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A Control on Desiccation Cracks in Clay Liner

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Abstract: Environmental authorities are always concerned about disposal of solid waste. Studies suggest that landfill is the most suitable ways for disposing of these wastes. Compacted Clay Liners and Geo-synthetic Clay Liners are commonly used for this purpose. But various atmospheric conditions such as alternate drying and wetting cause changes in the clay structures. The change occurs mainly in the form if desiccation cracks. Through these cracks leachate gets permeated which results in environmental pollution and also reduces the compatibility of liner system. Many studies suggest that addition of fiber reinforcement was adopted. In this study synthetic fiber such as Polypropelene were used to reduce the desiccation cracks in soil. The fibers were amended to soil in 0.4%,0.8% and 1.2% of dry weight. Fiber reinforcement to soil improves the strength properties of soil maintaining the plasticity characteristics within limits. Hydraulic conductivity increases with fiber reinforcement but was within acceptable limits for that of landfill liner. Desiccation cracks were observed for unreinforced and reinforced specimen. Hence the study also proved that the desiccation cracks could be controlled with the help of fiber reinforcement

Keywords: compacted clay liners, desiccation cracks, fiber reinforcement, polypropylene, hydraulic conductivity

1. Introduction

Urbanization is progressing at an alarming rate which results in the generation of very large quantities of municipal solid waste. Collection and disposal of municipal solid waste are one of the key service concerns faced by civic bodies. The quantity of solid waste generated, the scarce availability of land and the pollution caused to the soil and groundwater makes the management of municipal solid waste a major challenge in a dense urban environment. One of the preferred methods of dealing with this kind of environmental problem is to dispose of the waste in sanitary landfills. Solid waste undergoes Physico-chemical and biological changes. Consequently, the degradation of the organic fraction of the wastes in combination with percolating rainwater leads to the generation of a highly contaminated liquid called "leachate". To prevent contamination of the surrounding soil and underlying groundwater by leachate, landfills are lined and covered with an impermeable material. Compacted clayey soils or Geosynthetic Clay Liners (GCLs) are predominantly used in the construction of landfill liners. The main reason in using such materials is their low hydraulic conductivity which limits or eliminates the movement of not only the leachate from bottom of landfills but also the generated gases from the final cap of waste dumps.

Clayey soils possess numerous problems to geotechnical engineers because of their high compressibility and poor shear strength. The high compressibility of clays which leads to large scale volume changes is always a cause of concern to the field engineer. Volume changes in clayey soils occur in many ways. One is due to the expulsion of pore water from the voids upon static surcharge. This behavior, termed as consolidation is a well known and well defined phenomenon. The other volume change is due to the shrinking of clay soils during drying. Desiccation is the continuous process of pore water loss from a soil exposed to a warm environment. In response to drying, soil water volume decreases and in consequence the soil shrinks. The desiccation cracking of clay mass can have a significant impact on the performance of clayey soils in various geotechnical, agricultural and environmental applications. Fig:1.1 shows a clay liner system. Cracks affect the compressibility of the soil, its time rate of consolidation, its strength and the rate at which water can re-enter. Thus, several geotechnical constructions are affected directly or indirectly by the presence of cracks in a soil mass. Desiccation cracking is a common phenomenon in clayey soils and can change the hydraulic conductivity of soil. Compacted clay liners are essential components of both municipal and hazardous waste landfills and their design has typically been based on the premise that little leakage will occur if the soil has a laboratory measured hydraulic conductivity of less than $1x10^{-9}$m/s. According to EPA (1989), the soil liners be built so as to meet certain requirements. According to Daniel DE(1993) material selected for clay liner should have a compressive strength of at least 200kPa.

Many researchers have taken efforts have to address the problem of desiccation cracking. Some have considered the use of surface moisture barrier above the clay liner, but case histories show that repeated cycles with seasonal temperature changes result in significant desiccation of the clay layer and associated cracking.

As a solution to this problem some researches also used lime, cement and sand as additive to reduce the desiccation cracking in compacted clay .The reports suggest that soil shrinkage reduced and its hydraulic conductivity increased in some cases. Because of short coming of the materials and due to above drawbacks an attempt is therefore made here to conduct a comparative study to control the desiccation cracks by using different randomly distributed discrete fibers. With inclusion of fiber, the friction between soil particles and fibers occurred and contributing to the generation of the resistance during the desiccation process.

The soil–fiber resistance was mobilized when the soil tended to shrink. As a result, the cracks were effectively suppressed. It can be seen that the fiber surface is attached by many soil particles which make contribution to the strength and friction between soil particles and fiber. The main advantage of reinforcement of soil with fibers is the absence of single potential plane of failure compared to conventional Geosynthetic sheet. Fiber reinforcement improves properties of the soil subjected to various stresses.

2. Previous Research

Venkat Bhadriraju et.al (2015) carried experiment on carbon fibers mixed at dosages computed based on weight of the dry soil. There was a decrease in the dry unit weight and a simultaneous increase in the optimum moisture content with increasing fiber dosages. The influence of fibers on dry unit weight and optimum moisture contents has been consistent for all three types of fibers used in this research. All the fibers were found effective in minimizing shrinkage of the expansive soil. Carbon fibers were found to be the most effective when compared to other fibers. This may be due to relatively high tensile strength

Miller et.al (2008) Fiber intrusion impacted both optimum moisture content and dry density .The maximum dry density increased up to 0.8% fiber content for light compaction test .Crack intensity factor is defined as percentage cracked area to total surface area of sample .The fiber intrusion reduced the crack up to 90% .But the hydraulic conductivity of the amended sample increased But 0.5% maintained hydraulic conductivity with acceptable limits

Mahmood R. Abdi (2008) investigated the effects of random fiber inclusion on consolidation settlement, hydraulic conductivity, swelling, shrinkage limit and desiccation cracking characteristics of clay. Investigations showed that there is a maximum fiber content and length that can be used because of workability problems making uniform mixing of fibers with soil were very difficult. In this investigation the maximum fiber content and length determined were 8% and 15mm respectively. The addition of randomly distributed polypropylene fibers resulted in substantially reducing the consolidation settlement of the clay soil. Length of fibers had an in significant effect on this soil characteristic, whereas fiber contents proved more influential and effective. Inclusion of polypropylene fibers to the clay soil resulted in reducing the amount of swelling after unloading. The effect was proportional to the fiber content. But at constant fiber contents, the amount of swelling was not significantly affected by increasing fiber length. Hydraulic conductivity of the clay soil due to random inclusion of fibers was slightly increased as function of both fiber contentand length. However, the overall increase was not so significant to render the soil unsuitable for use as liner or cover inland fills. For all the fiber contents and lengths investigated, the hydraulic conductivities measured (i.e.10^{-9} cm/s) were well below the minimum requirement of 10^{-7}cm/s according to USEPA.

Al-Wahab and El-Kedrah (1995) studied the effect of polypropylene fibers to reduce tension cracks as well as the amount of shrink/swell in compacted clays. The soil was reinforced with fiber contents of 0.2, 0.4, and 0.8% of dry weight of soil with optimum fiber length of 12.7mm were used. Results showed that fiber content had no effect on maximum dry density and optimum moisture content. The result shows reduction in the amount of shrinkage and crack index .Crack index defined as the area of cracks deeper than 2mm to the total surface area of the soil sample.

B.R. Phanikumar et.al (2013) presents the swell-consolidation characteristics of fibre-reinforced expansive soils. Nylon fiber was used to reinforce expansive soil specimens. One-dimensional swell-consolidation tests were conducted to study the swell-consolidation characteristics of fiber-reinforced clay specimens. The fiber content(fc) was varied at0%,0.05%,0.10%,0.15%,0.20%,0.25%and0.30%bythe dry weight of the soil. The length of the fibers was varied at 15 mm and 20 mm .The swell potential and the vertical swelling pressure decreased up to 0.25% for both fiber lengths, but increased mildly when FC was increased to 0.30%. The swell potential and the vertical swelling pressure decreased with an increasing fiber length for all the fiber contents (fc). The rate of heave for the samples was also found to be in accordance with the above observations. The secondary consolidation characteristics of the fiber-reinforced samples were also studied and compared with those of an unreinforced specimen. It was found that these consolidation characteristics of the fiber-reinforced specimens improved compared to those of the un reinforced specimen.

3. Materials and Methodology

3.1 Materials

3.1.1 Soil

This soil was collected from a paddy field Tirur, Malappuram. Preliminary testing revealed that the soil was CH classification. Disturbed samples were collected at a depth 1.5 m below the ground. Physical properties of soil are tabulated in Table 1.

Table 1: Properties of soil

Sl. No	Properties	Values
1	Initial water content (%)	45
2	Specific gravity	2.58
3	Particle size distribution Fine Aggregate(%) Coarse Aggregate (%)	 56 44
4	Free swell index (%)	45.00
5	Liquid Limit (%)	54.00
6	Plastic Limit (%)	24.00
7	Plasticity Index (%)	30.00
8	Hydraulic conductivity (cm/s)	1.29×10^{-7}
9	Maximum Dry Density (kN/m^3)	16
10	Optimum moisture content (%)	21
11	Unconfined Compressive Strength (kN/m^2)	146
12	IS classification	CH

3.1.2 Polypropylene fiber

Clay liner has serious limitations, due to development of cracks on desiccation. Attempts were made to effectively control this. The cracks were controlled by reinforcing the soil with the help of randomly distributed discrete fibers. Polypropylene is the most common synthetic material used to reinforce concrete and soil. The primary attraction of this material is it's relatively low cost. It easily mixes with soil and has a relatively high melting point which makes it possible to place the specimens of the fibrous soil in the oven and conduct the tests for moisture content. Also, polypropylene is hydrophobic and it is unaffected by the presence of salts in soil or by biological and ultraviolet degradation. These properties of polypropylene make it an excellent fiber that can be used in clay liners. Virgin triangular polypropylene fibers were used in the study. The fibers were provided by Neptune Ready mix concrete pvt limited, Kochi. The properties of the fiber were given in table 2.

Figure 1: Polypropylene fiber

Table 2: Properties of polypropylene

Properties	Polypropylene
Length	6mm,12mm
Diameter	0.028mm

3.2 Methodology

The properties of soil selected for this study was determined in the laboratory according to the relevant I.S. code (IS 2720). Fibers were added to soil in 0.4%, 0.8%and 1.2% of dry weight of soil and geotechnical properties were determined.

4. Results and Discussion

4.1 Atterberg limits (IS 2720: part V & VI)

4.1.1 Liquid limit (LL)

The result shows the effect of varying percentages of fiber on the liquid limits of selected soil sample. The liquid limit decreases with increasing the percentage of fiber. This is due to reduction in the specific surface area of the soil.

4.1.2 Plastic limit (PL)

The results show variation of plastic limit with the addition of fiber. There is an increase in plastic limit with increase in percentage of fiber

4.1.3 Plasticity index (PI)

The results show variation of plasticity index with the addition of fiber. There is a decrease in plasticity index with increase in percentage of fiber

4.2Unconfined Compressive Strength of Soil (IS 2720: Part X, 1991)

The Unconfined compressive strength of polypropylene amended soil was shown in figure8. UCS values increased with increased percentage of fiber upto optimum value and then shows decreasing trend with further addition. The unconfined compressive strength value of obtained sample was 146 kN/m^2.Polypropylene fiber increase the resistance between soil particles and improves stiffness and ductility.

4.3 Consolidation Test (IS 2720: part-XV, 1986)

In order to determine the effects of fiber inclusion on hydraulic conductivity consolidation test was conducted .Polypropylene fiber of length 6mm and 12mm were amended to soil at 0.4%, 0.8% and 1.2%. The hydraulic conductivity increased with increase in fiber content in case of both length of fibers .The increase in hydraulic conductivity is mainly because the fibers act as water conduits thus by increasing flow .But the obtained values still satisfies the liner requirement of less than 1 x 10^{-9} m/s. The results were shown in figure 9.

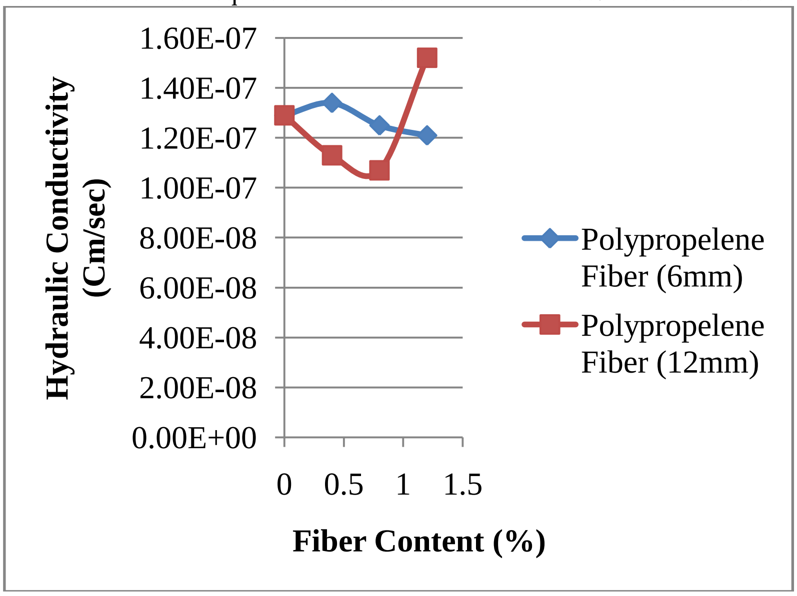

Figure 9: Variation of hydraulic conductivity with addition of polypropylene(Combination of 6mm and 12mm)

4.4 Desiccation Cracking

In order to analyze the desiccation cracks samples were prepared in circular mould and were used for observational examination of the extent of cracking. From the observational studies it was seen that reinforcing with polypropylene the extent of desiccation cracks were reduced .The main reason behind this is the tensile strength imparted by fiber to soil which effectively suppress cracking .At 0.8% polypropylene of 12mm and 1.2% for 6mm length. almost all the cracks were reduced .. Figure10. Shows surface cracking features of both length of fiber amended soil.

(a) (b)

(c) (d)

Fig.5.4.(a): Surface cracking features of Polypropylene fiber of 12 mm.(a) Unreinforced Sample(b) Reinforced Sample (0.4%) (c) Reinforced Sample (0.8%) (d) Reinforced sample (1.2%)

(a) (b)

(c) (d)

Fig.5.4.(b):Surface cracking features of Polypropelene Fiber of 6mm (a)Unreinforced Sample (b) Reinforced Sample (0.4%) (c) Reinforced Sample (0.8%) (d) Reinforced Sample (1.2%).

Deep and wide cracks were formed on unreinforced specimen .The reinforced sample shows reduction in cracks .In case of polypropylene reinforced soil at0.8% of 12mm length and 1.2% 0f 12mm length, almost all cracks were sealed.

5. Conclusions

In the current study the fiber reinforcement technique affected unconfined compressive strength, hydraulic conductivity and desiccation cracking of soil. Fiber has the ablity to impart tensile strength to the soil thus reduce the formation of cracks. It can be concluded that addition of fiber has improved the following soil properties considerably:

- PI decreased for fiber amended soil
- SL increased for both fiber amended soil.
- Hydraulic conductivity of clay soil due to random inclusion of fiber was slightly increased as a function of fiber content. However the increment was within limits satisfied by liner.
- Desiccation cracking of clay soil due to random inclusion of fiber reduced to great extent .The depth of cracks was more for unreinforced specimen compared to reinforced sample.

The overall results suggest the use of fiber additives for a landfill liner to improve the durability of system.

References

[1]. **Carol J.Miller**, ‘Fiber Reinforcement For Waste Containment Soil Liners’, *Journal of environmental engineering* ASCE: pp 891-895.

[2]. **Mahmood.R.Abdi**(2008), Desiccation Cracking Of Clays’. *International journal of civil engineering pp.3861-3868.*

[3]. **Qianget.al** (2014),’Cracking, Water Permiability And Deformation Of Compacted Clay Liners Improved By Straw Fiber’. *Engineering geology*.178:82-90

[4]. **Umachadvala** (2016)’Desiccation Cracking Behaviour Of Geofiber Reinforced Expancive Clay’ *International Journal of Geotechnical Engineering*-Geo chicago PP:152-169.

[5]. **Venkat Bhadriraju et.al** (2015) ‘Digital Image Technique To Evaluate To Evaluate Shrinkage Of Fiber Reinforced Expancive Soil’ Site characterization and modeling, *ASCE Journals*.