RESEARCH PAPER

Sustainable Approach for Soil Stabilization Using Industrial By-Product (Coal Dust) and Magnesium Chloride.

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Abstract

Enhancing the engineering characteristics of weak and problematic soils through soil stabilization is vital for developing safe and durable infrastructure. Expansive soils, such as black cotton soil, are prevalent in many regions and are known for their pronounced swelling and shrinkage behavior, which poses major difficulties for pavement and foundation construction. This study introduces an eco-friendly and economical technique by employing industrial by-products—specifically coal dust combined with magnesium chloride—as stabilizing agents. A series of laboratory experiments, including Liquid Limit (LL), Plastic Limit (PL), Standard Proctor Compaction Test (SPCT), and California Bearing Ratio (CBR), were carried out on both natural and modified soils with varying dosages of additives (2%, 4%, and 6%). The experimental findings show notable increases in maximum dry density, optimum moisture content, and CBR values upon the addition of coal dust and magnesium chloride. These results confirm that the selected additives significantly enhance the bearing strength and workability of expansive soils, presenting a sustainable solution for subgrade stabilization in pavement applications.

Keywords— Soil stabilization, Coal dust, Magnesium chloride, CBR, Expansive soil, Sustainable pavement

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I. INTRODUCTION

Soil forms the basis of all civil engineering structures, and the performance of these structures is highly influenced by the properties of the subgrade soil. Expansive soils, notably black cotton soils, possess a significant amount of montmorillonite minerals, which contribute to their pronounced swelling and shrinkage characteristics. These behaviors render them unsuitable for construction without proper stabilization measures.

While conventional stabilizers like lime and cement are effective in enhancing soil strength, their production is resource-intensive and raises environmental concerns. Consequently, the search for sustainable alternatives has led to increased interest in utilizing industrial waste materials as soil stabilizers. Coal dust, a residue from thermal power plants, and magnesium chloride, a hygroscopic compound, have both demonstrated potential in boosting soil strength and decreasing plasticity.

This study investigates the synergistic effects of coal dust and magnesium chloride on the geotechnical properties of black cotton soil through a series of laboratory experiments.

II. MATERIALS AND METHODS

A. Soil Sample

The black cotton soil utilized in this study was sourced locally and classified as highly plastic clay (CH) according to IS 1498:1970 standards.

B. Stabilizing Materials

1. **Coal Dust:** Obtained from nearby thermal power plants. It is a fine powder residue of incomplete combustion with high carbon content.
2. **Magnesium Chloride ($MgCl_2$):** A chemical stabilizer used in dust control and soil compaction applications.

C. Methodology

The stabilization process was carried out by mixing the soil with varying proportions (2%, 4%, and 6%) of coal dust and magnesium chloride, based on the dry weight of the soil sample. The prepared samples were then tested for the following parameters:Atterberg Limits (Liquid and Plastic Limit)

- Atterberg limits
- Free Swell Index (FSI)
- Standard Proctor Compaction Test (SPCT)
- California Bearing Ratio (CBR)

All experiments were performed following the procedures outlined in the IS: 2720 series of standards.

III. TEST RESULTS AND DISCUSSION

A. Atterberg Limits

Liquid limit and plastic limit tests were performed on both untreated soil and soil samples blended with 2%, 4%, and 6% of coal dust and magnesium chloride.

The results indicated that:

- The liquid limit decreased from 51.53% for the natural soil to 46.77% with 2% coal dust and further to 38.44% with 6% magnesium chloride.
- The plasticity index also declined, suggesting enhanced workability and a reduction in the soil's swelling potential.

This decrease in plasticity can be attributed to the substitution of fine clay particles with non-plastic coal dust, as well as ionic exchange processes facilitated by magnesium chloride.

B. Free Swell Index

The Free Swell Index (FSI) of the natural soil was measured at 62.5%, confirming its highly expansive nature. With the addition of coal dust and magnesium chloride, FSI values decreased markedly, indicating enhanced dimensional stability and improved engineering performance of the treated soil.

C. Standard Proctor Compaction Test (SPCT)

Compaction test results revealed a steady increase in Maximum Dry Density (MDD) and a moderate variation in Optimum Moisture Content (OMC) as the proportion of stabilizers was increased.

Table 1: Slandered Procter test results.

Sample	**Stabilizer Type**	**% Additive**	**MDD (g/cc)**	OMC (%)
Black Cotton soil	**-**	**-**	**1.31**	**22.33**
Soil + Coal Dust	**2%**	**1.66**	**24.39**	
Soil + Coal Dust	**4%**	**1.59**	**38.28**	
Soil + Coal Dust	**6%**	**1.50**	**25.33**	
Soil + $MgCl_2$	**2%**	**1.65**	**26.88**	
Soil + $MgCl_2$	**4%**	**2.15**	**21.39**	
Soil + $MgCl_2$	**6%**	**2.37**	**19.43**	

D. California Bearing Ratio (CBR)

CBR tests were performed on both untreated and treated soil samples.

Table 2: California Bearing Ratio results

Sample	**Stabilizer Type**	**% Additive**	**CBR (%) at 2.5 mm**	**CBR (%) at 5.0 mm**
Black Cotton soil	**--**	**--**		**2.74**
Soil + Coal Dust	**2%**	**2.42**	**3.23**	
Soil + Coal Dust	**4%**	**2.58**	**3.34**	
Soil + Coal Dust	**6%**	**2.66**	**3.24**	
Soil + $MgCl_2$	**2%**	**2.61**	**3.21**	
Soil+ $MgCl_2$	**4%**	**2.83**	**3.44**	
Soil + $MgCl_2$	**6%**	**3.06**	**3.71**	

The CBR value increased from 2.26% for untreated soil to 3.71% for soil treated with 6% magnesium chloride, representing an improvement of approximately 60%. These results confirm the effectiveness of $MgCl_2$ as a chemical stabilizer and highlight the positive interaction between coal dust and the soil matrix.

IV. Conclusions

Based on the experimental investigation, the following conclusions can be made:

1. The incorporation of coal dust and magnesium chloride leads to significant improvements in the engineering properties of black cotton soil.
2. Both the liquid limit and plastic limit decreased, reflecting reduced plasticity and enhanced soil stability.
3. Maximum dry density increased from 1.31 g/cc to 2.37 g/cc, while the optimum moisture content decreased to 19.43%.

4. The CBR value increased from 2.26% for natural soil to 3.71% with 6% magnesium chloride, indicating a substantial enhancement in load-bearing capacity.
5. Coal dust and magnesium chloride are effective, sustainable stabilizers, providing a cost-efficient and environmentally friendly alternative to conventional soil stabilization materials.

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