Strength Improvement of Clay Subgrade Soil Using Lime Kiln Dust (LKD): An Experimental Study

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Abstract

Subgrade strength is a critical parameter in pavement design, as weak subgrade soils often lead to excessive settlement and reduced pavement life. This research investigates the use of Lime Kiln Dust (LKD)—an industrial by-product rich in calcium oxide—as a stabilizing agent for locally available clay soil. Laboratory experiments including Atterberg limits, specific gravity, grain size distribution, Modified Proctor compaction, and California Bearing Ratio (CBR) tests were performed on raw soil and soil treated with 5%, 8%, and 10% LKD. Results show that LKD significantly enhances soil strength by increasing Maximum Dry Density (MDD) and CBR values, while reducing moisture susceptibility. The highest performance was observed at 10% LKD, where unsoaked CBR increased from 36.49% to 47.22–50%, and soaked CBR values improved by more than double compared to untreated soil. The findings indicate that LKD can be a cost-effective, sustainable, and highly efficient stabilizing material for clay subgrade applications.

Keywords: Soil Stabilization, Lime Kiln Dust, CBR, Subgrade Strength, Dry Density.

1. Introduction

Subgrade supports the entire pavement system and therefore requires adequate strength, durability, and resistance to moisture-induced deformation. Clay soils often exhibit high plasticity, swelling, shrinkage, and low bearing capacity, compromising pavement performance.

Traditional stabilizers such as lime, cement, and fly ash have proven effective, but rising costs and sustainability concerns encourage the adoption of industrial by-products. Lime Kiln Dust (LKD)—a by-product of lime manufacturing—is rich in CaO (55–70%), which reacts with clay minerals to improve soil strength and workability.

LKD provides: Pozzolanic reactions that increase long-term strength.

Immediate improvement in workability due to cation exchange.

Sustainable waste utilization.

This study experimentally evaluates the effectiveness of LKD to improve the geotechnical properties of clay subgrade soil.

2. Literature Review

Prior studies demonstrate that soil stabilization using chemical additives enhances engineering behavior:

Researchers (Chinkulkijniwat & Man-Koksung, 2010) noted compaction behavior depends on fines and gravel content.

Hussain (2008) reported higher CBR and shear strength with increased plasticity index.

Polymer and bitumen-based stabilizers (Lauren, 2011; Andavan & Kumar, 2020) improved CBR through waterproofing effects.

Yashas et al. (2016) and Mayank Korde et al. (2015) found strong correlations between MDD, OMC, PI, and CBR.

However, limited research exists on LKD-stabilized clay soils, highlighting the need for the present experimental investigation.

3. Materials and Methodology

3.1 Materials

Soil: Locally available clay soil from Rajasthan.

Lime Kiln Dust: Chemical composition includes CaO (55–70%), MgO (0.9–2%), SiO_2 (1.4–2%), Fe_2O_3 (1.32–2%) (from Table 1.1 in thesis).

3.2 Experimental Program

Tests conducted:

Water content (Oven drying)

Specific Gravity (Pycnometer)

Grain Size Distribution (Sieve analysis)

Atterberg limits

Modified Proctor Compaction Test

CBR Test (Unsoaked & Soaked for 48 hours)

3.3 LKD Mix Proportions

Four cases were investigated:

Case A: 0% LKD (Natural clay)

Case B: 5% LKD

Case C: 8% LKD

Case D: 10% LKD

Each mixture was compacted to maximum dry density and tested for CBR.

4. Results

4.1 Basic Soil Properties

Water Content: 35.8%

Specific Gravity: 2.62

Liquid Limit: 31.51%

Plastic Limit: 17.37%

Plasticity Index: 14.14%

Soil classification: Clayey soil (59.75% finer than 75 µm)

4.2 Compaction Results

Mix	OMC (%)	MDD (g/cc)
Case A	9.5	2.06
Case B	9.5	2.12
Case C	9.8	2.15
Case D	9.7	2.24

Observation:

MDD increased steadily with LKD addition, peaking at 10% LKD.

4.3 CBR Results

Unsoaked CBR

Mix	CBR (%)
Case A – 0% LKD	36.49
Case B – 5% LKD	44.16
Case C – 8% LKD	47.22
Case D – 10% LKD	~50.00

Soaked CBR (48 hours)

Mix	CBR (%)
Case A – 0%	9.70
Case B – 5%	14.81
Case C – 8%	18.32

Case D – 10% | ~20.00 |

Observation:

Soaked CBR nearly doubles with 10% LKD, indicating improved moisture resistance.

5. Discussion

5.1 Effect of LKD on Compaction

The increase in MDD indicates that finer LKD particles fill the soil voids, while calcium-based reactions improve particle bonding.

5.2 Effect on Strength (CBR)

Unsoaked CBR improved by ~37% to ~50% with LKD.

Soaked CBR improved by 100% (from 9.7% to ~20%).

This demonstrates:

Better load-bearing capacity

Higher soak resistance

Improved performance under wet conditions

5.3 Optimum LKD Content

While all LKD percentages improved strength, 10% LKD provided the best balance of compaction and CBR performance.

6. Conclusion

1. The natural clay soil shows poor engineering behavior with low soaked CBR (<10%).

2. LKD significantly enhances strength due to pozzolanic and cementitious reactions.

3. Maximum improvement occurs at 10% LKD, where:

- MDD increases from 2.06 to 2.24 g/cc
- Unsoaked CBR increases from 36.49% to ~50%
- Soaked CBR increases from 9.7% to ~20%

4. LKD is an economical, sustainable, and effective stabilizer for clay subgrade.

5. Use of LKD can lead to reduced pavement thickness and cost savings.

Recommended LKD Content for Field Application: 8%–10%

References

(References extracted from thesis; reformatted in journal style.)

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