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Comparison of strength characteristics of alluvial soil improved by marble dust and guar gum

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Abstract: In this investigation explore the possibilities of utilizing materials to improve the engineering behavior of problematic soil. Soil stabilization in alluvial soil is necessary, as their volume changes due to variation in water content. Generally, it expands throughout the rainy season owing to the addition of intake of water or shrink in water. In this investigation the type of admixture namely marble powder and guar gum for stabilization is selected to study the effects of same on the problematic soil. MP and GG were mixed by partial replacement of soil by weight in 5%, 10%, 15%, 20% and 0.5%, 1%, 1.5%, 2%, respectively. The key properties of natural soil were extracted and several tests, such as specific gravity, Atterberg limits, grain size analysis, unconfined compression strength, standard proctor test and Scanning electron microscopy test were performed on soil samples prepared with different percentages of MP and GG. An unconfined compression strength test was used to obtain desired comprehensive strengths following 7, 14, 28 days of curing time. Shear strength of different sample is compared to find optimum proportion of additives. It is observed that 20% of marble powder and 1.5% of guar gum provide maximum strength.

***Index Terms* – Soil Stabilization, Alluvial soil,, Marble dust (MD), Guar gum (GG), Atterberg limits, Compaction, Unconfined compressive strength.**

1. INTRODUCTION

Soils are comprised of mineral components mixed with air and/or water, forming a three-phase structure. They encompass a considerable area of the Earth's surface and play vital roles as construction materials and foundational elements. Soil mechanics, a discipline within engineering, is dedicated to comprehending soil properties and their reactions to external pressures. Within engineering contexts, soil refers to the loose, unconsolidated inorganic matter on the Earth's surface, originating from the breakdown of rocks, potentially containing organic material, and frequently situated atop solid rock strata.
India's soil deposits can be broadly categorized into five main types:
1 .Expansive black cotton soils, found in Maharashtra, Gujarat, Madhya Pradesh, Karnataka, parts of Andhra Pradesh, and Tamil Nadu, are challenging for foundation design due to their high swelling and shrinkage potential.
2. Soft marine soils, located along the coast, particularly in the Desert of Kutch, are characterized by low strength, high compressibility, and occasional presence of organic matter.
3. Desert soils in Rajasthan, deposited by wind and possessing a uniform grading.
4. Alluvial soils in the Indo-Gangetic plain, situated north of the Vindhyachal ranges.
5. Lateritic soils in Kerala, South Maharashtra, Karnataka, Orissa, and West Bengal.

Alluvial soil stands out as one of the most fertile soil types globally, originating from the deposition of sediment particles like silt, clay, sand, and gravel, carried and deposited by rivers and streams. Here are key aspects and details regarding alluvial soil:
1 .Formation: Alluvial soil forms gradually as sediments transported by flowing water accumulate over extensive periods, settling in river valleys, floodplains, and deltas.
2. Composition: It consists of a mixture of minerals including clay, silt, sand, gravel, and organic matter, with the proportions varying depending on factors such as sediment source and distance traveled.
3. Texture: Typically fine in texture due to clay and silt content, it may also contain coarser particles like sand and gravel.
4. Fertility: Its exceptional fertility arises from its rich mineral content and organic matter, making it highly suitable for agriculture and supporting diverse crop growth.
5. Drainage: Generally possessing favorable drainage characteristics, alluvial soil prevents waterlogging and promotes adequate root aeration, making it suitable for various crops.
6. Distribution: Alluvial soil is widespread in river valleys, floodplains, and deltas globally, with significant areas found in regions such as the Indo-Gangetic plains, the Nile Delta, and the Mississippi Delta.
7. Uses: Primarily used in agriculture, it supports the cultivation of crops like rice, wheat, maize, cotton, sugarcane, and various vegetables. Additionally, its stability and load-bearing capacity make it valuable for construction.
8. Challenges: Despite its fertility, it is prone to erosion, particularly under intensive agricultural practices or deforestation in surrounding areas. Excessive sediment deposition during floods can also lead to concerns regarding soil salinity.

Soil stabilization

Soil stabilization encompasses various methods—physical, chemical, biological, or combinations thereof—aimed at improving natural soil properties to suit specific engineering purposes. Typically, the process involves analyzing soil properties, selecting cost-effective methods for modification, assessing feasibility, and implementing chosen methods and materials during construction, with careful consideration of material, construction, and maintenance costs.

There are four main approaches to stabilization, each offering practical and economical solutions:

1. Granular stabilization: This method combines physical and chemical techniques to modify the granular bearing skeleton of soil using binding agents.

2 .Chemical stabilization: This is the oldest and most commonly used technique, involving the addition of chemical compounds to soil to improve its volume stability, strength, stress-strain characteristics, permeability, and durability. Chemical reactions such as hydration and ion introduction are pivotal in this process.

3. Thermal stabilization: This approach utilizes heat and cold treatments on soil to enhance its performance and strength.

4. Electrokinetic stabilization: This method applies an electrical charge to soil to induce physiochemical movement of electric charges, leading to the formation of binding agents within the electric double layer at the interface of solid and liquid phases.

To determine the origin and acquisition process of alluvial soil, the following steps will be undertaken:

Analyze the specific gravity and compaction characteristics of the original soil.

Assess compaction properties using the standard Proctor test for alluvial soil treated with varying proportions of Guar gum and marble powder (ranging from 0.5% to 2% for Guar gum and 5% to 20% for marble powder, based on the dry soil mass).

Perform Unconfined Compressive Strength (UCS) tests on alluvial soil samples treated with different percentages of Guar Gum (0.5%, 1%, 1.5%, and 2%) and marble powder (5%, 10%, 15%, and 20%). These samples will be air-dried for 3 days, 7 days, and 28 days and tested at Optimum Moisture Content (OMC) levels.

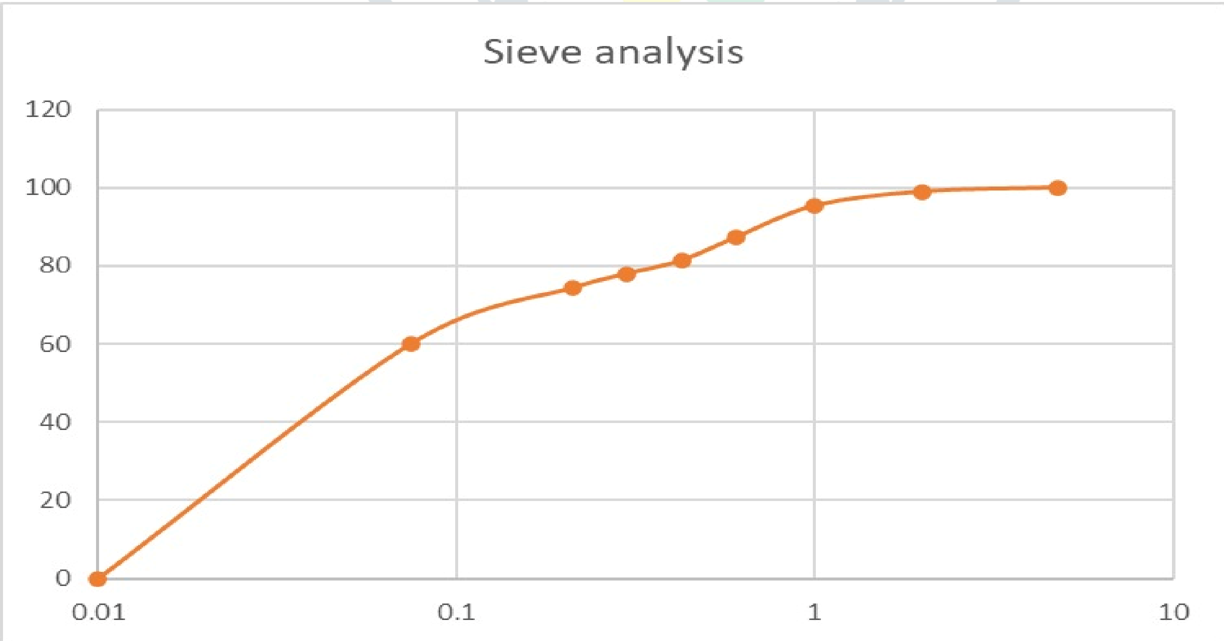
Examine the microstructural properties of samples containing a blend of marble powder and Guar gum with alluvial soil. These samples will be air-dried for 28 days and observed individually.

2. MATERIALS

2.1 Alluvial soil

The materials utilized in the experiments detailed in this study included Alluvial soil, Guar gum, and marble dust. The alluvial soil, sourced commercially, was acquired from Mahi River in Vadodara, Gujarat. This soil exhibits a specific gravity of 2.66, maximum dry density of 16.2 kN/m³ and optimum moisture content is 19.6. A specific gradation of the sand particles ranging from 4.75 to 0.075 mm was deliberately chosen. The grain size distribution curve of the fine sand used in the investigations is depicted in Figure 1.

Figure 1 Sieve analysis



The marble dust was collected from Aqua Minerals, Ahmedabad while the guar gum was collected from Hindustan Gum & Chemicals, Viramgam, Gujrat.

Table 1 Geotechnical properties of soil

Property	Value
Specific Gravity, (Gs)	2.66
Liquid Limit wL (%)	49.8
Plastic Limit wp (%)	38.2
Plasticity Index , Ip (%)	11.6
Maximum Dry Unit Weight cd (kN/m3)	16.2
Optimum Moisture Content(%)	19.6

2.2 Marble dust

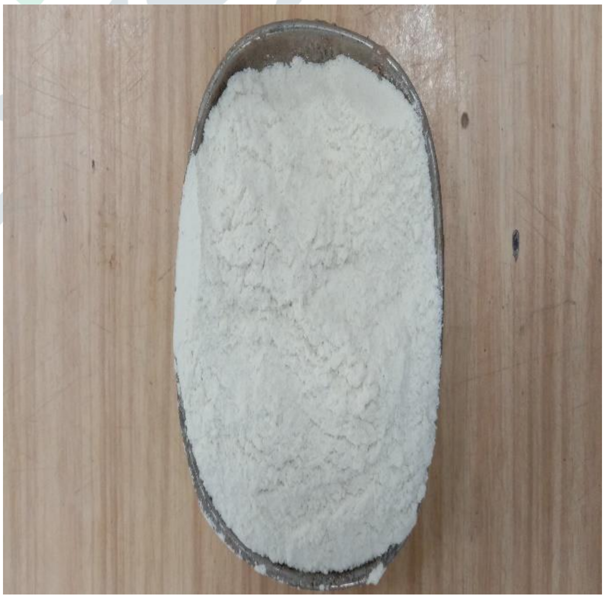
Marble Dust is obtained by dehydrating Marble Slurry, which is a fine residue generated during the cutting, grinding, and polishing of marble. This fine particulate matter becomes suspended in water during the processing and polishing phases, as water is employed as a coolant for the cutting blades.

Table 2 Physical and chemical properties of marble dust

Property	Value
Specific gravity	2.64
Uniformity coefficient, Cu	2.85
Coefficient of curvature, C	1.19
Density (g/cm3)	2.8
SiO2 (%)	71.18
AL2O3 (%)	19.42
Fe2 O3 (%)	3.7
CaO (%)	4.45
MgO (%)	1.25

Figure 2 Marble dust

Figure 3 Guar gum



2.3 Guar gum

Guar gum, scientifically known as Cyamopsis tetragonolobus, is a natural biopolymer extracted from the endosperm polysaccharide of guar seeds, belonging to the leguminosae family and categorized as a seed gum. It comprises polymers D-galactose and D-mannose in a 1:2 ratio. When fully hydrated, guar gum forms thick, colloidal dispersions with thixotropic properties. Borate ions present in guar gum act as cross-linking agents, aiding in the formation of dense, cohesive gels. High-quality guar gum must adhere to the minimum standards specified by the European Union Specification E-412. The chemical composition of the guar gum employed in this study was analyzed using X-Ray Fluorescence technique.

Table 3 Chemical properties of guar gum

Oxide	%	Oxide	%
K_2o	40.83	Mgo	3.18
Cao	16.26	Cuo	2.39
Fe_2o_3	10.24	Na_2o	1.78
So_3	7.03	Sio_2	1.32
P_2o_5	5.84	pd	1.07
pbo	4.50	zno	0.52
cl	4.25	Al_2o_3	0.46

3. SAMPLE PREPARATION

For sample preparation, there are two alternative mixing techniques to consider: dry mixing, where the guar gum is directly blended with the soil prior to water addition, and wet mixing, where the guar gum is combined with water to create a hydrosolution before being mixed with the soil. In this case, the dry mixing method was employed. Soil samples were mixed with different proportions of guar gum (0.5%, 1%, 1.5%, 2%) and marble dust (5%, 10%, 15%, 2%).

4. RESULTS AND DISCUSSION

The soil samples were blended with marble dust at concentrations of 5% 10%, 15%, and 20% and guar gum at 0.5%, 1%, 1.5% and 2%.The liquid limit and the plastic limit of treated soil increase with the increase in guar gum content as a result of the guar gum's tendency to hydrate and form strong hydrogels by way of hydrogen bonding. In the standard Proctor test, specimens were created by compacting poorly graded fine sand with guar or xanthan gum in a wet state. This involved distributing three equal layers with 25 blows per layer until achieving optimum moisture content (OMC). A 5% variation was introduced from the OMC for both dry and wet side water content. Optimum moisture content was determined to be 19.4%, 19.5%, 16.2 and 16.4% for concentrations of 0.5%, 1%, 1.5% and 2% of guar gum, respectively. Similarly, it was 18.8%, 18.9%, 15.7% and 15,8%% for concentrations of 5%, 10%, 15% and 20% of marble dust, respectively. The compaction curves and liquid limit are depicted in figures for treated with guar and marble dust. Unconfined compressive strength (UCS) tests were conducted to ascertain the sample's compressive strength using conventional laboratory testing methods. Experimental work was carried out with variations of 0.5%, 1%, 1.5% and 2% contents of guar guar and 5%, 10%, 15% and 20% of marble dust the samples were left to air dry for 7, 14 and 28 days. Samples were prepared to analyze the effects of admixtures and water content variation. The tests were performed according to the procedures outlined in IS code 2720-10.

Figure 4 Liquid limit for soil mixed with different % of MD

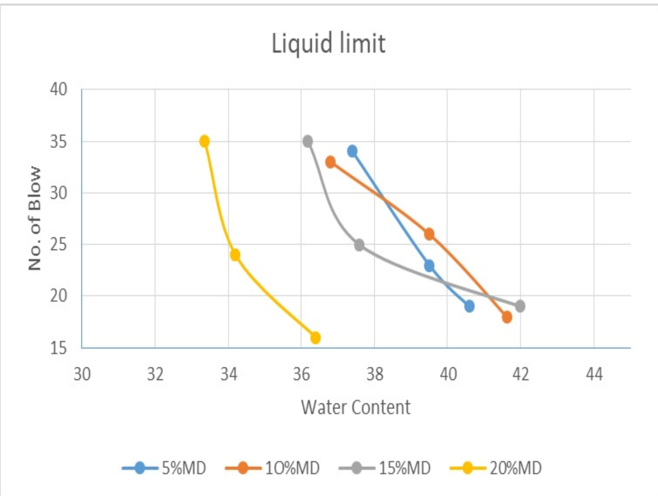


Figure 2 Liquid limit for soil mixed with different % of MD

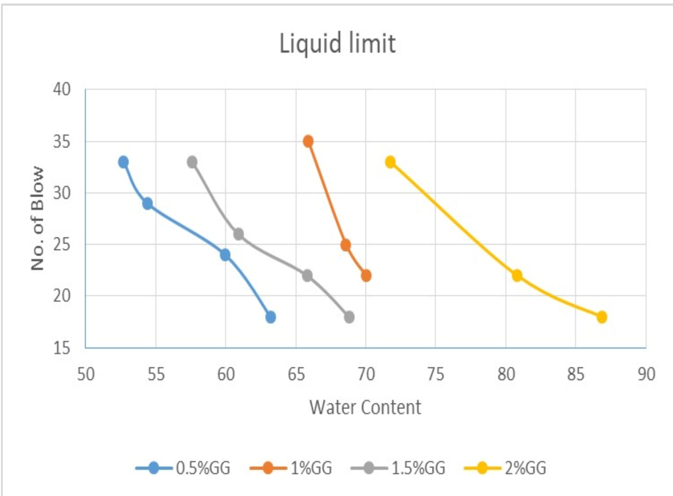
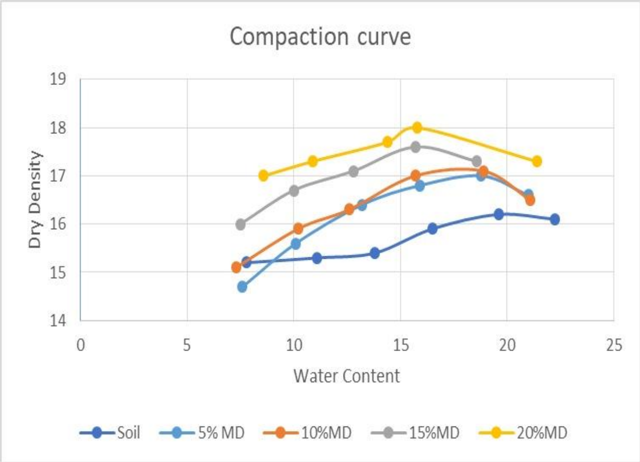


Figure 6 Compaction curve soil mixed with different % of MD Figure 7 Compaction curve for soil mixed with different % of GG



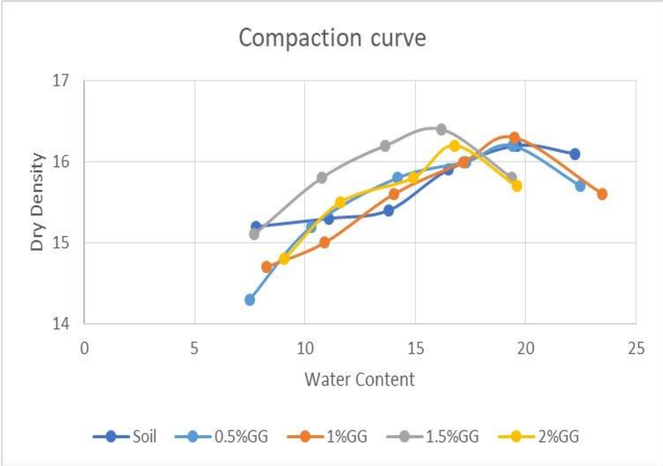


Figure 7 UCS curve

Figure 8 Failure sample

The strength characteristics of poorly graded fine sand were evaluated at three different ratios (0.5%, 1%, 1.5% and 2%) of Guar gum, and air-drying durations of 7, 14, and 28 days were considered. From these test outcomes, the compressive strength was determined.

The UCS (Unconfined Compressive Strength) initially decreased and then increased with varying concentrations of guar gum (0.5%, 1%, 1.5% and 2%). Additionally, the UCS increased with longer air-drying periods from 7 to 14 days and from 14 to 28 days. Moreover, the UCS increased as moisture content decreased from the optimum moisture content and decreased as moisture content increased beyond the optimum moisture content. Furthermore, the UCS value decreased for a 2% concentration of guar gum due to insufficient bonding between the soil-guar gum-water mixture. It is recommended to avoid high guar gum concentrations due to material cost and workability issues (e.g., high viscosity leading to poor mixing).

Thus, the most cost-effective and efficient concentration of guar gum for soil treatment appears to be approximately 0.5-2%.

Figure 9 Effect of GG on Strength after 0 days

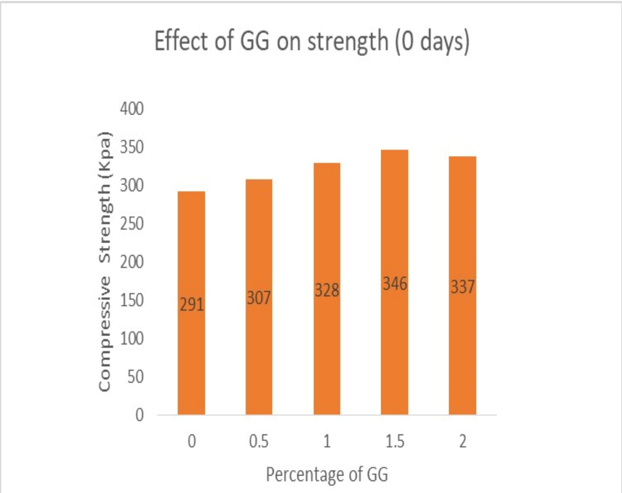


Figure 10 Effect of GG on Strength after 7 days

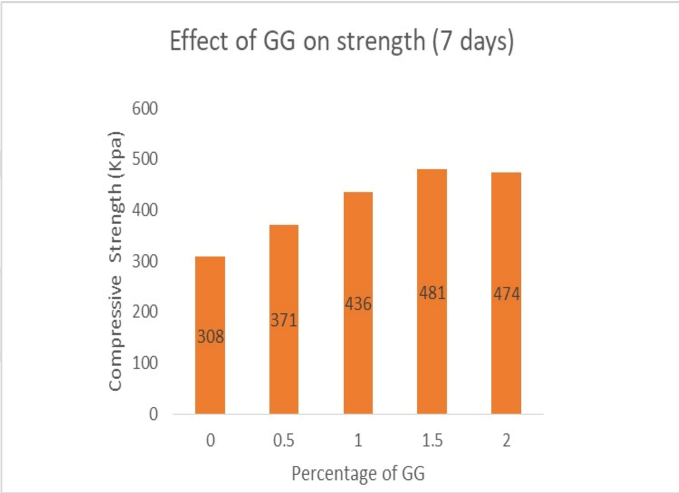


Figure 11 Effect of GG on Strength after 14 days

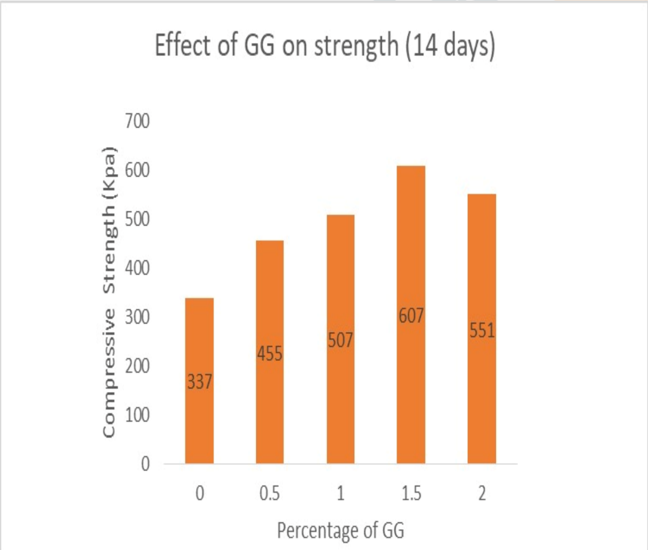
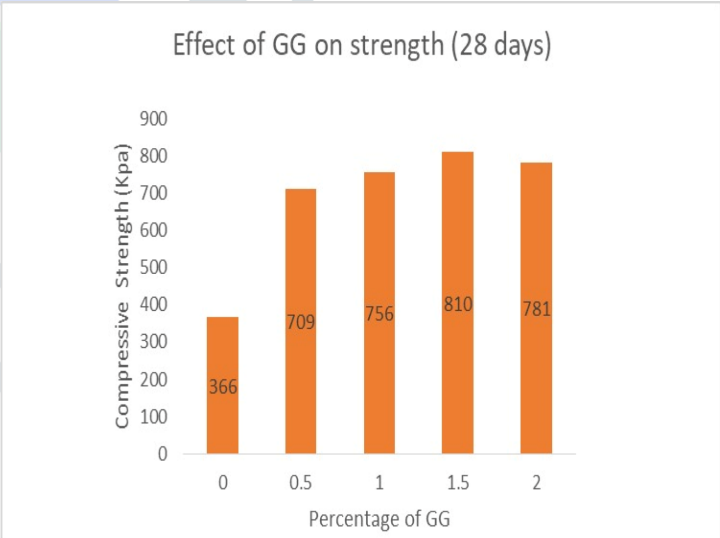


Figure 12 Effect of GG on Strength after 28 days

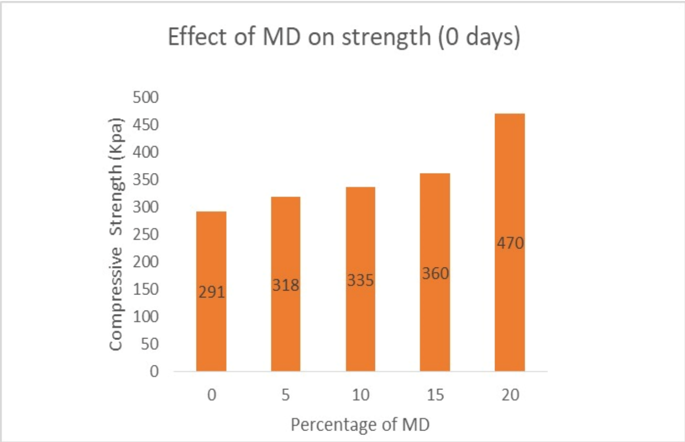


The strength characteristics of alluvial soil were evaluated at three different ratios (5%, 10%, 15% and 20%) of marble dust and air-drying durations of 7, 14, and 28 days were considered. From these test outcomes, the compressive strength was determined.

The UCS (Unconfined Compressive Strength) initially decreased and then increased with varying concentrations of marble dust (5%, 10%, 15% and 20%). Additionally, the UCS increased with longer air-drying periods from 7 to 14 days and from 14 to 28 days. Moreover, the UCS increased as moisture content decreased from the optimum moisture content and decreased as moisture content increased beyond the optimum moisture content. Thus, the most cost-effective and efficient concentration of marble dust for soil treatment appears to be approximately 5-20%

Figure 13 Effect of MD on Strength after 0 days

Figure 14 Effect of MD on Strength after 7 days



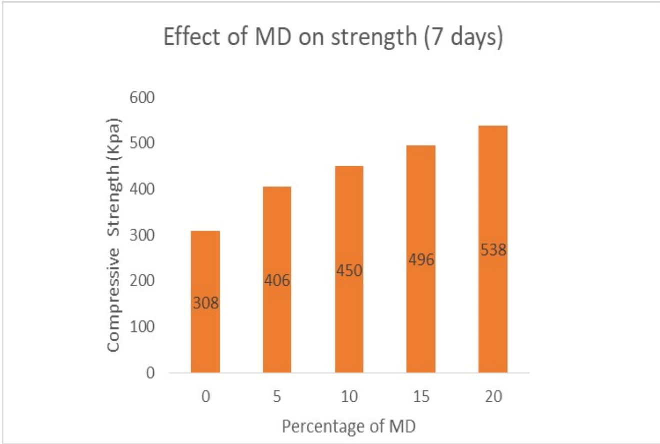
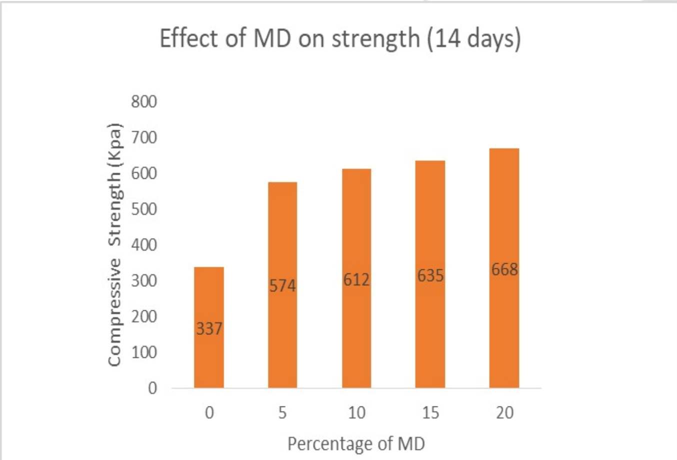
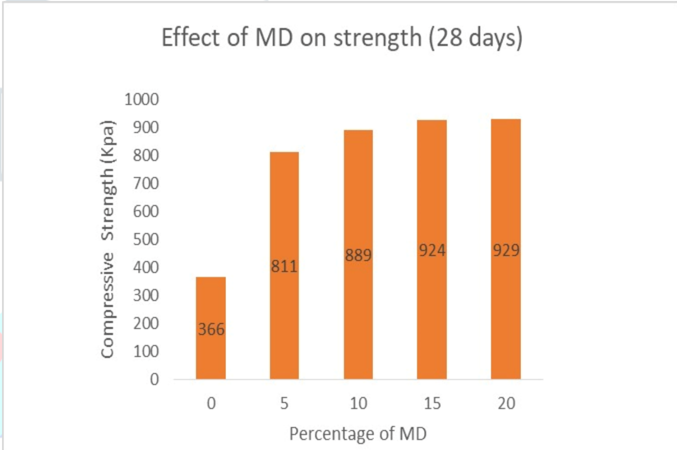


Figure 15 Effect of MD on Strength after 14 days

Figure 16 Effect of MD on Strength after 28 days





5. CONCLUSION

The current research examines how marble dust and guar gum affects alluvial soil. It has been demonstrated that the use of biologically induced cementation can notably enhance the compressive strength of this type of soil. The study investigates the strength characteristics of sand treated with different percentages (0.5%, 1%, 1.5%, 2%) of Guar gum and (5%, 10%, 15%, 20%) of marble dust along with varying air-drying durations of 7, 14, and 28 days. The findings of the tests conducted indicate that the behavior of alluvial soil mixtures containing different amounts of marble dust and guar gum leads to the following conclusions:

Increases of 60% and 31% in the liquid limit, and plastic limit, respectively, were observed when treating the soil with guar gum.
Decrease of 47% and 30% in the liquid limit and plastic limit, respectively, were observed when treating the soil with marble dust.
The optimum moisture content showed a decrease of 3.8%, while the maximum dry density of the treated soil showed a marginal change from 16.2 kN/m3 to 18 kN/m3 for marble dust.
The optimum moisture content showed a decrease of 3.4%, while the maximum dry density of the treated soil showed a marginal change from 16.2 kN/m3 to 16.4 kN/m3 for marble dust.
From UCS test it is observed that the UCS values increased by 18.9% for 0days of curing, 56.2% for 7 days of curing, 80% for 14 days of curing and 121% for 28days of curing with respect to virgin soil for guar gum.
From UCS test it is observed that the UCS values increased by 61% for 7days of curing, 98% for 14 days of curing and 153% for 28days of curing with respect to virgin soil for marble dust.

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