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Stabilization of Black Cotton Soil using Lime Kiln Dust

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Abstract: The soil that acts as the basis for roadways are frequently modified and stabilised using chemicals and cement concrete compounds. The strength of the paving foundation is increased as a result of sub - grade enhancement, which also offers a superior operating surface for the building of the sections atop.

In order to stabilise the black cotton soil, in the present research, a by-product like lime kiln dust is used as an additive to combine with the expanding soil. To get the Atterberg Limits, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCC), as well as other characteristics, scientific experiments are conducted as part of the current study. According to the study, it is advised to combine LKD up to 15% with black cotton soil so that it may be utilised for foundation work and the building of pavement.

Keywords; Black cotton soil, Atterberg Limits, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCC) etc.

I. INTRODUCTION

Expansive soils are those that experience volumetric changes as a result of variations in their moisture content. They expand when humid and contract when dry, a behaviour usually attributed to variations in seasonally wetness. Numerous elements, including expansive soils' mineral, sandy loam, textile texture, moisture levels, porosity, pore fluid chemistry, and stress circumstances, might affect the volumetric durability of expansive soils.

The expansive soil, also known as black cotton soil, is found in the Indian provinces of Madhya Pradesh, Andhra Pradesh, Maharashtra, Gujarat, Rajasthan, Telangana, and Jharkhand. It encompasses a region of around 800,000 km^2. In overall, the developer may think about the following prospective corrective initiatives when the soil at a specific site can offer consistency and reliability for the planned formation: (a) avert the location; (b) change the foundation layout; (c) substitute the troublesome soil with a max resilience non-swelling soil, like Murrum; and (d) reconfigure the current soil via soil stabilization to develop a fresh content willing to fulfil the required specifications.

Since each of the techniques have been explored, most professional architects choose options (c) and (d) when dealing with expansive soil. Soil stabilisation is the term used to describe option (d), which involves using a soil remediation technology to enhance the soil. The budget of constructing may rise dramatically if troublesome soil is replaced with greater quality borrowing dirt. Considering all this, soil stabilisation is an alternative strategy that has drawn engineers' interest throughout time.

For practically all construction developments, soil stabilisation is a typical practise. Mechanical stabilisation and chemical stabilisation are the 2 broad categories under which all kinds of soil stabilisation may be divided. When a soil is stabilised mechanically, its categorization is altered by combining it with various soil kinds of various grades. A mound of compressed earth can be produced in this way. Contrarily, chemical stabilisation refers to the alteration of soil characteristics by the inclusion of chemically functional substances. Understanding the substance characteristics included in the combination and the results after combining are crucial for soil stabilisation.

Additionally, it is critical to ascertain how the component will function upon stabilisation. In addition, it is necessary to assess how the procedure may affect neighbouring buildings and the environment. Therefore, choices may be made regarding the components to be used and their related dosages. The success of this approach is governed by a variety of criteria, including the choice of substances and dosages, blending, and distributing, rolling choice, compacted density, compressive force, operational order, drying, and weather circumstances, etc.

Chemical stabilisation is the process of modifying the chemical composition of soil by mixing various additions, such as lime, cement, fly ash, etc., or by adding chemicals, resins, and enzymes. It can be observed from the various study that for soil modification and stability, lime, cement, and fly ash were all employed effectively; but, rising value of ingredient and worries about accessibility have prompted researchers to look at substitutes. Thus, the objective of the present work is to investigate the efficacy of lime kiln dust applied as a substitute soil stabilising ingredient in the experimental level.

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II. RESEARCH METHODOLOGY

A. Materials

1) Black Cotton Soil

The soil for the experimental program was collected from a land excavation site in the central Indian region (Jabalpur district, M.P.) from road construction site known as residual soil at ~0–2 m depth. The soil testing has been carried out. Table 1 lists the usual structural and geological features of black cotton soil. Practically considered, the three conditions for possibly harmful swelling to happen are as follows:

- The soil contains the mineral montmorillonite clay;
- The naturally moisture level is close to the plastic maximum.
- Moisture for the clay's capacity to swell.

Table 1 Properties of black cotton soil (As per IS: 2720 (Part III)-1980).

Property	Values
Sp. Gravity	2.69
Gravel/Sand/Clay/Silt	1.1/8.4/78.7/11.8
Liquid Limit (%)	62
Plastic Limit (%)	39
Plasticity Index (%)	24
Shrinkage Limit (%)	14
Maximum dry density (gr/cm^3)	1.698
Optimum Moisture Content (%)	19.7

The soil's liquid, plastic limit, and plasticity index (PI) measured, correspondingly, 62%, 39%, and 24%. According to Indian Standard (IS) categorization, the soil is classified as high plasticity (CH) soil depending on such characteristics (IS: 2720–1980). According to IS: 2720 (Part III)-1980, the indexing qualities of BC soil are discovered and are displayed in Table 1. The soil has high degree of expansivity.

2) Lime Kiln Dust

A by-product from the manufacturing of lime is lime kiln dust (LKD). It is offered for sale as a powder that includes a sizable proportion of lime and a sizable portion of impermeable substance. When limestone is converted into lime in a lime kiln, gases and particles are produced. The dust is gathered, and the gases are discharged to the environment by an air emission treatment equipment. Lime, alumina, and silica are present in significant amounts in this LKD dust element. Since LKD is a by-product of lime, its molecular behaviour depends on the source rock and the method used to make lime. LKD includes considerable alkalis and is regarded as corrosive. LKD water combinations generally have a pH of around 12. In this study, LKD, was produced and supplied by an Indian material supplier. Typical physical and engineering properties of hydrated lime from Kakrasul et al. Table 2 shows the chemical analysis of LKD.

Table 2 Analysis of LKD

Minerals	Percent (%)
Calcium Oxide	85.0
Available Calcium Oxide	58.0
Magnesium Oxide	1.0
Silicon Dioxide	1.5
Iron Oxide	1.42
Aluminium Oxide	0.51
Sulphur	0.68

B. Sample Preparation

The obtained soil sample was air-dried for 24 hours before being placed in an oven to dry for a further 24 hours at 105C. Samples of the examined clay were obtained and combined with LKD. Lime kiln dust is the main ingredient of concern in this investigation (LKD). By incorporating the dry mix of LKD using 5%, 10%, and 15%, the expansive soil was stabilised. At every step of blending, great attention and effort were given to guarantee an even mixture of soil and chemicals.

III. TESTING

Various tests were conducted on this soil while mixing it with LKD and are as:

A. Grain Size Distribution

According to ASTM D442, grain size studies were carried out to categorise the particle size of the native (undisturbed) soils. 500 g of oven-dried soil sample were filtered using a No. 200 sieve (0.075 mm), as well as the material that was left behind was dehydrated once more. The proportion of soil getting passed via the No. 200 (0.075 mm) sieve was utilized to categorise the soil, and the dried matter of the particles remaining on the sieve were measured.

B. Atterberg Limits

As per ASTM D4318, the liquid limit, plastic limit, and plasticity index of the natural soils and the soil mixes processed with LKD are calculated. The multipoint liquid limit method (Method B) outlined in ASTM D4318 was used to perform liquid limits. For soils that had been processed with LKD, LKD and dry soil were combined, and water was then introduced to bring the mixture's humidity up to the appropriate degree. The soil was well mixed, then the mix was sealed and left to soften for one hour. Following that, Atterberg limits were established in line with ASTM D4318.

C. Proctor Test

For every soil/additive mixture, moisture-density correlation charts were created utilizing standard Proctor tests in compliance with ASTM D698-Method A. In a mould with a 4-inch diameter and a capacity of 1/30 ft^3, the soil being compressed. With 25 strokes per level, it was compressed into 3 levels. Freshwater subsequently mixed into the dry mixture of soil and LKD additives to bring the moisture levels up to the desired proportion. To mimic a typical time overrun, the solution was stored for a hr in an airtight container. The combination was then compressed using ASTM D698-Method A.

D. Unconfined Compression Strength

According to ASTM D2166, the unconfined compression tests were carried out. The Harvard setup was used to preparing samples for unconfined compression strength measurement. Every sample was created with a water content that was 1% below ideal. All wet and un-soaped samples were put through tests for unconfined compressive strength following varying drying times. The next two parts provide a description of the soaking and curing techniques used in this investigation.

E. CBR Test

CBR stands for California bearing ratio. It is a penetration test used to evaluate the subgrade strength of soil. It is a measure of resistance of soil to the penetration of standard plunger under controlled conditions. Load is applied at a rate of 1.25 mm/min.

IV. RESULTS

The soil characteristics with and without additives were determined using Atterberg limits, dry density, standard Proctor, and unconfined compression strength.

Figure 1 shows the outcomes of experiments for Atterberg limits using different soil mixtures. Only with inclusion of LKD, black cotton soil showed a considerable rise in the plastic limit. Even though the maximum liquid limit for additions is 10%, increments in the plastic limit are adequate to reduce the soil's plasticity index.

The native liquid limit (LL) and the plasticity index (PI) for the BC soil were 62 and 24, respectively. The PI value for this soil was reduced to 20 when it was mixed with 5% LKD. Further reduction in the PI value was attained (from 20 to 17) by adding 15% LKD.

The results of the unconfined compression strength tests are presented in Figures 4.2. Soil samples were cured for curing times of 1–2 hr, 1 day, 3 days, 7 days, and/or 28 days prior to the test. The LKD treated samples experienced an increase in strength with time. The strength of LKD-treated soil samples slightly increased with increasing LKD content.

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However, the rate of strength gain was not consistent with time for higher rates of LKD. The soil samples treated with 10% LKD showed the highest strength gain when compared with other LKD rates and additives. Overall, LKD-treated soil samples performed better than lime-treated samples about strength gain.

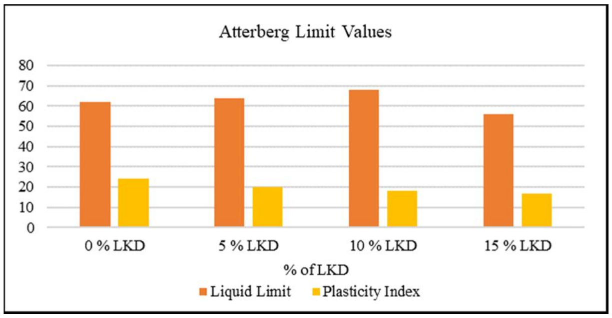
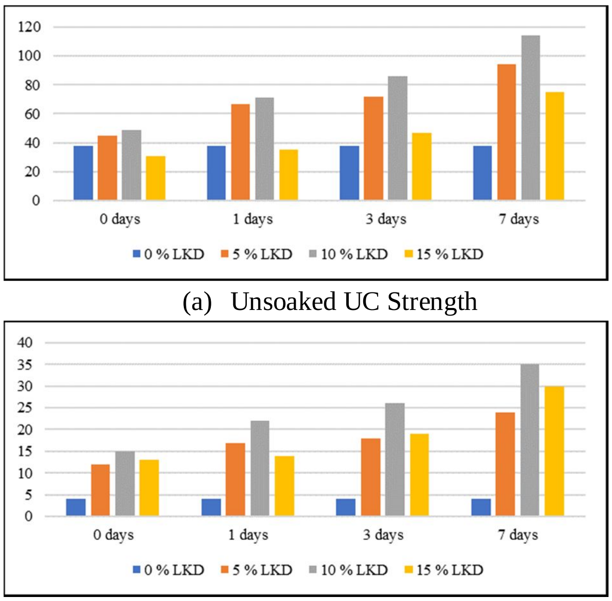


Fig. 1 Atterberg limit values for black cotton soil with different percentage of LKD



(b) Soaked UC Strength

Fig. 2 UC strength at different days of curing

The unsoaked and soaked strengths of LKD-treated specimens of Black cotton soil for varied drying durations are shown in Figures 2(a) and (b). All the treated samples got stronger with period, but the ones treated with 10% LKD gained the most strength. After seven days of curing, the strength of the soil increased by 60% and 200%, correspondingly, if 5% and 10% LKD were added, relative to the strength of the native soil. For various days of curing, the strength growth trend for samples treated with LKD was unstable. After 7 days of curing for LKD contents of 5%, 10%, and 15%, correspondingly, the soaked specimens of LKD-treated soil showed rises of 2, 2.4, and 2.3 times above the native soil-soaked strength.

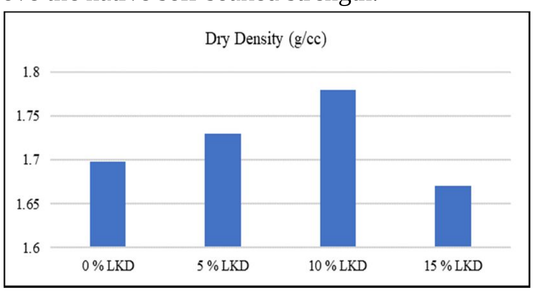


Fig 3 Dry density variation with respect to different % of LKD addition

Figure 3 shows the dry density variation with different additive percentage. At 10% LKD addition the dry density is maximum. Same trends can be observed for CBR values. (Fig 4)

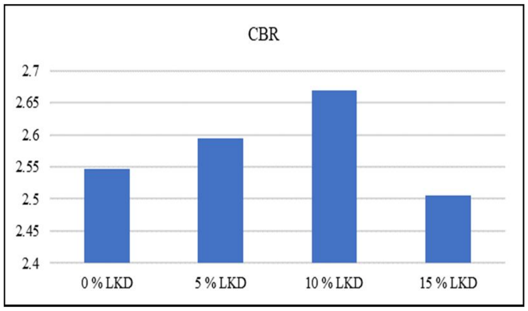


Fig. 4 CBR variation with respect to different % of LKD addition

V. CONCLUSION

A series of laboratory experiments and field investigations were conducted to evaluate the characteristics of LKD-stabilized subgrade soils.

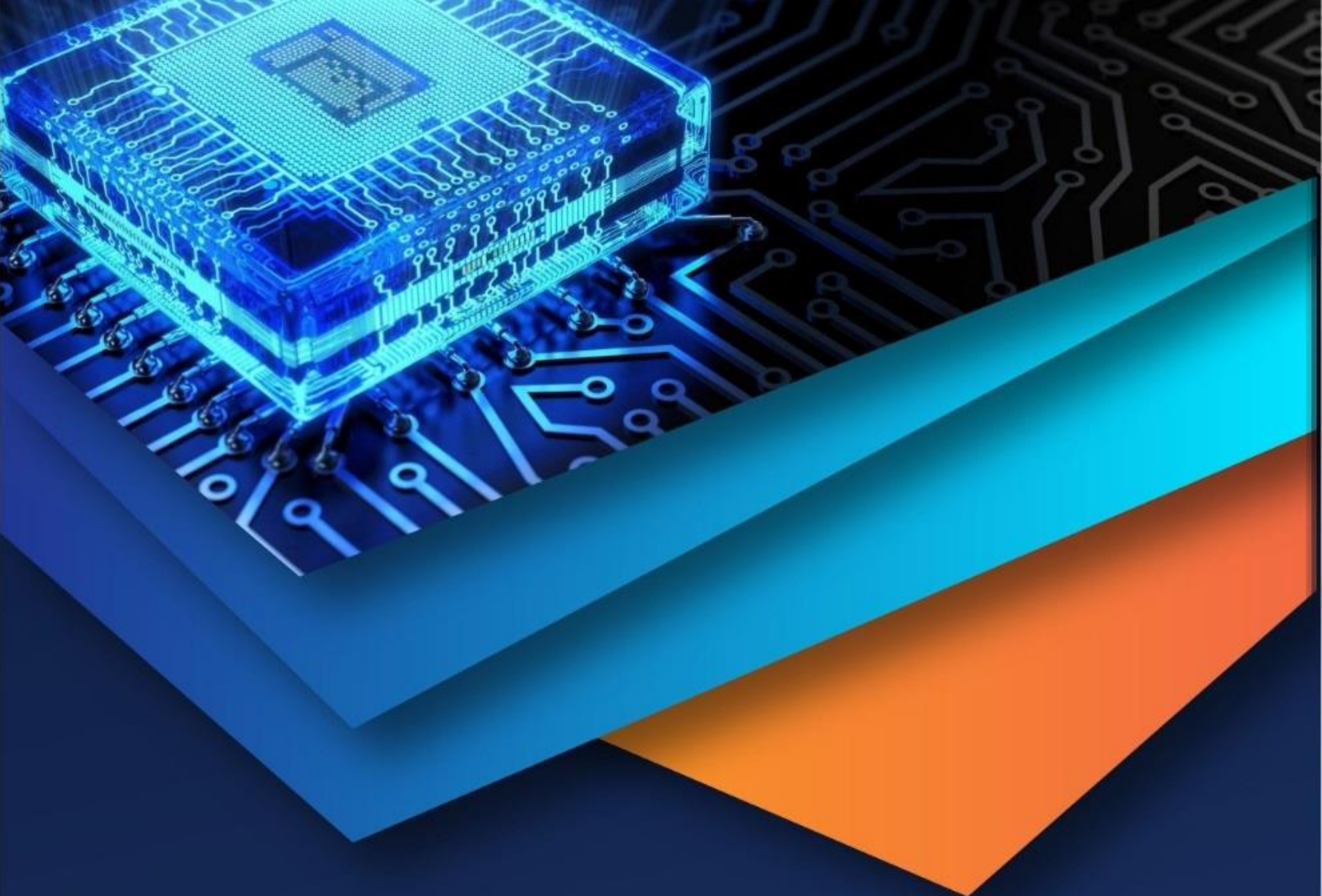
1) The addition of LKD was effective in reducing the plasticity of all soil, the addition should be upto 10% above that it makes opposite effect.
2) The UC strength of all samples increased substantially with the addition of LKD. LKD-treated soils showed the highest strength gain, and strength continued to increase with time.
3) The average of the estimated CBR values for LKD-treated black cotton soil was increased.

VI. NOMENCLATURE

1) CBR California Bearing Ratio,
2) UCC Unconfined Compressive Strength
3) PI Plasticity index
4) IS Indian Standard
5) LKD lime kiln dust
6) LL liquid limit

REFERENCES

[1] Diego Baragano, Jose Luis R. Gallego, Ruben Forjan 2021. Short-term experiment for the in situ stabilization of a polluted soil using mining and biomass waste. Journal of Environmental Management 296.
[2] Dharmendra Barman, Sujit Kumar Dash. 2022. Stabilization of expansive soils using chemical additives: A review" Journal of Rock Mechanics and Geotechnical Engineering 14:1319-1342
[3] Antonio Alberto S. Correia, Maria Graça Rasteiro. 2016. Nanotechnology Applied to Chemical Soil Stabilization. Procedia Engineering Volume 143, 2016, Pages 1252–1259
[4] Samuel J. Abbey , Eyo U. Eyo, Chukwueloka A.U. Okeke , Samson Ngambi. 2021.Experimental study on the use of RoadCem blended with by-product cementitious materials for stabilisation of clay soils. Construction and Building Materials 280
[5] M.S. Deepak, S. Rohini, B.S. Harini, G. Beulah Gnana Ananthi. 2020. Influence of fly-ash on the engineering characteristics of stabilised clay soil. Materials Today: Proceedings.
[6] Ya-Song Feng, Yan-Jun Du.2020. Environmental Properties of Industrially Contaminated Site Soil Solidified/Stabilized with a Sustainable By-product-based Binder. Science of the Total Environment DOI: https://doi.org/10.1016/j.scitotenv.2020.142778.
[7] P. Gireesh Kumar, S. Harika.2020. Stabilization of expansive subgrade soil by using fly ash. Materials Today: Proceedings.
[8] Peduruhewa H. Jeewani, Lukas Van Zwieten, Zhenke Zhu , Tida Ge, Georg Guggenberger, Yu Luo , Jianming Xu.2021.Abiotic and biotic regulation on carbon mineralization and stabilization in paddy soils along iron oxide gradients Soil Biology and Biochemistry 160 (2021) 108312
[9] Yonghyeon Lee, Mingcan Cui, Zhengchang Han.2021.Evaluation of stabilizing material and stabilization efficiency through comparative study of toxic heavy metal transfer between corn and peanut grown in stabilized field soil. Environmental Pollution 275 (2021) 116617



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