Effect of Different Additives on Properties of Sodium Bentonite

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***Abstract*— Bentonite formed by weathering of volcanic ash has a rich content of montmorollinite mineral .Such soils exhibits an alternate cycle of swelling and shrinkage. Amended betonites are used as a component of industrial liner to prevent groundwater contamination by leachate. In this study suitability of treated Na-bentonite mixed with different proportion of sand as a liner is to be studied. Na-bentonite stabilized by $CaCl_2$, $MgCl_2$,sand in various concentrations and its effect on Atterberg, Unconfined compressive strength and swell compression are verified. Addition of $CaCl_2$,$MgCl_2$,sand shows a reduction in liquid limit and increase in unconfined compressive strength. Compacted bentonite/sand mixtures are often considered as possible sealing materials due to their low permeability, good radionuclide retention capacity and swelling ability A comparative study on Na-bentonite and treated Na bentonite with inorganic salts and sand are done.**

Keywords*— *Sodium Bentonite, Swell Characteristics, Liner

I. INTRODUCTION

The swelling capacity is one of the most important properties of the bentonite clay. The swelling behavior is due two mechanisms, the crystalline swelling and the osmotic swelling. These mechanisms produce an increase in the distance between the layers of montmorillionite which is one component of bentonite. Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the earth. Bentonite is one among the expansive soils which shows high volumetric change .Destructive results caused by this type of soils have been reported in many countries. This phenomenon of change in volume depends on the mineralogical nature of materials that make up the soils and their proportion. It affects all types of structures. The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them.

Amended Clay liners are effective barrier materials for bottom liners and cover systems at waste containment facilities because clay minerals are compatible with long-term stability, deformability, and impermeability. Compacted bentonite/sand mixtures are often considered as possible sealing materials due to their low permeability, good radionuclide retention capacity and swelling ability. Nuclear and hazardous waste disposal issues have become universal issues and problems related to the final disposal of these waste including finding a suitable site, natural and engineered barriers used, construction of the repository, long-term performance assessment have gained increasing attention all over the world . There are many techniques for soil stabilization and the choice from one of these techniques depends on several parameters which are economic, practical and environmental. Among these techniques, there are chemical stabilization, thermal stabilization, stabilization by additives are used widely. Some research works have shown that the addition of inert materials to soil can be also a method of stabilizing. These works led to consider that the addition of inert materials is a promising technique for stabilizing such soil capacity. Bentonite clay, when used in the field as a hydraulic barrier, comes in contact with various organic and inorganic chemicals which eventually cause the performance of bentonite clay to diminish in terms of permeability and chemical out flux. The presence of sand in the mixture improves the shear strength and thermal properties of the compacted mixture. The swelling pressure and swelling potential of the compacted mixture of bentonite and sand are lower than those of the compacted pure bentonite at the same dry density (or void ratio).

This study is about the effect of organic and inorganic leachate components on geotechnical properties of bentonite and bentonite-sand mixture. For this two types of inorganic salts are added to bentonite soil and the best among them is selected for the liner preparation. In the initial stage sodium bentonite is treated with $CaCl_2$ and $MgCl_2$ in various concentrations like 0.1M, 0.3M, 0.5M and the variation in geotechnical properties are studied. The one with better hydraulic conductivity and shear strength is mixed with sand in 10%, and 20% by weight of bentonite and their suitability liner preparation has to be studied.

II. MATERIALS

A. Bentonite

Betonites are naturally occurring clay consisting mostly of montmorillionite clay mineral. Sodium betonites are usually preferred for constructing landfill liners due to its high swelling. Commercially available sodium bentonite used in this study is purchased from Associate Chemicals Ltd., Cochin. Proprieties of bentonite are provided in Table I.

Table I. Initial Properties of Bentonite

Properties	Values
Liquid limit	371.64
Plastic limit (%)	40
Plasticity index	331
IS classification	CH
Shrinkage limit (%)	10
Specific gravity	2.75
% of clay	67
% of silt	17
% of sand	8
OMC (%)	31.6
MDD (g/cc)	1.48
UCS(kN/m^2)	100.8
Free swell(ml/g)	18

B.Sand

Locally available sand was collected from Marian Engineering College, Kazhakootam .properties of sand are provided in Table II

Table II. Geotechnical properties of sand

Properties	Values
Uniformity coefficient	1.37
Coefficient of curvature	1.17
Relative density (%)	2.67
Angle of friction ((°)	36
Is classifications	SP
Relative density	7.4

III.METHODOLOGY

A. Atterberg limits

Atterberg limits were conducted out as specified in is 2720 (part 5) inoder to study the liquid limit, plastic limit and shrinkage limit of bentonite and treated bentonite . A salt solution of 0.1M, 0.3M, 0.5M of calcium chloride and magnesium chloride were added to the sodium bentonite

B. Unconfined compressive strength

Unconfined compressive strength was carried as per is 2720 (part 10)-1991. Strength variation for both bentonite and treated bentonite soil with salt solution in varying concentration of 0.1M, 0.3M, and 0.5M of calcium chloride and magnesium chloride were added to the sodium bentonite were studied.

C. Shrinkage limit

Cracks formed due to the alternate wetting and drying of expansive soil can be studied by about 30 g of soil passing through 425 is sieve is taken in an evaporating dish. The soils are mixed with 0.1 M, 0.3M, 0.5M of calcium chloride and magnesium chloride were added to the sodium bentonite.

D. Consolidation

Consolidation tests were carried out as per is 2720 (part 15) for various concentrations. A normal load was applied and readings were taken for 0,15,30,1,2,4,8,15,360,120,1440 seconds respectively

IV. RESULTS AND DISCUSSIONS

- *Effect of $Cacl_2$ and $Mgcl_2$ on Na-bentonite*

A. Liquid limit

Liquid limit of bentonite and treated bentonite were conducted .test was conducted by varying concentrations of calcium chloride 0.1 M, 0.3 M, 0.5 M .The variation in liquid of bentonite and treated bentonite were studied and is tabulated in the Table III

Table III. Liquid limit of treated Na bentonite

Various concentration	Liquid limit (W_p) of $CaCl_2$ treated bentonite	Liquid limit (W_p)of $MgCl_2$ treated bentonite
0M	371.64 %	371.64%
0.1 M	342.705%	332.201%
0.3M	330.705%	297.52%
0.5M	190.89%	150.23%

From the above Table III we can see that there is an decrease in trend of liquid limit this is due to the ion exchange capacity of clayey soil the increasing salt concentration there is an decrease in the inter particle repulsion of clayey particles which results particles to move freely in lower water content, thus the liquid limit of the mixtures decreases (Salami et al ,2011)

B.Unconfined compressive strength

UCC strength of both treated and untreated bentonite was determined. $CaCl_2$and $MgCl_2$ was added in various concentrations.There is an increase in trend for both the salt solutions but comparatively it is more for $CaCl_2$ as in the Table VI

Table IV. UCC strength of treated bentonite

Various concentration	UCC(kN/cm^2) of $CaCl_2$ treated soil	UCC (kN/cm^2)of $MgCl_2$ treated soil
0M	1.00	1.00
0.1 M	1.15	1.01
0.3M	1.23	1.10
0.5M	1.35	1.04

C .Shrinkage limit

Shrinkage limit were done for four samples of mixes with bentonite and treated bentonite .From the Table V we can see an increase in trend and it is high for 0.5 M of calcium chloride solution. This increase in trend is due to the increases in content of salt solution which reduces the water content (Salami et al, 2011) .

Table V. Shrinkage limit of treated Na- bentonite

Various concentration	Shrinkage limit(%)of $CaCl_2$	Shrinkage limit(%))of $MgCl_2$
0M	10	10
0.1 M	14.5	12.5
0.3M	18.10	16.3
0.5M	21.5	19

D. Consolidation

Three consolidation tests were done for treated bentonite mixture with0.1M, 0.3M, 0.5M of salt solution .From table VI we can see a decrease in C_v value .As the salt concentration increases, ionic substitution of sodium by calcium ions increases which reduces the size of clay particle and the decrease in diffused double layer effect .As a result compressibility increases (Salami et al ,2011)

Table VI .C_v of treated Na- bentonite

Various concentration	C_v(cm^2/min)of $CaCl_2$	C_v(cm^2/min))of $MgCl_2$
0M	0.036	0.036
0.1M	0.032	0.030
0.3M	0.026	0.024
0.5M	0.019	0.015

- *Effect of sand on Na- bentonite*

Sand is a previous material in nature. Mixing sand with appropriate bentonite contents yields sand bentonite mixtures having low hydraulic conductivity that can be used as hydraulic containment liners. Hydraulic conductivity test and UCS were conducted to assess the shear strength parameters and hydraulic conductivity of 10% and 20% sand-bentonite mixtures.

A. Permeability of sand bentonite mixture

Bentonite powder was fully mixed with water to prepare slurry having initial water content of 1.50 times of liquid limit (WL). The slurry was mixed with sand in 10 and 20% number and poured directly into the consolidometer ring. A series of variable head permeability were done as in the Table VIII.

Table VII. Permeability of bentonite sand mixture

% of sand	k (cm /sec)
0% Sand+bentonite	$1x10^{-6}$
10% Sand+bentonite	$1.76x10^{-7}$
20% Sand+bentonite	$1.10x10^{-8}$
30% sand +bentonite	$1.23x10^{-9}$
40%sand +bentonite	$1.17x10^{-10}$

C. UCC strength of sand bentonite mixture

An unconfined compressive strength was checked for 0%,10% and 20% sand with bentonite. As the content of sand increases there is an increase in strength of sand bentonite mixture as in the Table VIII

Table VIII. UCS of sand bentonite mixture

% of sand	**UCS (kN/cm$^{2)}$**
0% Sand+bentonite	1.01
10% Sand+bentonite	1.78
20% Sand+bentonite	1.65

IV.CONCLUSIONS

From various tests like Atterberg limits, UCS, Shrinkage limit and consolidation were done on sodium bentonite sand mixture and treated sodium bentonite and the following conclusions were obtained.

Liquid limit decreases and UCC increases for bentonite treated with both $CaCl_2$ and $MgCl_2$. This may be due to the decrease in diffused double layer effect of clayey soil (Salami et al ,2011). In sand bentonite mixture permeability generally increased when grain size of sand in increased reported that permeability increases with the increase of coarse fraction (Sivapullaiah et al,2000).

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