International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 05 | May 2025 www.irjet.net p-ISSN: 2395-0072

Enhancing the Engineering Properties for Stabilizing Soil

Bibek Bhandari

Undergraduate Student, Civil Engineering Department
Oxford College of Engineering and Management, Nepal

Abstract - *Soil stabilization is a crucial process in geotechnical engineering, significantly enhancing the strength, durability, and workability of soil used in construction. This study investigates the effect of using fly ash as a stabilizing agent in soil to improve its engineering properties. The research involved collecting soil samples from a depth of 18 inches and mixing them with fly ash in different proportions (0%, 7%, 14%, 21%, and 28%). A series of laboratory tests, including Specific Gravity Test, Standard Proctor Test, Unconfined Compression Strength (UCS) Test, and California Bearing Ratio (CBR) Test, were conducted to determine the optimum percentage of fly ash that enhances soil strength and stability. The results indicate that 21% fly ash addition yielded the highest compressive strength (412 kN/m²) and optimal CBR value (6.76%), making it the most suitable mix for soil stabilization. This research confirms that fly ash is a viable solution for improving soil performance while simultaneously contributing to sustainable construction by utilizing industrial by-products.*

Key Words: Soil Stabilization, Fly Ash, California Bearing Ratio, Standard Proctor Test, Unconfined Compression Strength, Sustainable Construction

1. INTRODUCTION

Soil is a fundamental element in civil engineering, forming the foundation of roads, buildings, bridges, and other infrastructure projects [1]. However, its natural properties—such as swelling, shrinkage, and low bearing capacity—can significantly affect structural stability. Soil stabilization techniques are widely adopted to address these issues by improving the mechanical and physical characteristics of soil [2].

Among various soil stabilizing materials, fly ash has gained prominence due to its availability, cost-effectiveness, and environmental benefits [3]. Fly ash is a fine by-product of coal combustion, often utilized as an additive to improve soil cohesion, reduce permeability, and increase strength [4]. This research aims to evaluate the effect of different proportions of fly ash on soil stability, with a particular focus on unconfined compression strength UCS and CBR values. By determining the optimal percentage of fly ash for stabilization, this study seeks to provide a sustainable and effective approach to improving soil quality in construction applications.

2. LITERATURE REVIEW

The concept of soil stabilization through the use of industrial waste materials has been extensively explored in past studies. Researchers have widely acknowledged the value of fly ash due to its abundant availability, cost-effectiveness, and positive impact on the environment. Fly ash serves as a supplementary cementitious material that, upon mixing with soil, undergoes a pozzolanic reaction leading to the formation of calcium silicate hydrates, which improve the soil's binding characteristics. Senol et.al (2002) emphasized that fly ash, especially Class F type, significantly improves the strength and durability of soft soils when used in appropriate quantities [5]. Ji-ru & Xing (2002) highlighted that combining fly ash with lime yields even better stabilization results, particularly for expansive soils [6]. Furthermore, studies by Zha et.al (2008) demonstrated that fly ash reduces the plasticity index and improves the workability of clayey soils [7].

3. OBJECTIVES OF THE WORK

The primary objective of the research was to assess and enhance the engineering behavior of natural soil using fly ash as a stabilizing additive.

- To determine the optimal percentage of fly ash that offers the highest strength and stability.
- To analyze the effect of fly ash on properties such as specific gravity, moisture content, dry density, compressive strength, and bearing capacity.
- To contribute to sustainable engineering by utilizing industrial by-products in civil infrastructure.

4. METHODOLOGY

The research commenced with an extensive theoretical review, aimed at understanding various soil stabilization techniques and the role of fly ash in modifying soil behavior. Multiple sources including academic journals, dissertations, engineering standards, and textbooks were studied to acquire the foundational knowledge necessary for the experiments.

For practical experimentation, soil samples were collected from a depth of 18 inches below the surface using manual excavation tools. This depth was chosen to obtain undisturbed soil with more consistent properties, as upper layers are often loose and contaminated. Fly ash was procured from a local industrial source and thoroughly dried before use.

Five distinct soil samples were prepared by mixing soil with fly ash in varying percentages: 0% (control), 7%, 14%, 21%, and 28%. Each mixture was then subjected to a series of laboratory tests as per Indian Standard Codes.

The Specific Gravity Test was conducted using the density bottle method, where oven-dried soil was weighed before and after adding water to determine the specific gravity. Next, a Standard Proctor Test was (SPT) performed on compacted samples to find the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). These values allow the determination of the best moisture condition for maximum compaction in the field.

Next, cylindrical specimens were tested in UCS tests to examine the axial load bearing capacity of each mix without lateral confinement. CBR tests were finally performed on soaked samples to simulate the real world subgrade conditions. The samples were submerged for 96 hours and then penetration resistance was measured at 2.5 mm and 5 mm depths to calculate the CBR values.

5. RESULTS AND DISCUSSION

The results of the tests showed that the behavior of soil with different levels of fly ash content was quite obvious. For the Specific Gravity Test, untreated soil had a value of 2.62 and at 28% fly ash it was 2.79, which means that the fine and dense particles of fly ash marginally increased the specific gravity.

The SPT indicated that as the percentage of fly ash increased, the Optimum Moisture Content also increased, with a maximum of 12.34% recorded at 28% fly ash. Conversely, the Maximum Dry Density decreased from 2.25 gm/cc to 1.88 gm/cc, likely due to the lighter nature of fly ash compared to natural soil.

In terms of strength, the UCS peaked at 412 N/m^2 with 21% fly ash content. The initial strength of untreated soil was only 218 N/m^2, demonstrating a significant improvement. However, further increase beyond 21% resulted in a slight decrease, suggesting that excess fly ash reduces cohesion.

Similarly, the California Bearing Ratio showed the best result at 21% fly ash with a value of 6.76%, surpassing the baseline value of 4.02% for untreated soil. Penetration resistance decreased at 28% fly ash, which aligns with the behavior observed in UCS testing.

The results confirm that while fly ash improves soil performance, there exists a threshold beyond which additional fly ash may become counterproductive. The optimum value of 21% not only provided superior strength and compaction but also aligned with economic and sustainability considerations.

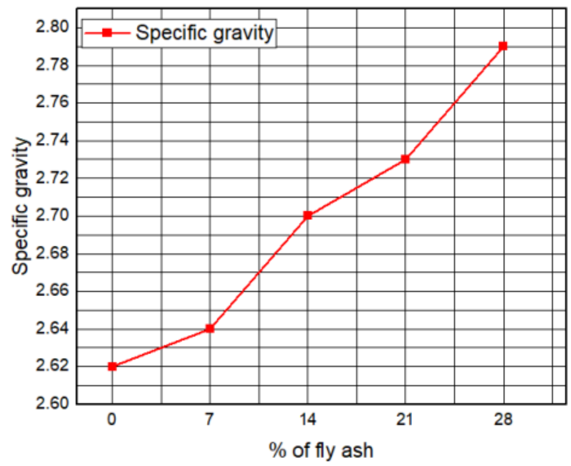

Chart -1: specific gravity with or without additives-fly-ash

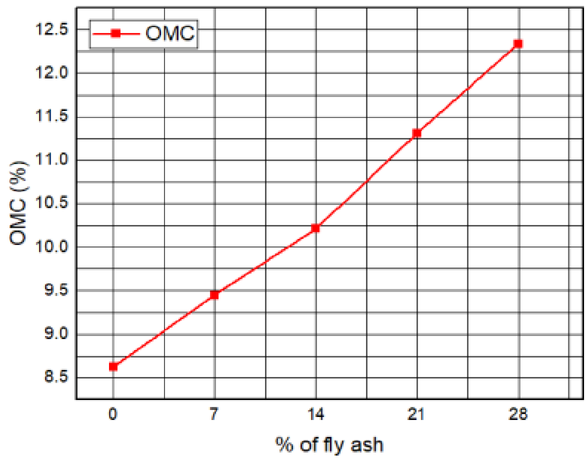

Chart -2: OMC with or without additives-fly-ash

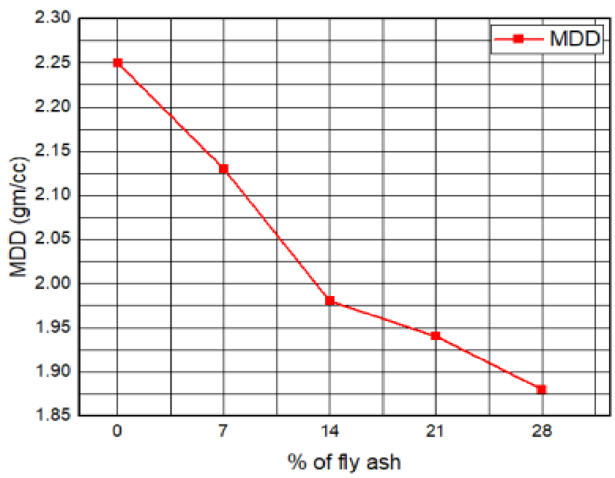

Chart -3: MDD with or without additives-fly-ash

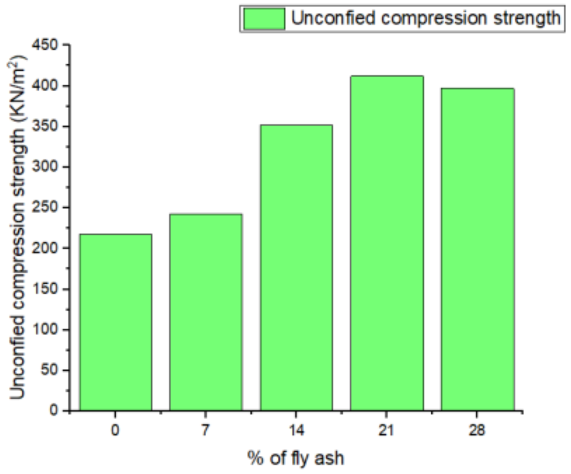

Chart -4: UCS with or without additives-fly ash

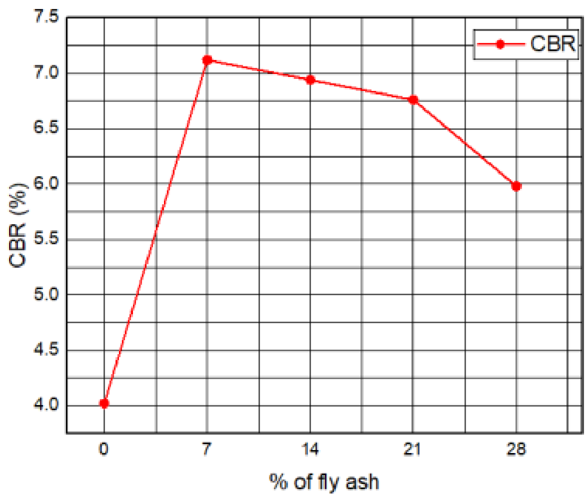

Chart -5: UCS with or without additives-fly-ash

6. CONCLUSIONS

The study successfully demonstrated that the inclusion of fly ash significantly enhances the geotechnical properties of natural soil. The most favorable results were achieved at 21% fly ash content, where the soil displayed maximum compressive strength and improved bearing capacity. Beyond this proportion, the benefits diminished slightly, confirming the need for optimization in additive use.

In addition to technical performance, the study supports the sustainable reuse of fly ash, an industrial by-product, thus aligning with environmental objectives in civil engineering. The findings of this research offer practical insights for future projects involving subgrade preparation and ground improvement, especially in regions where soil quality is a limiting factor.

REFERENCES

[1] Lambe, T. W., & Whitman, R. V. (1991). Soil mechanics. John Wiley & Sons.

[2] Little, D. N., & Nair, S. (2009). Recommended practice for stabilization of subgrade soils and base materials.

[3] Upadhyay, A., & Kamal, M. (2007). Characterization and utilization of fly ash (Doctoral dissertation).

[4] Jegandan, S., Liska, M., Osman, A. A., & Al-Tabbaa, A. (2010). Sustainable binders for soil stabilisation. Proceedings of the Institution of Civil Engineers-Ground Improvement, 163(1), 53-61.

[5] Senol, A., Bin-Shafique, M. S., Edil, T. B., & Benson, C. H. (2002, September). Use of class C fly ash for stabilization of soft subgrade. In Fifth international congress on advances in civil engineering (pp. 25-27). Istanbul, Turkey: Istanbul Technical University.

[6] Ji-ru, Z., & Xing, C. (2002). Stabilization of expansive soil by lime and fly ash. Journal of Wuhan University of Technology-Mater. Sci. Ed., 17(4), 73-77.

[7] Zha, F., Liu, S., Du, Y., & Cui, K. (2008). Behavior of expansive soils stabilized with fly ash. Natural hazards, 47, 509-523.