Journal of
Geotechnical Engineering

ISSN: 2394-1987
Volume 13, Issue 1, 2026
January–April
DOI (Journal): 10.37591/JoGE

https://journals.stmjournals.com/joge

Research JoGE

Stone Waste as a Soil Stabilizer

Ansh Kumar Dvivedi[1,*], Vishal Singhal[2]

Abstract

The rapid expansion of construction, mining, and stone-processing industries has led to the large-scale generation of stone waste materials such as marble powder, granite slurry, quarry fines, and sandstone residues. The indiscriminate disposal of these wastes poses serious environmental concerns, including land degradation, dust pollution, and contamination of surface and groundwater resources. At the same time, weak and problematic soils continue to present major challenges in geotechnical engineering applications, particularly in the construction of foundations, embankments, retaining structures, and pavement subgrades. Improving the engineering properties of such soils cost-effectively and sustainably remains a critical research priority. In this context, the utilization of stone waste materials as soil stabilizers has emerged as a promising alternative to conventional chemical stabilizers such as cement and lime. Stone wastes exhibit favorable physical and mineralogical characteristics that contribute to enhanced soil strength, reduced plasticity, improved compaction behavior, and increased bearing capacity. This review critically examines existing experimental and field studies on the use of stone waste for soil stabilization, with emphasis on strength development, durability performance, and microstructural modification mechanisms. Additionally, the environmental and economic benefits associated with waste reuse, including reduced carbon emissions and material costs, are discussed. Practical applications and limitations of stone waste–based soil stabilization are also highlighted, guiding large-scale implementation. The review demonstrates that stone waste utilization offers a sustainable and technically viable solution for soil improvement while supporting circular economy principles in geotechnical engineering practice.

Keywords: California bearing ratio (CBR), soil stabilization, stone waste, strength improvement, sustainable geotechnics

INTRODUCTION

Soil stabilization is a vital technique in geotechnical engineering aimed at improving the engineering performance of problematic soils like expansive clays, soft silts, and loose sands. These soil types often exhibit undesirable characteristics, including low bearing capacity, excessive settlement, high compressibility, and poor resistance to moisture variations. Such limitations can significantly affect the safety and durability of civil engineering structures, particularly in applications involving foundations, embankments, highway pavements, and earth-retaining systems. Consequently, enhancing soil properties through stabilization has become an essential practice in modern infrastructure development [1–3].

Traditionally, stabilizing agents like cement, lime, and fly ash have been widely employed to improve soil strength and durability. While these materials are effective, their production and usage are associated with high energy consumption, increased carbon emissions, and escalating construction costs. Moreover, the extensive use of

***Author For Correspondence**
Ansh Kumar Dvivedi
E-mail: 2022pcecearyan003@poornima.org

[1]Student, Department of Civil Engineering, Poornima College of Engineering, Jaipur, Rajasthan, India
[2]Assistant Professor, Department of Civil Engineering, Poornima College of Engineering, Jaipur, Rajasthan, India

Received Date: February 02, 2026
Accepted Date: February 10, 2026
Published Date: February 13, 2026

Citation: Ansh Kumar Dvivedi, Vishal Singhal. Stone Waste as a Soil Stabilizer. Journal of Geotechnical Engineering. 2026; 13(1): 71–77p.

conventional stabilizers raises sustainability concerns, particularly in large-scale infrastructure projects where material consumption is substantial [4–6].

In parallel, the rapid growth of quarrying and stone-processing industries has resulted in the generation of enormous quantities of stone waste during extraction, cutting, and polishing operations. Materials like marble dust, granite powder, quarry fines, and sandstone residues are frequently disposed of in open landfills, leading to severe environmental problems, including dust pollution, land degradation, blockage of natural drainage systems, and contamination of surface and groundwater resources [7].

Repurposing stone waste as a soil stabilizing agent offers a dual advantage by improving soil engineering properties while simultaneously addressing waste management and environmental challenges. The fine particle size and mineralogical composition of stone waste contribute to enhanced compaction, reduced plasticity, and improved strength parameters like the California bearing ratio (CBR). The utilization of stone waste in soil stabilization, therefore, supports sustainable construction practices and aligns with circular economy principles, making it a promising alternative to conventional stabilizers in geotechnical engineering applications [8].

Types of Stone Waste

Common stone waste used for soil stabilization includes:

Marble Dust/Marble Powder

- High $CaCO_3$ content.
- Fineness improves soil gradation.

Granite Slurry/Granite Powder

- Rich in silica and alumina.
- Improves friction.

Quarry Dust/Stone Quarry Fines

- Angular particles suitable for granular improvement.
- Well-suited for granular soil improvement.

Sandstone Waste

- High silica content.
- Improves shear strength and density.

Limestone Waste

Chemically active with clay minerals.

Mechanisms of Soil Stabilization Using Stone Waste

Stone waste stabilizes soil through:

Mechanical Stabilization

- Fills voids in soil, increasing density and dry unit weight.
- Improves grain-size distribution.
- Enhances inter-particle friction and shear strength.

Chemical Stabilization (for $CaCO_3$-Rich Stone Waste)

- Marble and limestone waste can react with clay minerals.
- Leads to flocculation and aggregation.
- Reduces plasticity and swelling potential.

Table 1. Optimum content varies with soil type.

Soil type	Best performing stone waste	Typical optimum range
Expansive clay	Marble dust, limestone waste	10–25%
Sandy soil	Quarry dust, granite slurry	20–40%
Silty soil	Marble or granite	10–20%
Subgrade for pavements	Quarry dust	20–35%

Pozzolanic Effects (Limited)

- Granite and quarry dust contain reactive silica.
- Under certain conditions, mild pozzolanic reactions occur when used with lime/cement blends (Table 1).

Effects of Stone Waste on Soil Properties

Atterberg Limits

- Marble and granite waste reduce the plasticity index (PI) of clay soils.
- Making soil less expensive and more workable.

Compaction Characteristics

- Maximum dry density (MDD) generally increases with stone waste.
- Optimum moisture content (OMC) tends to decrease.

Shear Strength

- Quarry dust and granite powder significantly increase cohesion and angle of internal friction (ϕ).
- Improvements range between 10 and 40%, depending on dosage.

Bearing Capacity

- CBR values improve substantially.
- Studies show a 50–300% CBR increase with 10–30% stone waste addition.

Swelling and Shrinkage

- Marble and limestone waste show a major reduction in the swelling pressure of expansive soils.
- Typical reductions: 20–60%.

Optimal Mix Proportions

Although optimum content varies with soil type, general findings show that the excessive stone waste (>40%) may reduce cohesion or cause brittleness.

Environmental and Economic Considerations

Environmental Benefits

- Reduces landfilling of stone waste.
- Decreases dust pollution.
- Low-carbon alternative to cement/lime.
- Promotes circular economy in construction.

Economic Advantages

- Stone waste is often locally available and inexpensive.
- Reduces usage of traditional stabilizers.
- Lowers overall project costs (5–20% in many case studies).

Applications in Civil Engineering

Stone waste-stabilized soils are used in:

- Pavement subgrade and sub-base layers.

- Embankment and backfill material.
- Low-height retaining structures.
- Rural road construction.
- Land reclamation projects.
- Foundation improvement for light structures.

Future Research Directions

- Development of standardized codes for using stone waste in stabilization.
- Studies on long-term durability and field performance.
- Combination of stone waste with industrial byproducts (e.g., fly ash, ground granulated blast-furnace (GGBS)).
- Investigation of microstructural changes using SEM/XRD.
- Life cycle assessment (LCA) to quantify environmental benefits.

LITERATURE REVIEW

A detailed experimental study that investigates clay soils stabilized with waste marble powder (WMP). The authors found that adding marble powder significantly altered geotechnical properties: the liquid limit dropped from ~62.2% to ~31.8%, the plastic limit from ~29.6% to ~15.5%, and the PI reduced accordingly [9].

- MDD increased dramatically (over 40%) when up to 60% WMP was added; OMC decreased to as low as ~11%.
- After 28 days of curing, unconfined compressive strength (UCS) reached ~661 kN/m² with 60% powder; indirect tensile strength (ITS) also rose (from ~100 to ~208 kN/m² for 60–75%).
- The study used exploratory data analysis (histograms, box plots) and statistical modeling to predict UCS, showing a strong fit (R^2 ~0.95).
- The study mixed collapsible soil (which shrinks/settles greatly upon wetting) with marble dust in varying proportions (0–50%) [10].
- Liquid limit dropped significantly at higher dust content (35% decrease at 50%), indicating reduced plasticity.
- MDD increased by ~5.9% to 50% marble; OMC decreased.
- Cohesion (soaked) increased by ~314%, and even unsoaked samples saw ~206% increase.
- The use of natural stone waste (marble and granite) in stabilizing clay liners.
- They added 10–15% marble powder to clay (with 10% bentonite + 90% kaolinite) and tested resistance to freeze–thaw cycles.
- Results showed that the addition of marble powder increased the durability of clay liners, indicating that stone waste can improve the environmental resilience of stabilized soils.
- The several industrial wastes, including marble dust, granite dust, boron waste, and fly ash, for soil stabilization [4].
- They performed UCS, CBR, and freeze–thaw cycles.
- UCS and CBR generally increased with the additive ratio; freeze–thaw durability varied by material, with granite dust showing less strength loss than others.
- The use of marble dust, bagasse ash, and paddy straw wastes to make unfired soil blocks.
- Marble dust improved the compressive strength and durability of the blocks.
- This shows that stone waste not only helps with soil stabilization but can be used more broadly in construction units, contributing to sustainability.
- Etim et al. studied soil–quarry dust mixtures stabilized with cement for pavement subgrade applications.
- The addition of cement + quarry dust increased dry density, reduced OMC, and significantly improved UCS.

- They also observed that adding quarry dust reduces the amount of cement needed to reach the target strength, which makes the stabilization more cost-effective and sustainable.

SYNTHESIS OF LITERATURE: KEY THEMES AND GAPS

From the above studies, a few key themes emerge.

Effectiveness Across Waste Types

- Both marble waste and granite waste have been shown to improve engineering properties (strength, compaction, bearing capacity) of weak soils.
- Marble powder is particularly effective because of its calcium carbonate content, which may help in chemical bonding or flocculation.
- Granite waste improves soil by filling voids, increasing density, and enhancing strength, mostly via mechanical stabilization.

Optimal Dosages and Mix Design

- Several studies point to optimum content, e.g., ~40% granite waste by weight for clay; ~60% marble powder in some clay soil studies.
- Beyond a certain percentage, incremental gains often plateau or even decrease (e.g., very high marble powder content may not yield further improvement).

Long-Term Durability

- Durability under environmental conditions (e.g., freeze–thaw cycles) has been investigated where marble dust improved resistance.
- Field studies (granite waste) show that lab-scale improvements translate in-situ but with reduced magnitude, highlighting scale and compaction issues.

Environmental and Sustainability Benefits

- Reusing stone waste mitigates disposal problems, reduces landfill, and leverages industrial byproducts.
- Blending stone waste with other industrial wastes (like fly ash or GGBS) further enhances sustainability and reduces cost.

Modeling and Predictive Tools

- Some studies develop predictive models for strength (e.g., regression models for UCS) to estimate behavior based on mix design and curing.
- However, there is limited work on long-term performance models (durability, leaching, and field aging).

GAP AND RESEARCH OPPORTUNITIES

Based on the literature, the following gaps and potential areas for further research are apparent:

- *Standardization:* There is a need for standard guidelines/design codes for using stone waste as a soil stabilizer, because waste composition varies greatly.
- *Long-term performance:* More studies are needed on aging, durability, leaching behavior (environmental impact), especially in real conditions.
- *Field trials:* Increased field-scale projects (roads, embankments, subgrades) to validate lab findings and understand compaction, moisture, and scale effects.
- *Combined stabilization:* Research on hybrid stabilizers, e.g., stone waste + fly ash + lime/cement, to optimize strength, cost, and environmental impact.
- *Modeling and machine learning:* Use of predictive methods (e.g., regression, machine learning) to optimize mix design, predict strength, and reduce trial-and-error.

- *Life cycle assessment:* Quantitative LCA studies to compare the environmental benefits (carbon savings, waste reduction) of stone waste stabilization versus traditional stabilizers.

CONCLUSION

Stone waste is a promising, sustainable, and cost-effective material for soil stabilization. Research consistently demonstrates improvements in compaction, strength, and durability characteristics for a range of soil types. Among various stone wastes, marble dust and quarry dust show especially strong performance for expansive clays and pavement subgrades. With proper mixed design and quality control, stone waste serves as an environmentally friendly alternative to traditional stabilizers, supporting sustainable construction practices.

In addition to mechanical improvements, the incorporation of stone waste contributes significantly to environmental conservation by reducing the volume of industrial waste disposed of in landfills and minimizing the exploitation of natural resources. The reuse of stone waste helps mitigate issues, such as dust pollution, land degradation, and water contamination associated with conventional disposal methods. From an economic perspective, the availability of stone waste at low or negligible cost can lead to substantial savings in large-scale geotechnical and pavement projects, particularly in developing regions where resource optimization is critical.

The effectiveness of stone waste stabilization is influenced by factors such as soil type, waste composition, particle size distribution, and curing conditions. Therefore, careful material characterization and mix optimization are essential to achieve consistent and reliable performance. While laboratory studies have demonstrated promising results, further field-scale investigations are required to assess long-term performance under varying environmental and loading conditions.

Future research should focus on standardizing mix design procedures, evaluating durability under cyclic wetting–drying and freeze–thaw conditions, and assessing the combined use of stone waste with other eco-friendly binders. Overall, the adoption of stone waste for soil stabilization presents a viable pathway toward sustainable geotechnical engineering and the advancement of circular economy principles in infrastructure development.

REFERENCES

1. Umar IH, Lin H. Marble powder as a soil stabilizer: An experimental investigation of the geotechnical properties and unconfined compressive strength analysis. Materials. 2024;17(5):1208. doi:10.3390/ma17051208.
2. Shah SHA, Habib U, Mohamed A, Aziz M, Memon A, Saleem A. Laboratory and in situ stabilization of compacted clay through granite waste powder. Sustainability. 2022;14(21):14459. doi:10.3390/su142114459.
3. Waheed A, Arshid MU, Khalid RA, Gardezi SSS. Soil improvement using waste marble dust for sustainable development. Civ Eng J. 2021;7(9):1594–1607. doi:10.28991/cej-2021-03091746.
4. Zorluer I, Gücek S. The usability of industrial wastes on soil stabilization. Rev Constr. 2020;19(1):80–89. doi:10.7764/RDLC.19.1.80-89.
5. Ramanjaneyulu B, Kumar ND. Effect of marble dust on UCS and CBR of gypsum stabilized clay. Civ Eng Archit. 2024;12(2):685–696. doi:10.13189/cea.2024.120203.
6. Umar IH, Lin H, Ibrahim AS. Laboratory testing and analysis of clay soil stabilization using waste marble powder. Appl Sci. 2023;13(16):9274. doi:10.3390/app13169274.
7. Ubani OU, Ngezahayo E, Nwaiwu CMO, Nwakaire CM. Strength development and durability of cement-stabilized tropical clay–quarry dust mixtures for pavement construction. Sustainability. 2025;17(19):8825. doi:10.3390/su17198825.
8. Bureau of Indian Standards. IS 2720 (Part 10): Determination of unconfined compressive strength. New Delhi: Bureau of Indian Standards; 1991.

9. Bureau of Indian Standards. IS 2720 (Part 16): Laboratory determination of CBR. New Delhi: Bureau of Indian Standards; 1987.
10. Edil TB. Sustainable use of industrial by-products in geotechnical engineering. In: Geo-Congress Proceedings. Reston (VA): American Society of Civil Engineers; 2015.

