Improving the Subgrade Soil Stability by Adding Lime Gypsum and Brick Ballast

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Abstract

Subgrade soil stability plays a crucial role in the durability and performance of road and pavement structures. Weak or unstable subgrade soil can lead to pavement failures, excessive settlements, and reduced load-bearing capacity. This study investigates the improvement of subgrade soil stability by incorporating lime, gypsum, and brick ballast in different proportions. The experimental analysis involves three mix ratios: **(6:2.5:10), (8:5:20),** and **(10:7.5:30),** where lime, gypsum, and brick ballast are added to the soil. Various geotechnical tests, including compaction and Atterberg limit tests, are conducted to evaluate the enhancements in soil consistency and plasticity characteristics. The results indicate that the addition of lime and gypsum improves soil cohesion and reduces plasticity, while brick ballast enhances soil structure by increasing particle interlocking. This study demonstrates that optimizing the mix proportions of these stabilizing agents can significantly improve the engineering properties of subgrade soil, making it a viable technique for sustainable and cost-effective soil stabilization in construction projects.

Keywords: Subgrade Soil, Soil Stabilization, Lime, Gypsum, Brick Ballast, Atterberg Limits, Soil Improvement, Pavement Performance, Engineering Properties.

1. Introduction

Subgrade soil stability is a fundamental factor in the long-term performance of roads, pavements, and other civil engineering structures. Weak or expansive subgrade soil can lead to structural failures, excessive settlements, and maintenance challenges, ultimately increasing construction and repair costs [1]. Improving the engineering properties of subgrade soil is essential for ensuring the durability and load-bearing capacity of infrastructure [2]. Soil stabilization is a widely used technique to enhance the strength and stability of weak soils by incorporating stabilizing agents [3]. Among various stabilizers, lime, gypsum, and brick ballast have proven effective in modifying soil properties [4]. Lime enhances soil strength by reducing plasticity, increasing shear strength, and promoting pozzolanic reactions that result in long-term strength gain [5]. Gypsum contributes to soil improvement by regulating moisture content and reducing soil shrinkage and expansion [6]. Brick ballast, a coarse aggregate, enhances soil stability by improving gradation, increasing interlocking between particles, and distributing loads more effectively [7].

This study aims to analyze the effects of lime, gypsum, and brick ballast on subgrade soil stability using three mix ratios**: (6:2.5:10), (8:5:20)**, and **(10:7.5:30).** Laboratory tests such as compaction and Atterberg limit tests are conducted to evaluate the impact of these additives on soil plasticity and consistency [8]. The findings of this research will provide insights into optimizing subgrade soil stabilization techniques for improved pavement performance and sustainable construction practices [9].

2. Materials and Methodology

2.1 Atterberg Limits

The Atterberg limits, including the liquid limit and plastic limit, are essential tests to evaluate the consistency and plasticity characteristics of subgrade soil. These tests were conducted as per **IS 1498** and **IS 2720 (Part 5)** standards. The liquid limit test was performed using the **Casagrande apparatus**, where the number of blows required to close the groove was recorded to determine the moisture content at which soil changes from a liquid to a plastic state. For the plastic limit test, soil samples were rolled into thin threads of **3 mm** diameter on a glass plate until they crumbled.

To assess the impact of stabilizers, lime, gypsum, and brick ballast were added in varying proportions to the soil. The changes in liquid and plastic limits were recorded to analyze improvements in soil workability and plasticity. The reduction in plasticity index due to these additives indicated a significant improvement in soil stability, making it more suitable for subgrade applications.

3. Results and Discussion

3.1 Atterberg Limits

The Atterberg limits, which include the liquid limit and plastic limit, are essential indicators of soil consistency and plasticity. These limits determine how the soil transitions between liquid, plastic, and solid states, influencing its stability as a subgrade material.

The liquid limit test was conducted to assess the moisture content at which soil changes from a liquid to a plastic state. As shown in the table, the liquid limit of the natural (unstable) soil was **39.05%.** With the addition of lime, gypsum, and brick ballast in different ratios, the liquid limit decreased progressively, reaching **25.4%** in the 3rd ratio **(10:7.5:30).** This reduction indicates an improvement in soil workability and a decrease in moisture susceptibility.

Similarly, the plastic limit measures the moisture content at which soil transitions from a plastic to a semisolid state. The plastic limit of the natural soil was **11.9%,** which increased with stabilization, reaching **19.6%** in the 3rd ratio. The increase in plastic limit, along with the decrease in liquid limit, resulted in a reduced plasticity index (PI = Liquid Limit - Plastic Limit), signifying better soil stability and reduced swelling potential.

These changes can be attributed to the flocculation and aggregation effect of lime and gypsum, which modify the soil structure by reducing clay content and enhancing soil strength. The decrease in plasticity makes the soil more suitable for construction as a subgrade, improving its load-bearing capacity and reducing shrinkswell behaviour. The vales of Atterberg Limits are given below in **Table 1:**

Table 1: Atterberg limit Values

Sample	LL	PL	PI
Expansive soil	39.05%	11.9%	27.15
1st Ratio (6:2.5:10)	33.12%	18.3%	14.82

2nd Ratio (8:5:20)	29.07%	20%	9.07
3rd Ratio (10:7.5:30)	25.4%	19.6%	5.8

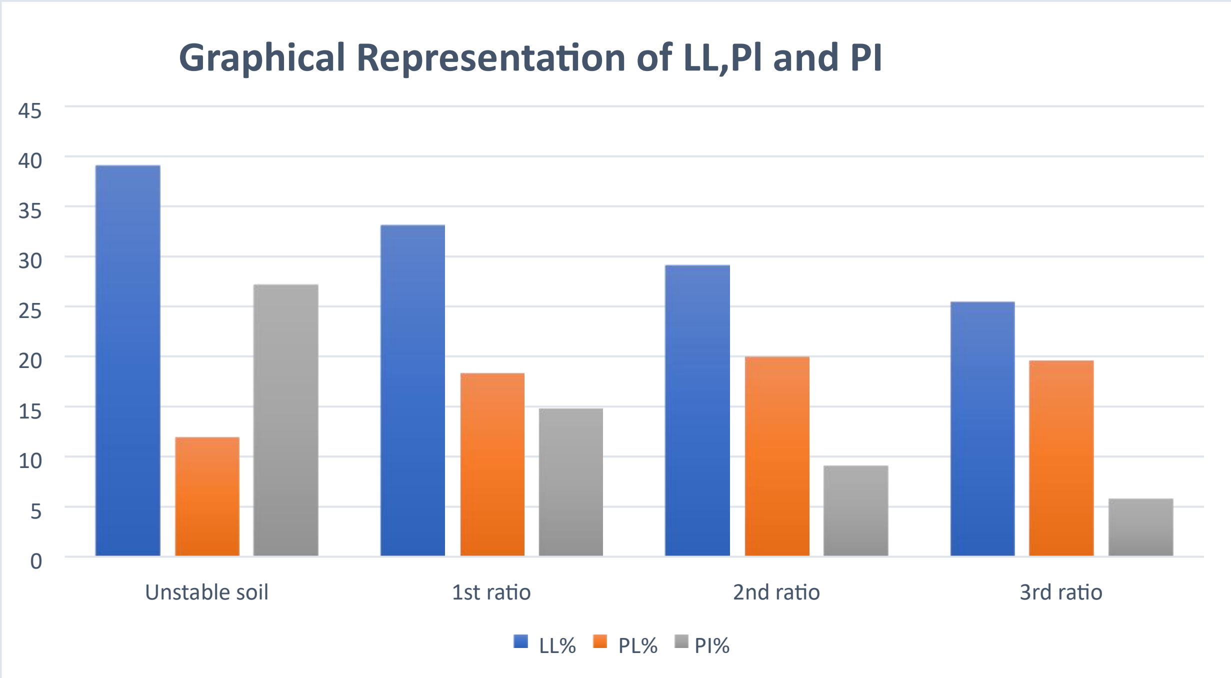

Figure 1: Graphical Representation of LL, PL and PI

4. Practical Implementation

This study focuses on improving subgrade soil stability by incorporating lime, gypsum, and brick ballast. The experimental results from the Atterberg limits test highlight the effectiveness of these stabilizing materials in enhancing soil performance.

1. Road Construction:

- Reduced plasticity and improved moisture stability from the Atterberg limits test suggest better workability and reduced shrink-swell behavior, preventing pavement failures.

2. Foundation Stabilization:

- **Lime** and **gypsum** improve soil cohesion, reducing settlement and increasing the bearing capacity of foundations.
- **Brick ballast** enhances compaction, ensuring long-term stability for structures built on expansive or weak soils.

3. **Embankments and Earthworks:**

- The **combination** of lime and gypsum minimizes water retention, reducing the risk of slope failures in embankments.

4. Airfields and Pavements:

- ✞ The improved soil properties from the Atterberg limits test contribute to better workability and long-term stability, making the stabilized soil suitable for airport runways and reducing maintenance costs.

5. Rural and Low-Cost Infrastructure:

- ✞ The use of locally available stabilizers like lime, gypsum, and brick ballast makes the technique costeffective for rural roads and low-cost housing projects.

5. Conclusion

This study confirms that incorporating lime, gypsum, and brick ballast in subgrade soil significantly enhances its engineering properties. The key findings are:

1. **Reduced Plasticity:**

   Atterberg limit results indicate a decrease in the plasticity index, making the soil more stable and less susceptible to shrinkage and swelling.

2. **Better Load-Bearing Capacity:**

   The addition of stabilizers improves soil gradation, interlocking, and overall structural integrity.

3. **Sustainable and Cost-Effective Solution:**

   The method uses locally available materials, making it an affordable and practical solution for construction projects.

These enhancements make stabilized subgrade soil a viable option for infrastructure development, ensuring durability and sustainability in road construction, foundations, embankments, and pavements.

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