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Experimental Study on Stabilization of Soil Using Marble Dust

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ABSTRACT
Soil stabilization is a crucial process in geotechnical engineering, aimed at improving the physical properties of soil to enhance its strength, durability, and load-bearing capacity. In recent years, the use of industrial waste materials in soil stabilization has gained attention due to environmental and economic benefits. Marble dust, a byproduct of marble processing, is one such material that shows promise in soil stabilization. This study focuses on the stabilization of weak soils using marble dust as an additive. The incorporation of marble dust into the soil has been found to improve its mechanical properties, including increased compressive strength, reduced plasticity index, and enhanced resistance to erosion. Marble dust, rich in calcium carbonate, reacts with the soil, reducing its permeability and enhancing its binding properties. Experimental tests conducted on different soil samples with varying percentages of marble dust demonstrate that a certain proportion of marble dust can significantly improve soil properties, making it suitable for construction projects such as road bases, embankments, and foundations. Additionally, utilizing marble dust in soil stabilization offers an eco-friendly solution by recycling industrial waste and reducing the environmental impact of marble processing industries. The results indicate that marble dust can serve as a cost-effective and sustainable alternative to traditional soil stabilizers, contributing to both economic and environmental sustainability in construction practices.
Keywords: Soil stabilization, Marble dust, Geotechnical engineering, Physical properties, Strength, Durability, Moisture content, Soil samples, Cost-effective, stainable alternative.

I. Introduction

The stabilization of soil using marble dust represents an innovative advancement in civil engineering, particularly beneficial in enhancing the strength and durability of soils, especially in regions where the native soil is weak or expansive. Marble dust, a byproduct of the marble industry, has gained recognition as a valuable material in this process due to its unique chemical composition and fine particle size. Primarily composed of calcium carbonate, marble dust can significantly improve the physical and mechanical properties of soil when mixed with it, making it a compelling option for construction applications.

One of the most notable benefits of incorporating marble dust into soil is its ability to enhance compressive strength and load-bearing capacity. This improvement is crucial for various construction projects, as stronger soil can better support structures and prevent issues such as settling or failure. Additionally, the inclusion of marble dust reduces the plasticity of the soil, which is essential for maintaining stability under varying moisture conditions. The finer particles of marble dust help to fill voids within the soil matrix, leading to increased density and decreased porosity. This stabilization effect is particularly beneficial for expansive clay soils, which are notorious for their tendency to shrink and swell in response to moisture changes. Such behavior can lead to significant damage to buildings and infrastructure if not adequately managed.

In addition to enhancing physical properties, the use of marble dust in soil stabilization offers substantial environmental and economic advantages. Recycling marble dust addresses the growing environmental challenge of marble waste disposal, providing a sustainable solution that minimizes landfill usage. This practice not only reduces the environmental footprint of the marble industry but also contributes to a circular economy by repurposing materials that would otherwise be discarded. From an economic perspective, utilizing marble dust as a soil stabilizer presents a cost-effective

alternative to traditional stabilization methods, which often rely on expensive chemical additives or natural materials that may not be readily available.
The process of soil stabilization with marble dust is relatively straightforward, making it an accessible option for many construction projects. Typically, the marble dust is mixed with the existing soil at specified ratios, followed by thorough compaction to ensure uniform distribution and effective bonding. Laboratory tests often precede field applications to determine the optimal proportions of marble dust required to achieve desired strength and stability characteristics. This experimental approach not only ensures the effectiveness of the stabilization process but also allows engineers to tailor solutions to specific soil conditions and project requirements.
Furthermore, the long-term performance of marble dust-stabilized soils has shown promising results in various studies. These stabilized soils exhibit reduced susceptibility to moisture-induced changes, enhancing their durability and longevity. As infrastructure faces increasing stress from environmental factors, the reliability of marble dust as a stabilizing agent could play a pivotal role in developing more resilient construction practices.

II. Scope of Work

Soil stabilization with marble dust enhances soil strength and stability, especially for construction projects like roads and foundations. It improves load-bearing capacity, reduces plasticity, and enhances shear strength, making the soil more resistant to deformation under varying moisture conditions. The use of marble dust is also environmentally beneficial, as it repurposes industrial waste and offers a cost-effective alternative to traditional stabilizers like cement. Its application is ideal for sub-base layers in roads, embankments, and slopes, where it helps prevent erosion and landslides. However, the effectiveness depends on the proper proportion of marble dust and the type of soil, with clayey soils often benefiting the most. Lab tests such as compaction and strength evaluations are crucial to optimize the mix for specific projects, ensuring the best results.

III. Past Studies

The research on utilizing marble waste in soil stabilization offers a comprehensive understanding of its potential as an alternative material for improving soil properties in construction projects. Marble waste, primarily in the form of marble powder or dust, is generated in large quantities during the marble-cutting, polishing, and grinding processes. Disposing of this waste material poses significant environmental challenges, as it is non-biodegradable and often accumulates in landfills. However, recent studies suggest that marble waste can be repurposed as a soil stabilizer, offering both environmental and economic benefits.
The incorporation of marble powder into soil has been shown to significantly enhance soil mechanical properties, making it more suitable for various construction applications, including road pavements, dam cores, and building foundations. Research has focused on the mechanical, physical, and chemical effects of adding marble waste to different types of soils, particularly cohesive soils like clay. The key areas of investigation include changes in soil plasticity, compressive strength, density, and overall stability.
In one study by Ashraf Nazir Moustafa El Sawwaf, Wasiem Azzam, and Mohamed Ata (2020), the use of marble powder as a soil stabilizer was analyzed through various soil tests, such as Atterberg limits and Standard Proctor compression tests. These tests revealed that adding marble powder to the soil reduced its plasticity index, which is a crucial factor in soil stabilization. The plasticity index indicates the soil’s ability to change shape without breaking, and a lower index suggests greater soil stability. The study found that incorporating marble powder between 10% and 15% by weight into the soil mix yielded optimal results, balancing improvements in soil properties with cost-effectiveness. This research also emphasized the environmental benefits of repurposing marble waste, as it reduces the need for traditional stabilizers like cement or lime and contributes to pollution reduction.
Another study conducted by B. B. Patel, H. B. Thakar, Dr. H. R. Varia, and C. B. Mishra (2017) explored the use of marble powder to stabilize clay soil. The findings were consistent with other research, showing that marble powder improves soil strength while reducing its plasticity. This study

used the California Bearing Ratio (CBR) test, which measures the strength of soil under load. Higher CBR values indicate improved load-bearing capacity, a crucial factor in road construction. The researchers found that adding between 20% and 60% marble powder by weight produced the best results, depending on the type of soil. Notably, the wide range of marble powder content highlights the need for customized mix designs tailored to specific soil types and project requirements. By reducing the expansive behavior of clay soil, marble powder makes it more stable and less prone to swelling or shrinking, problems commonly associated with clayey soils in construction.

In the context of road construction, a study by Rama Indera Kusuma, Enden Mina, Woelandari Fathonah, and Adjie Anfasha Bilhaq (2023) focused on the use of marble powder in Serang City, Indonesia. This research analyzed several soil properties, such as grain size, plasticity, and water content, and found that adding marble powder to the soil reduced its plasticity and increased its overall strength. Tests such as compaction and unconfined compressive strength (UCS) demonstrated that marble powder could enhance soil stability, making it more suitable for road construction. These findings are consistent with previous research that underscores marble powder's ability to decrease soil plasticity and improve strength, thus enhancing its suitability for construction activities. This study also highlighted the potential for marble powder to offer a sustainable solution to soil stabilization, helping reduce environmental pollution caused by the disposal of marble waste.

In a 2024 study by Mustafa Karaşahin, Ahmet Hüsrev Yıldız, and Murat Vergi Taciroğlu, the impact of marble powder on soil properties such as grain size and plasticity was examined. This research also focused on road construction and found that the addition of marble powder improved soil density and mechanical strength. UCS and compaction tests confirmed that marble powder waste enhances soil stability by reducing its plasticity index. The findings supported the idea that marble waste can replace more traditional soil stabilizers, offering both environmental and cost advantages.

Similarly, research by Hassan A. M. Abdelkader, Mohamed M. A. Hussein, and Haiwang Ye (2021) delved into the mechanical properties of soil treated with marble powder waste. The study found that as the percentage of marble dust in the soil increased, its strength improved. This was measured through various tests that showed a decrease in both the plasticity index and the liquid limit, which are indicators of improved soil stability. These findings reinforce the growing consensus that marble powder waste offers a viable solution for soil stabilization, contributing to both enhanced soil properties and environmental benefits by repurposing a waste material that would otherwise contribute to pollution.

Abid Ali and his colleagues (2020) also explored the use of marble powder for soil stabilization and found similar results regarding its impact on mechanical properties. By conducting unconfined compressive strength and compaction tests, the researchers demonstrated that marble powder reduces soil plasticity and increases strength. They concluded that marble powder waste is a sustainable option for improving soil properties, particularly in expansive soils that tend to swell and shrink with changes in moisture content. This makes marble-stabilized soil more suitable for a variety of construction applications, including foundation work and pavement subgrades.

In a study by Najwa Wasif Jassim and colleagues (2022), marble dust was used as a stabilizing material for clayey subgrade soils in pavement construction. The researchers found that adding marble dust to soil reduced its clay content and improved its overall gradation, as evidenced by a downward shift in the grain size distribution curve. The plasticity index decreased by approximately 22% with an increase in marble dust content from 0% to 12%, while the maximum dry density of the treated soil also increased. The optimal addition of marble dust was determined to be around 15%, which produced the best balance between increased soil density and decreased moisture content. These findings further highlight the benefits of marble dust as a stabilizer, particularly in improving the properties of clay soils used in road construction.

Isaac I. Akinwumi and Colin A. Booth (2015) focused their research on the effects of waste marble fines on lateritic soil. They found that the addition of marble waste reduced soil plasticity while increasing its strength, making it more suitable for use in construction, particularly for road pavement

layers and foundations. The study also noted that marble waste reduced the permeability of soil, making it less prone to water infiltration and therefore more stable in various construction contexts.
Another study by Jauhari Nitish, Varshney Harshit, and Bhatt Himanshu (2017) investigated the stabilization of expansive clay soils using waste marble dust. The researchers used the California Bearing Ratio (CBR) test to measure soil strength and found significant improvements with the addition of marble dust. However, they also observed a reduction in the maximum dry density of the soil as marble dust content increased, likely due to the flocculation and aggregation of soil particles caused by the marble dust. The study concluded that adding approximately 8% marble dust to expansive clay soils is optimal for improving their geotechnical properties.
Research by T. Raj Priyanka and S. Eswara Rao (2018) focused on the stabilization of black cotton soil using marble dust. This study found that adding 15% marble dust resulted in the highest unconfined compressive strength (UCS) values. The maximum dry density of the soil increased with the addition of marble dust, while the optimum moisture content decreased. The researchers attributed these improvements to a pozzolanic reaction between the fine-grained soil and the marble dust. This reaction enhances soil strength and stability, making it more suitable for construction applications.
In summary, the research reviewed indicates that marble waste, particularly in the form of marble powder or dust, is an effective soil stabilizer. Adding marble waste to soil can reduce plasticity, increase strength, and improve other mechanical properties, making it suitable for a range of construction applications. The studies consistently show that marble powder waste can serve as an environmentally friendly and cost-effective alternative to traditional soil stabilizers like cement and lime. The optimal percentage of marble waste to add to soil typically ranges from 10% to 15%, although higher percentages may be beneficial for certain soil types and project requirements. By repurposing marble waste, construction projects can reduce their environmental impact while improving soil properties for long-term stability and durability.
In conclusion, the use of marble waste in soil stabilization presents a promising solution for addressing both environmental challenges and the need for improved soil performance in construction projects. The potential for further research into the long-term performance of marble-stabilized soils, as well as the combination of marble waste with other industrial by-products, could lead to even more effective and sustainable soil stabilization methods.

IV. Methodology

Below is a detailed elaboration of the methodology for utilizing marble dust as a soil stabilizer, which includes descriptions of materials, characteristics, and the tests conducted. This structured methodology ensures clarity and comprehensiveness, covering each aspect thoroughly.

4.1 Materials Used

The methodology for this study centers around the materials employed in the experimental setup, including marble dust as an admixture and alluvial soil as the primary soil sample. Understanding the properties and characteristics of these materials is critical for the successful implementation of the experiments.

4.2 Marble Dust Definition and Source

Marble dust is a by-product generated during the processing of marble, which includes cutting, shaping, and grinding. This fine powder is predominantly composed of calcium carbonate ($CaCO_3$) and is produced in significant quantities within the marble industry. Due to its extensive production and non-biodegradable nature, marble dust is often considered a waste product. However, its potential as an environmentally friendly soil stabilizer presents an opportunity for repurposing industrial waste.

4.3 Chemical Composition

The primary constituent of marble dust is calcium carbonate, which is responsible for its alkaline properties. The chemical formula for calcium carbonate is $CaCO_3$, and it contributes to the dust’s ability to interact favorably with soil particles. Minor trace minerals such as magnesium, iron, and silica may also be present, depending on the marble source. Understanding the chemical composition is essential, as it influences the reactivity and performance of marble dust when mixed with soil.

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4.4 Physical Properties

Marble dust is characterized as a fine, powdery material that is typically non-cohesive and 0lightweight. Its high surface area, resulting from its small particle size, enables greater interaction with soil particles, which is crucial for enhancing soil properties. These properties play a pivotal role in its effectiveness as a soil stabilizer.

4.5 Color

The color of marble dust can range from pure white to off-white, with variations based on the type of marble it originates from. This aesthetic characteristic may not directly affect its stabilizing properties but is noteworthy for applications where appearance is a consideration.

4.6 Inert Nature

One of the significant attributes of marble dust is its generally inert chemical nature. It does not readily react with other materials, making it suitable for various industrial applications, including construction. The inertness of marble dust allows for its use without adversely affecting the properties of the soil or the stability of the structures built upon it.

Figure 1: Marble Dust (Powder)

Figure 2: Alluvial Soil

4.7 Alluvial Soil as a Soil Sample

Alluvial soil is a type of fertile soil formed through sedimentation by rivers and streams. This soil comprises a mixture of silt, sand, clay, and organic matter, which are carried by flowing water and deposited in riverbeds, floodplains, and deltas. The accumulation process results in nutrient-rich soil, making it highly suitable for agricultural use.

4.8 Formation Process

The formation of alluvial soil involves the erosion and transportation of sediments by water, followed by the deposition of these materials in calmer areas. The ongoing process of sedimentation contributes to the soil’s fertility, making it a valuable resource for agriculture and construction.

4.9 Properties of Alluvial Soil

Alluvial soil is known for its high fertility, which is primarily attributed to the presence of organic matter and essential nutrients. This soil type typically has good drainage properties due to its granular nature, making it suitable for various agricultural practices. However, its characteristics can vary depending on the location and the specific materials deposited.

V. Tests to be Conducted

The methodology includes a series of laboratory tests designed to assess the properties of both marble dust and alluvial soil. These tests are crucial for determining the effectiveness of marble dust as a soil stabilizer.

- Grain Size Distribution (Sieve Analysis)
- Water Content Test by Oven Dry Method
- Atterberg Limit Test by Casagrande’s Apparatus
- Standard Proctor Test

VI. Conclusion

Based on the methodology outlined, the expected conclusions of the study on using marble dust as a soil stabilizer can be framed as follows. The study is anticipated to demonstrate that marble dust can effectively enhance the physical and mechanical properties of alluvial soil. The tests conducted, such as grain size distribution, Atterberg limits, and compaction characteristics, should reveal improvements in soil density, strength, and stability when marble dust is added as an admixture.

The results of the Standard Proctor Test are expected to identify an optimal proportion of marble dust to be mixed with alluvial soil to achieve maximum dry density and optimum moisture content. This will provide clear guidelines for practitioners on the most effective usage of marble dust in soil stabilization applications.

The water content tests and Atterberg limits are likely to show that the inclusion of marble dust alters the plasticity characteristics of alluvial soil. This could lead to improved water retention capabilities and a reduction in the plasticity index, indicating a more stable and manageable soil mix for construction purposes.

The study is expected to highlight the environmental advantages of utilizing marble dust, which is often considered a waste product. By repurposing marble dust for soil stabilization, the research aims to contribute to sustainable construction practices and waste management efforts, reducing the ecological impact of both the marble industry and soil degradation.

Conclusions drawn from the study will likely emphasize the practical applications of using marble dust in various construction projects, such as road construction, foundation works, and embankments. The findings could advocate for the adoption of marble dust in engineering practices, particularly in regions with abundant marble processing industries.

The research may conclude with suggestions for further studies to explore additional aspects of using marble dust in soil stabilization, including long-term performance assessments, cost-benefit analyses, and the potential for other waste materials to be used alongside marble dust for enhanced results.

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References

[1] Ashraf Nazir, Moustafa El Sawwaf, Wasiem Azzam, Mohamed Ata, "Utilization of Marble Dust for Improving The Geotechnic Characteristics Of Collapsible Soil," Journal of Geological Research, Volume 02, Issue 04 October 2020.

[2] B. B. Pate, H. B.Thakar, Dr. H. R.Varia, C. B. Mishra, "Use of Waste Marble Powder to Improve the Characteristics of Black Cotton Soil," International Journal of Engineering Research & Technology (IJERT), Vol. 6 Issue 04, April-2017.

[3] Rama Indera Kusuma, Enden Mina , Woelandari Fathonah, Adjie Anfasha Bilhaq, "The Influence of Marble Waste Powder on Clay Soil Stabilization," Interbational Journal On Advanced Science Engineering Information Technology, Vol.13 (2023) No. 2.

[4] Mustafa Karaşahin, Ahmet Hüsrev Yıldız, Murat Vergi Taciroğlu, “Investigation of soil stabilization with waste marble powder according to mechanistic empirical design method,” Journal of the Faculty of Engineering and Architecture of Gazi University, 39:3 (2024) 1621-1636.
[5] Hassan A. M. Abdelkader,Mohamed M. A. Hussein, Haiwang Ye, “Influence of Waste Marble Dust on the Improvement of Expansive Clay Soils,” Hindawi Advances in Civil Engineering, Volume 2021, Article ID 3192122.
[6] Abid Ali, Nauman Izhar, Qaiser Iqbal, Tahir Ahmad, Rooh Ullah, “Improving the Mechanical Properties of Fine Soil using Marble Waste,” International Journal of Engineering Works ISSN-p: 2521-2419 ISSN-e: 2409-2770, Vol. 7, Issue 01, PP. 10-14, January 2020.
[7] Najwa Wasif Jassim, Hanan Adnan Hassan, Hadeel Ammar Mohammed, Mohammed Yousif Fattah. “Utilization of waste marble powder as sustainable stabilization materials for subgrade layer,” Results in Engineering 14 (2022) 100436.
[8] T Raj Priyanka1, S. Eswara Rao, “Stabilization of Black Cotton Soil with Marble Dust,” International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 6 Issue V, May 2018.
[9] Isaac I. AKINWUMI, Colin A. BOOTH, “Experimental insights of using waste marble fines to modify the geotechnical properties of a lateritic soil,” Journal of Environmental Engineering And Landscape Management, 2015 Volume 23(02): 121–128.
[10] Jauhari Nitish, Varshney Harshit, Bhatt Himanshu, “Sustainable Utilization of waste Marble Dust as a Chemical Stabilizer in Expansive Soils,” International Journal for Research in Applied Science & Engineering Technology (IJRASET), 45.98; SJ Impact Factor:6.887 Volume 5 Issue X, October 2017.