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Multivariate Experimental Investigation of Impacts of Using Waste Glass on Physical & Mechanical Properties of Clayey Soil

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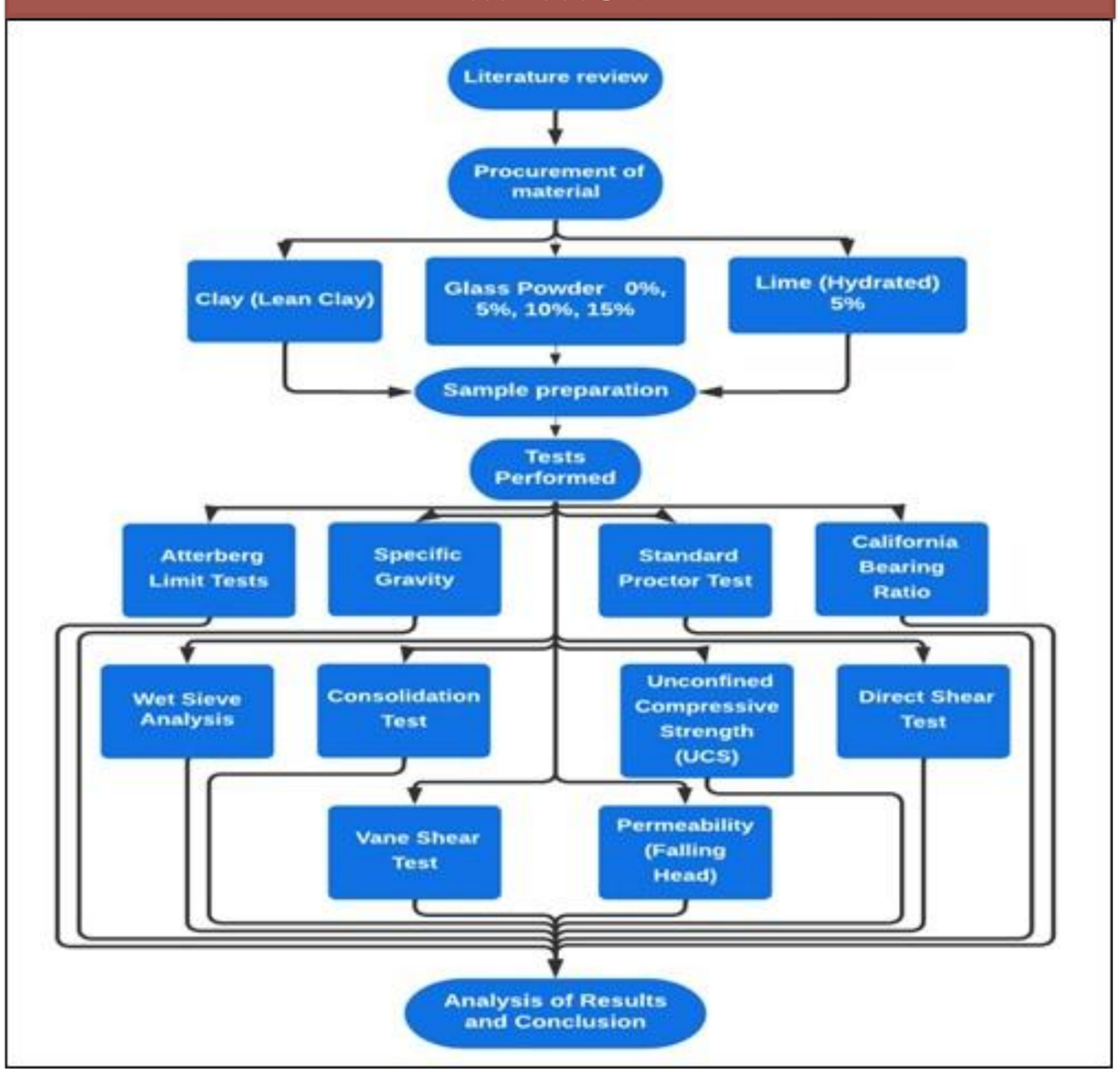
INTRODUCTION & AIM

This research investigates the use of waste glass powder (GP) as a sustainable additive to improve the engineering properties of clayey soil, in combination with lime. The study was driven by the need to find practical uses for non-biodegradable waste glass and to enhance the undesirable characteristics of clay soils, such as poor load-bearing capacity and low shear strength, which make them challenging for construction.

The primary aim was to determine the optimum percentage of GP that, when mixed with a fixed 5% lime content, would most effectively enhance the soil's physical and mechanical properties. An extensive laboratory testing program was conducted on soil samples with GP contents of 0%, 5%, 10%, and 15%. The key objective was to identify the mix design that yields the best improvement in critical properties like unconfined compressive strength, shear strength, and permeability, while also assessing the environmental benefits of reusing this waste material.

METHOD



the research followed a structured, multi-stage experimental process. It began with a literature review and procurement of materials, specifically lean clay, hydrated lime (fixed at 5%), and waste glass powder (varied at 0%, 5%, 10%, and 15%). The core of the investigation involved preparing samples with these mix designs and subjecting them to a comprehensive suite of nine standardized ASTM tests. These tests were designed to evaluate a wide range of physical and mechanical properties, including strength, compaction, and permeability, to thoroughly analyze the effects of the glass powder additive on the clayey soil.

RESULTS & DISCUSSION

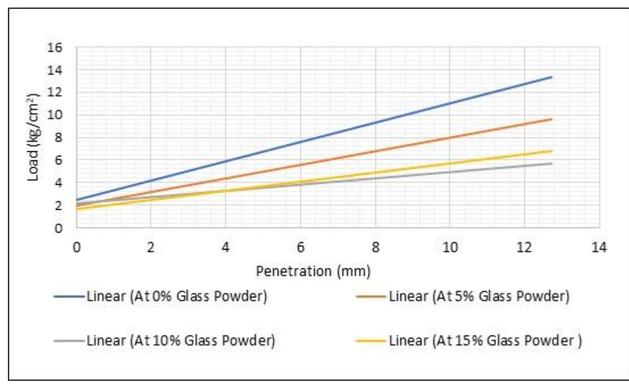
The experimental results demonstrate that the addition of glass powder (GP) significantly enhances key mechanical properties of the lime-stabilized clayey soil, with an optimum performance observed at 10% GP content.

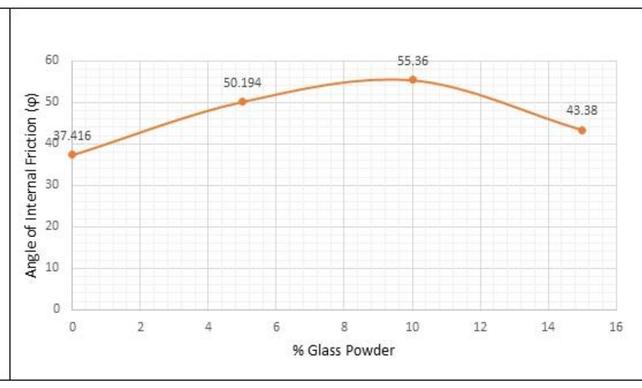
The most substantial improvement was in shear strength parameters. The Direct Shear Test (Figure 7) revealed that the angle of internal friction (φ) increased markedly from 37.4° (0% GP) to a peak of 55.4° at 10% GP before declining at 15%. This indicates that GP particles improve soil stability by providing better interlocking and friction. Consequently, the Unconfined Compressive Strength (UCS) showed a consistent positive trend, rising from 1.89 kg/cm² to 3.02 kg/cm² as GP increased to 15%. This confirms a significant enhancement in the soil's load-bearing capacity under static loading.

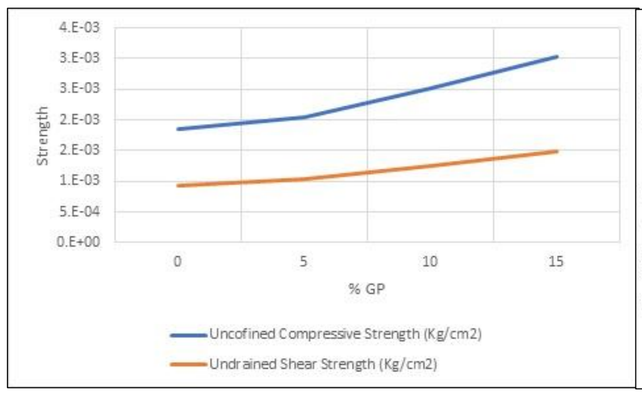
Furthermore, the permeability (Figure 12) improved slightly but consistently with higher GP percentages, suggesting enhanced drainage characteristics—a beneficial outcome for clay soils. The Standard Proctor Test results showed that the Maximum Dry Density was highest at 10% GP, achieved with a lower Optimum Moisture Content, implying more efficient compaction.

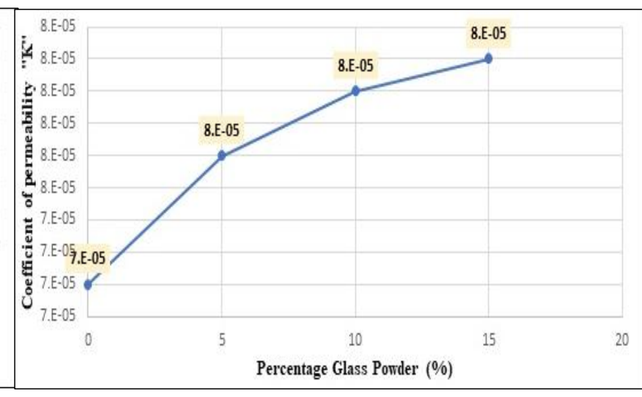
However, not all results were positive. The California Bearing Ratio (CBR), a key metric for pavement subgrades, exhibited a clear declining trend with the addition of GP and lime. This indicates that the stabilized soil may perform poorly under dynamic or penetrating loads, a critical limitation for road construction applications.

In conclusion, while the GP-lime combination excelled in improving strength and consolidation properties, its failure to enhance CBR values highlights a context-dependent applicability. The study establishes 10% GP with 5% lime as the optimum mix for projects requiring high shear and compressive strength, but not for pavement subgrades.









CONCLUSION

This study concludes that adding 10% waste glass powder (GP) with 5% lime optimally stabilizes lean clay. This mix significantly improved the soil's shear strength and unconfined compressive strength, making it more suitable for foundations. However, its bearing capacity for pavements (CBR) decreased. Thus, GP-lime stabilization is recommended for static loads but not for road subgrades. The research confirms the dual benefit of enhancing soil properties while promoting sustainable waste reuse.

FUTURE WORK / REFERENCES

Future research should conduct field trials to validate these laboratory findings under real-world conditions. Additionally, a comprehensive lifecycle assessment is recommended to quantitatively compare the environmental and economic benefits of using glass powder against traditional stabilizers.

Key References:

Lakhouit, A. (2025). *Cleaner Waste Systems*.

Tucker et al. (2018). *Resources, Conservation and Recycling*.