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ANALYZING BEHAVIOUR OF COHESIVE SOIL REINFORCED WITH OR WITHOUT FIBRE FOR A LINER MATERIAL- A REVIEW

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Abstract- Disposal of municipal solid waste in landfill is the major environmental issue in India. During the rainy season, the moisture interacts with the municipal solid waste the liquid that seepage is called leachate. The leachate contains a large amount of organic, inorganic and hazardous substances. When the leachate percolated into the soil and contaminating the groundwater. To prevent the intrusion of leachate into the surrounding soil, impermeable landfill liners are used to block the migration of pollutants to the groundwater systems or to reduce its rate of flow to a reasonable amount. For improving the index properties, strength and control of crack formation in landfill clay liners are reinforced with natural or synthetic fibre.

Keywords*:* Clay Liner, Leachate, Geotechnical Properties, Fibre.

I. Introduction

Disposal of municipal solid waste is the major environmental problems in all over the world. One of the preferred methods of dealing with this kind of environmental problem is to dispose of the waste in sanitary landfills (Arasan and Yetimoglu, 2008). Because of its low permeability, a clay liner is a main material used in such landfills. According to Environmental Protection Agency (EPA), the compacted clay liner must be at least approximately 60 cm thick and must have a hydraulic conductivity of no more than 1x10-7 cm/sec (Anonymous, 1993). To satisfy the requirement, the soils should contain at least 15-20% of silt or clay-sized material. The Plasticity Index (PI) should be greater than 10%. Soils with very high PI, greater than 30 to 40%, are sticky and are difficult to work with. Also, high PI soils form hard clumps when the soils are dry and difficult to break down during compaction. The coarser fragments should be screened to no more than about 10% gravel-size particles (Sivapullaiah and Lakshmikantha, 2004). However; compacted clays can have problems with shrinkage and/or desiccation cracking especially those containing an appreciable amount of bentonite. Many studies have shown that compacted clays undergo large changes in physicochemical properties when exposed to shrink-swell and/or freeze-thaw cycling (Othman and Benson, 1993; Benson and Othman, 1993; Othman et al., 1994; Benson et al., 1995; Abdullah et al., 1999; Kaya and Durukan, 2004). Especially, bentonite clays are preferred, because of its fine particle size and consequent micro pores and high surface charges; it possesses low hydraulic conductivity and a high adsorption capacity (Sivapullaiah et al., 2000). In recent years, the interest of using fibers has arisen to suppress desiccation cracks problem. Polypropylene fiber is becoming a common synthetic material used to reinforce soil and concrete (Maher and Ho 1994; Nataraj and McManis 1997; Synthetic Industries 1998).

II. Landfill Liners

Liner system acts as impermeable barrier, which prevents the migration of leachate and from polluting the ground water. Many investigators have used different material for landfill liner such as Fly ash, Quicklime, Silica fume, Bentonite, Geosynthetics clay liners, Cement etc. Montmorillonite minerals i.e. bentonite is the most common material due its large cations exchange capacity, large specific surface area, high swelling potential and low hydraulic conductivity to water. Though it is a suitable for liner material using alone make it uneconomical and low durable. Also possess high swelling and shrinkage potential and hence can crack under unsaturated conditions causing instability and increase in leakage rates. So mixing bentonite with some other locally available soil can improve the geotechnical properties of liner. Bentonite used in this experiment is commercially available sodium bentonite. It consists of 96.59% fines in which clay is predominant (60%). The Specific gravity(SG), liquid limit(LL), plastic limit(PL) and shrinkage limit (SL) of this soil are found to be 2.52, 130%, 48% and 16.2% respectively. As per ASTM D2487, the bentonite is classified as clay with high compressibility (CH).

III. Leachate

Rainfall is the main contributor to the generation of leachate. The precipitation percolates through the waste and gains dissolved and suspended parts from the biodegrading waste through many physical and chemical reactions. Different contributors to leachate generation embrace groundwater inflow; surface water runoff and biological decomposition (Reinhart, D.R et.al 1998).There are several factors moving the standard of leachate, i.e.,

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age, precipitation, seasonal weather variation, waste kind and composition (Silva, A.C., et.al 2003).

Table I. Different Type of Landfill Liners

Sl.no	Mixing Materials	testing parameters	Reference	Conclusion
1	Bentonite-amended natural zeolite	• Specific gravity	Kamil Kayabah et.al (1996)	Liquid limit, plastic limit and plasticity index vary linearly with increase in bentonite content.
2	Bentonite-embedded zeolite	• Liquid limit	Abidin Kaya et.al (2003)	The maximum dry density of enhanced soil decreased from 18.05 to 16.57 kN/m^3 and optimum moisture content
3	Bentonite-sand mixture	• Plastic limit	Y.Y Tay et.al (2000)	The unconfined compressive strength varied from 111.83 to 288.4 kN/m^2
4	Composite lining	• Shrinkage test	P.J. Hewitt et.al - 1999	
5	Compacted Silty Loess	• pH, Total Solids (TS)	G.M. Aiassa et.al (2010)	The hydraulic conductivity of the optimum soil bentonite mixture varied from 1.31x 10^{-6} to 9.07 x10^{-11} cm/sec.
6	Natural soil-sodium bentonite	• Suspended Solids (TSS),	Kavya M.P et.al (2016)	
7	Marine clay	• Total Dissolved Solids (TDS)	Z.A. Rahman et.al(2013)	The marine clay was dominated by finer fraction of silt and clay (78%-88%) followed by sand (12%-22%). The clay minerals commonly present were montmorillonite, kaolinite and illite as well as quartz as the non-clay mineral.
8	Singapore marine clay	• EC	A. Arulrajah et.al (2008)	
9	Marine clay	• BOD,COD	G.Rajasekaran et.al(2000)	
10	Cochin marine clay	• Swelling pressure	Benny et.al , (1993)	
11	Marine clay	• XRD,SEM	Narain and Ramanathan et.al	

Table II. Characteristics of leachate

Parameter	Unit	Typical Leachate Compositions	Synthetic Leachate Compositions	Reference
NH4+	Mg/l	30 – 1040	750	Samudra Jayasekera et.al (2011)
Na+	Mg/l	400-2400	1500	
Ca2+	Mg/l	54-6240	3400	
Mg2+	Mg/l	5-525	400	
K+	Mg/l	20-3000	1500	
Cl-	Mg/l	500-6000	4000	
$SO4^{2-}$	Mg/l	5-1800	1500	
Carboxylic Acids	Mg/l	1000-22000	8000	
Alkalinity	Mg/l	80-26000	9000	
Total Phosphorus	Mg/l	Jan-33	-	
pH	Mg/l	3.8-8.9	5.6	

IV. Effect of Contaminant Liquids on Landfill Liners

Due to its low permeability, a clay liner is that the main material employed in solid waste disposal landfills. It's exposed there to numerous chemical, biological and physical events, and also the clay liner is plagued by the ensuring leachate.

Some researchers additionally compared the standard of clays on interaction chemically (Gleason et al. 1997) investigated some geotechnical properties of Ca and Na-bentonite with completely different concentrations of CaCl2 (varying between 0.01 and 0.735 M), NaCl (varying between zero.01 and 0.1 M), and methanol (pure methanol and five hundredth methanol in distilled water), and gasoline. They reported that calcium bentonite would be a lot of resistant than sodium bentonite to chemical constituents of the distributive fluids. Also, it had been finished that permeation with a strong calcium chloride solution would cause giant will increase the hydraulic conductivity of sodium bentonite.

V. Development of Desiccation Cracking In Compacted Clay Liners

Formation of cracks is increased by supply of clay (Holtz, 1981). Once the plasticity index is high, the chance of shrinkage and swelling will increase whereas the extent of reduction in size drops to a minimum. However, the danger of shrinkage and cracking be decreased by invigorating clay soil with coarse-grained materials (Kleppe, 1985). For the fabrication of a liner in arid sites, Daniel and Wu dialect, (1993) instructed the utilization of clayey sand with a low hydraulic conductivity and low shrinkage values. Compression activities and water content level have an impact on the drying pattern and hence the cracking of soil. Low-density porous and wet soil has the tendency to shrink. This makes the soil a lot of pronto susceptible to cracking, whereas extremely dense and well-drained soil exhibits reduced shrinkage and a reduced risk of cracking. Daniel and Wu dialect (1993) instructed the utilization of extremely dense and well-drained soil for construction works in arid areas to discourage cracking.

VI. Effects of Fibres and Admixture to Reinforce Soil and Control the Desiccation Cracks in Clay Liner

Soil reinforcement is defined as a technique to improve the engineering characteristics of soil. There are two different kinds of fibre 1.Natural fibers: Coconut (coir) fiber, Sisal Palm fibers, Jute, Flax, Barely straw, Bamboo Cane. 2. Synthetic (man-made) fibers : Polypropylene (PP) fibers, Polyester (PET) fibers, Polyethylene (PE) fibers, Glass fibers, Nylon fiber, Steel fibers, Polyvinyl alcohol (PVA) fibers.

Desiccation cracking may be a downside encountered in compacted clay liners, after they are subjected to alternate wetting and drying that are inevitable due to seasonal differences. With respect to the future performance of the clay liners, the desiccation risk of compacted clay liners is of cardinal relevance as desiccation can induce cracks within the liner and will reduce the sealing effect of the cover system significantly. A variety of research efforts have attempted to address the problem of desiccation cracks. Some have thought of the utilization of surface wetness barriers on top of the soil layer whereas some others have thought of the utilization of fibres and soil additives like lime, sand and cement. But makes an attempt to quantify the distribution and depth of cracks and to manage the crack potential by suitable amendments are restricted. In specific polypropylene fiber behaviour (length 25mm and 50mm, 25mm referred as short fiber and 50mm as long fiber) is reported that short fibers inspired additional in effective stabilization by reducing swell pressure and additionally it management desiccation cracks.

VII. Conclusion

This study presents a review of analysis on the geotechnical properties (consistency limits, hydraulic conductivity, shear strength, swelling, and compressibility) of clay liners conducted chemically. This chemicals impact the strength of compacted soil, by exploitation fibre reinforcement methodology may be a technique to improve the strength and management of crack formation within the compacted soil. The subsequent conclusions are created, supported the studies within the literature and on the discussion presented:

The chemicals considerably have an effect on the geotechnical properties of clay and clay liners.

There has not been a general agreement relating to the impact of chemicals on the geotechnical properties of clay and clay liners.

The behavior of the low plasticity clays (CL and kaolinite clay) is totally different from the high plasticity clay (CH and bentonite clay).

The liquid limit and swelling decrease with increasing chemical concentration for high plasticity clay. However, the liquid limit and swelling will increases with increasing chemical concentration for low plasticity clay.

The hydraulic conductivity will increase with increasing chemical concentration for high plasticity clay. However, the hydraulic conductivity decreases with increasing chemical concentration for low plasticity clay.

Limited data is presently out there on the shear strength of clay and clay liners interacted chemically. However, it may be aforementioned that the shear strength of clays will increases chemically.

Table III.Effect of contaminant liquids on landfill liners

Sl.no	Types of liner	Effluent	Parameter analyzed	Reference	Conclusion
1	Geosynthetic clay liners	Leachate	· Specific gravity,Hydraulic conductivity,	Mochamad Arief Budihardjo et.al- 2012	Clay leachate interactions could significantly influence the soil properties such as shrink-swell characteristics, particle size distribution, consistency, properties and percentage and type of clay minerals of the original experimental soil.
2	Natural Zeolite and Perlite	Leachate	· Particle size analysis,Atterberg limits,	Ummukulsum Ozel et.al (2012)	
3	Low plasticity clay, High plasticity clay	Chemical	· Compaction tests,Mineralogical analysis of soil.	Seracettin Arasan et.al (2010)	
4	Clayey soil	Industrial waste leachate	· pH,Total Solids (TS)	David E. et.al(1988)	
5	Clayey soil	Acidic waste	Suspended Solids (TS	Noureddine Hamdi et al (2013)	
6	Sodium Bentonite	Municipal solid waste leachate	Total Dissolved S	Darshika Wanigarathna et al.	

Author concluded that by improving the strength of compacted clay using fiber reinforcement.

It improves the strength of the soil, thus improving the soil bearing capacity.

The CBR values are observed to increase by 47%, 70.5%, 100% and 111.76% of that of the unreinforced sand with 0.5%, 1%, 1.5% and 2% of polypropylene fibers inclusions respectively, under unsoaked condition.

Tensile strength and CBR increases with increase in fibre content.

Also by using the fibres with an addition of chemical binders improves the stability of the soil, but reduce the brittleness factor of the composite soil.

By using the discrete fibres reduction of tensile cracks and improvement in the hydraulic conductivity and liquefaction strength are achieved.

The improved clay with fibre content 0.3% had the highest resistance to cracking.

The improved clay has higher anti-seepage ability than traditional clay.

Table IV. Effect of Desiccation cracking in compacted clay liner

Sl.no	Types of soil	Parameter analyzed	Reference
1	Kaolinite and fire clay	• Physical properties of soil,Hydraulic conductivity	Stephen S. Boynton et.al (1985)
2	Naturally clay soil	• Consolidation,Compaction	Craig H. Benson et.al (2001)
3	Clay-rich soil	• Permeability,Liner Desiccation cracks test	David E. Daniel et.al (1993)
4	Bentonite enhanced sand	• Cracking observation	Y.Y.Tay et.al (2001)
5	Soil-bentonite	UCS,Shrinkage test	Omer Muhie Eldeen Taha et.al (2015)

Table V. Use of fibre to reinforce soil

Sl.no	Fibre type	Length , diameter mm	Fibre property	Soil types	Testing parameters	Conclusions
1	Palm fiber	L= 20 or 40	Diameter (mm)	Fine sand		CBR value Maximum of 41% increased in strength for the specimen with 1% of 40-mm fibres
2	Palm fiber	L=20 or 40mm	Length (mm)	Fine sand		It was observed that adding 0.5–1% fibres enhance the CBR strength significantly by up to 56% compared with plain specimens. The strength at 2% fibre content decreases slightly.
3	Coir fibre	L=10mm	Density (kN/m3)	Clay		MDD showed a decrease of 6.06 %, 10.6 % and 13.1 % respectively, for 0.5, 1 and 1.5% addition of coir fibers to the soil. OMC values are constantly increasing upon increasing percentage of coir
4	Oil Palm fibre		Natural moisture content	Lateritic soil		Compressive strength for reinforced clay may be in the order of 1.2 times that of the unreinforced clay.
5	Coir fibre	L=10, 15 and 20 mm	Water absorption to saturation		SG,LL,PL,SL, UCS, XRD, SEM, compaction test, CBR, FSI,Permeality,Consolidation test	Thus, minimum *Cc* value is observed at fiber contents of 0.6% and 0.8% for soil coir fibers.
6	Sisal fibers	L=10, 15, 20 and 25;20 mm: optimized	Tensile strength	Silty sand		increased non-linearly with increase in length of fiber up to 20 mm and 0.75% fiber content
7	Jute fibers	L=5, 10, 15 and 20;10 mm: optimized	Modulus of elasticity	Clay		Fiber reduces the MDD while 5ncreases the OMC. CBR value is increased more than 2.5 times compared to the plain soil CBR value
8	polypropylene fiber	L=12 mm,D= 0.06 mm	Strain at failure	Soft clayey soil		MDD showed a decrease of 2.5 %, 8.08 % and increased 13.6 % respectively, for 0.5, 1 and 1.5% addition of Polypropylene fibers to the soil.
9	Polyester	L=12 mm,D=30 – 40 µm		Clayey soil		SBC increases from 93-105 KN/m^2 in fiber content up to 0.50%. Beyond that inclusion of fibers it decreases to 85 KN/m^2.

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