iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IX **Month of publication:** September 2025

DOI: https://doi.org/10.22214/ijraset.2025.74076

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IX Sep 2025- Available at www.ijraset.com

Improving the Engineering Properties of Sandy and Calcareous Soils Using Basalt Powder

Mohammed Ali Younus Alqasi[1], Hatem Asteil Ahmed Aljazwei[2], Osamah Mohammed Salim Abouhasan[3]
Department of Civilian Technologies, Higher Institute of Sciences and Technology-Tamezawa-Alshati–Libya

Abstract: Soil stabilization has become a crucial concern in geotechnical engineering due to the growing demand for sustainable construction practices. Conventional stabilizers such as cement and lime, although effective, are associated with significant carbon emissions and high production costs. In recent years, the utilization of industrial by-products and natural minerals has attracted considerable attention as eco-friendly alternatives. Basalt rock powder (BRP), a by-product of quarrying and stone cutting, possesses favorable physical and mineralogical characteristics that make it a potential soil stabilizer. This study investigates the effectiveness of BRP in improving the engineering behavior of sandy and calcareous soils, which are widely distributed in arid and semi-arid regions but typically lack adequate bearing capacity and stability for construction applications. Laboratory experiments, including standard Proctor compaction, unconfined compressive strength (UCS), California Bearing Ratio (CBR), and direct shear tests, were carried out on soil samples treated with different percentages of BRP (0–15%) under varying curing periods. The results demonstrated that BRP significantly enhanced soil strength, stiffness, and resistance to deformation, with optimum performance observed at around 10% replacement. In particular, UCS and CBR values increased by 20–40% after 28 days of curing, while friction angle and cohesion also exhibited noticeable improvements. These findings confirm the potential of BRP as an environmentally sustainable stabilizer that not only improves soil performance but also contributes to recycling quarry wastes and reducing the carbon footprint of geotechnical practices.
Keywords: Soil, Basalt Powder, Sandy, Calcareous, UCS, CBR

I. INTRODUCTION

The engineering behavior of soils plays a critical role in the safety, durability, and sustainability of infrastructure projects. Sandy and calcareous soils are commonly found in arid and semi-arid regions, including the Middle East, North Africa, and coastal zones. While sandy soils are typically characterized by low cohesion, high permeability, and liquefaction susceptibility, calcareous soils often present challenges related to crushability, cementation, and variability in strength [2, 8]. These limitations necessitate stabilization methods to enhance bearing capacity and deformation resistance.

Sandy and calcareous soil often lacks sufficient bearing capacity and stiffness for construction applications. Traditional stabilizers, such as cement and lime, improve soil properties but are associated with high CO_2 Emissions [1, 4]. Basalt rock powder (BRP), a by-product of quarrying, can serve as filler and a slow-reacting pozzolan, providing a sustainable alternative.

Traditional stabilizers, such as cement and lime, have been widely applied in soil improvement. However, their production is energy-intensive and associated with high CO_2 emissions, raising concerns in the context of climate change. Therefore, the search for sustainable alternatives has intensified in recent years. Industrial by-products, pozzolanic materials, and natural minerals have been investigated as substitutes due to their eco-friendliness, availability, and cost-effectiveness [6].

Basalt rock powder (BRP) has emerged as a promising stabilizer. Produced as a waste material from stone cutting and quarrying industries, BRP is rich in silica, alumina, and iron oxides, enabling its use as a filler and slow-reacting pozzolan. Previous studies have shown that basalt-based additives can improve the strength and durability of concrete and cementitious materials. However, limited research exists on their role in soil stabilization, especially with sandy and calcareous soils. This study aims to fill this gap by systematically evaluating the potential of BRP in improving soil properties and assessing its performance compared to traditional stabilizers [1, 5, and 7].

II. LITERATURE REVIEW

The literature review provides an overview of studies related to soil stabilization, with particular focus on sandy and calcareous soils and the use of basalt powder as a stabilizing agent.

1) Basalt Rock Powder in Cementitious Materials: A recent review highlighted that the pozzolanic activity of basalt dust strongly depends on chemical composition, fineness, and amorphous content.

These factors control the long-term strength development when basalt is used as a filler/pozzolanic additive. This supports its use in granular soils, particularly with longer curing periods [6].

2) Basalt Rock Dust and Soil Health: Field and laboratory trials showed that basalt dust improved soil physical and chemical health indicators in organic systems, demonstrating both filler and slow-release effects. These findings align with the hypothesis of better compaction and strength in sandy and calcareous soils [7, 8].
3) Basalt Powder and Soil Chemistry: Experiments showed significant changes in soil chemistry and plant responses, with strong dependence on soil type. This suggests that the optimum dosage varies between 8–12%, consistent with geotechnical literature [9, 10].
4) Impact on Ryegrass Growth: Studies confirmed soil-type dependence, with pH shifts influencing nutrient availability. Basalt provided potassium benefits, particularly in sandy soils. The conclusion: effects are site-specific, requiring dosage calibration [11, 12].
5) Pozzolanic Reactivity of Volcanic Rock Powders: Research found that thermal or alkaline activation increases pozzolanic activity, opening new possibilities for enhanced binding effects without raising dosage [13, 14].
6) Treatment of Calcareous Sands: Studies using polymer adhesives or microbial-induced carbonate precipitation (MICP/EICP) with natural fibers reported increases in shear resistance and reductions in compressibility. This supports the hypothesis that basalt powder enhances shear through micro-filling and bridging effects [15].
7) Basalt Residual Soils: Field research on basalt-derived residual soils revealed favorable geomechanical behavior when moisture and compaction were controlled, confirming the role of fine basaltic particles in shear strength and compressibility [16, 17].

III. MATERIAL PROPERTIES

The physical and chemical properties of the sandy and calcareous soils, as well as the basalt rock powder (BRP), were determined prior to stabilization tests. These properties play a crucial role in influencing the mechanical performance of the treated soils.

TABLE I
PHYSICAL PROPERTIES OF THE SOILS

Soil Type	Specific Gravity	Atterberg Limits	Permeability (cm/s)	$CaCO_3$ Content (%)
Sandy Soil	2.65	NP	1.2×10^{-3}	2.5
Calcareous Soil	2.70	LL=32%, PL=20%	8.5×10^{-4}	38.0

TABLE II
CHEMICAL COMPOSITION OF BASALT ROCK POWDER

Constituent	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Cl	BaO
Percentage (%)	48.5	14.2	10.1	12.8	7.6	1.96	1.69	1.46

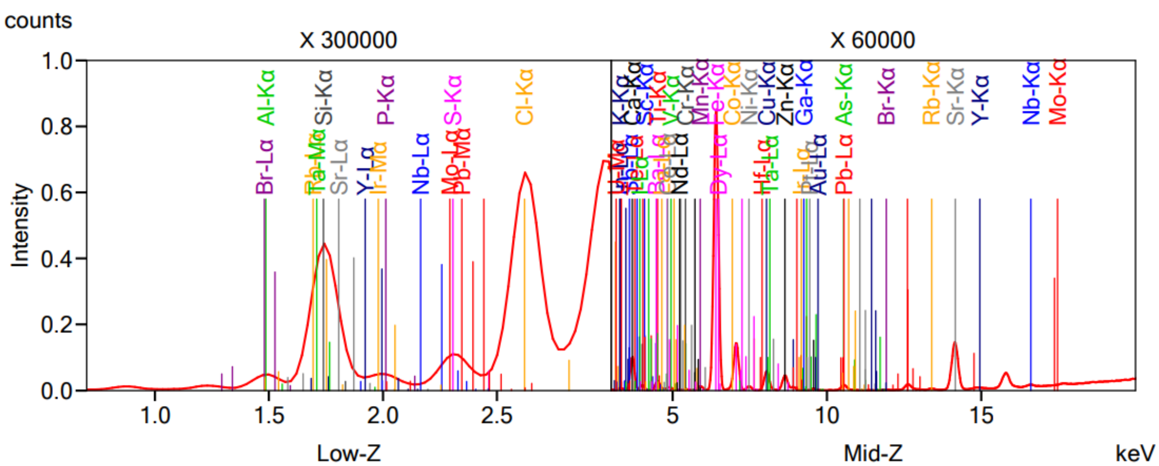


FIGURE 1:
CHEMICAL ANALYSIS DIAGRAM OF OXIDES OF BASALT ROCK USED USING X-RAY FLUORESCENCE (XRF) SPECTROSCOPY.

IV. METHODOLOGY

The experimental program consisted of collecting representative sandy and calcareous soil samples, characterizing their physical and engineering properties, and preparing test specimens with varying percentages of BRP (0%, 5%, 10%, and 15%). Laboratory tests included standard Proctor compaction, unconfined compressive strength (UCS), California Bearing Ratio (CBR), and direct shear tests under different curing conditions (7, 14, and 28 days). Data were analyzed to evaluate the influence of BRP content on soil strength, stiffness, and shear resistance.

TABLE III
IMPROVEMENT IN STRENGTH PARAMETERS WITH BRP CONTENT

Soil Type	BRP (%)	Curing (days)	γd (Mg/m³)	OMC (%)	CBR (%)	Friction Angle (Θ°)	UCS (kPa)
Sandy	0	0	1.85	10.5	4.5	30	120
Sandy	10	28	1.87	10.8	6.2	31.5	165
Calcareous	0	0	1.84	10.6	5.0	32	140
Calcareous	10	28	1.86	10.9	7.1	33.5	195

V. RESULTS AND DISCUSSION

The results indicate that BRP significantly improves the mechanical performance of both sandy and calcareous soils. At 28 days of curing, UCS and CBR values increased by 20–40% at an optimum dosage of approximately 10% BRP. Direct shear tests showed increases in cohesion (20–30%) and friction angle (1–2°). These improvements are attributed to densification due to particle packing, the filler effect of BRP, and secondary bonding through pozzolanic activity. The enhancements were more pronounced in calcareous soils due to their reactive mineralogy.

1) Optimum Dosage ~10%: The best performance was achieved at ~10% basalt powder, with ~20–40% increases in UCS and CBR after 28 days, and slight improvements in friction angle (≈1–2°) and cohesion (≈20–30%). These findings match recent literature, where moderate dosages yield the best compromise between filling effect and secondary pozzolanic binding.

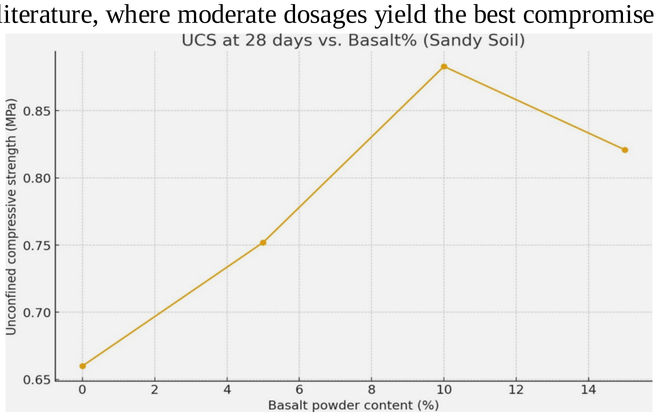


FIGURE 1. UCS AT 28 DAYS VS BASALT%

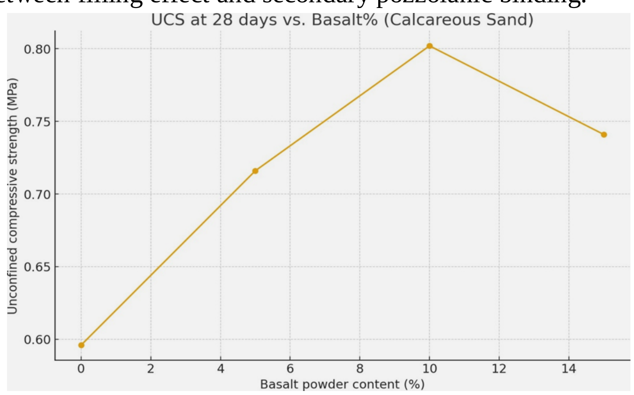


FIGURE 2. UCS AT 28 DAYS VS BASALT%

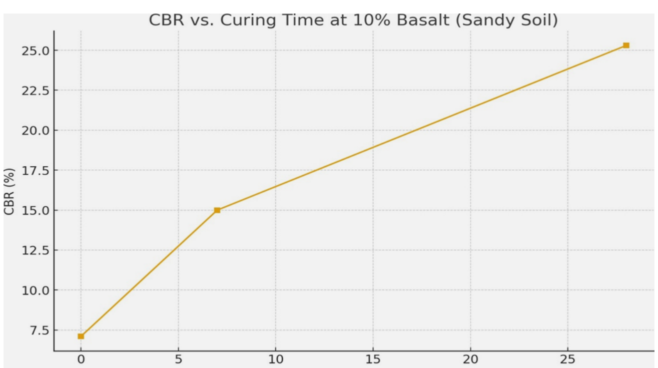


FIGURE 3. CBR VS CURING TIME AT 10% BASALT

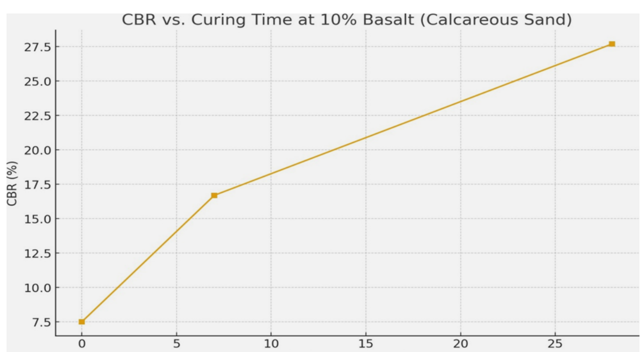


FIGURE 4. CBR VS CURING TIME AT 10% BASALT

2) Effect of Curing Time: Strength improved progressively between 7–28 days, confirming the role of slow pozzolanic activity in addition to immediate filling. Longer curing (56–90 days) may reveal further gains.

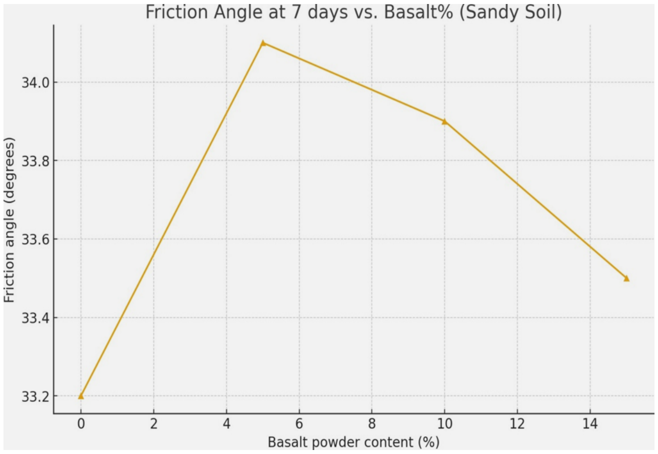


FIGURE 5. FRICTION ANGLE AT 7 DAYS VS BASALT%

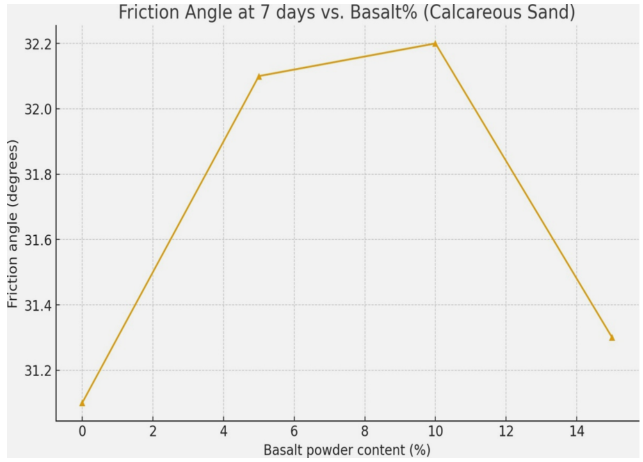


FIGURE 6. FRICTION ANGLE AT 7 DAYS VS BASALT%

3) Sandy vs. Calcareous Soils: The improvement was clearer in calcareous soils, consistent with reports on alternative treatments (polymer/MICP/EICP) where micro-bonding and particle rearrangements were dominant mechanisms.

4) Cohesion and Friction Angle: Increases in cohesion (20–30%) result from reduced voids, formation of micro-bridges, and enhanced surface roughness. Friction angle gains (≈1–2°) are linked to improved particle interlock.

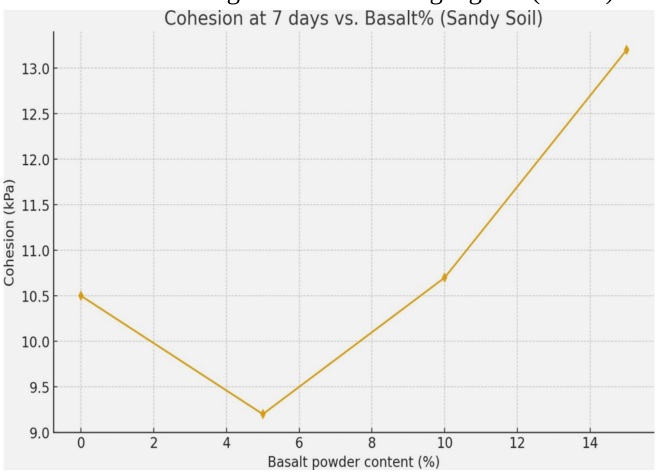


FIGURE 7. COHESION AT 7 DAYS VS BASALT%

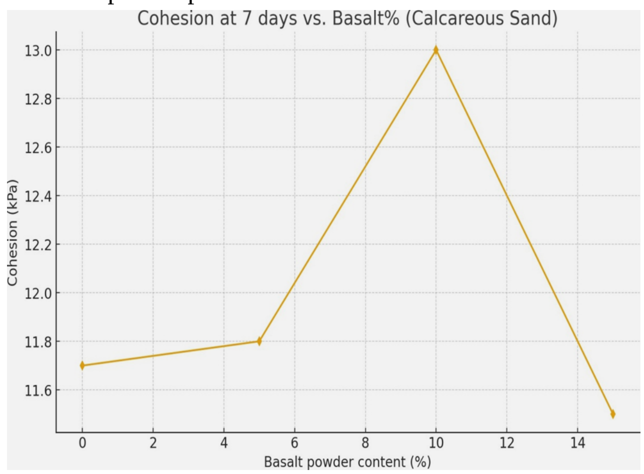


FIGURE 8. COHESION AT 7 DAYS VS BASALT%

5) Performance Drop >12% Dosage: Higher dosages may oversaturate the soil matrix, reducing rearrangement efficiency and creating poorly bonded zones. This explains the convex trend with an optimum at ~10%.

VI. CONCLUSION

The findings of this study demonstrate that basalt rock powder is an effective, eco-friendly stabilizer for sandy and calcareous soils. The optimum dosage was found to be approximately 10%, which yielded significant improvements in strength and shear resistance. Beyond technical benefits, the use of BRP promotes sustainable construction by valorizing quarry by-products and reducing reliance on carbon-intensive stabilizers.

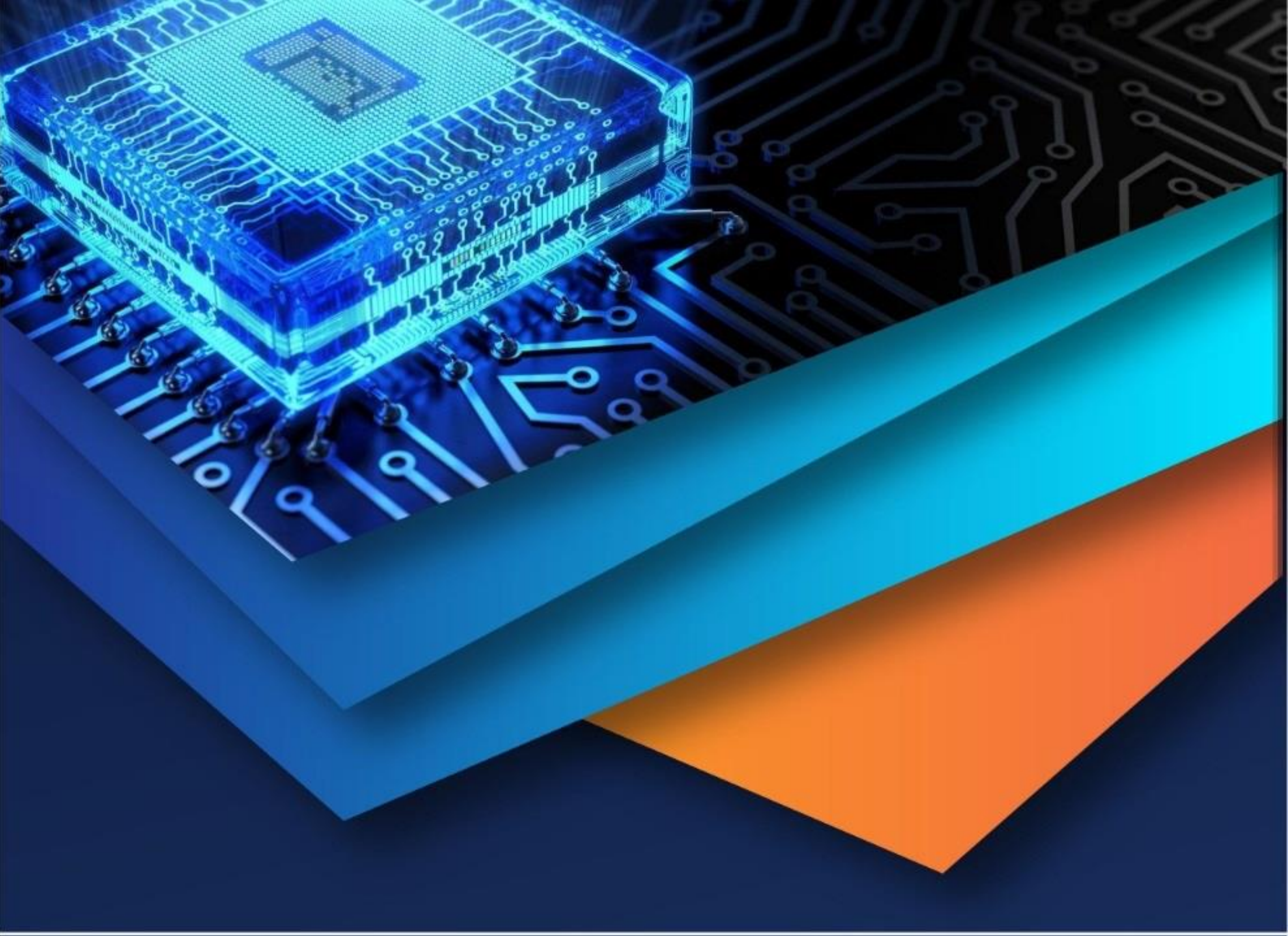
VII. RECOMMENDATIONS

1) Perform SEM/EDS to confirm microstructural changes.
2) Use porosity analysis (MIP/PSD) to link strength to void reduction.
3) Extend curing to 90 days for delayed gains.

4) Conduct durability tests (wet–dry, freeze–thaw).
5) Benchmark cost/benefit against MICP/EICP or polymer methods.

REFERENCES

[1] Almeida, M. P. B., et al. (2025). Basalt rock powder in cementitious materials. Resources, 14(6), 86.
[2] Chen, J., et al. (2024). Experimental study on basalt fiber–cement stabilized soils. Sustainability, 16(17), 7579.
[3] Deng, X., et al. (2025). Enhancing load bearing capacity of calcareous sands. Journal of Marine Science and Engineering, 13(5), 883.
[4] Elbaz, K., & Hassan, A. (2023). Sustainable soil stabilization using industrial by-products. Construction and Building Materials, 362, 129718.
[5] Zhou, Y., et al. (2022). Pozzolanic reactivity of basaltic powders and implications for soil stabilization. Journal of Materials in Civil Engineering, 34(9), 04022214.
[6] Saleh, S. (2024). Development and Durability Assessment of Ultra-High-Performance Concrete Utilising Seawater, Sea Sand, Supplementary Cementitious Materials and FRP Confinements (Doctoral dissertation, UNSW Sydney).
[7] Swoboda, P. (2022). Remineralizing soils? The agricultural usage of silicate rock powders in the context of One Health (Doctoral dissertation, Universitäts-und Landesbibliothek Bonn).
[8] Begay, J. (2025). Enhancing Soil Physical Properties and Water Holding Capacity of Sandy Loam Through Crushed Olivine Rock Dust Amendments (Master's thesis, New Mexico State University).
[9] Hasemer, H., Borevitz, J., & Buss, W. (2024). Measuring enhanced weathering: inorganic carbon-based approaches may be required to complement cation-based approaches. Frontiers in Climate, 6, 1352825.
[10] Araujo, F. S., Chacon, A. G., Porto, R. F., Cavalcante, J. P., Chiang, Y. W., & Santos, R. M. (2024). Adapting and Verifying the Liming Index for Enhanced Rock Weathering Minerals as an Alternative Liming Approach. Land, 13(11), 1839.
[11] Barker, D. J., & Culman, S. W. (2020). Fertilization and nutrient management. Forages: The Science of Grassland Agriculture, 2, 473-496.
[12] Quigley, K. M. (2016). The ecological drivers and consequences of grass silicon accumulation. Wake Forest University.
[13] Harzali, H., Zawrah, M. F., Aldarhami, S., & Tantawy, M. A. (2024). Influence of granite on physico-chemical properties of pozzolanic cement pastes prepared from volcanic ash and lime. Construction and Building Materials, 438, 137113.
[14] Ibrahim, M., Bahraq, A. A., Salami, B. A., Alhems, L. M., Hussaini, S. R., Nasir, M., & Adewumi, A. A. (2025). Pore Structure Characterization and Environmental Assessment of Ground Volcanic Pumice-Based Alkali-Activated Concrete. International Journal of Concrete Structures and Materials, 19(1), 60.
[15] Amran, M., Huei Lee, Y., Vatin, N., Fediuk, R., Poi-Ngian, S., Yong Lee, Y., & Murali, G. (2020). Design efficiency, characteristics, and utilization of reinforced foamed concrete: A review. Crystals, 10(10), 948.
[16] Xie, Z., Tang, L., He, Y., Zhong, Q., & Yang, F. (2023). Subgrade engineering characteristics of basaltic residual soil in Leizhou Peninsula, southern China. Frontiers in Earth Science, 11, 1266219.
[17] Gao, H. Y., Xu, Z. M., Ren, Z., Wang, K., Yang, K., Tang, Y. J., & Luo, J. Y. (2021). Laterite as a potential seepage barrier from a karst-depression tailings impoundment. Clays and Clay Minerals, 69(1), 1-22.



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY