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Effect of Calcium Salts on the Index Properties of Expansive and Non Expansive Soils In The Presence Of Bagasse Ash and Lime

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Abstract: *Index properties of soils are greatly associated with fine grained soils and the amount of water present in them. Liquid limit, Plastic limit and Shrinkage limit are the important water content parameters and the changes in Index properties of expansive and non expansive soils brought about by the addition of bagasse ash is studied and has been presented in this paper. An attempt also has been made to investigate the alteration in Index properties with the addition of Calcium salts to soil, bagasse ash and lime mixture on immediate and 7 days of curing. Plasticity Index decreased marginally due to the reduction in diffuse double layer thickness caused by the flocculation of particles brought about by the reaction between reactive silica and free lime content present in bagasse ash and also due to the pozzolanic reactivity of Lime. With the addition of Calcium Sulphate and Calcium Chloride, Plasticity Index decreased further for non expansive soils. Plastic limit and shrinkage limit increased due to the increase in divalent ions with increased supply of Calcium ions and as a result, double layer thickness further reduced.*

Key words: *flocculation, cation exchange, bagasse ash, lime, Calcium Sulphate, Calcium Chloride*

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I. Introduction

The expansive soils are problematic soils due to the swell shrink behavior exhibited with the change in moisture content with seasonal variations and severely damage the structures built on them and are covered extensively in North Karnataka, India. The chief mineral constituent in these soils is montmorillonite, which is expansive in nature. Due to uneven settlement of these soils, well defined cracks are seen on the buildings built on them; doors of the buildings jam and sometimes the building topple due to excessive settlements. The natural ground in Bangalore, Karnataka, India covers sand or silty loam known as non expansive soil and also called as red earth soil (RES). The predominant mineral constituent of non expansive soil is Kaolinite. The workability of clayey soils is an important aspect in the construction activities and can be brought about by improving the Index properties of the soil. The variation in Index properties are highly influenced by the clay content and the type of clay minerals present in the soil. Atterberg's limits can be correlated with the various engineering properties such as specific surface area, cation exchange capacity, mineralogical and geological history, swelling behaviour, California bearing ratio, shear strength, compaction characteristics etc. Further these correlations have been used to check new data or to predict the soil behaviour for design work [1]. Ion exchange, pozzolanic reactivity and diffuse double layer formation contribute to the alteration in the Index properties with the addition of various industrial wastes such as fly-ash, rice husk ash, bagasse ash etc. to the clayey soils [2] and [3]. The silty particles present in the ashes, reduce the activity of clay. Generally liquid limit and plasticity index decreases, plastic limit and shrinkage limit increases and thus engineering properties of the soil are enhanced [4]. Several research works were being carried out from the past on beneficial use of Lime to improve the engineering properties of soil. Cation exchange is the basic mechanism involved with the addition of lime to soil and cation exchange process brings about agglomeration and flocculation of particles [5]. Research works were also being carried out by using Calcium based stabilizers to study the change in Index properties of the soil [6]. Addition of Sulphate to soil has undesirable effects on engineering properties of soil. Detrimental effect of Sulphate addition is mainly due to the growth of ettringite needles developed in the clay matrix. In the present study, bagasse ash, an agro industrial waste is added to expansive and non expansive soils. Bagasse ash is an industrial waste from sugarcane industry and is very rich in amorphous Silica and has very low lime content. Lime is added to non expansive soil and bagasse ash mixture and the effect of these additives were studied in the presence of Calcium Sulphate and Calcium Chloride.

II. Material and Methods

2.1 **Materials**

The materials used for the preparation of samples are expansive soil, non expansive soil, bagasse ash, lime, Calcium Sulphate and Calcium Chloride.

2.1.1 Expansive Soil

Expansive soils also known as black cotton soil is obtained from Hubli, Karnataka, India. The soil is passed through 425 micron BIS sieve before it is used for the test and the soil is oven dried and is classified as classified as clays of high plasticity (CH) according to BIS Soil Classification system.

2.1.2Non expansive Soil

Naturally available non expansive soil also called as red earth soil (RES) with predominant non expansive Kaolinite clay mineral was procured from Bangalore University, Jnanabharathi campus, Bangalore, India. The soil was collected at a depth of 1.5 meter below the ground. The soil was oven dried and sieved through 425 micron B.I.S sieve before being used in the present investigation. Red earth soil is classified as clays of medium plasticity (CI) as per BIS Soil Classification system.

2.1.3 Bagasse ash

Bagasse ash (BA) is an agro industrial waste collected from Koppa sugar industry, Mandya district in Karnataka, India. The organic content of bagasse ash is removed by burning ash in an oil fired furnace and contains predominant silt size particles.

2.1.4 Lime

Hydrated lime supplied by Vasa Scientific Company, Avenue road, Bangalore is used in the present investigation.

2.1.5 Calcium Sulphate (Gypsum)

Calcium Sulphate is also called as Gypsum, supplied by Vasa Scientific Company; Bangalore has been used in the present investigation.

2.1.6 Calcium Chloride

Calcium Chloride is procured from Vasa Scientific Company Bangalore is being used for laboratorypurpose. Physical properties of expansive soil, non expansive soil and bagasse ash are shown in Table1 and chemical composition of bagasse ash is shown in Table 2.

Table1. Physical properties of expansive soil, non expansive soil and bagasse ash

Property	Black cotton soil	Red earth soil	Bagasse ash
Specific gravity	2.65	2.68	1.71
Sand (4.75–0.075 mm) (%)	4	8	77.2
Silt (0.075–0.002 mm) (%)	36	52	22.8
Clay (<0.002 mm) (%)	60	40	--
Liquid limit (%)	91	39	61
Plastic limit (%)	39	22	Non plastic
Plasticity index (%)	52	17	--
Shrinkage limit (%)	11	15	--
Optimum moisture content (%)	32	16.4	43
Max. dry unit weight (kN/m^3)	12.95	18	10.34
BIS soil classification	CH	CI	--

Table 2 Chemical composition of bagasse ash

Material	Silica (SiO_2)	Alumina (Al_2O_3)	Ferric oxide (Fe_2O_3)	Calcium oxide (CaO)	Magnesium oxide (MgO)	Sodium oxide (Na_2O)	Potassium oxide (K_2O)	Loss on ignition
Bagasse ash	65.92	11.96	2.86	5.6	4.03	1.79	3.19	16.18

2.2 Methods

Liquid limit test:

Liquid limit tests of non expansive soils were carried out by using cone penetration method as per BIS: 2720 (Part V)-1985 [7]

Plastic limit test:

The plastic limit tests were conducted as per BIS: 2720 (Part VI) – 1985 [8]
Shrinkage limit test:
The shrinkage limit tests were conducted as per BIS: 2720 (Part VI)-1972 [9]. The samples were wrapped in polythene covers and stored in desiccators for curing

III. Results and Discussion

Atterberg's limit tests were conducted for expansive and non expansive soils and for the soils treated with 5% to 30% of bagasse ash in an increment of 5% and further studies were made by conducting Atterberg's limit tests by adding 1% to 6% lime to soil-optimum bagasse ash mixture in an increment of 1%. Same tests were conducted for soil- optimum bagasse ash- optimum lime mixture by adding 1% Calcium Sulphate and 1% Calcium Chloride. The tests were conducted for immediate as well as for 7 days curing and the results are discussed and are presented.

3.1 Effect of bagasse ash on the index properties of expansive and non expansive soils

With the addition of 5% bagasse ash to soil, the Liquid limit decreased marginally by 11% and same results were observed and reported by [10] and this may be attributed to the lower liquid limit of bagasse ash. From Table 3, it was observed that Liquid limit further reduced with the addition of bagasse ash up to 30% and this may be due to decrease in clay content , and alteration in grading because of coarser particle sizes of bagasse ash and lower liquid limit of bagasse ash [11]. Plastic Limit and Shrinkage limit increased on addition of bagasse ash due to decrease in diffuse double layer thickness caused by the free lime content of bagsse ash imparted to soil and leads to flocculation of particles. From in Fig.1, it was observed that, Plasticity index of BC soil is reduced with the addition of bagasse ash from 5% to 30% and the soil changes its classification from highly plastic clays (CH) to highly plastic silts [12]. From Table 3, it was observed the change in index properties beyond 15% addition of bagasse ash is marginal and therefore 15% of bagasse ash is the optimum dosage. Reduction of Plasticity Index indicates that the workability of soils is improved and with 7 days curing, marginal change in Index properties was observed.

The Liquid Limit of non expansive soil increased with the addition of bagasse ash as shown in Table 4 and this may be due to decrease in clay content and an alteration in grading because of coarser particle sizes and higher liquid limit of bagasse ash [13].The soil changes its classification from clays of medium plasticity (CI) to silt of medium plasticity (MI). The increase in Plastic limit and an increase in Shrinkage limit are mainly due to the flocculation and aggregation of soil particles brought about by the cation exchange mechanism with the addition of bagasse ash [14]. Plasticity Index decreased with variation in bagasse ash percentage and is shown Fig.2. Alteration in Index properties is marginal at 7 days of curing. From Table 4, it can be observed that, Index properties altered up to 10% bagasse ash and beyond which the improvement is marginal and therefore 10% bagasse ash is the optimum dosage in the present study.

Table 3 Index properties of expansive soil blended with varying bagasse ash content

Combinations	LL (%)		PL (%)		SL (%)		PI	
Curing days	0	7	0	7	0	7	0	7
Soil alone	91	-	39	-	11	-	52	-
BA alone	61	-	Non plastic		-	-	-	-
BCS+5% BA	88	88	44	45	11	12	44	43
BCS +10% BA	86	87	48	49	14	14	38	38
BCS +15% BA	83	83	52	51	15	15	31	32
BCS +20% BA	81	81	54	55	16	17	27	26
BCS +25% BA	79	78	58	59	17	18	21	19
BCS +30% BA	75	76	61	61	22	23	14	15

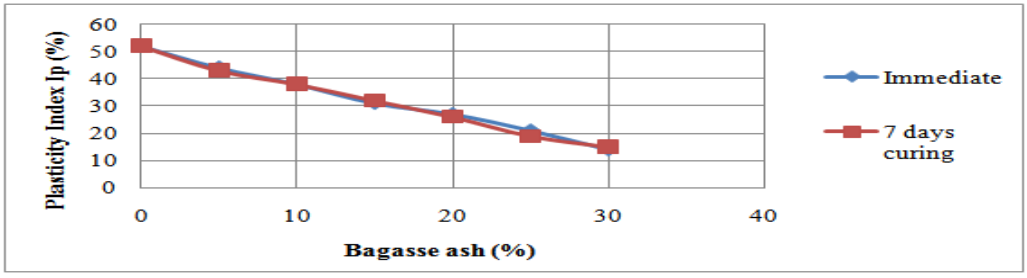

Fig1. Variation of Plasticity index of expansive soil and bagasse ash mixture on immediate and 7 days of curing

Table 4 Index properties of non expansive soil with varying bagasse ash content

Combination	LL (%)		PL (%)		SL (%)		PI	
Curing days	0	7	0	7	0	7	0	7
Red earth soil alone	39	-	22	-	15	-	17	-
BA alone	61	-			-	-	-	-
RES+5%BA	41	43	24	26	17	19	17	17
RES+10%BA	44	46	28	30	20	22	16	16
RES+15%BA	45	47	30	32	21	23	15	15
RES+20%BA	46	48	32	34	22	24	14	14
RES+25%BA	47	49	34	37	23	26	13	12
RES+30%BA	49	51	37	40	25	27	12	11

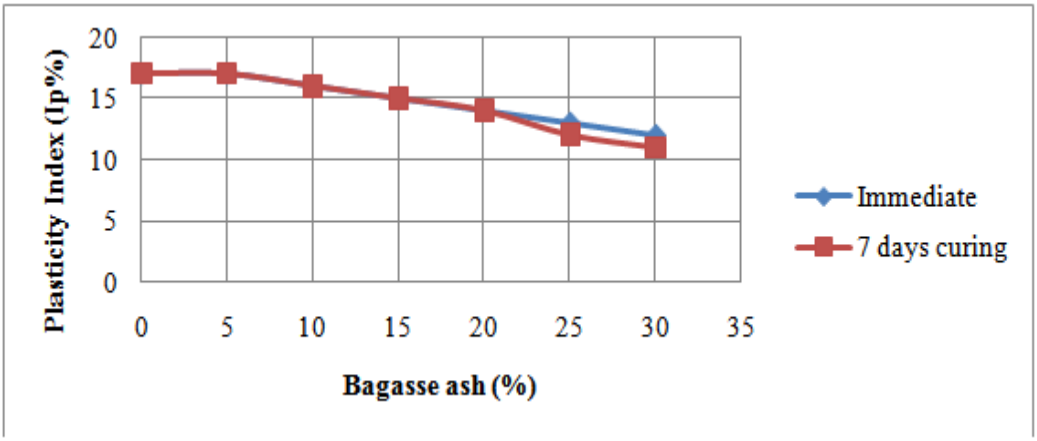

Fig 2 Variation of Plasticity index of non expansive soil and bagasse ash on immediate and 7 days of curing

3.2 Effect of Lime on the index properties of expansive and non expansive soils and bagasse ash mixture

With the addition of 1% lime to black cotton soil and bagasse ash mixture on immediate test, marginal decrease in liquid limit of 5.5% is observed initially compared to that of black cotton soil alone as shown in Table 5 and is attributed to the reduction in the thickness of diffused double layer of the soil caused by increased electrolyte concentration and also due to replacement of monovalent ions by divalent Calcium ions. Further addition of lime leads to an increase in the liquid limit of the soil and this may be due to equilibrium of the lime–soil-bagasse ash mixture results in the formation of coarser aggregates and a more flocculated particle arrangement [15]. Plastic limit and Shrinkage limit of soil increased due to rise in cation concentration and resulted in increase in the viscosity and flocculation of the clay particles. [11]. Plasticity index reduced with lime addition as shown in Fig. 3 and this may be due to the flocculation of the soil particles in the presence of lime. Plasticity index decreased which indicates the improvement in properties of soils. No significant improvement in index properties is seen with 7 days curing. From Table 4, it was observed that beyond 4% lime addition, the alteration in Index properties are marginal and therefore 4% of lime is the optimum dosage in the present study.

With the addition of 1% lime to non expansive soil and bagasse ash mixture, increase in liquid limit of 5% is observed immediately as shown in Table 5, compared to that of non expansive soil alone. The increase in Liquid limit is marginal since the dominant clay mineral is Kaolinite, which is already flocculated and the effect of addition of lime to flocculate the particles is negligible, however with curing, liquid limit increases indicating that the particles are more flocculated [2]. Plastic limit and Shrinkage limit increased and this may be due to rise in cation concentration, increase in viscosity and flocculation of the clay particles [11]. Plasticity Index of soil reduced as shown in Fig. 4 and this may be attributed to the flocculation of the soil particles in the presence of lime and no significant improvement in index properties is seen with 7 days curing. From Table 5, it can be observed that index properties are altered up to 2% lime and beyond 2% lime addition, alteration in Index properties are marginal and therefore 2% lime is chosen as the optimum dosage in the present investigation.

Table 4 Index properties of expansive soil and biogases ash mixture treated with lime

Combinations	LL (%)		PL (%)		SL (%)		PI	
Curing days	**0**	**7**	**0**	**7**	**0**	**7**	**0**	**7**
B.C Soil alone	91	-	39	-	11	-	52	-
BA alone	61	-	Non plastic		-	-	-	-
BCS+15%BA	83	83	52	51	15	15	31	32
BCS +15% BA + 1% Lime	86	86	59	65	37	38	27	21
BCS +15% BA + 2% Lime	85	87	67	75	42	44	18	12
BCS +15% BA + 3% Lime	87	92	74	84	49	51	13	8
BCS +15%BA+4% Lime	90	91	79	86	50	52	11	5
BCS +15%BA+ 5% Lime	89	94	82	92	52	53	7	2
BCS +15% BA + 6% Lime	89	94	84	94	55	56	5	0

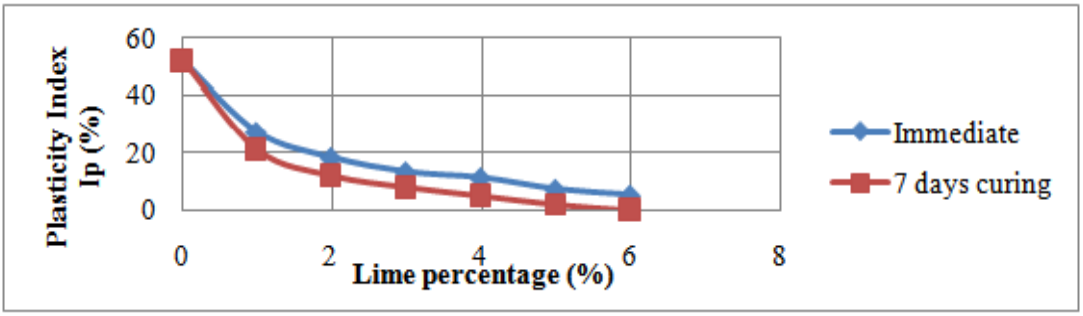

Fig 3 Variation of Plasticity index of expansive soil and bagasse ash mixture treated with lime on immediate and 7 days of curing

Table 5 Index properties of non expansive soil and bagasse ash mixture treated with lime

Combination	LL (%)		PL (%)		SL (%)		PI	
Curing days	**0**	**7**	**0**	**7**	**0**	**7**	**0**	**7**
Red earth soil alone	39	-	22	-	15	-	17	-
BA alone	61	-	Non Plastic		-	-	-	-
RES+10%BA	44	46	28	30	20	22	16	16
RES +10% BA + 1% Lime	46	48	31	33	22	23	15	15
RES +10% BA + 2% Lime	49	51	35	37	24	25	14	14
RES +10% BA + 3% Lime	50	52	37	39	25	26	13	13
RES +10% BA + 4% Lime	51	53	39	42	26	27	12	11
RES +10% BA + 5% Lime	52	54	41	46	27	29	11	8
RES +10% BA + 6% Lime	54	56	44	49	29	31	10	7

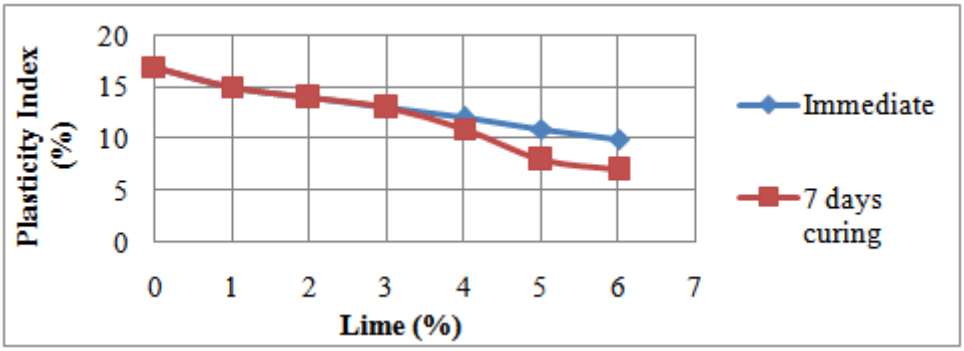

Fig 4 Variation of Plasticity indexes of non expansive soil and bagasse ash mixture treated with Lime on immediate and 7 days of curing

3.3 Effect of Calcium salts on the index properties of expansive and non expansive soil, bagasse ash mixture in the presence of Lime

To study the effect of Calcium salts on the index properties of soil, 1% Calcium Sulphate and 1% Calcium Chloride are added to the soil -bagasse ash-lime mixture. It was found that further reduction in plasticity index is noticed for both the soils as shown in Table 6 and Table 7 and this may be attributed to the increase in electrolyte concentration which compresses the diffuse double layer by the absorption of additional Calcium ions present in Calcium Sulphate and Calcium Chloride [16]. The shrinkage limit increases and increasing tendency of shrinkage limit may be due to the formation of amorphous gel and replacement of monovalent ions of soil by divalent ions of Calcium [17]

Table 6 Index properties of expansive soil and bagasse ash mixture treated with lime in the presence of Calcium Sulphate and Calcium Chloride.

Combination	LL (%)		PL (%)		SL (%)		PI	
Curing days	0	7	0	7	0	7	0	7
Soil alone	91	-	39	-	11	-	52	-
BA alone	61	-	Non plastic		-	-	-	-
Soil+15%BA	83	83	52	51	15	15	31	32
Soil+15%BA+4% Lime	90	91	79	86	50	52	11	5
Soil+15%BA+4%L+1% Calcium Sulphate	88	89	79	79	55	56	9	10
Soil+15%BA+4%L+1% Calcium Chloride	88	89	79	79	55	56	9	10

Table 7 Index properties of non expansive soil and bagasse ash mixture treated with lime in the presence of Calcium Sulphate and Calcium Chloride.

Combination	LL (%)		PL (%)		SL (%)		PI	
Curing days	0	7	0	7	0	7	0	7
Soil alone	39	-	22	-	15	-	17	-
BA alone	61	-	Non Plastic					
Soil+10%BA	44	46	28	30	20	22	16	16
Soil+10%BA+2%Lime	49	51	35	37	24	25	14	14
Soil+10%BA+2%Lime+1% Calcium Sulphate	47	49	33	35	25	26	14	14
Soil+10%BA+2%Lime+1% Calcium Chloride	46	48	33	34	25	26	13	14

IV. Conclusions

Based on the results, the following conclusions are drawn

- Liquid Limit decreased marginally for expansive soils due to the low liquid limit of bagasse ash, decrease in clay content and alteration in grading because of coarser particle sizes of bagasse ash and the soil changes its classification from highly plastic clays (CH) to highly plastic silts. The Liquid Limit of non expansive soil increased because the structure of soil is already flocculated and the soil changes its classification from clays of medium plasticity (CI) to silt of medium plasticity (MI). Plastic Limit and Shrinkage limit increases for both the soils due to decrease in diffuse double layer thickness caused by the free lime content of bagsse ash imparted to soil and leads to flocculation of particles. Plasticity index is reduced for both the soils.
- With the addition of Lime to soil-bagasse ash mixture, Liquid limit of expansive and non expansive soils increased marginally because of reduction in the thickness of diffused double layer of the soil caused by increased electrolyte concentration and also due to replacement of monovalent ions by divalent Calcium ions. Plastic limit and shrinkage limit increased due to the pozzolanic reactivity of Lime causes decrease in diffuse double layer.
- With the addition of Calcium salts to soil-bagasse ash-lime mixture, Plasticity Index decreased further for both the expansive non expansive soils. Plastic limit and shrinkage limit increased and this is attributed to the increase in divalent ions with increased supply of Calcium ions and double layer thickness further reduced.

References

[1]. Sridharan.A, Nagaraj.H.B, Prasad.P.S (2000) Liquid Limit of Soils from Equilibrium Water Content in One-Dimensional Normal compression, Geotech. Engg, 143, pp: 165-169

[2]. Sivapulliah P.V, Ramesh H.N, Sridharan A (1992) Effect Of Sulphate On The Physical Properties Of Lime-Stabilized Kaolinitic Soils, Clay research, 11 (1), pp:6-12

[3]. Adrian O. Eberemu, (2013) Evaluation of bagasse ash treated lateritic soil as a potential barrier material in waste containment application, Acta Geotechnica, 8, pp: 407–421.

[4]. Ramesh H.N, Siva Mohan M, Sivapullaiah P.V, Srinivas S.P (2002) Effect of Muddanur flyash on index and compaction behavior of expansive soils, *IGC*, 1, pp:249-252 Ibtehaj Taha Jawad, 5Mohd Raihan Taha, Zaid Hameed Majeed and Tanveer A. Khan

(2014) Soil Stabilization Using Lime: Advantages, Disadvantages and Proposing a Potential Alternative Research Journal of Applied Sciences, Engineering and Technology 8(4), pp : 510-520
[5]. Sharma RS, Phanikumar BR, Rao BV (2008) Engineering behaviour of a remolded expansive clay blended with lime, calcium chloride, and rice-husk ash. J Mater Civ Eng 20(8):509–515
[6]. Sivapullaiah PV, Moghal A AB (2011) Role of gypsum in the strength development of fly ashes with lime. J Mater Civ Eng 23(2):197–206
[7]. IS: 2720 (Part V)-Indian Standard Methods of tests for soils: Determination of Liquid limit., 1985
[8]. IS: 2720 (Part V)-Indian Standard Methods of tests for soils: Determination of Plastic limit., 1985
[9]. IS: 2720 (Part V)-Indian Standard Methods of tests for soils: Determination of Shrinkage limit., 1972
[10]. Adrian O. Eberemu, (2013) Evaluation of bagasse ash treated lateritic soil as a potential barrier material in waste containment application, Acta Geotechnica, 8, pp: 407–421.
[11]. Sivapullaiah, P. V. and Arvind Kumar Jha. (2014). Gypsum Induced Strength Behaviour of Fly Ash-Lime Stabilized Expansive Soil, Geotech Geol Eng, 32, pp: 1261–1273.
[12]. Sivapulliah P.V, Prashanth J.P, Sridharan A (1996) Effect of Flyash on the Index properties of Black cotton soil, Soils and foundations, 36(1) pp: 97-103
[13]. Sivapullaiah, P.V, Lakshmikantaha, H, Kiran, M. (2003) Geotechnical properties of stabilised Indian red earth, Geotechnical and Geological Engineering, 21, 399–413.
[14]. Mohammed Abdullahi., (2007) Evaluation of Plasticity and Particle Size Distribution Characteristics of Bagasse Ash on Cement Treated Lateritic Soil, Leonardo Journal of Sciences, 28(1) pp :1525-1536.
[15]. Ramesh H.N,.Krishnaiah A.J, Shilpa S (2013) Effect of Lime on the Index Properties of Black Cotton Soil and Mine tailings mixtures, IOSR,3(4) pp:1-7.
[16]. P.V.Sivapullaiah, A.Sridharan and H.N.Ramesh (1995) Mechanisms Controlling the Index Properties of Lime Treated Black Cotton Soil in the Presence of Sulphate, Indian Geotechnical Journal, 25(3), pp : 379-394.
[17]. Rajasekharan G, Murali K, SrinivasanRaghavan R (1997) Effect of Chlorides and Sulphates on lime treated Marine clays, Soils and Foundations, 37 (2), pp: 105-115.

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