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Electrokinetic Geotextile Stabilization Of Embankment Slopes

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Abstract— ***The choice of repair of slope depends on site conditions and cost. This includes reducing the slope, installing horizontal drains, soil nailing and providing stability by structural methods. All these methods have their limitations and some are very costly. Another alternative is the electrokinetic stabilization of slopes. EKG reinforcement or soil nails not only provide reinforcement, but also increase the shear strength of the soil in which they are placed as well as improving soil-reinforcement bond. The development of EKG materials offers slope stabilisation of embankments and cuttings in fine grained soils, which will significantly increase the factor of safety , address pore pressure changes and also avoids importing earthwork materials or aggregates. By inserting a grid of anodes and a cathode into the ground and applying an electrical potential difference across the slope drives water away, via the cathodes and creates physical changes in the embankment, promoting consolidation of the slope materials. Anodes and cathodes were connected to a DC power circuit and electrified for a calculated period based on water content, strength and electrode spacing. The conductive geotextile used was coir geotextile and it was woven with steel filament in weft direction only. The steel filament made the geotextile conductive. The geotextile used was natural geotextile and it is required after the end of construction of embankment only, till the completion of dissipation of pore pressure.***

Keywords— slope, EKG, clay,natural geotextile

I. Introduction

Basal reinforcement is the incorporation of geogrids or geotextiles at the base of embankments constructed over soft, compressible ground. It is often used in conjunction with prefabricated vertical drains or band drains or other forms of ground improvement. Woven geotextiles are usually preferred for basal reinforcement [19]

The lack of conventional cohesionless fill material and its cost has lead to the use of cohesive soils in major reinforced soil structures. This includes a drainage layer along the side of the reinforcement [1]. The potential benefits identified for EKG in reinforced soil are they dramatically reduce pore pressure in cohesive fill in excess of that which can be achieved using permeable reinforcement alone, inducing additional consolidation and associated increase in shear strength to that obtained by the self-weight of the fill material above; and dissipating positive pore pressure at the soil/reinforcement interface to a greater degree than with impermeable reinforcement, thereby increasing reinforcement/soil bond along its entire length[4].

For low permeable soils, the normal pumping methods of dewatering may not be adequate. In such cases, the electro-osmosis procedure may be helpful. In any event, it is much cheaper and faster. When an electrical potential is applied across a wet soil mass, cations are attracted to the negative terminal and anions to the positive terminal . As the ions migrate they carry their water of hydration and they exert a viscous drag on the water around them. Since there are more cations than anions in soil containing negatively charged clay particles, there is a net water flow towards the cathode Mitchell (1991). This flow is called electroosmosis. Since the flow of water towards the cathode causes soil consolidation, soil undrained strength would be increased.

Bjerrum et al. (1967) employed electroosmosis technique to stabilize an excavation in very soft Norwegian quick clay near Oslo, resulting in almost fourfold increase in average undrained shear strength. Lo et al. (1991) demonstrated that in a field test by an appropriate design of electrodes and polarity reversal, pumping at the cathode could be cancelled. The increase in soil shear strength was demonstrated as the expansion of the effective strength envelopes and increase in the pre-consolidation pressure (Lo andHo, 1991). Burnotte et al. (2004) showed that the effect of electro-osmotic consolidation of soft clay could be improved by minimizing power loss at electrodes through chemical treatment in a laboratory study and a large field demonstration test. Hu (2004) reported a highway subgrade reinforced effectively by electro osmosis. The results of the test done on 700 m^3 of clay for 48 days of treatment confirm that soft clay deposits can be successfully treated by electroosmotic consolidation, at a competitive cost compared with other alternatives[9]. Results of electroosmotic consolidation on hydraulic fill using silt of test area 1400m^2 for 15 days of testing process and analysis showed that the maximum shear strength of silt increased 3 times and the maximum moisture content decreased by 20%[10]. Various types of electrodes, like copper, H-shaped steel pile were used to increase the shear strength of sensitive Leda clay and marine clay respectively[15,16].

Traditional geosynthetics carry out a range of functions including drainage, reinforcement, filtration, separation, containment etc. Electro-kinetic geo-synthetics (EKG) are prepared by combining the electro-kinetic phenomena of electro-osmosis, electrophoresis and associated electro-kinetic functions with traditional functions .

This paper evaluates the effectiveness of coir geotextile as basal reinforcement with electrokinetic process for embankments constructed in soft clay. The effectiveness is

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measured by Atterberg's limit and unconfined compressive strength before and after the test.

II. Material and Methodology

Kuttanad clay

Kuttanad clays are dark brown coloured medium sensitive alluvial deposits, spread over the Kuttanad region in the state of Kerala in India [11]. The dominant mineral constituents in this clay are montmorillonite and illite [12]. These clays are characterized by high compressibility, low shear strength and high percentage of organic matter [14]. A substantial change in the plasticity characteristics on drying is one of the distinct aspects of these clays [13].Total area of 1100 km^2 lies 0.6-2.2 m below mean sea level [12].The properties of soil sample collected are shown in Table-1.

Coir geotextile

Coir is a 100% organic fibre, from the coconut husk. It is naturally resistant to rot and moisture and it needs no chemical treatment. It is hard and strong and it can be spun and woven into matting. They have the right strength and durability to protect the slopes from erosion, while allowing vegetation to flourish. The greater the geo-textile density, the steeper the embankments it can be utilized on. Geo-textiles can improve soil strength at a lower cost than conventional soil nailing. Coir geo-textiles last approximately 3 to 5 years depending on the fabric weight. Reinforcement with natural fibre in composites weight. Reinforcement with natural fibre in composites has recently gained attention due to low cost, easy availability, low density, acceptable specific properties, ease of separation, enhanced energy recovery, CO_2 neutrality, biodegradability and recyclable in nature [21]. The properties of woven geotextiles are shown in Table -2.

TABLE-1. Properties of soil sample

Properties	Values
Specific gravity	2.64
Void ratio	0.63
Liquid limit %	88
Plastic limit %	44
Shrinkage limit%	31
Plastic index	38
Percentage of clay	71
OMC	38
Maximum dry density gm/cc	1.34
Unconfined compressive strength kPa	2.3
Compression index	0.7233

TABLE-2. Properties of woven geotextile

Density (gm/m2)	Thickness(mm)	Tensile stress (kN/m)	Failure strain (%)
681	7.16	5.2	24.6

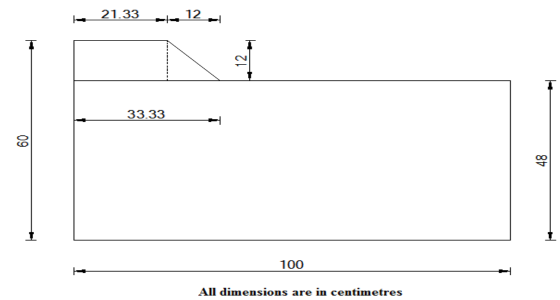

Fig. 1 . Dimensions of Model

Laboratory scale model was constructed using 12 mm thick waterproof plywood. The dimensions of the model are 100cm X 100cm X 60cm as shown in Fig.1 .The model tank was provided with a mouthpiece, a 1 cm diameter small PVC pipe provided at a small distance from the bottom of cathode using an acrylic sheet as a separator for allowing free flow of water during the process and the water is collected in a graduated cylinder. Wattman No. 42 filter paper was placed over this partition to restrict the flow of any soil particles. Conductive geotextile was placed on acrylic sheet to act as cathode with the graphite electrodes being placed horizontally at a distance from the cathode to act as anode. Cathodes are created from geotextile by interlacing steel wires in the textile.

The clay was placed in a very fluid state with unconfined compressive strength of 1.5 kPa with water content 88%.. Embankment was constructed with the cohesive soil over the soft Kuttanad clay with coir geo-textile as basal reinforcement with electrokinetic process.

A 10 mm diameter and 300 mm long graphite electrode was used as the anode and two electrodes was placed along the slope. The conductive geotextile used was woven with steel filaments in warp direction only. The steel filament made the geotextile conductive. The electrodes were then connected using standard flexible copper wire to an AC-DC convertor unit. A voltage of 30V was applied to the soil. After the test water content and unconfined compressive strength were noted. Tests were repeated two times..Before and after treatment Atterberg limits and unconfined compressive strength of the soil were found out.

III. Results and Tables

Table-3. Variation of UCC and water content after EKG treatment of 30VV

UCC before	UCC after treatment	Water content	Water content

treatment (kPa)		before treatment	after treatment
1.4	8.3	84.4	64.3
1.6	9.2	88.2	61.4
1.2	10.4	86.4	62
1.4	10.2	86	59

TABLE-4. Variation of properties of soil sample with different voltage

	0 V	15V	45V
Liquid limit%	88	73	54
Plastic limit%	33	32	36
UCC(kPa)	2.2	9.2	14.4

The variation of UCC and water content of the soil sample after the EKG treatment for the two models are shown in Table-3. The variation of properties of soil sample with different voltages is shown in Table-4. From Table-4, it can be observed that as the voltage increases liquid limit decreases and plastic limit increases. Owing to this the plasticity index decreases. In the case of UCC, it is found to increase with increase in voltage.

IV. Conclusion

Model test was conducted to evaluate the effectiveness of coir geotextile as basal reinforcement with electrokinetic process for embankments constructed in soft clay. The effectiveness is measured by UCC and Atterberg's limit before and after the test For treatment with different voltages, the results show that the liquid limits and plasticity indices decrease significantly with increasing applied voltage. In the case of UCC, it is found to increase with increase in voltage. The EKG treatment is an effective method for slope stabilization. The benefits of EKG treatment includes reduced cost, reduced access requirements for labour and plant and materials. The treatment can proceed while maintaining the highways in service . Long term drainage of the slope can be provided for by the filtration and drainage functions of the EKGs in the passive mode. Sustainability benefits including reduced carbon footprint and elimination of the use of primary aggregates.

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