UTILIZATION OF RED SOIL BENTONITE MIXES AS CLAY LINER MATERIALS

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Abstract:

Large quantities of Red soils are locally available in and around Vishakhapatnam are coarse grained soils. To meet the requirements of a good liner material like clayey soils, improvement of such soils are needed to function as a liner material. Stabilization is one such method with additives, here bentonite was chosen as an additive and various geotechnical test programme has conducted on Bentonite - Red soil mixes. From the test results it is identified that 15% dosage of Bentonite satisfies the hydraulic conductivity and other functions as a liner material.

1.0 Introduction:

North coastal districts of Andhra Pradesh consist of large quantities of Red soils**.** These are coarse grained texture dominated by fine sand particles with little or absence of clay binding materials. These soils exhibit high strength in dry condition and collapse in wet condition. These soils possess honeycombing structure with high void ratio and porosity having pervious characteristics. Urbanization and industrialization in these areas help to grow several Towns and Cities produce high quantities of municipal solid waste. Generally disposal is in the form of open dumping or land filling. Leachate from open dumping yards and unscientific landfills cause environmental pollution especially ground water. Therefore barriers have to play a big role in arresting seepage of Leachates from landfills. In this an attempt is made for the utilization of locally available Red soils in the construction of the barrier material such as liners and top covers. Red soil was collected from engineering college premises of Andhra University Vishakhapatnam. This soil exhibited high coefficient of permeability i.e, 4.4 x 10^{-5} cm/sec which is greater than 10^{-7} cm/sec to suit as barrier material. To achieve the above coefficient of permeability, Bentonite was selected as an additive to the Red soils and tested for various geotechnical properties.

Sivapullaiah et.al, (2003, 2005) studied Red earth with sodium Bentonite and lime as liner material and also studied liner materials exposed to different pore fluid environment. Quadri et.al, (2010) studies additives like granite powder, Sodium Bentonite on Red mud and clayey soils as a liner material. Tiwari and Srivastava et.al, (2000) studied the effect of flyash and sodium Bentonite for permeability and compression characteristics. Dutta et.al, (1999) studied the effect of flyash on clay and alluvial soils. Daniel et.al, (1993) identified that hydraulic conductivity of compacted clay liners has a value less than 10^{-7}cm/sec. Rowe K.R, et.al,(1995) Studied Clay barrier systems for waste disposal, Albright (1995) studied the physical and hydraulic characteristics of Bentonite added to soil and identified that decrease in permeability characteristics were observed. Kolawole, J.O., et. al.,

(2006), and Sheela Evangiline .Y, et.al. (2012) also studied bentonite amended Laterite soils as clay liner materials.

2.0 MATERIALS:

Red soil was collected from Andhra University College of Engineering premises, Visakhapatnam and laboratory tests were carried out for salient geotechnical characteristics such as gradation, Atterberg limits, compaction and strength etc., and are shown in table 1. The additive used was bentonite and laboratory test results are shown in table 2.

Properties of Red soil

Property	Values
Gravel (%)	0
Sand (%)	76
Fines (%)	24
a. Silt(%)	16
b. Clay(%)	8
Liquid Limit (%) w_L	23
Plastic Limit (%) w_P	18
Plasticity index I_P	5
I.S Classification	SM-SC
Specific gravity	2.66
Shrinkage limit(%)	16
Optimum moisture content (%)	8.0
Maximum dry density (g/cc)	1.95
Coefficient of hydraulic conductivity (k) cm/sec	$4.4x10^{-5}$
Unconfined compression strength (kPa)	140

Table 1

Properties of Bentonite

Property	Values
Gravel (%)	0
Sand (%)	5
Fines (%)	95
c. Silt(%)	18
d. Clay(%)	77
Liquid Limit (%)	275
Plastic Limit (%)	54
I.S Classification	CH
Specific gravity	2.70
Shrinkage limit(%)	10
Optimum moisture content (%)	35.0
Maximum dry density (g/cc)	1.40
Permeability (k) cm/sec	$2.4x10^{-9}$
Unconfined compressive strength (kPa)	225

Table 2

From the experimental data it is observed that Red soil is of coarse grained soil with domination of fine sand particles along with silts and low percentage of clay particles. This soil is of low plastic (Ip< 7) and semi impervious ("k" is in between 10^{-4} to 10^{-6} cm/sec), to achieve coefficient of permeability of 10^{-7} cm/sec to use as liner material, Bentonite was added to the Red soil with

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different percentages such as 5,10,15,20 etc., The prepared Red soil bentonite mixes were tested as per IS 2720 for various geotechnical properties to suit as barrier material. The following geotechnical properties are described below in various contexts.

3.0 Results and Discussions:

3.1 Consistency limits:

The Red soil-Bentonite mixes were tested for consistency limits and corresponding consistency indices are shown in table 3 and Fig1.Form the data it is observed that as percentage of Bentonite increases liquid limit (w_L), plastic limit (w_P), and plasticity index (I_p) values are increases. A small decrease in shrinkage limit (w_s) was observed. As percentage of bentonite increases the availability of clay particles in the given soil matrix increases the plasticity characteristics by taking more water to deform and filling up of the voids by these clay particles make the mix impervious.

Bentonite (%)	W_L (%)	W_P (%)	W_s (%)	I_P (%)
0	23	18	16	5
5	26	19	15.5	7
10	32	21	15	11
15	38	24	14.5	14
20	45	25	14.0	20
25	58	26	13.6	32

Table 3

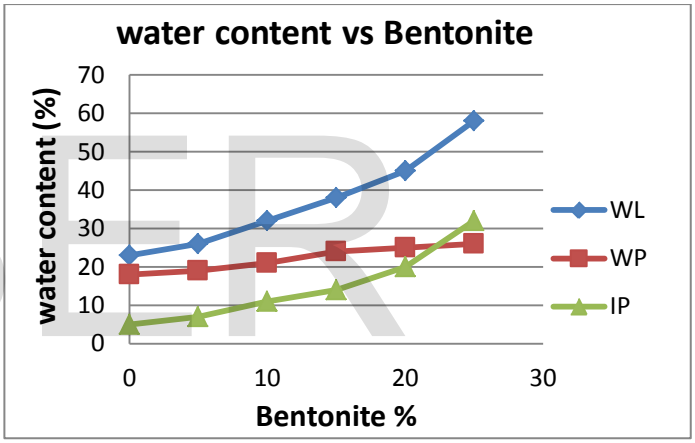

Fig: 1

3.2 Compaction Characteristics (Optimum Moisture Content & Maximum Dry Density):

Similarly the above Red soil-Bentonite mixes were also tested for compaction characteristics to achieve their densities in the field as well as to verify their strength and stability. The test results are shown in table 4 & fig 2 & 3.

Bentonite (%)	OMC (%)	MDD (g/cc)
0	8	1.92
5	8.5	1.88
10	10	1.85

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15	11.5	1.8
20	13	1.75
25	15.5	1.7

Table 4

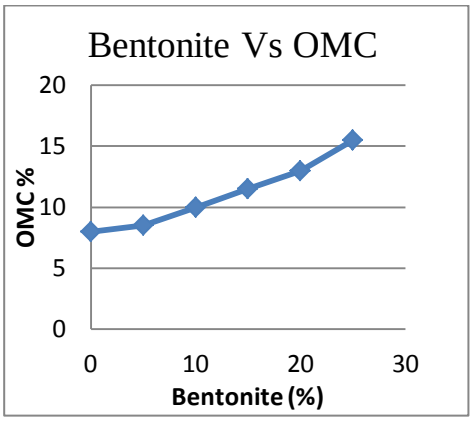

Fig 2

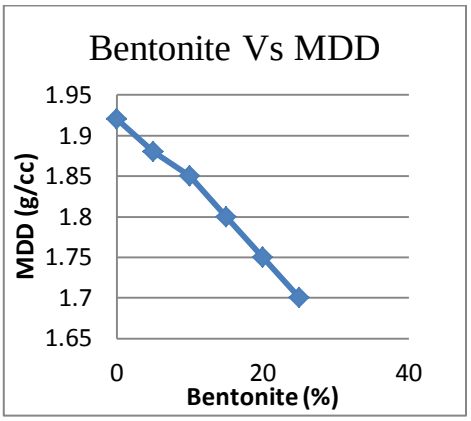

Fig 3

Bentonite (%)	UCS (kPa)
0	140
5	220
10	350
15	410
20	380
25	300

From the test results it is seen that with increase in percentage of Bentonite increases optimum moisture content and decreases maximum dry densities. The increase in optimum moisture contents and decrease in maximum dry densities are due to increase in percentage of clay content in a given mix and continued with increases the percentage of Bentonite, they require more water to coat the soil particles to slide one over the other and decrease in dry densities are due to formation of flocculent structure by occupying less solids in a given soil volume.

3.3 Unconfined compressive strength (UCS):

To verify the strength characteristics of the Red soil - Bentonite mixes, samples of 38 mm diameter and 76mm height were prepared and tested at a strain rate of 1.25 mm/min as per IS 2720 part 10. The test was carried out for various percentages of Bentonite and results are shown in table 5 and Fig 4.

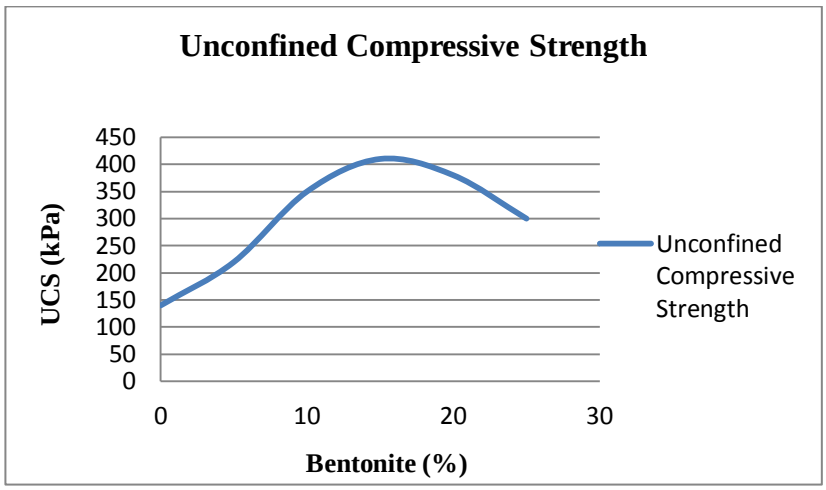

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Table 5 Fig 4

From the test results it is observed that increase in Bentonite content increases Unconfined Compressive Strength values. The natural soil is a sandy soil and addition of Bentonite supplies clay particles to the red soil improved the bond between sand and clay particles and make the Red soil Bentonite mixes hard and strong.

3.4 Coefficient of Permeability /Hydraulic conductivity ('k' cm /sec):

To verify the Red soil – Bentonite mixes as liner materials, the samples were prepared at their maximum dry densities and tested for coefficient of permeability using falling head permeability test as per IS 2720 part 17. These results are shown in table 6 and fig 5.

Bentonite (%)	Coefficient of Permeability (K) cm/sec
0	$4.4x10^{-5}$
5	$3.5x10^{-6}$
10	$8.8x10^{-7}$
15	$3.2\ x10^{-7}$
20	$2.4x10^{-7}$
25	$1.8x10^{-7}$

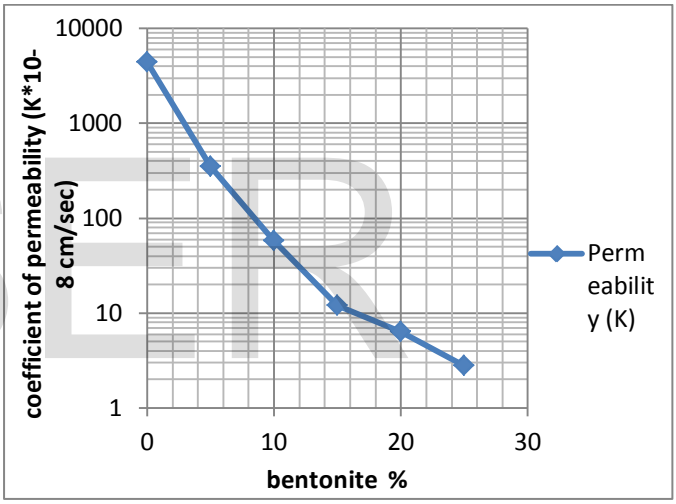

Table 5 Fig 4

From the experimental data it is identified that increase in the percentage of bentonite decreases the coefficient of permeability. Originally the natural soil is a coarse grained soil with less quantities of fines (<75 μ) with low percentage of clay particles resulting the soil with a coefficient of permeability as 4.4×10^{-5} cm/sec comes under semi- impervious nature. Addition of Bentonite increases the availability of fines (<75 μ) in the given soil Bentonite mix and filling the voids by the fines make them impervious by reducing void ratio and hydraulic conductivity comes to 10^{-7} cm/sec and also obtained further lower values.

3.5 Free swell Index (FSI):

To know the swelling characteristics of Red soil bentonite mixes various percentages of Bentonite 5, 10, 15, 20, 25 to the Red soils at their dry weights and 10gm of each poured in distilled

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water and kerosene. The free swell index was calculated as below. FSI = (V_w – V_k / V_k) x 100. The results are shown in table 6 and fig 5.

Bentonite (%)	FSI
0	0
5	10
10	20
15	30
20	45
25	60

Table 6

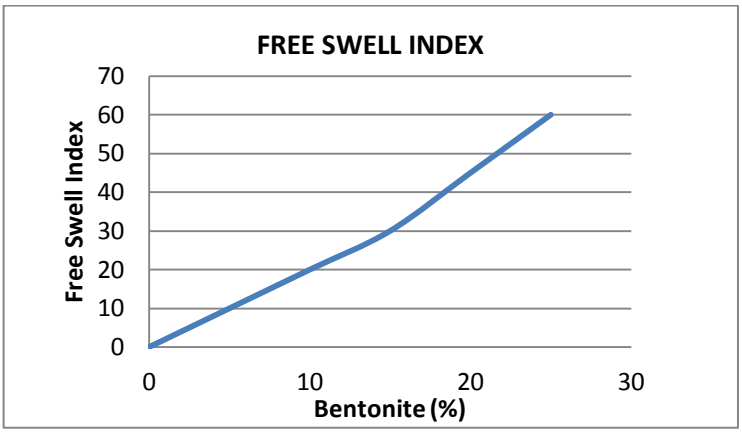

Fig 5

From the test results it is observed that with increase in percentage of bentonite increases the free swell index. It is marginal upto 15% and is rapid beyond 15%.

CONCLUSIONS:

From the test result it is observed that when the percentage of Bentonite increases, consistency properties such as liquid limit, plastic limit and plasticity index are increasing. At 10% Bentonite the soil exhibited low compressibility (W_L< 35%) and medium plastic (I_p= 7to 15) and low swelling (FSI <20%) from 15-20% onwards it turns to intermediate compressible and high plastic (I_p>15) and medium swelling (FSI<20-35), above 20% it moves to high compressible (W_L>50) and high plastic (I_P>15) and attaining medium swelling characteristics (FSI>30). It is also observed that as Bentonite increases and the Red soils Bentonite mixes exhibit good strength at higher percentages of Bentonite and the soil Bentonite mixes become impervious (k <10^{-6} cm/sec). Hence from the test data it is identified that a dosage of 10-15 percent Bentonite yields satisfactory results for the use of these mixes as liner materials.

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