International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.14 No.01, pp 109-120, 2021

Characterization of Utilization of Industrial Waste By-Products for Construction of Low Volume Roads

*[1]C.Rajakumar, [2]S.V.N.Sandhya kumarai, [3]Pavanteja. R, [4]U.Suresh, [5]S.Siddheswar, [6]T.Prudhvi Raj

[1] Associate Professor, [2,3,4,5,6]B.Tech Students,
[1, 2,3,4,5,6] Department of Civil Engineering, Gudlavalleru Engineering college , Gudlavalleru– 521-356, Andhra Pradesh, India.

Abstract : Black cotton soil is one of the major soil deposits in India becomes problematic because of its properties of higher degree of swelling and shrinkage. These Soils existing at a particular site may not be appropriate for construction of engineering structures. The present study made an attempt to enhance the geotechnical properties of a soil replaced with industrial waste like Lime waste (LW). For this soil samplings were done on Gudlavalleru village, Krishna district as per IRC recommendations. Soils are replaced with LW 5%, 10%, 15% and 20% to dry weight of soils. The performance of Lime Waste stabilized soils were evaluated using physical and strength performance tests namely; Plasticity index, Specific gravity, Free swell index, Compaction, California bearing ratio (CBR) and Unconfined compressive strength Test (UCC). These tests were conducted in order to evaluate the improvement in strength characteristics of the sub-grade soils. Hence using of such advanced materials in road construction can prove efficient in increasing the strength of soils and in turn reduce the project cost. From the results, it was observed that the basic tests carried out proved significant after the addition of Lime Waste.

Keywords : Black cotton Soil, Lime waste, Atterberg limits, Specific gravity, Free swell index, California bearing ratio, Un-Confined compressive strength, Standard proctor test.

1. Introduction

Expansive soils are common in Africa, Australia, South America, United States and some countries in Europe. These soils also occur in India. About 20 per cent of total area (almost the entire Deccan Plateau, Western Madhya Pradesh, parts of Rajasthan, Bundelkhand region in Uttar Pradesh and parts of Andhra Pradesh and Karnataka) is covered by expansive soils. There is considerable damage to build up property. The damage to structures is mainly by differential heaving of the dried-up soil. Climatic environment is the most important for the swelling and shrinkage behavior of these soils (Figure.1). Besides this, local manmade conditions also cause changes in moisture content and volume of the soil mass (1-15). The shear strength of soil is very high in dry state and it reduces considerably in wet state. Expansive soils in India are a boon to farmers but problematic to Civil Engineers. Usually even the lowest cost of the design alternative will be associated with high degree of risk. Hence, the properties of the soil may be improved to make the soil suitable for construction purposes. There are several techniques available to improve the soil properties. The scarcity and rising cost of traditional stabilizers like Lime and Cement has led to the research into clay soil stabilizing potential of Lime waste that is cheaper, readily available and environmental friendly and has a serious disposal problem (Figure.2) (15-31).

2. Materials and Properties

2.1. Materials

a. Bulk BC soil samples for the analysis were collected back side of the Gudlavalleru Engineering college (Sample-1) and near Railway station at Gudlavalleru (sample-2).
b. Location of sample-1 : 16°21'12.1"N 81°02'29.0"E (Figure.1)
c. Location of sample-2: 16°20'10.0"N 81°02'49.2"E
d. Representative soil samples were collected from an open pit at a depth of which is clear of organic soil.
e. Pulverizes the Black cotton soil samples and sieve under 4.75 and 4.25 mm.
f. The soil used for analysis is cohesive soil predominantly clay (Table.1).

Table 1 Properties of Black Cotton Soil

Properties	Sample-1	Sample-2
Natural moisture content, %	27.20	15.63
Free swell index,%	70	35
Liquid limit, %	91	120
Plastic limit,%	50	62
Plasticity index,%	41	58
OMC,%	36.56	34.351
M.D.D g/cc	1.37	1.43
Specific gravity	2.73	2.70
CBR, kN/m^2	6.2	5.8
UCC, kN/m^2	11.23	5.08

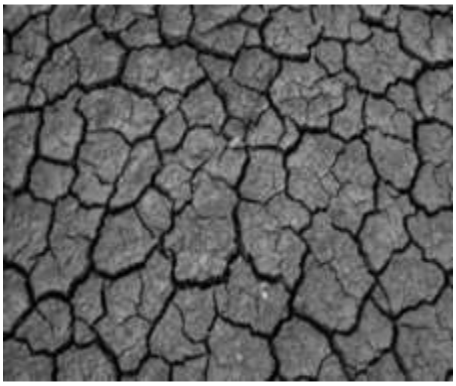


Fig 1Picture of an Expansive soil

Figure.1.Gudlavalleru Clay

2.2 Lime waste

Lime Waste were collected from the waste material disposed by industries at Piduguralla. Lime Kiln Dust (LKD) is the by-product of Quick Lime (QL) production (Table.2). QL used as a material in purification of steel, manufacturing of Calcium Carbide, effluent treatment for waste water and many more. QL is white in color and granular. QL production requires lime stone as its raw material. The process involves using natural gas to heat the lime stone ($CaCO_3$) to the temperature of 800°C to 1000°C to turn $CaCO_3$ into QL (CaO) as shown in equation 1.

$CaCO_3 + \triangle \longrightarrow CaO + CO_2$----- (1)

The heating process is a continuous process throughout the lime kiln. This also generates CO_2 gases with dust or particulate matter (PM). The gas is filtered using fabric dust filter collector. The PM that is captured is called LKD. LKD chemical compositions may vary for different plants, because it is influenced by type of lime stones, kiln, fuel used, and also the kiln operating parameters. However, it generally contains relatively high percentage of CaO. It has been estimated that production of Lime kiln dust is majorly dominated by Asian-pacific countries like China and India, followed by Europe and the U.S. As the lime industry thrives the production of lime kiln dust industries. Globally, massive quantity of LKD is produced. The aim of this study is to experimentally investigate the potential benefits of Lime Kiln dust used in Stabilization soil (Table.2).

Table 2 Properties of Lime waste

Properties	
Appearance	White or grayish-white material.
Physical State	Solid
Odor	Odorless
Odor threshold	Not applicable
pH at 25 degrees C	12.45 appox
Boiling Point	Not applicable
Melting Point	4658° F. 2570°C
Flash Point	Not applicable
Evaporation Rate	Not applicable
Upper/Lower flammability or explosive limits	Not applicable
Flammability	Not applicable
Vapor Pressure	Not applicable
Vapor and Relative Density	Not applicable
Auto-ignition temperature	Not applicable
Solubility in Water	Reacts with water to produce $Ca(OH)^2$ and large amounts of heat.
Partition co-efficient	n-octanol/water
Decomposition temperature	Not applicable
Viscosity	Not applicable
Stability	Chemically stable and reacts vigorously with water to form calcium hydroxide, releasing heat. LKD also reacts with carbon dioxide to form calcium carbonate.

3. Methodology

Methodology explains about the works carried out in this study. The characterization of utilization of industrial waste by-products for construction of low volume roads were studied (Fig.2).

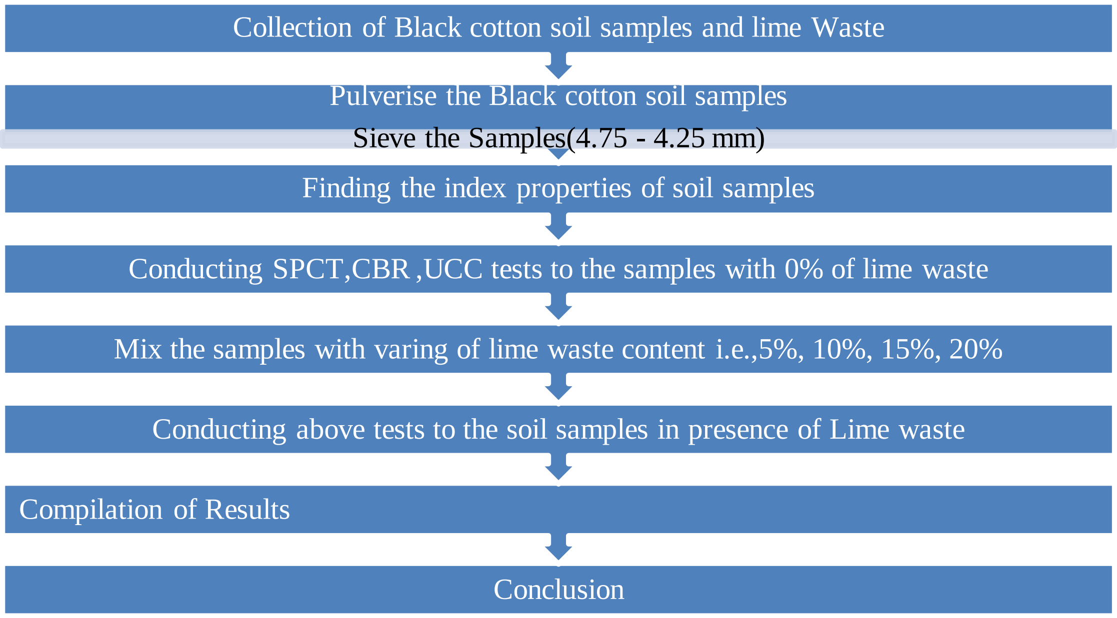


Fig.2.Methodology

4 Experimental programs

After the determination of basic properties of black cotton soils, soils stabilized with Lime waste and the strength parameters like MDD, CBR and UCC were determined by conducting compaction, CBR (California bearing ratio) and UCC (unconfined compressive stress) tests.

4.1 Atterberg Limits

The values of liquid limit, plastic limit and plasticity index obtained when tested with Lime waste are shown in table 3.

Table 3 Atter Berg's Limits of Soils with addition of Lime Waste

S. No	Description	Sample-1				Sample-2			
		5	**10**	**15**	**20**	**5**	**10**	**15**	**20**
1	Liquid limit(W_L)	63.62	56.98	49.47	43.82	82.56	64.99	51.22	36
2	Plastic limit(W_P)	32.18	30.88	28.52	27.84	44.26	35.66	28.22	23.0
3	Plasticity index(I_P)	31.44	26.10	20.95	15.98	38.3	28.9	23	12.45

From the table.3, it is observed that liquid limit at 0% of Lime waste are higher when compared to other percentages and the values are 91% and 120% of sample soils. The maximum decrease in Liquid limits are47.2% and 84% which occurs at 20% of Lime waste. There are a relation between compression index and liquid limit of the soils. Therefore, consolidation settlements are decreased due to Lime waste. It is found that plastic limit value of the Lime waste mixed sample soils are decreases with increase in percentage of Lime waste (Table.4). The maximum decrease in plastic limit occurs at 20% of Lime waste are 22.16% and39%. The plasticity index values of the Lime waste mixed sample soils for all percentages of Lime waste are smaller than that of the unmixed sample soils. The maximum reduction in plasticity index are 25.2% and 45.22%, which occurs at 20% of Lime waste (Figure 3,4 and 5).

4.2 Index Properties

Standard procedures recommended in the respective I.S. Codes of practice [IS:2720 (Part-5)- 1985] followed while finding the Index properties(Figure 3,4,5 and Table 4).

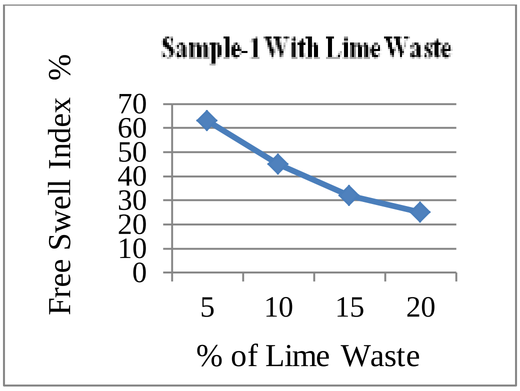


Fig3: Variation of free swell index with different Percentages Lime waste.

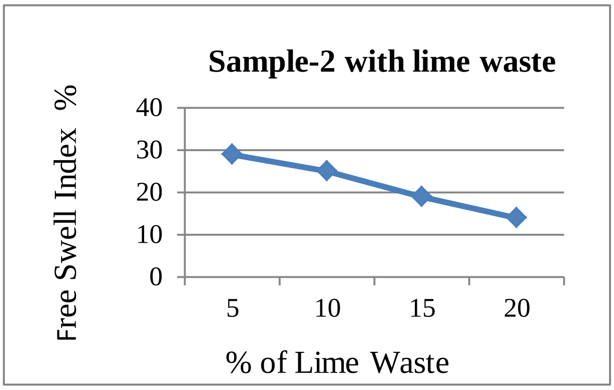


Fig.4: Variation of free swell index with different Percentages Lime waste.

Table 4:Free swell index values with addition of LW

S. No	Description	Proportions	Result	
			Sample-1	Sample-2
1	Free Swell index	5	63	29
2		10	45	25
3		15	32	19
4		20	25	14

Fig 5 : Freee swell index

4.3 Compaction Properties

Standard Proctor's compaction tests are carried out on local sample soils mixed with Lime waste at various percentages of 5%, 10%, 15% and 20% by dry weight of the sample soils and the test are conducting according to test IS: 2720 (Part VIII)-1983. Compaction curves for sample soils mixed with Lime waste for various percentages are shown in graph 3and 4. The optimum moisture content and maximum dry unit weight of the sample soils are for sample-1 are 28.35% and 1.69 g/cc and sample-2 are 27.99% and1.59 g/cc respectively. Figure.6,7 depicts the relationship between the optimum moisture content and percentage of Lime waste (Table.5).

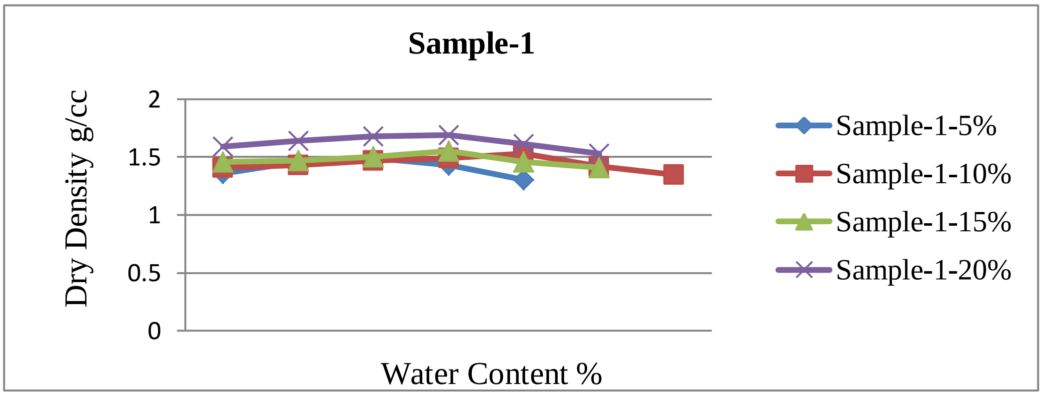


Figure6: Variations in Compaction curves with Addition of Lime waste

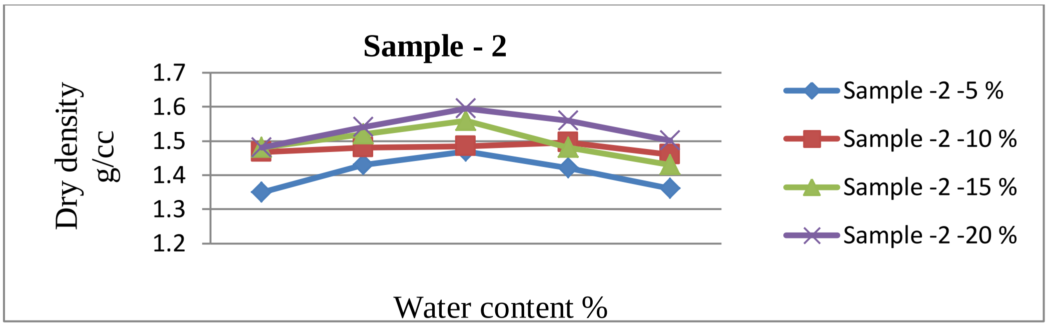


Figure7:Variations in compaction curves with Addition of Lime waste

Table 5:Compaction values with addition of Lime Waste

S. No	Description	Sample-1				Sample-2			
		5	10	15	20	5	10	15	20
1	Max Dry Density(g/cc)	1.491	1.53	1.55	1.69	1.47	1.496	1.56	1.595
2	Optimum Moisture Content(%)	34.55	32.55	30.3	28.35	32.36	31.69	28.05	27.99

4.4 California Bearing Ratio (CBR) Test

Un-soaked California Bearing Ratio tests are conducted on soil samples prepared under Light compaction under un-soaked condition to determine CBR value of soil with varying Lime Waste content (Figure.11). The test is conducted on soil samples with 5%, 10%, 15% and 20% lime waste to determine the optimum Lime Waste content. The following are the Load Vs Penetration curves obtained from the tests. And the tests are conducted as per recommendations in IS: 2720 Part XVI-1987 (Figure 8,9)(Table.6).

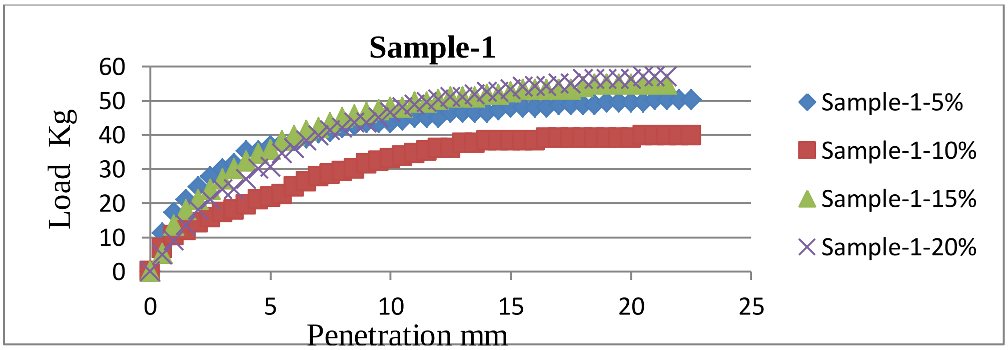


Figure. 8 : Variation in un-soaked CBR with Different percentage of Lime waste.

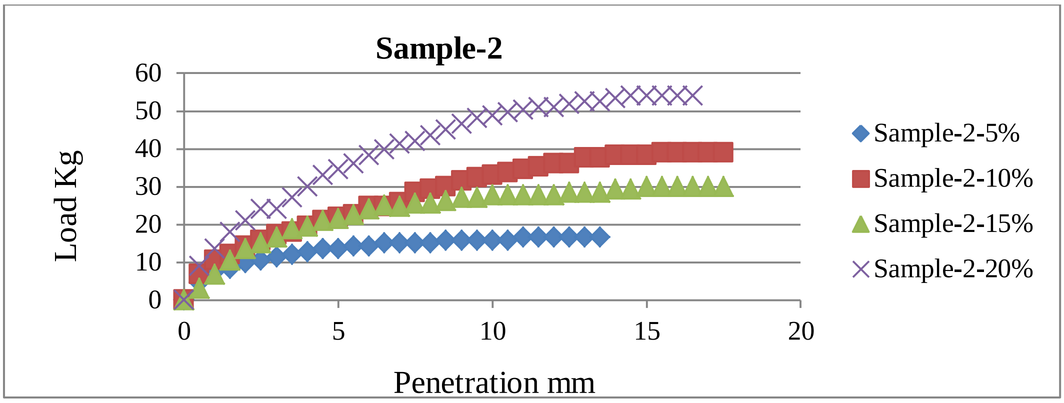


Figure.9: Variation in un-soaked CBR with Different percentage of Lime waste.

Table 6:CBR values with addition of Lime Waste

S. No	Description	Sample-1				Sample-2			
		5	10	15	20	5	10	15	20
1	CBR at 2.5mm Penetration (%)	1.09	1.14	1.751	1.53	0.76	1.094	1.53	1.75
2	CBR at 5mm Penetration (%)	1.080	1.05	1.73	1.48	0.65	1.046	1.46	1.67
3	CBR	1.09	1.14	1.751	1.53	0.76	1.094	1.53	1.75

Fig.10 : UCC test

Fig.11: CBR test

4.5 Unconfined Compression Strength Test

The unconfined compression strength tests were conducted in the laboratory as per IS Code (IS: 2720, Part X (1991). Unconfined compressive strength is one of the most widely referenced properties of stabilized soils. For strength testing, specimens are generally tested at their maximum dry density and optimum moisture content. The load frame of compression testing machine apparatus was used for conducting the unconfined compressive strength test. The strain rate was kept as 1.2 mm/min in all the experiments. The proving ring of capacity 2 kN was used for testing specimens as shown in the figure.12,13 and table 7.

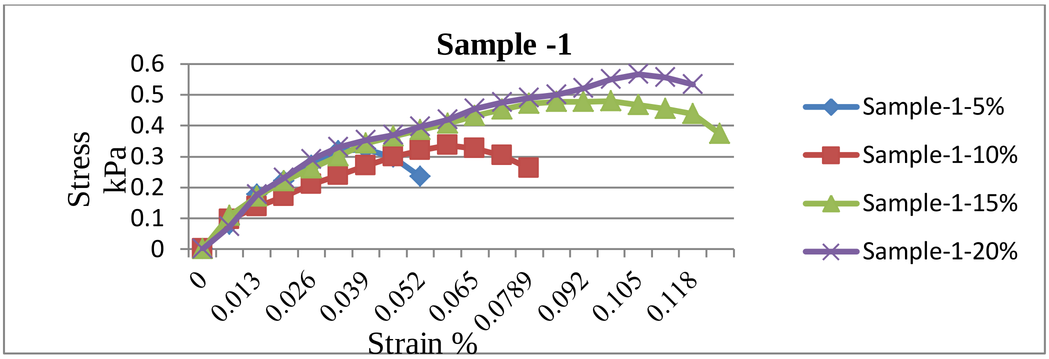


Figure 12 : UCS Variations with different percentage of Lime waste.

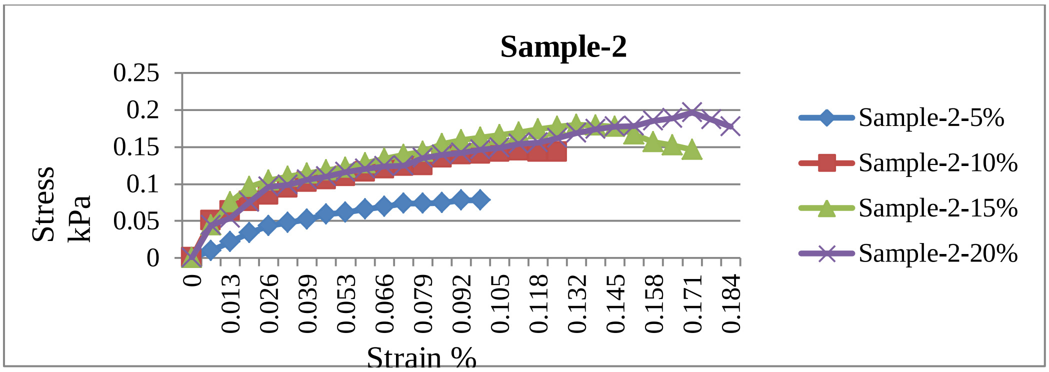


Figure 13: UCS Variation with different percentage of Lime waste.

Table 7: UCC values with addition of Lime Waste

S. No	Description	Sample-1				Sample-2			
		5	10	15	20	5	10	15	20
1	Unconfined Compressive Strength KN/m^2	32.4	33.6	47.9	56.6	12.0	14.2	18.0	19.6
2	Cohesion KN/m^2	3.9	5.9	9.8	10.5	9.2	10.5	13.2	17.1

5.Results and Discussion

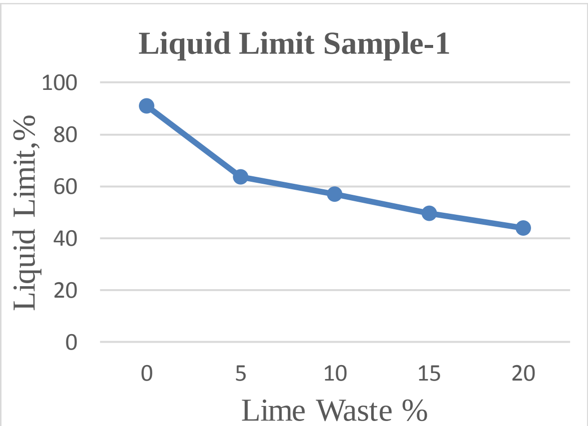


Figure: 14

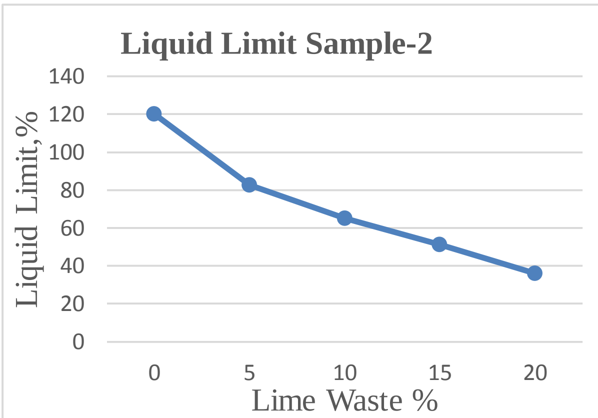
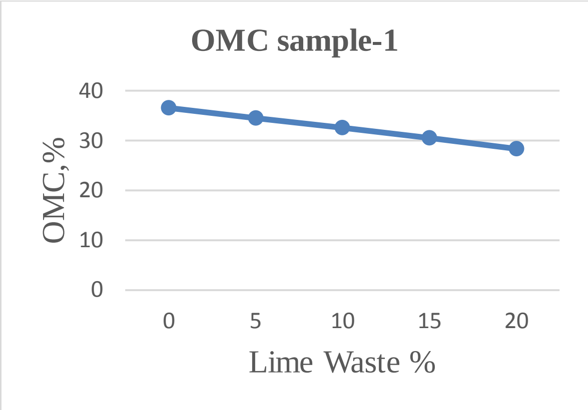


Figure: 15

Figure: 14,15 shows variation in liquid limit of black cotton soil samples, it shows that maximum reduction in liquid limit was found with addition of 20% lime waste in black cotton soil samples.



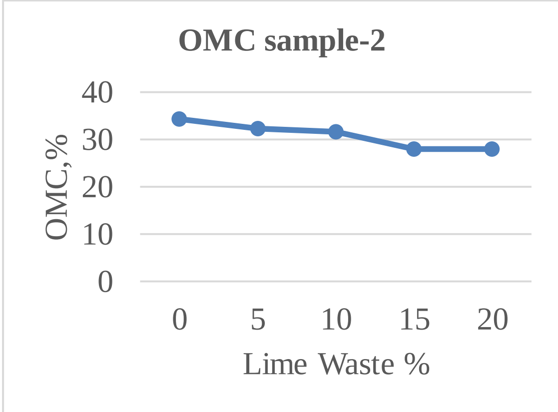
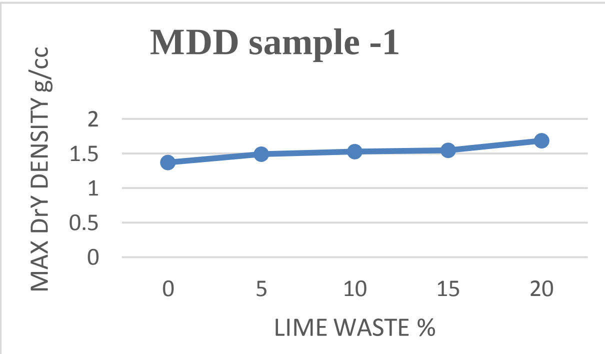


Figure: 16 **Figure: 17**

Figure: 16,17 shows variation of optimum moisture content of black cotton soil samples, it shows that maximum reduction in OMC was found with addition of 20% lime waste in black cotton soil samples.



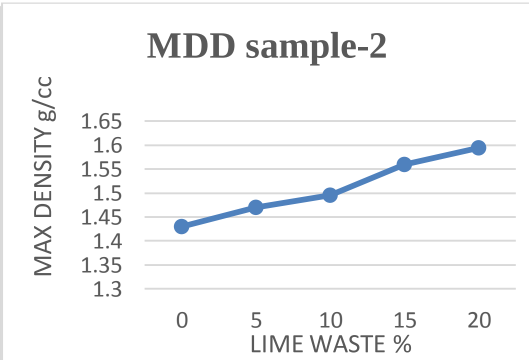
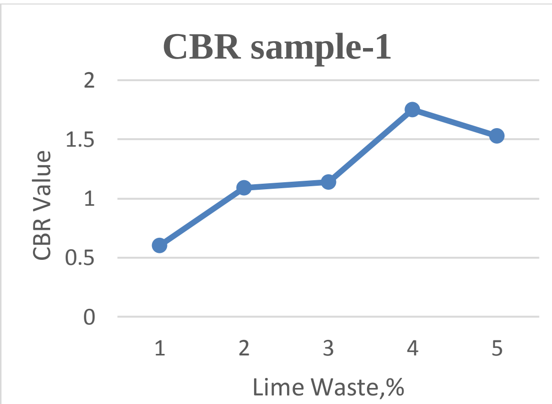


Figure: 18 **Figure: 19**

Figure:18,19 shows variation in maximum dry density of black cotton soil samples, it shows that maximum dry density is increased with addition of 20% lime waste in black cotton soil samples.



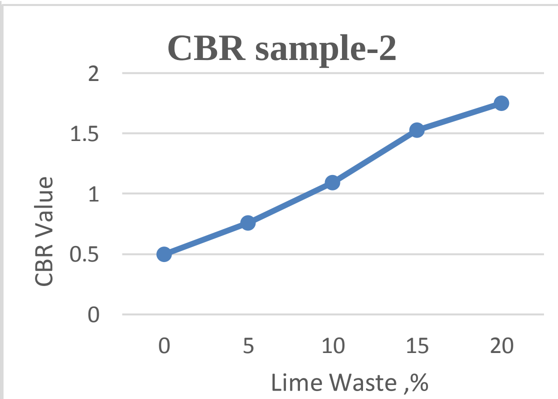


Figure: 20 **Figure: 21**

Figure: 20,21 shows variation in CBR of black cotton soil samples, it shows that maximum CBR value was found with addition of 20% lime waste in black cotton soil samples.

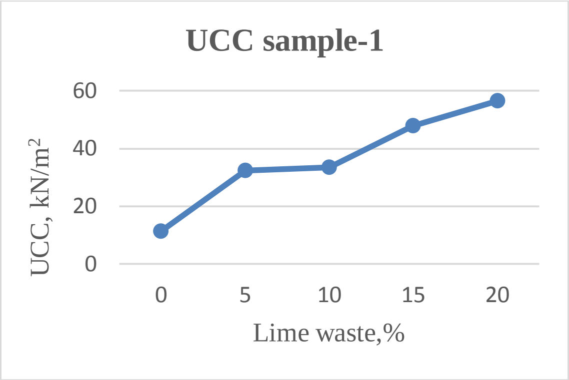


Figure: 22

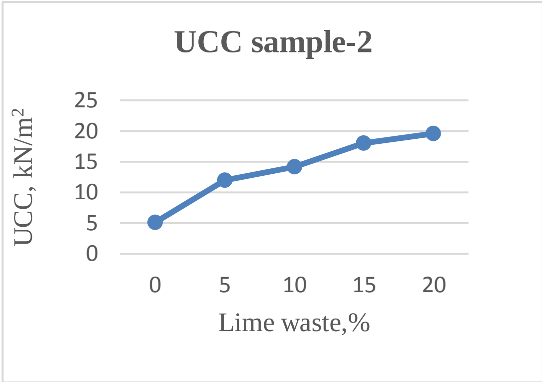


Figure: 23

Figure:22,23 shows variation in UCC of black cotton soil samples, it shows that maximum UCC value was found with addition of 20% lime waste black cotton soil samples.

Discussion

- Maximum Dry density was increased upto addition of 20% Lime waste for both the soil samples i.e.,for sample -1 is 1.37 - 1.69% and sample-2 is 1.43 - 1.59%.This is because of the frictional resistance in addition to the cohesion from Black cotton soil and lime waste gives the binding property to soil.
- Optimum moisture content decrease upto addition of 20% Lime waste for both the soil samples i.e.,for sample-1 is 36.56 - 28.35% and sample-2 is 34.251 - 27.99%.
- The values of liquid limit obtained when tested with Lime waste. liquid limit at 0% of Lime waste are higher when compared to other percentages and the values are 91% and 120% of sample soils. The maximum decrease in Liquid limits are 47.2% and 84% which occurs at 20% of Lime waste. There are a relation between compression index and liquid limit of the soils. Therefore, consolidation settlements are decreased due to Lime waste. It is found that plastic limit value of the Lime waste mixed sample soils are decreases with increase in percentage of Lime waste
- Unconfined compressive strength increases upto addition of 20% Lime waste for both the soil samples i.e., for sample-1 is 11.23-56.6% and sample-2 is 5.93 - 19.6%.This is because of the additional frictional resistance. Reduction in UCC occurs due to reduction in cohesion because of the reduction in expansive soil content.
- CBR increases upto addition of 20% Lime waste for both the soil samples i.e.,for sample-1 is 0.62-1.53% and sample-2 is 0.58 - 1.75%.The reason of this effect is the pozzolanic reactions of lime waste with the amorphous silica and Alumina present in soil. After addition of 20% lime waste the strength decreases because of the availability of extra admixtures to react with the insufficient amorphous silica and Alumina present in soil which results in carbonation reaction and thus strength decreases.

5 Conclusion

The Lime waste production is increasing in day to day for manufacturing of lime. Our work may be use full to use in stabilization of soils. Liquid limit and Plastic limit values of the Lime waste mixed soil samples are observed to be decreased with increase in percentage of Lime waste. The addition of Lime waste reduces the plasticity index of the soil samples slightly. The optimum moisture content decreases with increase in percentage of Lime waste. There is a slight increase in maximum dry density with per cent increase in Lime waste. The Unconfined compressive strength of the soil increases with increase in percentage of Lime waste. At 20% replacement of Lime waste to soil samples optimum moisture content reduced by 8.204% and 11.261%. At 20% replacement of Lime waste to soil samples maximum dry density increased by 32% and 16%. At 20%

replacement of Lime waste to soil unconfined compressive strength increased by 45.37% and 13.67%.The stability of a soil samples mass is increased due to the replacement of Lime waste at 20%.

6 References

1. JeejaMenon, M.S. Ravikumar," Evaluation of Laterite Soil Stabilized using Polymer Sack Fibers", IJITEE,ISSN: 2278-3075, Volume-8 Issue-6, April 2019.
2. R.C. Omar ,HairinTaha R. Roslan and I.N.Z. Baharuddin," Geotextile from pineapple leaves and bio-grout for slope stabilization and erosion control", International Journal of GEOMATE, Aug. 2019, Vol.17, Issue 60, pp.219-224 Geotec.
3. Satyam Tiwari, Nisheet Tiwari " Soil stabilization using waste materials", International Journal of Innovative Technology And Research, vol. 4, 2016
4. Anggraini, Vivi, et al. "Effects of coir fibers on tensile and compressive strength of lime treated soft soil", Measurement, Vol. 59, 2015, pp: 372-381.
5. A.S Soganci, " The effect of Polypropylene in the stabilization of expansive soils", International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, vol. 9, 2015.
6. Taherkhani. H, Pour. A. F. (2014), "Investigating the viability of using recycled aggregates in unbound base layer", MAGNT Research Report, (Iran)., 2, (4), 124-125.
7. Jha. J. N., Choudhary. A.K., Gill. K. S., (2014), "Behaviour of plastic waste fiber-reinforced industrial waste in pavement applications", International Journal of Geotechnical Engineering., 8, (3), 277-286
8. DebashishKar, Mahabir Panda and JyotiPrakashGiri. "Influence of fly-ash as a filler in bituminous mixes." ARPN Journal of Engineering and Applied Sciences, 2014: 895-900.
9. Bshara, A.S.; Bind, Y.K. and Sinha, P.K. (2014). Effect of Stone Dust on Geotechnical properties of Poor soil. Int. Journal of Civil Engineering and Technology (IJCIET), vol. 5, issue 4, 37-47
10. Akanbi, D.O. and Job, F.O (2014). "Suitability of Black Cotton(Clay)Soil Stabilized with Cement And Quarry Dust for Road Bases and Foundations". EJGE Vol. 19 [2014], Bund. V. pp 6305-6313
11. Roobhakhshan, A. and Kalantari, B. (2013). Stabilization of Clayey Soil with Lime and Waste Stone Powder. Int. Journal of Scientific Research in Knowledge, vol. 1, issue 12, 547-556.
12. C.K. Subramania Prasad, E.K Kunhanandan Nambiar, and Benny Mathews Abraham. "Plastic Fibre Reinforced Soil Blocks as a Sustainable Building Material", Int. J. Adv. Res. Technol, vol. 1, 2012, pp: 42-45.
13. VenkataKoteswaraRao Pasupuleti, Satish Kumar Kolluru, Blessingstone T, "Effect of Fiber on Fly-Ash Stabilized Subgrade Layer Thickness" International Journal of Engineering and Technology (IJET), ISSN : 0975- 4024 Vol 4 No 3 Jun-Jul 2012.
14. Ramadas, T.L. Kumar, N. Darga, Aparna, G.1 (2010). "Swelling and Strength Characteristics of Expansive Soil Treated with Stone Dust and Fly Ash", Indian Geotechnical Conference – 2010, GEOtrendz, December pp. 16–18.
15. Hemalatha. B.R., Prasad. N. &Subramanya. B. V. (2008),"Construction and demolition Waste recycling for sustainable growth and development", Journal of Environmental Research and Development. 2, (4), 759-765.
16. Rajakumar .C, Dr.T.Meenambal,Dr.P.D.Arumairaj, " California bearing ratio of expansive subgrade stabilized with waste materials, International Journal of Advanced Structures and Geotechnical Engineering ISSN2319-5347, Vol.03, No. 01, 2014.
17. Rajakumar.C, Dr.T.Meenambal, "Study on the performance of geosynthetics in flexible pavement system", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 19 (2015), 13791-13795, 2015.
18. Rajakumar.C, Dr.T.Meenambal, "Chemical analysis of expansive soil under the influence of bagasse ash", International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 19 (2015), 13796-13800, 2015.
19. Rajakumar.C, Dr.T.Meenambal, "Characterization and Effective utilization of fly ash in Road application", Indian Journal of Environmental protection, ISSN2537141, Volume35, Number 5 (2015), 367-374, 2015.
20. Rajakumar.C, Dr.T.Meenambal, "Effect of Coal Ash in the Stabilization of Expansive Soil for the Pavement, International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290, Vol.8, No.1, pp170-177, 2015.

21. Rajakumar.C, Dr.T.Meenambal, "Experimental Study on utilization of Bottom ash to Stabilize expansive Soil subgrades" International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290, Vol.8, No.1, pp170-177, 2015.
22. Rajakumar.C, Dr.T.Meenambal, "Effect of industrial and agricultural wastes in the stabilization of expansive soil for the pavement subgrades, Indian Journal of Environmental protection, ISSN 2537141,Volume35, Number 9 (2015),715- 723.
23. Rajakumar.C, Dr.T.Meenambal, CBR and UCC Strength Characteristics of Expansive Soil Subgrade Stabilized with Industrial and Agricultural Wastes, International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN: 0974-4290, Vol.8, No.7, pp 1-17, 2015.
24. Rajakumar.C, Dr.T.Meenambal " Experimental study of bagasse ash utilization for road application on expansive soil, Nature Environment and Pollution Technology ISSN 0972-6268 Vol.14, No.4, pp 903-908, 2015.
25. Rajakumar.C, Dr.T.Meenambal, "Experimental study on the utilization of industrial and agricultural wastes to stabilize the expansive soil sub grades", Nature Environment and Pollution Technology ISSN 0972-6268 Vol.15,No.1,pp 67-72,2016.
26. Rajakumar.C, Dr.T.Meenambal ,"Artificial Neural Network Modeling of Sub grade Soil stabilized with Bagasse Ash and Geogrid", International Journal of Innovation and Scientific Research ISSN 2351-8014Vol. 25 No. 1 Jun.2016, pp. 87-100.
27. Rajakumar.C, Dr.T.Meenambal "Artificial Neural Network Modelling and Economic Analysis of soil Subgrade Stabilized with Flyash and Geotextile", Indian Journal of GeoMarine Sciences (IJGMS),I SSN 0379-5136 ,Vol.46, No.7, pp 1454 -1461, 2017.
28. Rajakumar.C, Dr.T.Meenambal,Chemical and Geotechnical Properties of Expansive Soil Stabilized with Fly Ash and Geotextiles, International Journal of ChemTech Research CODEN (USA): IJCRGG ISSN:0974-4290,Vol.10, No.10, pp10-26, 2017.
29. Rajakumar.C, Dr.T.Meenambal, Stabilization of Expansive Subgrade soil with Bagasse ash and Geosynthetic Reinforcement, Indian Journal of Environmental protection, ISSN 2537141, Volume 38, Number 1 (2018), 29-35.
30. Rajakumar.C, Dr.T.Meenambal, Characterization and Effective Utilization of Coal Ash With Geosynthetics in Pavement Subgrade, Indian Journal of Environmental protection, ISSN.2537141,Volume 38, Number 3 (2018), 234-238.
31. Jenin Rajasingh J., C. Rajakumar, Ashiga T.S., Shruthi R., Jenisha G., Kalaiyarasan.G., A study on Environmental Contamination at Coimbatore city and Assessment of Municipal solid Waste impact on the Soil Environment in Vellalore Dumping yard, Coimbatore city, Tamilnadu, India. Pak. J. Biotechnol. Vol. 15 (4) 875-877 (2018)

*****