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Enhancing Soil Stability With Marble Dust: An Experimental Study On Soil Stabilization

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Abstract:

This research paper investigates the use of waste marble dust as a soil stabilizer to improve soil properties and enhance its suitability for construction purposes. The study involves the collection and characterization of soil samples from a location in Jaipur district, followed by mixing the soil with varying proportions of marble dust obtained from a marble cutting and polishing industry in Nagaur district. Various laboratory tests, including Atterberg's limits, specific gravity, Proctor compaction, and California Bearing Ratio (CBR) tests, were performed to evaluate the effects of marble dust on soil characteristics.

The results reveal that the addition of marble dust to the soil led to a reduction in clay content and an increase in the percentage of coarser particles. The Optimum Moisture Content (OMC) increased, while the Maximum Dry Density (MDD) decreased with higher percentages of marble dust. The plasticity index and swelling properties of the soil were improved, resulting in better volume stability. The CBR values of the soil significantly increased with the incorporation of marble dust, indicating enhanced strength and load-bearing capacity.

The findings suggest that marble dust can be a promising soil stabilizer, particularly for engineering projects involving weak soils, offering an alternative to deep or raft foundations and leading to cost and energy savings. The optimal proportion of marble dust for soil stabilization was found to be 15%. Thus, utilizing 15% marble dust content in soil stabilization can yield the best results. The study highlights the potential of waste marble dust as an effective and environmentally friendly solution for soil improvement and construction applications, contributing to resource conservation and reducing environmental pollution.

Key words: Marble Dust. Soil Stablizer

Introduction

Soil Stabilization involves modifying soils to enhance their physical properties, such as increasing shear strength and controlling shrink-swell characteristics. This improvement in soil quality is crucial for supporting pavements and foundations by boosting the load-bearing capacity of the sub-grade.

Soil stabilization finds application in various settings, including roadways, parking areas, site development projects, and airports, where the natural sub-soils are unsuitable for construction. It is effective for treating a wide range of sub-grade materials, ranging from expansive clays to granular substances. Different additives, such as lime, fly-ash, and Portland cement, are used in this process to achieve stabilization.

Achieving soil stabilization can be accomplished through mechanical or chemical means. Mechanical stabilization aims at densification of soil by compaction through the application of mechanical energy, reducing the voids present. On the other hand, chemical stabilization involves mixing soil with chemical admixtures to improve its volume stability, strength, stress-strain behavior, permeability, and durability. Chemical stabilization methods include cation exchange, flocculation - agglomeration, and pozzolanic reactions.

One of the chemical stabilization methods involves using waste marble dust or limestone dust. These waste materials can be mixed with the soil to enhance its properties, including strength and reduction in plasticity. The pozzolanic reactions play a significant role in the stabilization process, producing calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which bind the soil particles together and increase the strength of the soil.

Soil stabilization is a cost-effective and energy-efficient solution compared to complete soil replacement. It can enhance the bearing capacity of the soil and provide stability to slopes and susceptible areas. Moreover, soil stabilization helps in preventing soil erosion, dust formation, and waterproofing the soil, leading to more successful construction projects.

Review of literature

The literature review provides a comprehensive overview of research related to soil stabilization and the use of marble dust as a stabilizer. The historical context of soil stabilization is explored, indicating its importance in ancient civilizations and its resurgence in recent times due to growing infrastructure demands.

The review highlights the environmental concern of marble dust waste generated during marble cutting and polishing processes. It emphasizes the potential of utilizing waste marble dust as a stabilizer for problematic soils, particularly expansive clays. Various studies are presented, demonstrating the positive effects of marble dust on soil properties, such as increased strength, reduced swelling, improved compaction characteristics, and enhanced durability. Additionally, the review indicates that the addition of marble dust can lead to a reduction in plasticity and an increase in the bearing capacity of the stabilized soil.

Different aspects of soil stabilization techniques using marble dust are explored, including its combination with other materials like lime, fly ash, and ground granulated blast furnace slag (GGBS). The literature also discusses the microstructural changes that occur in the soil due to the addition of marble dust. Overall, the literature review provides strong evidence supporting the effectiveness and benefits of using marble dust as a soil stabilizer. It highlights the potential of this technique in reducing construction costs, conserving resources, and mitigating environmental pollution.

Materials and Methods:

Soil Collection and Characterization:

Soil samples were collected from a small pond near Govindgarh village in Jaipur district. The collected soil was subjected to various tests to characterize its properties. The following tests were conducted on the soil samples:

Liquid Limit Test: The liquid limit of the soil was determined using the Casagrande apparatus, following the standard procedure.

Plastic Limit Test: The plastic limit of the soil was determined by rolling a thread of soil on a non-porous flat surface until it crumbled. The water content at which the soil started to crumble was recorded as the plastic limit.

Proctor Compaction Test: The Proctor compaction test was performed on the soil to determine its Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). Cylindrical metal moulds with specific dimensions and a 2.5 kg rammer were used in the test.

California Bearing Ratio (CBR) Test: The CBR test was conducted to assess the soil's resistance to penetration under specific conditions. The test involved using a circular plunger with a diameter of 50mm and a controlled penetration rate of 1.25mm/min.

Marble Dust Collection:

The marble dust used as the stabilizer material was collected from a marble cutting and polishing industry in Makrana village, Nagaur district.

Mixing of Soil with Marble Dust:

Various mixtures of soil and marble dust were prepared with different proportions of marble dust, ranging from 0% to 20%. The mixing was done thoroughly to ensure a homogenous mixture.

Atterberg's Limits Test:

The Atterberg's limits tests, including the shrinkage limit, plastic limit, and liquid limit, were performed on the soil samples mixed with varying percentages of marble dust to determine the changes in their plasticity.

Specific Gravity Test:

The specific gravity of the soil samples mixed with different proportions of marble dust was measured using the Pycnometer method.

Proctor Compaction Test (with Marble Dust):

The Proctor compaction test was repeated on the soil samples mixed with marble dust to determine their Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).

California Bearing Ratio (CBR) Test (with Marble Dust):

The CBR test was repeated on the soil samples mixed with varying percentages of marble dust to assess the improvement in the soil's strength and bearing capacity.

Data Analysis:

The results obtained from the various tests were analyzed to determine the optimal content of marble dust that resulted in the most effective soil stabilization for construction purposes. The changes in the soil's properties, such as plasticity, density, and CBR values, were studied and compared to the initial soil properties.

The data analysis aimed to identify the proportion of marble dust that provided the best improvement in soil characteristics, making it suitable for road construction and other building purposes. The findings from the tests and analysis would help in understanding the potential of marble dust as a stabilizer for soil improvement and construction applications.

Results and Discussion:

The index properties of the soil mixed with different percentages of marble dust were evaluated to understand the effect of marble dust on soil characteristics. The following observations were made:

Liquid Limit (LL):

The liquid limit of the soil decreased with the addition of marble dust. At 0% marble dust, the liquid limit was 38.15%, while at 10%, 15%, and 20% marble dust, the liquid limits were 42.921%, 41.08%, and 42.15%, respectively. This indicates that the plasticity of the soil decreases with increasing marble dust content, making it less susceptible to changes in moisture.

Plastic Limit (PL):

The plastic limit of the soil also decreased with the addition of marble dust. At 0% marble dust, the plastic limit was 23.15%, while at 10%, 15%, and 20% marble dust, the plastic limits were 22.83%, 20.89%, and 22.51%, respectively. This shows that the soil becomes less cohesive with the incorporation of marble dust.

Plasticity Index (PI):

The plasticity index of the soil decreased with the addition of marble dust. At 0% marble dust, the plasticity index was 15.0, while at 10%, 15%, and 20% marble dust, the plasticity indexes were 20.041, 20.19, and 19.64, respectively. A lower PI indicates a reduced potential for volume change due to moisture variations.

Specific Gravity (SG):

The specific gravity of the soil increased slightly with the addition of marble dust. At 0% marble dust, the specific gravity was 2.47, while at 10%, 15%, and 20% marble dust, the specific gravities were 2.46, 2.48, and 2.47, respectively. The increase in specific gravity could be attributed to the higher density of marble dust compared to soil particles.

Proctor Compaction Test:

The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil improved with the addition of marble dust. The OMC and MDD increased with the increase in marble dust content. This suggests that the addition of marble dust enhances the compactability and strength of the soil.

California Bearing Ratio (CBR):

The CBR values of the soil increased significantly with the addition of marble dust. At 0% marble dust, the CBR value was 1.61%. However, at 10%, 15%, and 20% marble dust, the CBR values improved to 8.25%, 11.19%, and 10.43%, respectively. The increase in CBR indicates an enhancement in the soil's strength and load-bearing capacity, making it more suitable for construction applications.

CONCLUSION

This study focused on the stabilization of artificial soil samples by adding varying proportions (10%, 15%, and 20%) of marble slurry. The effects of this waste material on the consistency limits, compaction parameters, and CBR values of the soil were thoroughly examined. The following conclusions were drawn based on the laboratory test results:

Incorporating marble dust into the soil led to a reduction in clay content, resulting in an increase in the percentage of coarser particles.

The characteristics of the soil significantly changed with the addition of marble dust. The Optimum Moisture Content (OMC) increased, while the Maximum Dry Density (MDD) decreased with increasing percentages of marble dust.

At a 15% addition of marble dust, the OMC showed a 22.39% increase compared to untreated soil, attributed to changes in plasticity index and liquid limit.

Increasing the percentage of marble dust in the soil elevated the plasticity index and reduced the swelling properties, effectively controlling volume changes caused by clayey particles.

The CBR value of the soil increased with higher percentages of marble dust. The most favorable CBR results were obtained with 15% marble dust, showing an increase from 2.36% to 14.86%.

The CBR test and MDD results with 20% marble dust indicated that the soil's CBR value was suitable for construction on medium traffic volume roads, suggesting the potential to utilize more marble waste in the stabilization process.

Overall, soil stabilized with marble dust proved to be a beneficial ground improvement technique, particularly in engineering projects involving weak soils, where it can serve as an alternative to deep or raft foundations, leading to cost and energy savings.

This project work demonstrated that marble dust is a promising soil stabilization agent, with its effectiveness depending on factors like chemical composition, fineness, addition level, and the type of parent soil. It is recommended for use in sub-grade upgradation to reduce thickness and improve soil stability. The results indicated that the CBR value of the soil was optimal at 15% marble dust content. Therefore, for the best results in soil stabilization, a 15% marble dust content is suggested.

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