An Experimental Analysis on The Strength Characteristics of Bagasse Ash Stabilized Black Cotton Soil Using Lime And Waste Tyre Rubber

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Abstract- *Expansive soils, such as black cotton soils, are basically susceptible to detrimental volumetric changes, with changes in moisture. This behaviour of soil is attributed to the presence of mineral montmorillonite, which has an expanding lattice. Among several techniques adopted to overcome the problems posed by expansive soils, lime stabilization gained prominence during the past few decades due to its abundance and adaptability. Various remedial measures like soil replacement, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations. Many researchers, all over the world are working, to evolve more effective and practical treatment methods, to solve the problems caused to pavements laid on expansive soils. Investigations on soil stabilization revealed with some other availability materials like Bagasse ash, quarry-dust, lime, waste rubber, waste plastics, etc., may be effectively used. From the present study, it can be summarized that the materials Bagasse ash, Lime, and Waste Tire Rubber had shown promising influence on the properties of problematic expansive soil, thereby giving a two-fold advantage in improving a problematic expansive soil and also solving a problem of waste disposal.*

Keywords- *Expansive Soil, Volumetric Changes, Montmorillonite, Bagasse ash, Lime, Waste Tire Rubber.*

I. INTRODUCTION

Soil is a natural body consisting of layers (soil horizons) that are primarily composed of minerals which differ from their parent materials in their texture, structure, consistency, and colour, chemical, biological and other characteristics. It is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth. Soil is the end product of the influence of the climate (temperature, precipitation), relief (slope), organisms (flora and fauna), parent materials (original minerals), and time. In engineering terms, soil is referred to as regolith, or loose rock material that lies above the 'solid geology'. In horticulture, the terms 'soil' is defined as the layer that contains organic material that influences and has been influenced by plant roots and may range in depth from centimetres to many meters.

Soil is altered from its parent material by the interactions between the lithosphere, hydrosphere, atmosphere, and biosphere. It is a mixture of mineral and organic materials in the form of solids, gases and liquids.

Expansive soils are found in arid and semi-arid regions of the world and, hot climate and poor drainage conditions are usually associated with the formation of these soils. In INDIA, these soils are generally called as black cotton soils and cover about 20% of the total land area. They are found in the states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Tamilnadu.

Expansive soils are highly problematic because of their alternate swelling and shrinkage. World over, problem of expansive soils has appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, sewer lines, canal and reservoir linings. The losses due to extensive damage to highways running over expansive soil sub-grades are estimated to be in billions of dollars all over the world.

OBJECTIVE

To identify the strategy of techniques to overcome the problems posed by expansive soil with a view to adopt suitable methodology through critical review of literature.

- To study the impact of proposed additives and admixtures on the properties of expansive soils through laboratory experimentations.
- To evaluate the performance of expansive soil when stabilized with proposed additives and admixtures and their suitability for fill material and sub grade material.
- To investigate the suitability and adoptability of Waste Tire Rubber (WTR) as discrete reinforcement.

II. REVIEWOFLITERATURE

Expansive soils are the soils which expand in presence of water and shrink in the absence of water. The clay mineral montmorillonite is mainly responsible for the expansive nature of the soil. The expansive soils are also called swelling soils are black cotton soils. Expansive soils are generally residual soils left at the place of their formation after chemical decomposition of the rocks such as basalt and trap.

Origin and Occurrence of Expansive Soils

The key element which imparts swelling characteristics to any ordinary non-swelling soil is a clay mineral. There are several types of clay minerals of which Montmorillonite has the maximum swelling potential. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of important clay mineral takes place under alkaline Environments. Due to weathering conditions if there is adequate supply of magnesium of ferric or ferrous oxides and alkaline environments. Along with sufficient silica and aluminum, it will favor the formation of montmorillonite. The depth of expansive soil is shallow at the place of formation with the parent rock underneath.

Clay Mineralogy

Generally clay-minerals can be divided into three general groups on the basis of their crystalline arrangements such as:

- Kaolinite Mineral,
- Montmorillonite Mineral,
- Illite Mineral.

Of these minerals montmorillonite and illite are responsible for swelling of soils.

Kaolinite: This is the mineral type of non-expansive because of containing a stronger hydrogen bond that can holds individual particle of clay together and wound allow to expand

Illite: this is the mineral type of limited expansion because of containing weaker potassium bonds and that allowed limited expansion. The properties of this mineral group are intermediate between that of kaolinite and montmorillonite. The swelling of illite mineral is more than that of kaolinite and lesser than montmorillonite

Montmorillonite: This mineral type weakly linked and water can easily flow into this montmorillonite clays and separate the particles.

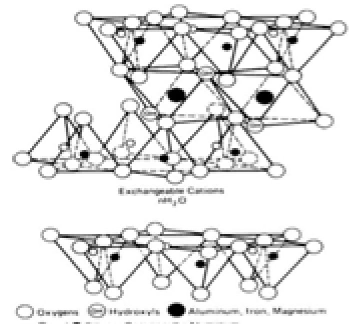


Figure1.Montmorillonite Structure

Need for Study of Expansive Soil

From the last few decades, inexorable trials were made to minimize losses and problems occurred with engineering the problems caused by expansive soils are processing. Because these soils commonly involve in beneath areas covered by slabs, buildings, pavements like highways, airport runways, canal linings and pipe lines. The damage may be in the form of vertical movement due to the corresponding changes in the environment.

High expansion may be occurred some times. Shrinkage of this soil due to particles displacement results from pore water tensions developed by capillary menisci. For preferred orientation of platy particles parallel to the horizontal, vertical shrinkage on drying is greater than lateral shrinkage. For example vertical shrinkage of seven sisters" clay was three times greater than horizontal shrinkage.

Expansive soils act more slowly and losses that incurred due to these are in worldwide and much of it may be avoided by recognition of the concerned severity and working on it and following some remedial measures like in design calculations, maintenance of new facilities. Although expansive soils are most common sources of heave, other mechanism also observed. Sedimentary rocks formed from clays, such as clay stone and shale are often expansive. Swelling pressures and heave are often very high because of the high unit weight of rocks. By oxidation or carbonization some rocks can able to expand. These processes create by products, which occupy a larger volume than the original materials. Swelling mainly due to water infiltrates between and interstices itself, leads to separation.

Problems Associated With Expansive Soil

- Damages to the Pavement Sub grades
- Rutting
- Longitudinal cracks
- Damages to the building foundations

- Damages to super structure
- Cracks in buildings

Remedial Measures to Overcome Problems of Expansive Soil

If soil has a high deformation, the preventive measures are required. These measures can be broadly classified into the following categories.

- Avoiding highly compressible soils
- Alterations to these soils

In case of foundations, Sand Cushion method, Stiffening the foundation by adopting Alterations, Mat Foundations, Heat treatment, Chemical stabilization, soil replacement technique are some of the remedial measures to overcome the problems of compressible marine clay soils.

In case of Pavement sub grades, stabilization techniques can be adopted using various industrial waste considering the economy and also chemical additives for easy mixing and early results. The reinforcement techniques also plays vital role in improving the load carrying capacity of the marine clay beds.

- Soil Replacement
- Sand Cushion Method
- Stiffening the Foundation and Super structure
- Mat Foundation
- Stone Columns
- Heat Treatment
- Stabilization

Figure 2. Expansive Soil Showing Cracks

STABILIZATION

Stabilization is the process of improving the engineering properties of the soil and thus making it more

stable. Although there is an immediate strength improvement due to textural changes, stabilization involves the formation of cementitious compounds within the clay structure over time. Stabilization alters the following engineering properties.

- Increases load bearing capacity and shear strength of the soil
- Decreases the permeability and compressibility
- There are different types of stabilization. They are:
- Mechanical stabilization
- Cement stabilization
- Lime stabilization
- Bituminous stabilization
- Chemical stabilization
- Thermal stabilization

Various Investigations on Expansive Soils

Amit S. Kharade1, Vishal V. Suryavanshiare studied and investigation done on “waste product Bagasse ash” from sugar industry can be used as stabilizing material for expansive soils” in 2014. The effective percentage replacement of Bagasse ash was found to be 6%. The results improved at 6% replacement are as follows – The maximum dry density increased by 5.8%, California bearing ratio (CBR) increased by 41.52% and Compressive strength increase by 43.58%.

A.T.Manikandan, M.Moganraj studied on “consolidation and rebound characteristics of expansive soil by using lime and Bagasse ash” in April 2014, based on the test results in this study reveals that a series of liquid and plastic limit tests were performed on the untreated and Bagasse ash - Lime treated soil samples. It is observed that as the increases in Bagasse ash content with Lime, there is a marked reduction in liquid limit whereas plastic limit is increases.

Akshaya Kumar Sabat Experimented on “Utilization of Bagasse Ash and Lime Sludge for Construction of Flexible Pavements in Expansive Soil Areas” in 2013 the following conclusions are drawn from this study. The addition of Bagasse ash to expansive soil decreases the MDD and increases the OMC of the expansive soil irrespective of the percentage of addition of Bagasse ash. The UCS and soaked CBR are observed to have maximum values corresponding to the mix having proportion of, soil 76%,bagasse ash 8% and lime sludge 16%.The optimum proportion of soil: Bagasse ash: lime sludge is found to be 76:8:16.The swelling pressure goes on decreasing with addition of both Bagasse ash and lime sludge.

N. K. Ameta D.G. M. Purohit, A. S. Wayal are studied on "Characteristics, Problems and Remedies of Expansive Soils" of Rajasthan, India in 2007 Suggested Remedies For Swelling Soils are as follows. The swelling soil causes due to its expansive nature with water cracks are formed in buildings, canal lining etc. various suggestions to overcome the problem is as under. Provide CNS layer.

Dr. D S V Prasad, Dr. G V R PrasadaRaju, M Anjan Kumar studied on "Utilization Of Industrial Waste In Flexible Pavement Construction" in 2009 have made an attempt to use sand soil as sub grade, murrum and Bagasse ash as sub base soils, waste plastics and waste tyre rubber as reinforcing materials in sub base soils, WBM Grade - 2 as base course in the flexible pavement system. It is observed from the results of CBR tests that for murrum and Bagasse ash materials reinforced with different percentages of waste plastics, the optimum percentages were equal to 0.30 % for murrum and 0.40 % for Bagasse ash.

C. Rajakumar, T. Meenambal, P. D. Arumairaj done a team work on "California Bearing Ratio Of Expansive Sub grade Stabilized With Waste Materials"in2014 Based on the experimental studies the following conclusions were drawn. Sub grade soil used in this project was classified as clay of high plasticity. The soaked CBR value of untreated soil is 1.63% and 2.24% under both light and heavy compaction and hence it requires to be stabilized.CBR values increased for 4%, 8%, 12%, 16%,20% of Coal ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations with uniform proportions. The UCC strength also increased for 4%, 8%, 12%, 16%, 20% of Coal Ash + Groundnut shell ash, Coal ash + Bagasse ash and Bagasse ash + Groundnut shell ash combinations with uniform proportions.

METHODOLOGY

In this we will discuss about the properties of different types of materials used during the laboratory experimentation were presented. And a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

Materials Used and Their Properties

The details of the various materials used in the laboratory experimentation are reported in the following sections.

Expansive Soil

The soil used was a typical black cotton soil collected from 'Kothapeta' near Amalapuram, in East Godavari District, Andhra Pradesh State, India. The properties of soil are presented in the Table All the tests carried on the soil are as per IS specifications.

Table 1.
Table 3.1 Properties of Expansive Soil

S.No.	Properties	Value
1	SpecificGravity	2.72
2	DFS (%)	113
	Atterberglimits	
3	LiquidLimit(%)	69.4
	PlasticLimit(%)	23.5
	PlasticityIndex(%)	45.9
4	ISSoilClassification	CH
	CompactionProperties	
5	O.M.C. (%)	30.6
	M.D.D.(g/cc)	1.56
	CBR(%)	
6	UnSoaked	2.01
7	Soaked	0.74
	ShearTestProperties	
8	C_u(kpa)	56
	$Ø_u$(degrees)	0^0

G Radhakrishnan Dr M Anjan Kumar and Dr GVR PrasadaRaju done a study on "Swelling Properties of Expansive Soils Treated with Chemicals and Bagasse ash" in 2014 the following conclusions are drawn based on the present laboratory study. Engineering Properties of the collected expansive soil samples indicate that soil samples comes under CH group. The Differential Free Swell value of the soil is 140%, indicating that the soil is highly expansive. Consistency limits indicate that the soil is high plasticity. The Swelling Pressure value is very high of the order of 295 KPa. From the experimental study it is observed that the treatment of the expansive soil with Aluminium Chloride (AlCl3) and Bagasse ash at 1% and 10% respectively is more effective than the other.

III. METHODOLOGY

In this we will discuss about the properties of different types of materials used during the laboratory

Bagasse Ash

For the present study, the Bagasse ash has been brought from the sugar factory at mallam village, AP. The major ingredients present in this Bagasse ash are Silicon, Aluminium and Iron. The properties of Bagasse ash are given in the below tables

Table2.
Table3.2 Properties of Bagasse ash

S.No.	Properties	Value
1	SpecificGravity	2.12
	GrainSizeDistribution	
2	Sand(%)	25
	Silt (%)	70
	Clay(%)	5
	Atterberglimits	
3	LiquidLimit(%)	44
	PlasticLimit(%)	NP
	PlasticityIndex(%)	NP
	Compactionproperties	
4	O.M.C. (%)	17.4
	M.D.D.(g/cc)	1.29
	CBR(%)	
5	UnSoaked	10.5
6	Soaked	3.15

Table3.
Table3.3 Chemical Composition of Bagasse ash

S.No	Nameofthe chemical	Symbol	Rangeof%by Weight
1	Silica	SiO_2	61to64.29
2	Alumina	Al_2O_3	21.6to 27.04
3	FerricOxide	Fe_2O_3	3.09to 3.86
4	TitaniumDioxide	TiO_2	1.25to 1.69
5	ManganeseOxide	MnO	Upto0.05
6	CalciumOxide	CaO	1.02to 3.39
7	MagnesiumOxide	MgO	0.5to1.58
8	Phosphorous	P	0.02to 0.14
9	SulphurTrioxide	SO_3	Upto0.07
10	PotassiumOxide	K_2O	0.08to 1.83
11	SodiumOxide	Na_2O	0.26to 0.48
12	Lossofignition		0.20to 0.85

Lime

Commercial grade lime mainly consisting of 58.67% of Cao and 7.4% Silica was used in the study. The quantity of lime was varied from 0% to 12% by dry weight of soil + quarry dust.

Waste Tire Rubber

Waste tyre rubber is collected from Sree Anjaneya traders in Kakinada. The mixing of waste tyre rubber in soil not only reduces the waste in the environment but also increases the strength of the soil.

Specific gravity of rubber = 0.94

List of Laboratory Tests

- The grain size distribution
- Specific gravity
- Swell Tests- Differential Free swell
- Index properties –Liquid Limit, Plastic Limit
- Compaction tests
- Penetration tests- California bearing ratio tests.
- Strength tests- Tri- axial shear tests

SAMPLEPREPARATION

The soil was initially air dried, pulverized and then was sieved through 4.75mm sieve, prior to the testing. The samples were prepared by mixing the pulverized and sieved soil with the needed stabilizing agents in dry condition and then required amount of water is added to make a consistent mix by thorough mixing. The following tests were conducted as per IS Codes of practice to assess the influence of Bagasse ash, Lime and WTR on the problematic expansive soil.

i. Compaction tests
ii. Penetration tests- California Bearing Ratio test.
iii. Strength tests- Tri-axial shear test

The following table lists the different variables and their respective contents used in the present study.

Table4.
3.4 TableDifferentVariablesStudied

S.No.	StabilizingAgent	%Content
1	Bagasse ash	0,5,10,15 &20
2	Lime	0,4, 8, &12
3	WTR	0,0.5, 1.0,&1.5

IV. RESULTS AND DISCUSSIONS

Details of the laboratory experimentation carried out by stabilizing expansive soil with Bagasse ash, lime and waste tyre rubber scrap had been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from laboratory experimentation are presented.

Table5.
Table 4.1 Variation of OMC & MDD with %Replacement ofFAinE.S

S. No	%ofFA	OMC (%)	MDD(gm/cc)
1	0	30.6	1.56
2	5	28.8	1.58
3	10	27.1	1.59
4	15	25.8	1.61
5	20	24.2	1.6

Table6.
Table4.2 VariationofOMC&MDDwith%ofLime

S. No	%ofFA	OMC (%)	MDD(gm/cc)
1	0	25.8	1.61
2	4	26.4	1.62
3	8	27.3	1.64
4	12	28.1	1.63

Table7.
Table4.3 VariationofOMC&MDDwith%ofWTR

S. No	%ofFA	OMC (%)	MDD(gm/cc)
1	0	27.3	1.64
2	0.5	26.9	1.63
3	1	26.7	1.62
4	1.5	26.1	1.61

Table8.
Table4.4 VariationofCohesionwith%ofWTR

S. No	%of WTR	C_u	% Increase inCu
1	0	102	-
2	0.5	104	1.9
3	1	108	5.9
4	1.5	107	4.9

Table9.
Table 4.5 Variation of Angle of Internal Friction(AIF)with% ofWTR

S.No	% of WTR	AIF	%Increase in AIF
1	0	40	-
2	0.5	50	25
3	1	80	100
4	1.5	70	75

Table10.
Table4.6 VariationofCBRwith% WTR

S. No	%of WTR	Un Soaked	%Increase
1	0	7.4	-
2	0.5	7.9	6.7
3	1	8.1	9.5
4	1.5	8	8.1

Table11.
Table4.7 VariationofCBRwith% WTR

S.No	%of WTR	Soaked	% Increase
1	0	7.9	-
2	0.5	8.3	5.1
3	1	8.8	11.4
4	1.5	8.5	7.6

Table12.
Table4.8 Variation of OMC & MDD with various mixproportions

S. No.	MixProportions(P)	OMC (%)	MDD (gm/cc)
1	OnlySoil(P1)	30.6	1.56
2	E.S+15%F.A(P2)	25.8	1.61
3	E.S+15%F.A+8%Lime(P3)	27.3	1.64
4	E.S+15%F.A+8%Lime+0.5%WTR (P4)	26.9	1.63
5	E.S+15%F.A+8%Lime+1.0%WTR (P5)	26.7	1.62
6	E.S+15%F.A+8%Lime+1.5%WTR (P6)	26.1	1.61

Table13.
Table4.9 Variation of Shear Parameters with various mixproportions

S.No.	MixProportions(P)	C_u	AIF
1	OnlySoil(P1)	56	0
2	E.S+15%F.A(P2)	81	0
3	E.S+15%F.A+8%Lime(P3)	102	4
4	E.S+15%F.A+8%Lime+0.5%WTR (P4)	104	5
5	E.S+15%F.A+8%Lime+1.0%WTR (P5)	108	8
6	E.S+15%F.A+8%Lime+1.5%WTR (P6)	107	7

Table14.
Table4.10 Variation of Un Confined Compressive Strngth withvariousmixproportions(kN/Sq.m)

S. No.	MixProportions(P)	UCStrength
1	OnlySoil(P1)	110
2	E.S+15%F.A(P2)	160
3	E.S+15%F.A+8%Lime(P3)	235
4	E.S+15%F.A+8%Lime+0.5%WTR(P4)	250
5	E.S+15%F.A+8%Lime+1.0%WTR(P5)	285
6	E.S+15%F.A+8%Lime+1.5%WTR(P6)	265

Table 15.
Table4.11 Variation of CBR Values with various mixproportions

S. No.	MixProportions(P)	Un Soaked	Soaked
1	OnlySoil(P1)	2.01	0.74
2	E.S+15%F.A(P2)	4.3	3.6
3	E.S+15%F.A+8%Lime(P3)	7.4	7.9
4	E.S+15%F.A+8%Lime+0.5%WTR (P4)	7.9	8.3
5	E.S+15%F.A+8%Lime+1.0%WTR (P5)	8.1	8.8
6	E.S+15%F.A+8%Lime+1.5%WTR (P6)	8	8.5

Table16.
Table4.12 Variation of Bearing Capacity with various mixproportions(kN/Sq.m)

S. No.	MixProportions(P)	SBC
1	OnlySoil(P1)	125
2	E.S+15%F.A(P2)	195
3	E.S+15%F.A+8%Lime(P3)	290
4	E.S+15%F.A+8%Lime+0.5%WTR(P4)	320
5	E.S+15%F.A+8%Lime+1.0%WTR(P5)	390
6	E.S+15%F.A+8%Lime+1.5%WTR(P6)	360

Table17.
Table4.13 Variation of Pavement Thickness with various mixproportions(m)

S. No.	MixProportions(P)	Un Soaked	Soaked
1	OnlySoil(P1)	0.6	0.99
2	E.S+15%F.A(P2)	0.39	0.42
3	E.S+15%F.A+8%Lime(P3)	0.26	0.28
4	E.S+15%F.A+8%Lime+0.5%WTR (P4)	0.23	0.27
5	E.S+15%F.A+8%Lime+1.0%WTR (P5)	0.23	0.26
6	E.S+15%F.A+8%Lime+1.5%WTR (P6)	0.23	0.26

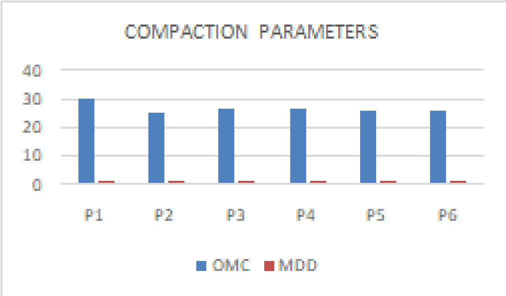
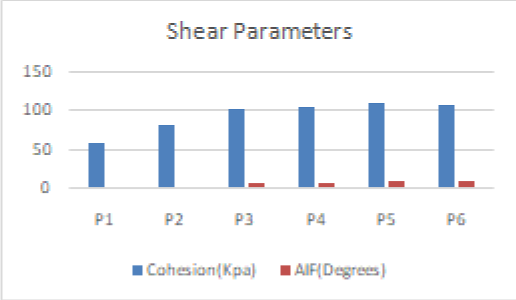


Figure 3. Bar chart showing the effect of F.A, Lime & WTR oncompactionparametersofProblematicExpansiveSoil.



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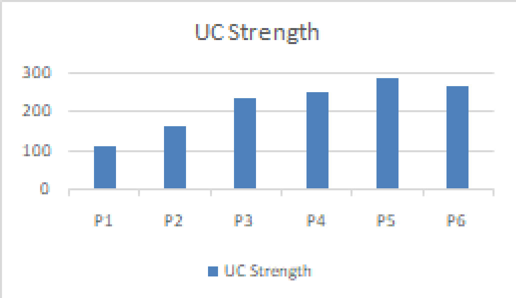

Figure 5. Bar chart showing the effect of F.A, Lime & WTRonUn confined compressivestrength ofProblematicExpansiveSoil.

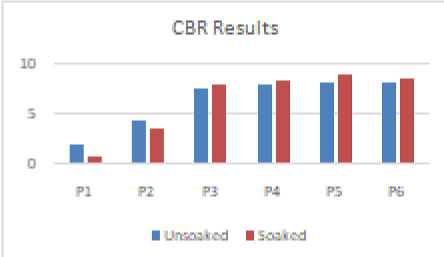

Figure 6. Bar chart showing the effect of F.A, Lime & WTRonCBRValuesofProblematicExpansiveSoil.

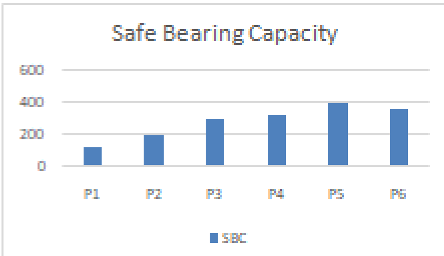

Figure 7. Bar chart showing the effect of F.A, Lime & WTRonsafebearing capacityofProblematicExpansiveSoil.

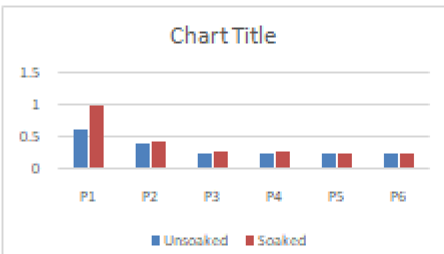

Figure 8. Bar chart showing the effect of F.A, Lime & WTRonpavementthicknessofProblematicExpansiveSoil.

EFFECT OF F.A, LIME & WTR ON THE PROPERTIES OF EXPANSIVE SOIL

Table 4.8 to 4.13 shows the summarized results of the behaviour of expansive soil stabilized with Bagasse ash, Bagasse ash + lime, Bagasse ash + lime + WTR. From the tables it is evident that the addition of Bagasse ash to the virgin expansive soil showed an improvement in maximum dry density by about 3.2% and on further blending it with lime, it increased to 5.1%.

The corresponding optimum moisture content reduced for only Bagasse ash mixing and then increased slightly when lime is added to Bagasse ash soil mix. The shear parameters also were improved with the addition of Bagasse ash, lime – Bagasse ash and lime – Bagasse ash – WTR. There is an improvement of 45% in cohesion when the virgin soil was replaced with 15% Bagasse ash and when it is further blended with lime, it improved by about 26% further.

The addition of lime had mobilized little amount of friction to the mix. The angle of internal friction was further improved by about 100% when the mix was blended with 1%WTR scrap and also the cohesion has improved by about 93% when compared to that of virgin expansive soil.

The corresponding unconfined compressive strength was improved by about 245%. There is an improvement in unsoaked and soaked C.B.R values also by about 3 times and 11 times respectively. From the above discussions, there is a significant improvement in the shear as well as C.B.R parameters of the virgin expansive soil by part replacing with 15% Bagasse ash and then blending it with 8% lime and further reinforcing it with 1% discrete inclusions of WTR.

Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 shows the bar chart of various parameters studied to assess the behaviour of expansive soil when treated with optimum contents of Bagasse ash and lime i.e. 15% and 8% and further mixing it with different percentages of WTR scrap i.e. from 0% to 1.5% with an increment of 0.5%. From the figures, it is clear that the problematic expansive soil was improved by stabilizing it with Bagasse ash, lime, WTR scrap.

This results in reducing the construction material by effective utilization of waste materials, solving the problem of waste disposal to some extent. From the above discussions, it can be ascertained that the materials Bagasse ash, lime, and waste tyre rubber has shown promising influence on the properties of problematic expansive soil, thereby giving a two-fold advantage in improving a problematic soil and also solving a problem of waste disposal.

V. CONCLUSIONS

1. From the laboratory studies, it is observed that the expansive soil chosen was a problematic soil having high swelling, with high plasticity and low strength characteristics.
2. There is a gradual increase in maximum dry density with an increment in the % replacement of Bagasse ash up to 15% with an improvement of 3.2% and the corresponding optimum moisture content values decreased with a % reduction of 21%.
3. The shear parameters also were improved with the addition of Bagasse ash, lime – Bagasse ash and lime – Bagasse ash – WTR. There is an improvement of 45% in cohesion when the virgin soil was replaced with 15% Bagasse ash and when it is further blended with lime, it improved by about 26% further
4. The angle of internal friction was further improved by about 100% when the mix was blended with 1%WTR scrap and also the cohesion has improved by about 93% when compared to that of virgin expansive soil.

5. The corresponding unconfined compressive strength was improved by about 245%. There is an improvement in unsoaked and soaked C.B.R values also by about 3 times and 11 times respectively.
6. There is a reduction in pavement thickness by about 288% in soaked CBR condition.

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