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International Journal of Recent Advances in Engineering and Technology

ISSN: 2347-2812
Volume 14 Issue 01, 2025

Effect of fly ash on the consistency of black cotton soil

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Peer Review Information

Submission: 29 Jan 2025
Revision: 04 March 2025
Acceptance: 10 April 2025

Keywords

Shrinkage Index
Plasticity Index
Black Cotton Soil

Abstract

This research investigates the effect of fly ash on the consistency of black cotton (BC) soil. The study aims to improve the soil's plasticity characteristics by incorporating different percentages of fly ash and examining the results through the Atterberg limits test. Fly ash procured from the Koradi thermal power station, categorized as F-type, was added to BC soil in proportions of 5%, 10%, 15%, and 20%. The soil samples underwent testing before and after adding fly ash, followed by 7-day and 14-day curing periods. The results showed a notable enhancement in the soil's plasticity index (PI) and Shrinkage Index with the increasing percentage of fly ash. The most notable enhancement was observed at 20% fly ash content after 14 days of curing, where the plasticity index improved substantially. This improvement indicates that adding fly ash effectively stabilizes black cotton soil, enhancing its suitability for construction and geotechnical applications. The study highlights the potential of utilizing industrial by-products like fly ash to improve problematic soils, promoting sustainable construction practices and efficient waste management.

INTRODUCTION

Black cotton soil, known for its expansive nature and high plasticity, poses significant challenges in construction due to its susceptibility to volume changes with moisture variations. These changes in consistency, swelling when wet and shrinking when dry, often lead to structural damage, cracks, and instability in civil engineering projects. Soil stabilization techniques are necessary to mitigate these issues. One such approach is fly ash, a byproduct of coal combustion, which has shown promising results in enhancing the properties of black cotton soil. As a pozzolanic material, fly ash reacts with the soil's components to form stable compounds, improving the soil's consistency. By reducing black cotton soil's plasticity and swelling potential, fly ash helps make the soil more stable and suitable for construction. This project aims to study the effect of fly ash on the consistency of black cotton soil, focusing on its impact on the soil's plastic and liquid limits, shrinkage limits, and overall stability. Through this investigation, we seek to determine how fly ash can be utilized to improve the engineering properties of black cotton soil, providing a sustainable solution for construction on expansive soils.

Advantages of soil stabilization:

- Improved Soil Stability
- Cost-Effective Solution
- Eco-Friendly
- Easier for Construction
- Long-Term Durability

AIM AND OBJECTIVE OF THE STUDY

Aim: This project explores the impact of fly ash on the consistency of black cotton soil and examines how its addition enhances the soil's engineering properties, improving stability and suitability for construction.

Objective:

- **Analyze untreated black cotton soil's physical and chemical properties**, including its consistency limits (liquid, plastic, and shrinkage limits).
- **Determine the effects of different proportions** of fly ash on the consistency of black cotton soil by conducting laboratory tests, such as Atterberg limits and compaction tests.
- **Evaluate the reduction in plasticity** and swelling potential of black cotton soil after adding fly ash.
- **Investigate the pozzolanic reaction** between fly ash and black cotton soil and its contribution to soil stabilization.
- **Identify the optimal percentage of fly ash** required to significantly improve soil consistency and overall behavior.
- **Assess the practicality and cost-effectiveness** of using fly ash for black cotton soil stabilization in construction projects.

MATERIAL

Black Cotton Soil: Black Cotton Soil, also known as Regur Soil, is a clay-rich soil found in regions like India. It is dark in color and has a smooth texture. This soil is known for its tendency to expand when wet and shrink when dry, which can cause cracks in buildings and roads. It has high plasticity, meaning it can be easily molded when wet, but it becomes difficult to work with during construction due to its volume changes. Black cotton soil is fertile and suitable for farming, especially for crops like cotton. However, it needs to be stabilized using materials like fly ash or lime to reduce its shrink-swell behavior and improve its strength for construction.

Fly Ash: A fine, powdery substance produced as a byproduct of coal incineration in power plants. It is collected from the flue gases produced during the combustion process. Fly ash is rich in minerals like silica, alumina, and iron, which can be used to improve the properties of soil and concrete. In construction, fly ash is often added to soil, like black cotton soil, to stabilize it by reducing its plasticity and improving its strength and durability. It also helps with waste management by recycling industrial byproducts. Fly ash is considered an eco-friendly and cost-effective solution for enhancing the quality of construction materials.

Virgin Fly Ash is collected from Koradi Power Plant. It is a fine powder produced from burning coal in thermal power stations. It mainly contains silica, alumina, and iron oxides, which help improve soil properties.

Physical Properties:

- Light to dark grey in color
- Very fine, like dust or powder
- Small, round particles that help mix well with soil
- Lighter than normal soil particles

Chemical Properties:

- Contains silica and alumina, which react with lime to make soil stronger
- Has low carbon, making it better for construction use
- Can be of two types:
- Class F (low calcium, mostly from burning hard coal)
- Class C (high calcium, from soft coal, and can harden on its own)

Engineering Properties:

- Makes Black Cotton Soil stronger and more stable
- Reduces how much the soil swells when wet
- Helps in better soil compaction and reduces cracks

Experimental Programme:

This experiment aims to observe how adding fly ash (a waste product from power plants) changes the consistency and behavior of Black Cotton Soil (BCS). We'll focus on the Liquid Limit, Plastic Limit, Plasticity Index, and Shrinkage Limit to see how fly ash affects the soil.

Sample Preparation:

1. Soil Collection: BCS is collected and tested for its basic properties.
2. Fly Ash: Collected from a power plant and tested.
3. Mixing Proportions: Fly ash is added to the BCS in 5%, 10%, 15%, and 20% proportions by weight.

EXPERIMENT STEPS

1. Mixing Soil and Fly Ash

- Take 500 grams of BCS.
- Add fly ash (5%, 10%, 15%, and 20%).
- Mix thoroughly and add water slowly until the mixture reaches the desired consistency for testing.

2. Liquid Limit Test:

- Use the Casagrande device to determine the Liquid Limit (the water content at which the soil is sufficiently fluid flow when the device is given 25 blows.
- Repeat the test to determine the number of blows needed to close a groove in the soil.

3. Plastic Limit Test:

- Roll the soil mixture into thin threads on a glass plate.
- Find where the soil crumbles when rolled into a 3mm diameter thread. This is the Plastic Limit.

4. Shrinkage Limit Test:

- Take a sample of soil and dry it in an oven.
- Measure the volume of the soil before and after drying.
- The Shrinkage Limit is defined as the highest water content at which further reduction does not significantly decrease the volume of the soil mass.

This helps determine how much the soil shrinks when it dries out, which is vital for construction projects to understand soil behavior in dry conditions.

5. Plasticity Index:

- Calculate the PI using the formula:
- PI = Liquid Limit - Plastic Limit
-

What to Observe:

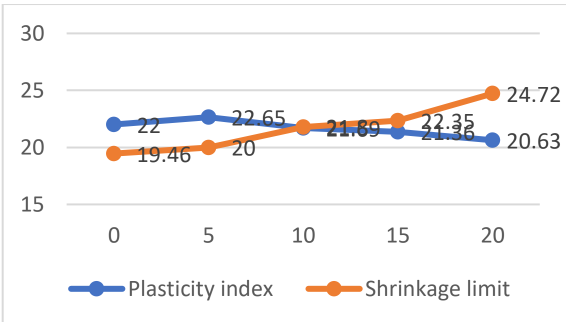
- Liquid Limit: Tells us how much water the soil can hold before it changes consistency.
- Plastic Limit: Tells us the moisture content where the soil becomes workable.
- Plasticity Index: A lower PI indicates less expansion and contraction of the soil with moisture changes, which is better for construction.
- Shrinkage Limit: The moisture content at which the soil stops shrinking further, helping to predict how much the soil will shrink in dry conditions.

DATA ANALYSIS

The data analysis in this study focuses on how the consistency limits (liquid limit, plastic limit, plasticity index, and shrinkage limit) of black cotton soil change when mixed with different percentages of fly ash (5%, 10%, 15%, and 20%).

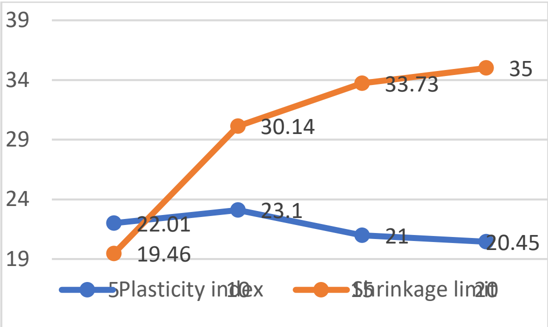
7 Days

Fly ash %	Liquid limit %	Plastic limit %	Plasticity index%	Shrinkage limit%
0	58	36	22	19.46
5	55	32.35	22.65	20
10	44	22.31	21.69	21.8
15	43	21.64	21.36	22.35
20	46	25.37	20.63	24.72



14 Days

Fly ash %	Liquid limit %	Plastic limit %	Plasticity index%	Shrinkage limit%
5	58	35.99	22.01	19.46
10	55	31.9	23.1	30.14
15	51	30	21	33.73
20	50	23.06	20.45	35



This section analyzes how the plastic limit, liquid limit, plasticity index, and shrinkage limit of black cotton soil change after 7 days and 14 days with different percentages of fly ash (5%, 10%, 15%, and 20%). The study helps determine increase or decrease in Plasicity index and Shrinkage Limit for improving soil stability, reducing shrink-swell behavior, and making it more suitable for construction and the results help assess the long-term impact of fly ash on soil stability and its suitability for construction.

CONCLUSION

The addition of fly ash to black cotton (BC) soil significantly influences its plasticity and shrinkage behavior over curing periods of 7 and 14 days. As the percentage of fly ash increases from 0% to 20%, the plasticity index decreases, while the shrinkage limit increases, indicating an improvement in soil properties due to fly ash stabilization.

At 7 days of curing: Plasticity index decreased from 22 (0% fly ash) to 20.63 (20% fly ash).Shrinkage limit increased from 19.46% (0% fly ash) to 24.72% (20% fly ash).

This indicates a reduction in soil plasticity and an enhancement in its resistance to volume change upon drying.

At 14 days of curing: Plasticity index decreased from 22.01 (5% fly ash) to 20.45 (20% fly ash).Shrinkage limit increased significantly from 19.46% (5% fly ash) to 35% (20% fly ash).

This shows a continuous improvement in soil behavior with extended curing, especially in terms of shrinkage control.

Overall, increasing fly ash content up to 20% leads to a 6.23% reduction in plasticity index and a 27% increase in shrinkage limit at 7 days, and a 7.05% reduction in plasticity index and a 79.93% increase in shrinkage limit at 14 days. These results confirm that fly ash is effective in improving the engineering properties of BC soil, especially with increased curing time.

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