Characterization of Na_2CO_3 activated Calcium Bentonite and its application as a GCL

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***Abstract*—Liners are the major component of landfills. They are provided at the base of the landfill. The main function of landfill liners is to eliminate the percolation of leachate to the soil beneath and ground water table. Modern lining systems integrate clay minerals sealing layers with feasible geosynthetic liners to evolve a nearly impermeable layer which is called Geosynthetic Clay liner (GCL).The permeability of clay used in GCL should be below 10^{-11}cm/sec. Calcium bentonite is the most commonly available clay in India with permeability between 10^{-5} to 10^{-7} cm/sec. Permeability and other properties of bentonite can be improved by additives or activation include exchange activation, grinding or pulverizing. In this study commercially available calcium bentonite is treated with sodium carbonate (Na_2CO_3) at three different ratios and the properties of the treated bentonite are studied and check the suitability of sodium carbonate activated calcium bentonite as GCL. The properties include Atterberg's limit, free swell, UCC and permeability are also studied.**

Keywords— liner system,GCL, permeability, calcium bentonite

I. INTRODUCTION

GCL is a composite liner comprised of geosynthetic material and low permeability earth material like clay. The main advantages of the GCL are the limited thickness, the good compliance with differential settlements of underlying soil or waste, easy installation and low cost. On the other hand, the limited thickness of this barrier can produce: (1) vulnerability to mechanical accidents, (2) limited sorption capacity, and (3) an expected significant increase of diffusive transport if an underlying attenuation mineral layer is not provided. The geosynthetic liner system of GCL is almost impermeable; therefore the thickness of the GCL depends on the thickness of the clay layer.

The lowest permeability clay available in India is Calcium Bentonite with permeability varying from 10^{-6} to 10^{-7} cm/sec. Therefore, if it has to be used in GCL its permeability has to be reduced to the range of 10^{-10} cm/sec. The properties of calcium bentonite can be modified to some extend by processing, e.g. to remove impurities or to incorporate additives or by activating the bentonite. Additives may include dispersants, flocculants or gelling agents and are usually designed to improve performance and manageability of bentonite suspension. Activation includes exchanging activation grinding or pulverizing and is designed primarily to improve dispersion.

II MATERIALS AND METHODS

A. Soil

Commercially available bentonite was purchased from quarry near Coimbatore. The Fig. 1 shows the soil sample collected. The bentonite was high permeability calcium bentonite. Hence it was decided to treat it with Na_2CO_3 to improve its properties. The selected calcium bentonite was activated with Sodium compounds at different mass ratios (2.5, 5 and 7.5g/100g of clay). Index and engineering properties of calcium bentonite were found out in the laboratory as per Bureau of Indian Standards. The properties of bentonite are presented in Table I. Chemical analysis of the soil sample was done at Central Tuber Crops Research Institute, Thiruvananthapuram. Chemical constituent of the selected bentonite sample are presented in Table II . Fig. 2 shows the particle size distribution curve of soil.

Fig.1.Soil sample collected

TABLE I. PROPERTIES OF CALCUIM BENTONITE

PROPERTIES	VALUES
Specific Gravity	2.67
Natural water content (%)	8.064
Liquid limit (%)	276
Plastic limit (%)	52
Plasticity index (%)	224
IS classification	CH
OMC (%)	19.12
Dry density(g/cc)	1.463
% clay	82
% silt	18
Coefficient of permeability(cm/s)	$2.79x10^{-5}$
Free swell (ml/2g)	15.8
UCC strength (kN/m^2)	43.16

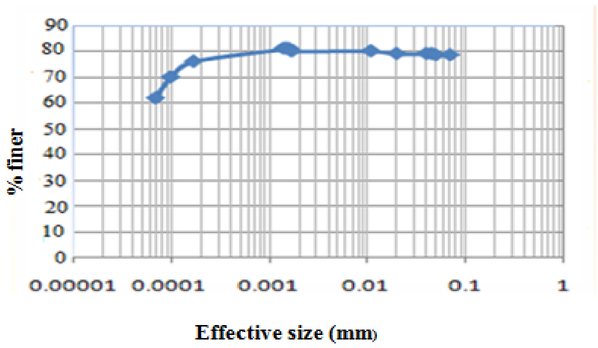

Fig.2 Particle size distribution curve

TABLE II Chemical Composition of Calcium Bentonite

Sample	Unit	Values
Available N	Kg ha^{-1}	44.69
Available P	Kg ha^{-1}	44.69
Available K	Kg ha^{-1}	44.69
Available Ca	Kg ha^{-1}	44.69
Available Na	Kg ha^{-1}	44.69a
Available Carbon	Kg ha^{-1}	44.69

B . Na_2CO_3

Sodium carbonate (also known as washing soda, soda ash and soda crystals, and in the monohydrate form as crystal carbonate),Na_2CO_3,isthe water soluble sodium salt of carbonic acid. It most commonly occurs as a crystalline decahydrate, which readily effloresces to form a white powder, the monohydrate. Pure sodium carbonate is a white, odorless powder that is hygroscopic (absorbs moisture from the air). It has a strongly alkaline taste, and forms a moderately basic solution in water. Sodium carbonate is well known domestically for its everyday use as a water softener. The sodium carbonate molecule is quite basic, or alkaline, meaning that it's the chemical opposite of an acid. Acids lower the pH of solutions, while bases, conversely, increase it. While the related chemical sodium bicarbonate, or baking soda, is a mild base, sodium carbonate is a much stronger base, notes the "CRC Handbook of Chemistry and Physics." As such, it can counteract acids in solution

D Preparation Of Sodium Activated Bentonite

The bentonite and the sodium compounds were added to 800ml boiling water. It is kept boiling for one hour. Then it is diluted with large quantity of water .Clay settled at the bottom of the container was collected, dried in atmospheric temperature and dried in the oven at 105^0C (N.Yildis et.al.,1998).Properties of these activated soils have been studied and compared with Na bentonite.

Fig 3 Bentonite treating with 2.5% *Na_2CO_3*

II. RESULTS AND DISCUSSIONS

Effect of *Na_2CO_3* on calcium bentonite

1) Variation in liquid Limit

Liquid Limit of Ca Bentonite was 272 and that of commercial Na Bentonite was 407. After activating with *Na_2CO_3* compounds ,it shows an increase in liquid limit. Liquid limits of the samples are shown in Table III. Variation of liquid limits are shown in Fig 4

TABLE III. LIQUID LIMITS OF VARIOUS SAMPLES

Type of sample	Ca Bentonite	Ca Bentonite activated with Na_2CO_3		
% additives		2.5 %	5%	7.5%
Liquid Limit	276	416	408	436

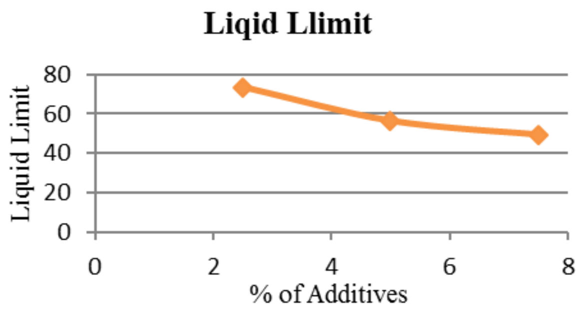

Fig 4 Variation in liquid limit of sodium activated bentonite

Liquid Limit of Ca bentonite treated with 7.5% of Na_2CO_3 is 436, which is near to the Liquid Limit of Na bentonite. Clay particles are dispersed when the clay interacted with chemicals. Due to the dispersion and deflocculation of clay, the geotechnical properties (especially,hydraulic conductivity) of clay were significantly changed Increase in Liquid Limit could be attributed to dispersion of the clay particle. Additionally salt solution might cause the formation of new swelling compounds and these new compounds lead to the increase of Liquid Limit(Sivapullaiah et,all,2005)

2) Variation in Plasticity Index

Plasticity Index of Ca Bentonite is 238 and that of comercially available Na Bentonite is 373. After activating with *Na_2CO_3* compounds ,it shows an increase in plasticity index. Plasticity Index of the samples are presented in Table IV. Graphical Representation is shown in Fig 5.

Table IV Plastic Limits of Various Samples

Type of sample	Ca Bentonite	Bentonite activated with NaCl		
% additives		2.5 %	5%	7.5%
Platicity Index	238	310	352	390

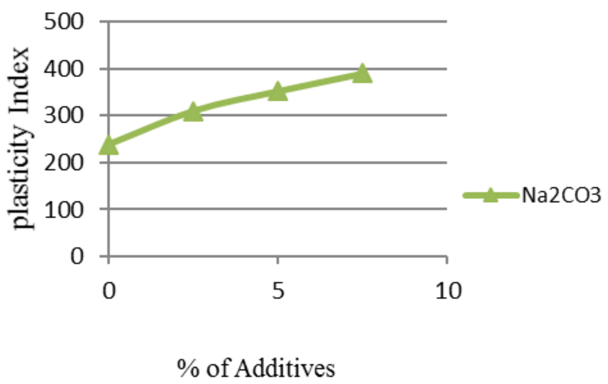

Fig 5.variation in plasticity index of sodium activated bentonite

PI of Ca bentonite treated with 5% of Na_2CO_3 is 204,which is near to the PI of Na bentonite

3) Variation in Free Swell

Free swell of Ca Bentonite was 16 ml/2mg and Free swell of Na Bentonite was 22 ml/2mg. Addition of Sodium Carbonate shows increase in the free swell. Free swell of Na_2CO_3treated Ca Bentonite increases sharply. Maximum free swell of 19.2 ml was obtained for Ca bentonite treated with 7.5% of Na_2CO_3. Free swell of the samples are presented in table 5.Variation of free swell are shown in Fig 6. Smaller ions tend to have greater hydration energies, and thus $_{within}$ the interlayer of clays can attract more water than large ions. The degree of attraction to the clay surface of Na^+ is less, so a Na^+ is more conductive to swelling when present at the clay surface, because adjacent negatively charged layers can be made to repel one another during the absorption of water into the interlayer. N. Yildiz and A. Calimli.(1999) On the other hand, Ca^{2+} saturation results in only limited swelling because the attraction of the cation for adjacent surface is stronger.

Table V Free Swell Of Various Samples

Type of sample	Ca Bentonite	Bentonite activated with Na_2CO_3		
% additives		2.5 %	5%	7.5%
Free swell (ml/2g)	16	16.5	17.9	19.2

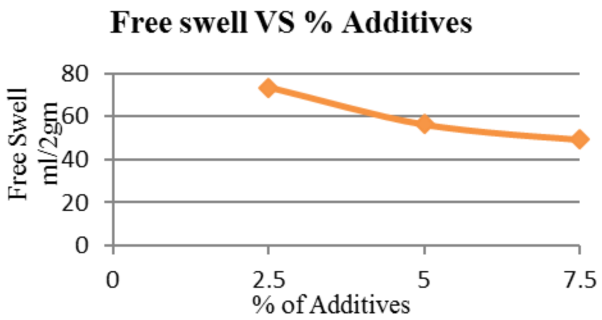

Fig 6.variation in fee swell of sodium activated bentonite

4) Variation in Unconfined Compressive Strength

UCC Tests were conductd to study the change in strength of calcium bentonite due to sodium activation. UCC of Ca Bentonite 43.16 KPa and that of Na Bentonite is 29.3 KPa.After an initial increase ,UCC value for all the samples were observed to be consistently reducing . UCC values of the samples are presented in Table VI. Variation of UCC values are shown in Fig 7.

Table VI.UCC of Various Samples

Type of sample	Ca Bentonite	Bentonite activated with Na_2CO_3		
% additives		2.5 %	5%	7.5%
UCC (Kpa)	43.16	73.5	89.6	94.3

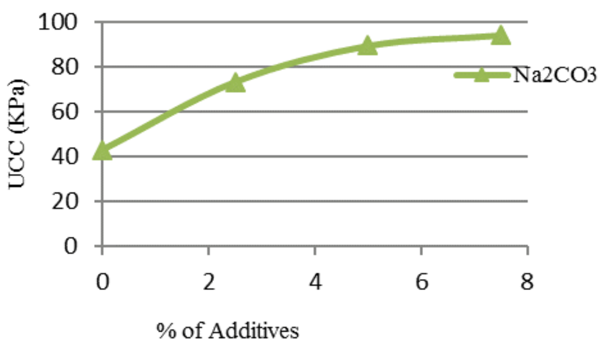

Fig 7 variation in UCC values of sodium activated bentonite

The increase in UCC values can be attributed to the formation of stabilizing chemicals during chemical treatment. Na^{+} ions replace divalent ions such as Ca^{2+} Mg^{2+} etc. These ions react with the anions in the additives such as OH^{-} Cl^{-} CO_3^{2-} SiO_2^{2-} etc to form stable compounds (Lowenstam and Weiner,1989)

5) Variation in Permeability

Permeability was found to be decreased by several orders due to chemical treatment. Permeability of the calcium bentonite treated with Na_2CO_3 are shown in table VII.

Table VII. Permeability Of The Calcium Bentonite Treated With Na_2CO_3

Type of sample	Ca Bentonite	Bentonite activated with Na_2CO_3		
% additives		2.5%	5%	7.5%
Permeability	2.79×10^{-6}	4.2×10^{-9}	1.19×10^{-8}	**8**.31x10^{-7}

6) Chemical analysis

Percentage of sodium oxide and calcium oxide present in the samples were analyzed in NCESS,Akkulam . Ca ions of the samples are replaced by Na ions. CaO % decreases consistently and the Na_2O % increases. Percentage of Na_2O and CaO present in Bentonite samples treated with Na_2CO_3 are shown in Table VIII.

Table VIII Percentage Of Na_2O and Cao Present In Bentonite Samples Treated With Na_2CO_3 (Chemical Analysis Result)

Na_2CO_3 %	0	2.5	5	7.5
Na_2O	1.33	6.52	8.10	8.00
CaO	2.09	1.44	1.33	1.39

IV CONCLUSIONS

The index properties, strength and permeability of calcium bentonite changes considerably when treated with Na_2CO_3.From the chemical analysis conducted on modified soil it has been observed that the percentage of Na_2O increases and the percentage of CaO decreases. This is due to the replacement of Ca^{2+} ions by Na^{2+} ions. Liquid limit of the samples have been increased and permeability decreases due to activation. The results show that for Na_2CO_3, 7.5 % is optimum. Treatment of Calcium Bentonite with 7.5% of Na_2CO_3 additive is better because of its less permeability and high UCC strength.

The availability of Na Bentonite is less and also it is costly. Hence Calcium bentonite modified with 7.5% Na_2CO_3 shall be opted for the construction of GCL.

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