qrAs per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology
Volume 10, Issue 03, pages 58-63.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue03.html
DOI: https://doi.org/10.46501/IJMTST1003011

Stabilization of Black Cotton Soil (Subgrade Soil) using Lime and Fly Ash

Abdul Kareem.Sk, Jhansi Rani.S , Sathish.K , Hari Babu.L , Vinod Reddy.N

Department of Civil Engineering, Chalapathi Institute of Technology, Guntur, India.

To Cite this Article
Abdul Kareem.Sk, Jhansi Rani.S , Sathish.K , Hari Babu.L , Vinod Reddy.N, Stabilization of Black Cotton Soil (Subgrade Soil) using Lime and Fly Ash, International Journal for Modern Trends in Science and Technology, 2024, 10(03), pages. 58-63.https://doi.org/10.46501/IJMTST1003011

Article Info
Received: 30 January 2024; Accepted: 22 February 2024; Published: 01 March 2024.

ABSTRACT

From the recent past years people are facing the problems on construction of road on black cotton soil. In construction of roads on BC soils, the behavior of soils with respect to water poses a big problem. The soil undergoes high swelling shrinkage and has poor subgrade strength. Stabilization of sub grade soil helps to achieve required strength of subgrade, eliminate the associated problems and this reduces the thickness of pavement. Our project aims to stabilize black cotton soil using fly ash and lime mixture; thus the project work includes finding optimum proportion of soil, fly ash, lime mixture which is acceptable, applicable and economical.

Keyword: black cotton soil, high swelling shrinkage, subgrade strength, thickness of pavemen, soil, fly ash, lime mixture

1. INTRODUCTION

Road needs good quality paving material having adequate strength and durability characteristics. Subgrade soil is an integral part of the road pavement from beneath. The subgrade soil and its properties are important in the design of pavement structure. The main function of the subgrade is to give support to the pavement. And for this, the subgrade should possess sufficient stability under adverse climate and loading condition. In developing countries like India the biggest handicap to provide a complete network of road system is its limited financial availability to build road by the conventional methods.

The soils of north india are residual, derived from the underlying basalts. In the semi-dry plateau, the regular (black-cotton soil) is clayey, rich in iron, but poor in nitrogen and organic matter; it is moisture-retentive.

Therefore, there is a need to resort to one of the suitable methods of low cost road construction. Under this circumstance use of locally available material after suitable treatment is only solution to meet the growth demand of road constructions. The construction cost can be considerably decreased by selecting local materials including local soils for the construction of the lower layers of the pavement. If the stability of the local soil is not adequate for supporting wheel loads, the properties can be improved by soil stabilization techniques. The principle of soil stabilized road construction involves the effective utilization of local soil and other suitable stabilizing agent. Therefore the first and foremost task is to characterize the locally available soil and after proper assessment, suitable treatment is to be provided, if required.

Soil stabilization is any process which improves the physical properties of a soil, such as increasing the shear strength, bearing capacity and the resistance to erosion, dust formation, or frost heaving. The stabilization methods used are divided into mechanical, chemical, and electrochemical methods. Mechanical methods are those in which the compaction or bulk density is increased by dynamic or vibro- compaction. Electrochemical methods of stabilization involve the reduction of water content by electro-osmosis. Chemical stabilization is one of the effective stabilization techniques.

1.1 Objectives of the projects

As stated above, road construction in black cotton soil area is difficult and hence there is need of increasing the strength of black cotton soil as a subgrade for road. Thus, the soil properties can be improved by soil stabilization techniques. Thus, the problem statement of the project is to stabilize the subgrade soil(black cotton soil) using a suitable stabilizer.

Chemical stabilizers like cement, lime are added to soil to improve soil strength, stress-strain behavior, and durability etc

1. To study the properties of black cotton soil available locally.
2. To check the suitability of fly ash-lime combined mixture as a stabilizer for the black cotton soil in Maharashtra
3. To obtain the correct proportion of soil, fly ash and lime to be mixed forstabilization.

2. LITERATURE REVIEW

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in Maharashtra. They are characterized by high shrinkage and swelling properties. Because of its high swelling and shrinkage characteristics, the Black cotton soil has been a challenge to the highway engineers. The Black cotton soil is very hard when dry, but loses its strength completely when in wet condition. It is observed that on drying, the black cotton soil develops cracks of varying depth. As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. The roads laid on Black cotton soil (BC soil) bases develop undulations at the road surface due to loss of strength of the sub grade through softening during monsoon. Around 40 to 60% of the Black cotton soil (BC soil) has a size less than 0.001 mm. At theliquid limit, the volume change is of the order of 200 to 300% and results in swelling pressure as high as 8 kg/cm^2/ to 10 kg/cm^2. As such Black cotton soil (BC soil) has very low bearing capacity and high swelling and shrinkage characteristics. Due to its peculiar characteristics, it forms a very poor foundation material for road construction. Soaked laboratory CBR values of Black Cotton soils are generally found in the range of 2 to 4%. Due to very low CBR values of Black cotton soil (BC soil), excessive pavement thickness is required for designing for flexible pavement.

Prof. katti has studied 13 black cotton soils, most of them from Maharashtra state. The studies conducted on these soils were consistency, density, swelling pressure, consolidation, shear, permeability, thixotropic property and effect of inorganic chemicals etc.

Qubain et al. (2000) incorporated the benefits of sub-grade lime stabilization, for the first time, into the design of a major interstate highway pavement in Pennsylvania. The project comprised widening and complete reconstruction of 21 Km of the Pennsylvania turnpike in somerset-county. Field explorations indicated that the sub-grade is fairly homogeneous and consists primarily of medium to stiff clayey soils. To safeguard against potential softening due to rain, lime modification has been traditionally utilized as a construction expedience for highway project with clayey sub-grade. Lime improves the strength of clay by three mechanisms: hydration, flocculation, and cementation. The first and second mechanisms occur almost immediately upon introducing the lime, while the third is a prolonged effect. Qubain et al. investigated the first and second mechanisms. Laboratory tests were performed to accurately capture the immediate benefits of lime stabilization for design. Both treated and natural clayey samples were subjected to resilient modulus and California bearing ratio testing. To prevent cementation, the lime- treated specimens were not allowed to cure. Nevertheless, they showed significant increase in strength, which, when incorporated into design, reduced the pavement thickness and resulted in substantial savings.

Weber (2001) investigated the effect of both curing (storage) and degree of compaction on the loss loam stabilized using different additives. He obtained the best results under condition of moisture atmosphere storage. At the water storage condition, the tempering of the stabilized specimens delayed due to the changing of pH-value in the pores water. The reactivity of lime stabilized specimens was continuing under this water storage condition. He noticed that the variation of compaction degree of the stabilized specimens affected on the behavior of the stabilized specimens and the compaction at the highest densities lead to brittle failure behavior.

Ismail (2004) studied materials and soils derived from the Feuerletten (Keuper) and Amaltheenton (Jura) formations along the new Nuernberg-Ingolstadt railway line(Germany).

His work included petrological, mineralogical studies and scanning electron microscope analysis. Ismail treated and stabilized these materials related to road construction using lime (10%), cement (10%), and lime/cement (2.5%/7.5%). He determined consistency

3. MATERIALS AND METHEDOLOGY

3.1 Properties of black cotton soil

Locally available fine grained black cotton soil from nearby site was acquired and fly ash from Nashik thermal power station was procured. The necessary experiments to be carried out on BC soil are sieve analysis, Standard proctor test, Atterberg‟s limits test, Differential swell test and unconfined compressive test.

Lime: Lime can be used either to modify some of the physical properties and thereby improve the quality of soil or to transform the soil into a stabilized mass, which increases its strength and durability. The amount of lime additive will depend upon either the soil to be modified or stabilized. Generally, lime is suitable for clay soils with PI ≥ 20% and > 35% passing.

Flyash: Fly ash is a by-product of burning coal at electric power plants. It is a fine residue composed of unburned particles that solidifies while suspended in exhaust gases. Fly ash is carried off in stack gases from a boiler unit, and is collected by mechanical methods or electrostatic precipitators. Fly ash is composed of fine spherical silt size particles in the range of 0.074 to 0.005 mm. Fly ash collected using electrostatic precipitators usually has finer particles than fly ash collected using mechanical precipitators

4. RESULTS AND DISCUSSIONS

4.1 Properties of black cotton soil

The engineering properties of soil are investigated as follows:

Liquid limit: 60.33%

Plastic limit: 21.5%

Plasticity index: 38.83%

Shrinkage limit: 13.66%

Differential swell: 70%

Optimum moisture content:26.4%

Maximum dry density: 1.33 gm/cc

Unconfined compressive strength: 30KN

Table 1: Unconfined compressive strength tests results of different proportions

Sr.no.	Proportion	7-day strength	14-day strength	21-day strength
1	4:10:100	63.26674	80.75306	79.10641
2	4:20:100	72.43254	45.99188	56.36429
3	4:30:100	67.97688	51.76302	104.6748
4	6:10:100	64.94172	127.2587	134.8742
5	6:20:100	91.38305	104.0796	104.0796
6	6:30:100	74.17492	81.52757	142.4454
7	8:10:100	99.61802	24.2101	123.7935
8	8:20:100	154.3113	123.8668	115.0261
9	8:30:100	88.99083	75.49722	191.4123

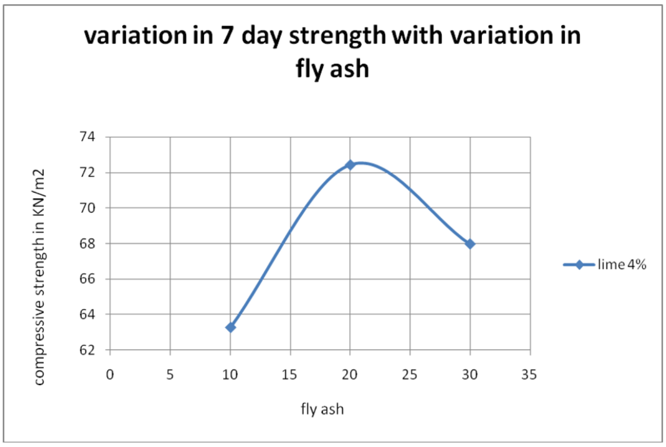

Figure 1: Effect on strength when fly ash is varied keeping lime constant

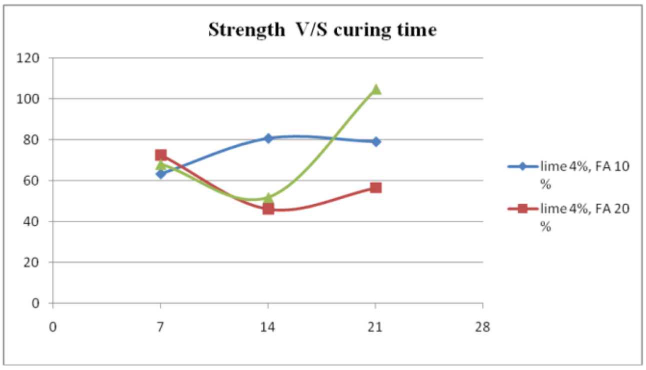

Figure 2: Effect of curing time on the strength of the sub grade with lime 4%

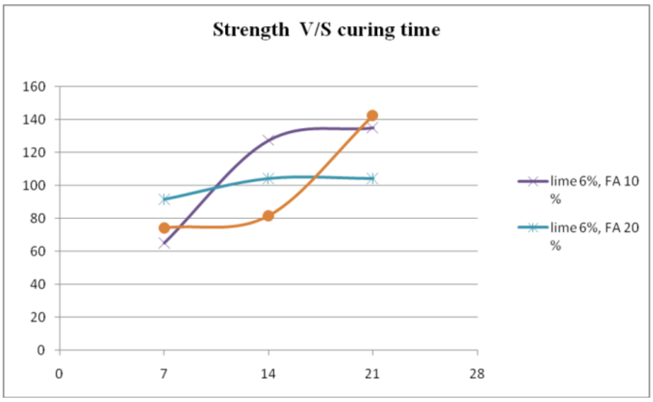

Figure 3: Effect of curing time on the strength of the sub grade with lime 6%

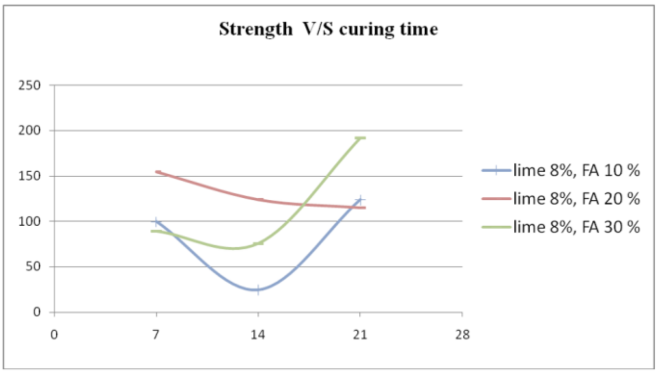

Figure 4: Effect of curing time on the strength of the sub grade with lime 8%

- The graphs of different combinations with different curing times have been drawn and analyzed keeping two parameters constant.
- The graphs show variation in strength with variation with fly ash keeping lime constant. From the graph, we come to know that the graphs are increasing with the increase in fly ash. Thus, 30 % fly ash gives us the maximum strength. However, we cannot understand whether the 30% is optimum proportion or not. Hence we need to take tests with increasing the percentage of fly ash.
- The graphs show variation in strength with variation with lime keeping fly ash constant. From the graph, we come to know that the graphs are increasing with the increase in lime. Thus, 8 % lime gives us the maximum strength. However, we cannot understand whether the 8% is optimum proportion or not. Hence we need to take tests with increasing the percentage of lime.
- The graphs show variation in strength with variation with curing time. From the graph, we observe that the better and reliable readings can be observed at the curing time of 21 days. Hence, the final readings are taken for the curing time of 21 days.

Table 2: unconfined compressive strength of black cotton soil taken after 21-day curing

Sr. no.	lime	fly ash	21-day compressive strength
1	4	10	79.10
2	4	20	56.36
3	4	30	104.67
4	4	40	43.4
5	4	50	22.28
6	4	60	21.06
7	6	10	134.87
8	6	20	104.07
9	6	30	142.44
10	6	40	38.3
11	6	50	15.24
12	6	60	21.08
13	8	10	123.79
14	8	20	115.02
15	8	30	191.41
16	8	40	62.90
17	8	50	38.75
18	8	60	64.19
19	10	10	100
20	10	20	105
21	10	30	112.51
22	10	40	111.06
23	10	50	100
24	10	60	50.34
25	12	10	140.4
26	12	20	160.3
27	12	30	195.66
28	12	40	190.2
29	12	50	117.4
30	12	60	100.56
31	14	10	120.7
32	14	20	140.64
33	14	30	180.24
34	14	40	179.19
35	14	50	115.57
36	14	60	70.8

- The final observation and readings have been analysed using bar charts and line graphs.
- From the graphs, we come to know that the strength of BC soil increases with increase in lime content and then decreases with increase in lime. Thus, the strength V/S lime percentage increases first and then drops down showing us the optimum proportion of lime as 8%.
- From the graphs, we come to know that the strength of BC soil increases with increase in fly ash content and then decreases with increase in fly ash. Thus, the strength V/S lime percentage increases first and then drops down showing us the

optimum proportion of lime as 8%.

- Thus, we come to know that the optimum proportion for black cotton soil of sangli is 12% lime and 30% fly ash.

Table 3: Comparison between black cotton soil with no stabilizer and black cotton soil addedwith 12% lime and 30% fly ash

Index properties	Black cotton soilwith no stabilizer	Black cotton soil with12 %	remarks
Liquid limit	60.33 %	42.00	Liquid limit has decreased
Plastic limit	21.50	27.14	Plastic limit has increased
Plasticity index	38.83	14.86	Plasticity index has reduced
Shrinkage limit	13.66	19.01	Shrinkage limit has increased
Differential swell	70%	25%	Swelling has decreased considerably
Optimum moisture content	26.4%	30%	OMC has increased
Maximum dry density	1.33 gm/cc	1.3 gm/cc	MDD has decreased little.
Unconfined compressive strength	30 KN	195 KN	Strength has increased considerably

Desired properties of soil have been achieved. Hence, stabilization method and proportion of lime, fly ash and soil is correct.

5. CONCLUSIONS

ii. Lime and fly ash are effective and efficient stabilizer. The strength of black cotton soil can be increased by using fly ash and lime combination.

iii. Through our research, we have come to know the optimum proportion of lime and fly ash for the locally available BC soil in Guntur. The optimum proportion is 12%lime and 30% fly ash.

iv. Through the differential swell reading, we come to know that for the optimum proportion the swelling is considerably reduced. Thus, fly ash and lime can effective in both increasing strength as well as reducing swelling of BC soil.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

References

[1] Baban ram and Sunil kumar chaudhary, " Cost effective and eco friendly construction of rural roads- need of hour", Indian highways, Nov 2010

[2] Raju, B. G., & Rao, K. N. S. (2015). Characterization of fibre reinforced bituminous mixes. International Journal of Science and Research (IJSR), 4(12), 802-806.

[3] Kiranmai, Y., & Rao, K. N. S. (2018). Strength permeation and nano studies on fly ash based magnetic water concrete. International Journal of Scientific Engineering and Technology Research, 7(6), 1088-1093.

[4] Pandey, S., Singh, N. K., Rao, K. N. S., Yadav, T. C., Sanghavi, G., Yadav, M., ... & Nayak, J. (2020). Bacterial production of organic acids and subsequent metabolism. Engineering of Microbial Biosynthetic Pathways, 153-173.

[5] SUSHMA, K. V. N., & RAO, K. N. S. Designing Liquid Retaining Frame for Overhead Tank.

[6] KUMAR, M. C. N., & RAO, K. N. S. Moderate Density Fly Ash Blend to Erect Geopolymer Binders.

[7] PRASAD, U., & RAO, K. N. S. AN EXPERIMENTAL INVESTIGATION ON UTILIZATION OF LOW DENSITY TESLON WASTE IN THE MANUFACTURING OF PAVER BRICK.

[8] GOPI, G. V., & RAO, K. N. S. STUDY OF STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH SILICAFUME, METAKAOLIN AND GGBS.

[9] Saikrishna, P., & Rao, K. N. S. An Investigational Work on Mechanical Properties of Low Calcium Fly Ash Based Geopolymer Concrete with GGBS.

[10] S. Bhuvaneshwari , S. G. Robinson , S. R. Gandhi . "Stabilization of expansive soils using fly ash", fly ash utilization program, TIFAC, DST, new Delhi

[11] Srikanth N, et.al, Experimental Investigation on Strength and Toughness Properties of Self Compacting Concrete Mineral Admixtures, Test Engineering Management, March - April 2020 ISSN: 0193-4120 Page No. 17246 – 17253.

[12] Erdal Cocka (2001) " Use of class c fly ashes for the stabilization of an expansive soil", Journal of geotechnical and geoenvironmental engineering, vol. 127, July, pp. 568-573

[13] N.Srikanth, et.al, Experimental Investigation on Strength of Concrete by Using Nano- Silica and Fly Ash As Partial Replacement to the Cement, International Research Journal of Engineering and Technology , Volume: 09 Issue: 12 | Dec 2022, e-ISSN: 2395-005

[14] Pandian, n.s.,krishna, k.c. leelavathamma b., (2002), effect of fly ash on the cbr behavior of Soils , Indian geotechnical conference , Allahabad , vol.1,pp.183-186.

[15] Phanikumar b.r., & radhey s.sharma(2004) "effect of fly ash on engg properties of expansive Soil" journal of geotechnical and geoenvironmental engineering vol. 130, no 7,july, pp. 764-767.

[16] O.o. amu, a.b. fajobi and b.o. oke. "effect of eggshell powder on the stabilizing potential of lime on an expansive clay soil". Research journal of agriculture and biological sciences 1(1): 80-84, 2005 © 2005, insinet publication

[17] N. Srikanth, et.al, Study on Different Internal Curing Agents on Properties Self-Compacting Concrete, The International journal of analytical and experimental modal analysis, ISSN NO: 0886-9367, Volume XV, Issue VI, June/2023, Page No: 254-262

[18] A. Shrirama rao and G. Shridevi , " Improving the performance of expansive soil subgrades with lime – stabilized fly ash cushion, Indian highways , oct 2010

[19] A.N. Ramakrishna and A.V. Pradeepkumar, "Effect of moisture content on strength behavior of BC soil- Rice husk ash- lime mixes, Indian Highways, jan 2008.

[20] N. K. Ameta, d.g. m. Purohit, a. S. Wayal ."Characteristics, problems and remedies of expansive soils of rajasthan", india.