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ENGINEERING PERFORMANCE OF CEMENT-STABILIZED SOFT CLAY SUBGRADES IN THE KATHMANDU VALLEY

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ABSTRACT

This study evaluates the effectiveness of cement-based pozzolanic stabilization in improving the geotechnical properties of soft clay subgrade soils collected from Sanepa and Sankhamul in the Kathmandu Valley. These soils exhibit high plasticity, low bearing capacity, and poor California Bearing Ratio (CBR) values, making them unsuitable for direct use as pavement subgrade materials. Conventional construction practices in the region commonly involve soil replacement or lime stabilization; however, these approaches often result in increased construction costs, material transportation requirements, and environmental impacts.

To address this engineering problem, laboratory investigations were conducted by stabilizing the soils with Ordinary Portland Cement at proportions of 4%, 6%, 8%, and 10% by dry weight of soil. The influence of cement stabilization on key geotechnical parameters including Atterberg limits, compaction characteristics, unconfined compressive strength (UCS), soaked California Bearing Ratio (CBR), and swelling potential was evaluated under different curing durations.

The results indicate substantial improvement in the engineering behavior of the soils following cement stabilization. Regression analysis and three-dimensional response surface plots further illustrate the combined influence of cement dosage and curing period on strength development. The analysis indicates that cement contents between 6% and 8% provide the most efficient balance between strength improvement and material economy.

The findings highlight the technical feasibility of cement stabilization for improving soft clay subgrades in the Kathmandu Valley and contribute experimental data that may support the development of locally relevant design guidelines for stabilized road subgrades.

1. INTRODUCTION

Soil stabilization is a widely adopted geotechnical technique used to improve the engineering behavior of weak or problematic soils so that they can meet the requirements for construction and infrastructure development. The process involves modifying the physical and mechanical properties of soil through the addition of stabilizing agents, resulting in improved strength, stiffness, and durability. Among the various stabilization methods, cement stabilization has gained significant attention due to its ability to produce substantial improvements in soil strength, reduce plasticity, and enhance long-term durability through hydration and pozzolanic reactions.

Soft clay soils are commonly encountered in many urban regions and often exhibit unfavorable engineering properties such as high plasticity, excessive compressibility, low bearing capacity, and significant moisture sensitivity.

Cement stabilization has been widely applied in many countries as an effective technique for improving weak subgrade soils. The addition of Ordinary Portland Cement (OPC) initiates hydration and pozzolanic reactions that bind soil particles together, resulting in increased strength and reduced plasticity and swelling potential. As a result, key geotechnical parameters such as Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) are significantly enhanced. These improvements contribute to better load-bearing capacity and long-term pavement performance.

In Nepal, however, road construction in areas with weak subgrade soils commonly relies on traditional approaches such as soil replacement or the use of capping layers. Although these methods can improve subgrade performance, they often involve high construction costs, transportation of large quantities of materials, and environmental impacts associated with the disposal of excavated soils performance enhancement for road subgrade applications.

2. MATERIALS AND METHODOLOGY

This chapter describes the materials, experimental procedures, and laboratory testing methods used to evaluate the performance of cement-stabilized soft clay soils. The methodology was designed to ensure reproducibility and to comply with recognized geotechnical testing standards. The procedures include site selection, soil sampling, sample preparation, cement mixing, curing conditions, and laboratory testing of stabilized and untreated soil samples.

Study Area

The study focuses on soft clay soils collected from selected locations within the Kathmandu Valley, where weak subgrade conditions frequently affect road performance.

Site Selection

Two locations were selected for soil sampling based on observed pavement distress, accessibility, and the presence of soft subgrade soils.

- **Sanepa, Lalitpur –** an active road construction site where subgrade soil was exposed during pavement works.
- **Sankhamul, Kathmandu –** a building construction site with exposed natural clay layers representative of local subgrade soils.

METHODOLOGY

The methodology adopted in this research consists of a systematic experimental program designed to evaluate the influence of cement stabilization on the engineering properties of soft clay soils. The methodology includes site selection, soil sampling, laboratory testing of natural soils, preparation of stabilized soil mixtures, curing procedures, and evaluation of strength and compaction characteristics.

3.RESULTS AND DISCUSSION

This chapter presents and interprets the results of laboratory testing conducted on both untreated (natural) soils and cement-stabilized soil mixtures collected from two locations in the Kathmandu Valley. The primary objective of the analysis is to evaluate the effectiveness of cement stabilization in improving the engineering properties of soft clay subgrade soils.

Laboratory testing was carried out on disturbed soil samples collected from two locations: Sanepa and Sankhamul, both situated within the central basin of the Kathmandu Valley. These areas are characterized by deposits belonging to the Kalimati Formation, which consists primarily of soft lacustrine clay with high moisture content and low bearing capacity.

The laboratory tests included:

- Specific gravity
- Grain size distribution
- Atterberg limits
- Compaction characteristics (MDD and OMC)
- California Bearing Ratio (CBR)
- Unconfined Compressive Strength (UCS)

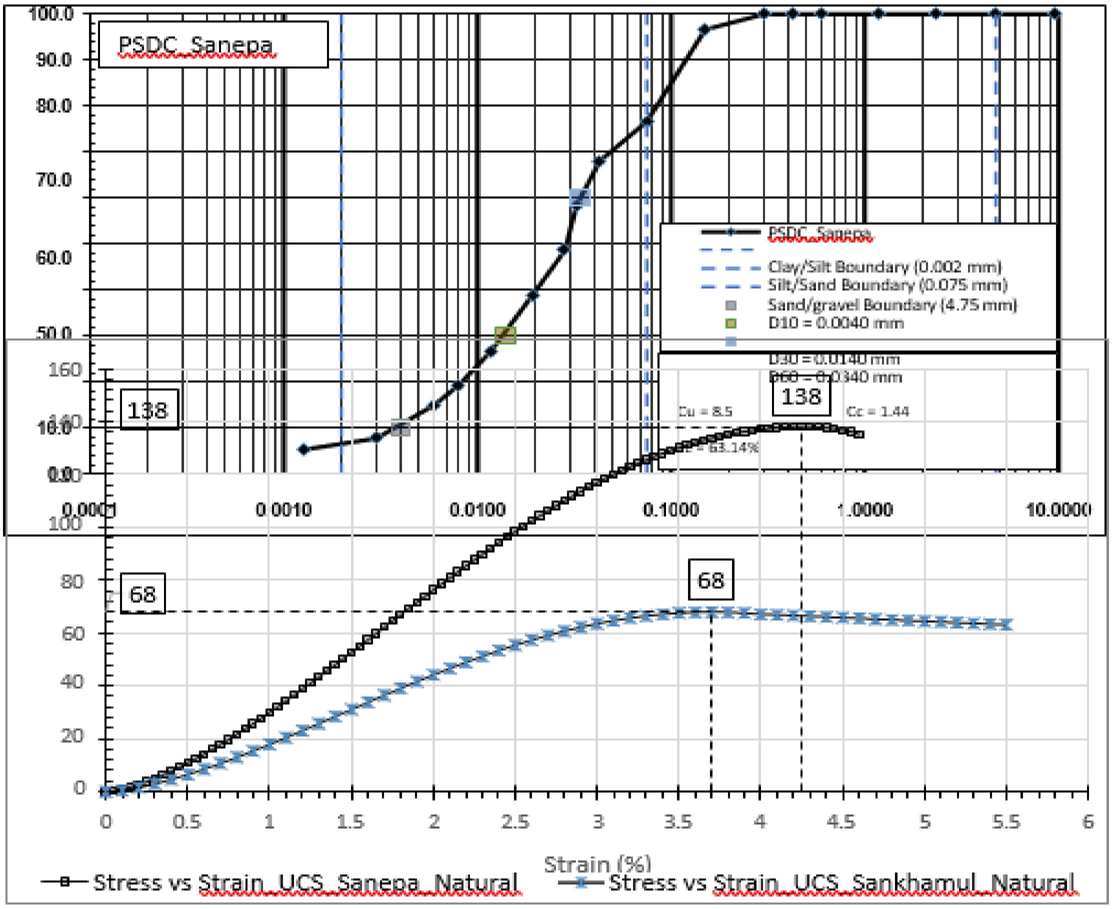
Table 3 Physical of Natural Soil (Without cement stabilization)

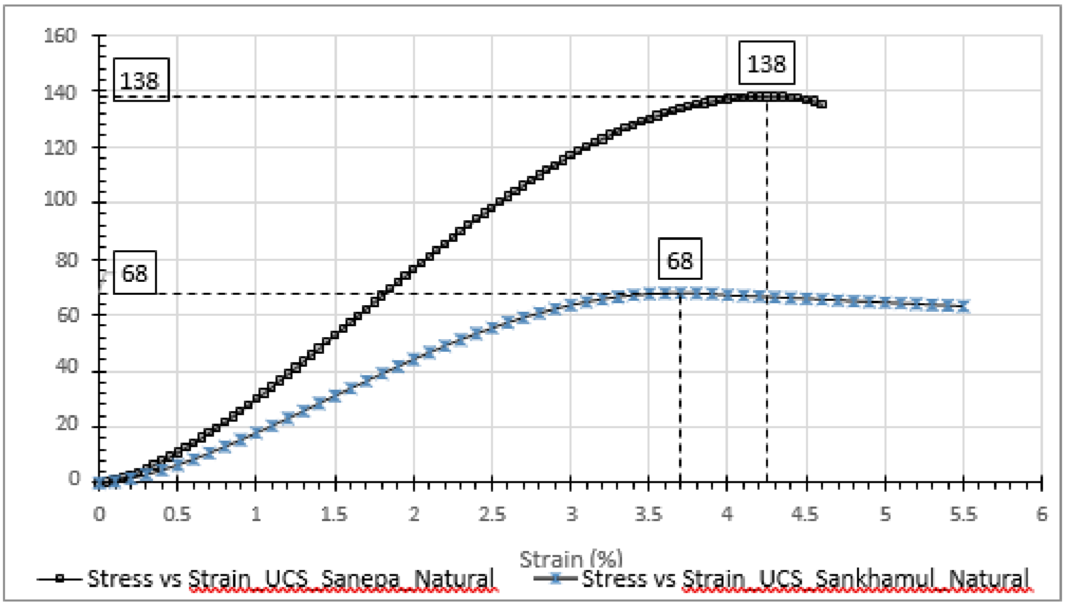
S.N.	Property	Sanepa Soil	Sankhamul Soil
1	Specific Gravity	2.58	2.61
2	Liquid Limit (%)	63.14	43.25
3	Plastic Limit (%)	35.12	21.45
4	Plasticity Index (%)	28.02	21.80
5	Classification of Soil (USCS)	CH	CL
6	Optimum Moisture Content, OMC (%)	33.4	28.4
7	Maximum Dry Density, MDD (g/cm³)	1.406	1.397
8	Swell (%)	0.73	0.67
9	CBR @ 95% MDD (Soaked) (%)	1.237	1.682
10	Unconfined Compressive Strength, UCS (kPa)	138	68

From an engineering perspective, these characteristics indicate:

- Difficulty in achieving high field compaction
- Increased susceptibility to **post-construction settlement**
- Higher sensitivity to **construction moisture variations**

Therefore, strict moisture control during construction would be required if these soils were used in





RESULT AND DISCUSSION OF CEMENT-STABILIZED SOILS

Since the untreated soils from both sites did not satisfy the minimum California Bearing Ratio (CBR) requirement for subgrade applications according to Department of Roads (DOR) standards, cement stabilization was adopted to improve their engineering performance. Cement was incorporated at different dosages (4%, 6%, 8%, and 10% by dry weight of soil) to investigate its influence on the physical and mechanical properties of the soil.

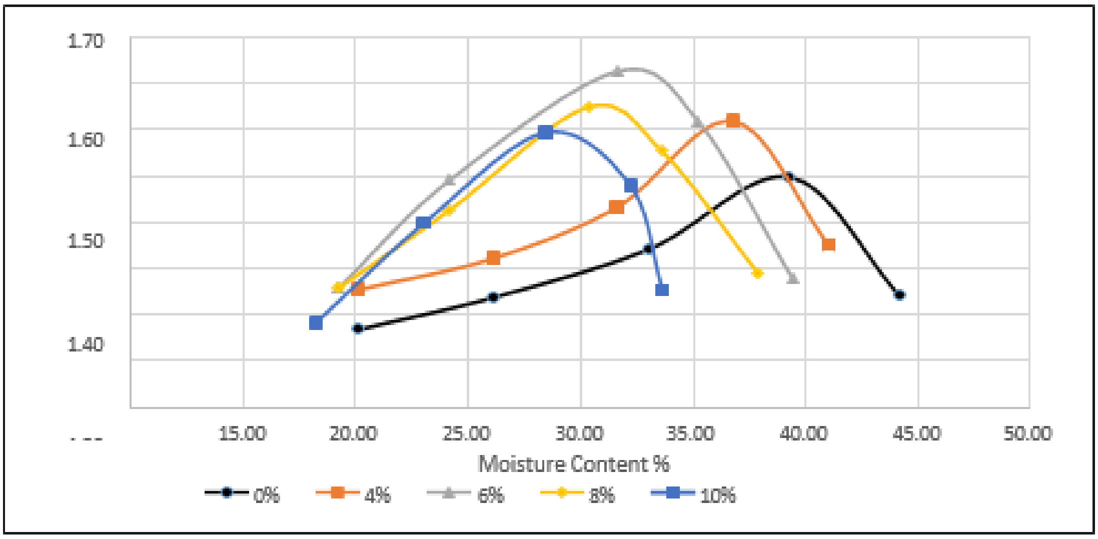


Figure: Moisture Density Relation for different cement content for Sanepa Soil

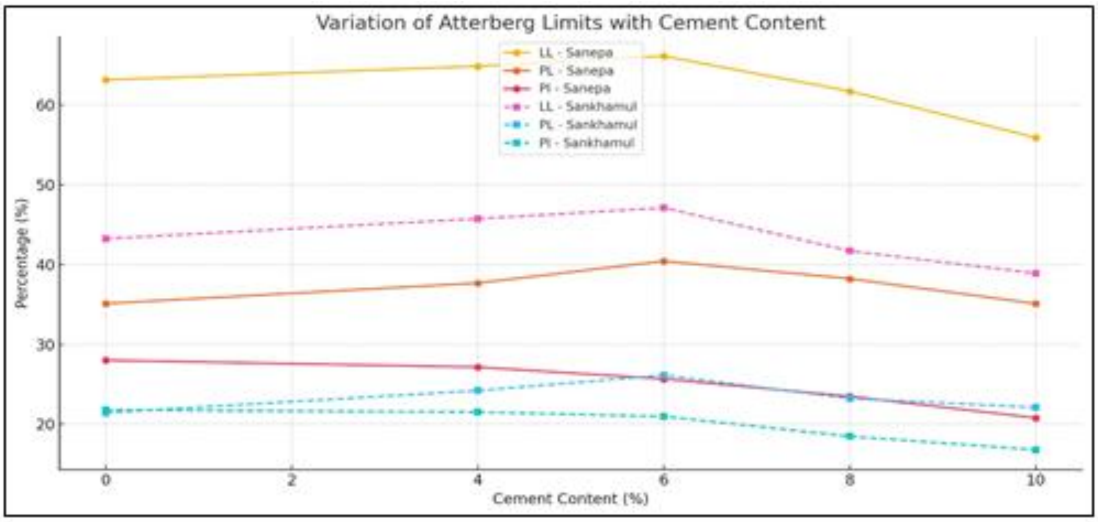


Figure: Comparative graph showing the variation of LL, PL, and PI with cement content for both soils.

4. CONCLUSION

This research evaluated the effectiveness of cement stabilization in improving the engineering performance of weak subgrade soils collected from the Sanepa and Sankhamul areas of Kathmandu Valley. The investigation focused on determining the optimum cement dosage required to enhance soil strength, reduce plasticity, and improve bearing capacity for pavement subgrade applications.

Based on the experimental findings and analytical evaluation, the following conclusions are drawn:

1. Unsuitability of Natural Soils for Subgrade Use
2. The natural soils from both locations exhibit high plasticity, low strength, and extremely low bearing capacity.
3. Effectiveness of Cement Stabilization
4. Cement stabilization significantly enhanced the geotechnical properties of both soils.
5. Reduction in Plasticity and Improved Soil Structure
6. The addition of cement resulted in a consistent reduction in the Plasticity Index (PI) for both soils.
7. Improvement in Compaction Characteristics
8. The Maximum Dry Density (MDD) increased with cement addition up to approximately 6% cement content, after which a slight reduction was observed.
9. Significant Strength Development with Cement and Curing Time

10. Unconfined Compressive Strength increased substantially with both cement dosage and curing duration, demonstrating the progressive formation of cementitious bonds within the soil matrix.
11. Substantial Improvement in Bearing Capacity
12. Soaked CBR values increased dramatically after stabilization. The CBR values increased from 1.24% to 21.27% for Sanepa soil and from 1.68% to 24.73% for Sankhamul soil, far exceeding the minimum subgrade requirements for flexible pavement design.
13. Reduction in Swelling Potential
14. Swelling potential decreased significantly with increasing cement content, reaching 0.03% for Sanepa and 0.02% for Sankhamul soils at 10% cement.
15. Optimal Cement Content for Practical Application
16. Although strength continued to increase with higher cement content, the rate of improvement diminished beyond 8% cement.
17. Engineering Implications for Pavement Design
18. The results demonstrate that cement stabilization can effectively convert marginal clay soils into suitable subgrade materials, reducing the need for soil replacement or thick pavement layers.

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