit (%)	49
Plastic Limit (%)	22
Plasticity Index (%)	27

**B. Sand**

Sand was collected from Perumathura Beach, Thiruvananthapuram district. Passing through 4.75 mm IS sieve. The sand selected satisfies the general requirements of permeability and piping. The properties of sand are shown in table 2

TABLE II. SAND PROPERTIES

Property	Result
Coeff. of curvature	0.83
Coeff. of uniformity	1.97
D 15,mm	0.35

**C. Prefabricated vertical drains**

Prefabricated vertical jute drain was collected from Indian National Jute Board, Kolkata. JPVD was made from single woven jute geotextile as the filter and core material consists of four, 4 mm diameter coir strands separated by longitudinal stitches. Synthetic Prefabricated vertical drain was collected from a Road Project, for ground Improvement, Kottayam, Kerala. The Prefabricated Vertical Drain comprises of a polypropylene double-sided fin-shaped core that is wrapped with a durable fabric of excellent filtration properties. The core is designed to allow free flow of water on both sides. This ensures the integrity of the drainage system when subjected to settlement and lateral movements in the soil. Properties of SPVD and JPVD are shown below



Fig. 1. Prefabricated vertical jute drain.



Fig. 2. Synthetic Prefabricated vertical drain

TABLE III. PROPERTIES OF VERTICAL DRAINS

Properties	SPVD	JPVD
Nominal Width	100mm	100mm
Nominal thickness	5mm	5mm
Discharge capacity	120x10 <sup>-6</sup> m <sup>3</sup> /sec (240 kPa)	13litre/sec at 50 kPa
Tensile strength	2800N	45 kN/100 mm
Elongation at break	20%	-
Apparent opening size	90µm	150-400 micron
Puncture resistance	80N	0.4kN

## V. EXPERIMENTAL SET UP AND METHODOLOGY

Studies were conducted for reinforced and un-reinforced soil specimens, with and without installation of SPVD and JPVD. These tests were conducted in order to evaluate the time-settlement behavior of un-reinforced and reinforced clay Soil due accelerated consolidation.

### A. Tests on Un-Reinforced soil with and without using Vertical Drains

Mild steel cylindrical test mould was made-up with 8 mm thick steel plate of 500 mm internal diameter, 710 mm height. The test mould was provided with two inlet pipe at the top and two outlet pipe at the bottom, both of 20mm diameters, to facilitate free drainage of the water during the consolidation process. The inside of the tank was oiled in order to reduce frictional resistance between soil slurry and wall of the tank.

Before the beginning of each test, a remoulded clay test sample of water content slightly greater than liquid limit was prepared by adding water to soil. The soil was soaked in water for three to six days for making them to thick slurry form. A sand layer of 50 mm thickness was provided at the bottom of the test mould to act as a permeable layer. Above this layer, saturated jute textile was provided to act as a separator. Over this soil slurry were placed. Soil sample of 500 mm height was filled by pouring thick slurry in small quantities. On top of the soil sample, a layer of jute textile was placed. A layer of sand of 50mm thickness was provided at the top, to act as level-surface for the application of preloads. A flat surface made of treated perforated plywood (of 480 mm diameter, and 12 mm thickness) was provided above the sand layer. Three days rest period was given before commencing the experiment, so that the slurry formed a natural state of stability.

For doing test with PVD, PVD tied with a small metal mass at the bottom was installed at the centre of the tank vertically and was hung from horizontal steel rod placed over the top of tank. The metal block helped in holding the PVD in its central position during filling of the tank with soil slurry. Saturated non-woven jute geotextile with a slit should be used to project the PVD into top drainage layer.

The load was applied to the loading plate by 'lever arm mechanism'. The vertical loads were increased in sequence to produce stresses of 10, 50, 100 and 150 kPa. Settlement measurements at regular time intervals were made with the help of two dial gauges and the average value was considered in calculations. Details of the test set-up are shown in Fig.3.

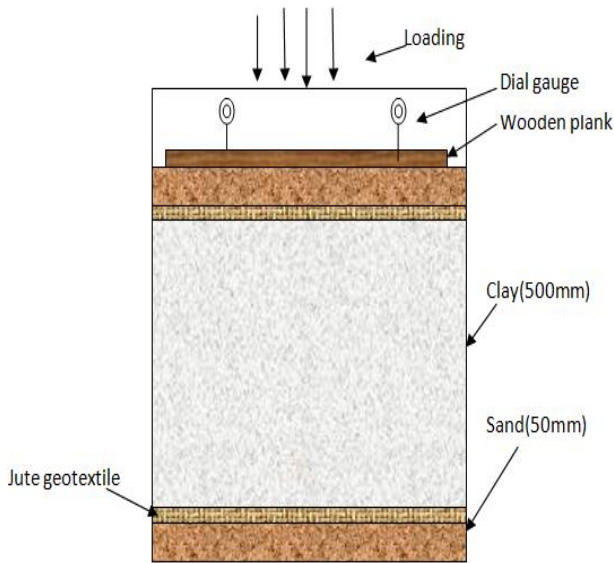


Fig. 3. Experimental set-up (without vertical drains)

**B. Performance Tests on Reinforced soil with and without using Vertical Drains**

*a) Determination of Optimal Fiber Content for Soil Samples Using CBR Tests.*

CBR tests were conducted with various percentages of coir fiber content randomly reinforced with 0.25 %, 0.5 %, 0.75 %, 1.0 %, and 1.25 % of coir, and the CBR values at 2.5 mm and 5 mm penetrations were noted for soaked and un-soaked soil samples. The CBR values were determined for the soil sample, and 1% of coir is found as optimum fiber content

**VI. RESULTS AND DISCUSSIONS**

**A. Time-Settlement Behavior of unreinforced clay with and without PVD**

The settlements observed at regular intervals of time in clay alone (not reinforced with coir) and clay with PVJD and SPVD are plotted in the graphs shown in Figure 4.

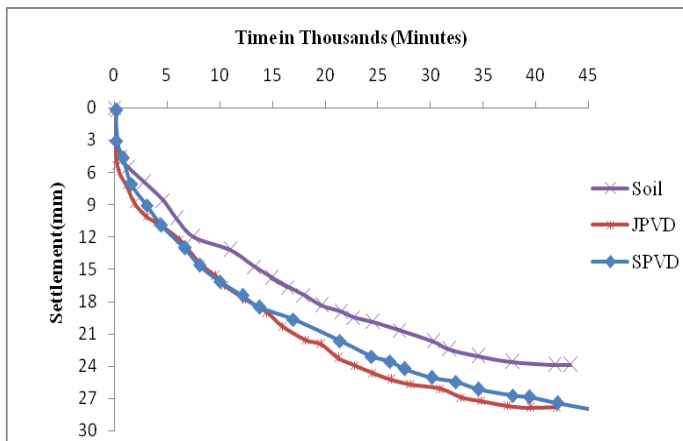


Fig. 4. Time-Settlement Profile of unreinforced clay with and without PVD

The magnitude of settlements by the end of primary consolidation of clay with PVJD and SPVD were almost the same, 27.4 mm and 27.6mm respectively. PVJDs and SPVD have almost identical settlement rates in all the clay samples installed with them. This indicates the efficiency of all PVJD and SPVD in accelerating the consolidation in clay. In the first case, without any use of vertical drain, total settlement occurred in 29days was 23.9mm. In the second case, with SPVD used in soil the same settlement took place in 18.19 days while with Jute PVD the same settlement took place in 15.83 days.

**B. Time-Settlement Behavior of coir reinforced clay with and without PVD**

The settlements observed at regular intervals of time in remolded clay alone and Coir-reinforced clay with PVJD and SPVD are plotted in the graphs shown in Figure 5.

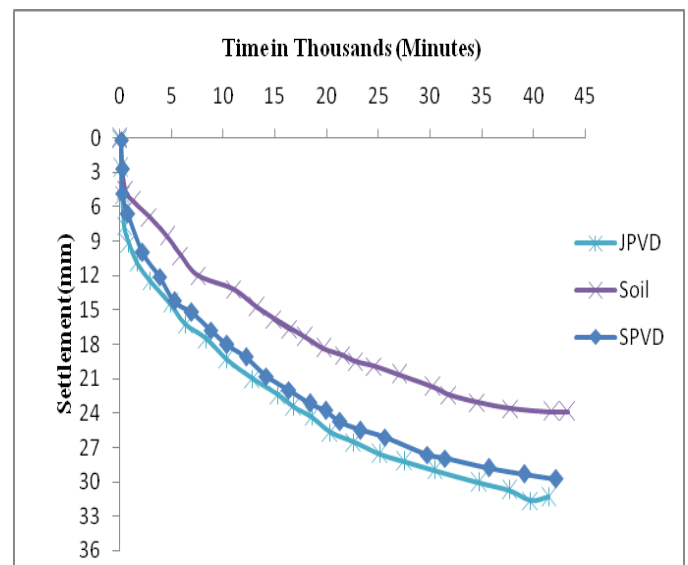


Fig. 5. Time-Settlement Profile of Coir-reinforced clay with and without PVD

The magnitude of settlements by the end of primary consolidation of Coir-reinforced clay with PVJD and SPVD were almost the same, 29.5 mm and 31.2mm respectively. PVJDs and SPVD have almost identical settlement rates in all the clay samples installed with them. In the first case, without any use of vertical drain, total settlement occurred in 29 days was 23.9 mm. In the second case, with SPVD used in Coir-reinforced clay soil, the same settlement took place in 13.8 days while with jute PVD used in Coir-reinforced clay soil; the same settlement took place in 11.8 days.

## VII. CONCLUSIONS

- The test results obtained in this study clearly shown that prefabricated vertical drain accelerates the consolidation process. The pore water pressure dissipation and consolidation were much faster than without vertical drains.
- It was found that the time required for the case of with vertical drains was only half of the time required without drains
- The rate of settlement was almost the same in all clay samples installed with JPVDs and SPVD. This indicates the efficiency of all JPVD and SPVD in accelerating the consolidation in clay
- Coir reinforced clay with vertical drains are much effective than unreinforced soil with drains.
- Magnitude of settlement of the clay was observed as 23.9mm at 29<sup>th</sup> day. In un-reinforced soil, a settlement of 23.9 mm took place in 18.19 days with SPVD, while the same settlement took place in 13.8 days in coir-reinforced soil with SPVD.
- Magnitude of settlement of the clay was observed as 23.9mm at 29<sup>th</sup> day. In un-reinforced soil, a settlement of 23.9 mm took place in 15.83 days with JPVD, while the same settlement took place in 11.8 days in coir-reinforced soil with JPVD.
- As coir geotextiles are biodegradable, ecofriendly and cheap in comparison with the polymeric counterparts the use of coir geotextile is an appropriate technology, which enhances process of consolidation and act as soil reinforcement.

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