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EVALUATING THE EFFICACY OF ROCK DUST IN GEOTECHNICAL ENHANCEMENT OF SOFT CLAYEY SOIL: ENGINEERING PERFORMANCE AND ENVIRONMENTAL PSYCHOLOGY PERFORMANCE

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Abstract
The lateral displacement of subgrade due to water absorption by the pavement, as well as excessive deflection and differential settlement of the material beneath the pavement, is typically linked to pavement failures. These blunders may have an influence on the community's sense of safety in addition to having engineering adverse effects. Psychological distress may also be experienced by those who reside or work close to damaged infrastructure. The study's objective is to investigate how certain soils in Mardan City, Pakistan, are affected by rock dust additives in terms of stability and increased bearing capacity, while considering the psychological impacts of using ecologically friendly geotechnical methods In order to stabilize the native soil, the physical, chemical, and engineering characteristics of the soil were examined, and the soils were treated with additions (rock dust). Rock dust is added to soils in the range of 0 to 85% with percentage increases of 5%, 10%, and 15%, respectively, to modify the soil. According to the results of the particle size analysis, the soil's gradation is thin. The addition of rock dust reduced the plasticity index (P.I.), liquid limit (L.L.), and plastic limit (P.L.). It was determined that adding rock dust raised the maximum dry density value; the highest value was attained when 10% rock dust was added, and the content decreased beyond 10%. It was discovered that adding rock dust improved the California bearing ratio (CBR) and the cohesiveness c value reduced the angle of internal friction. The improved stability achieved at an optimal 10% dosage may have a substantial psychosocial impact on stakeholder trust, risk perception, and acceptance of rock-dust-based stabilization as a reliable and sustainable solution. According to the study, rock dust is the greatest stabilizer for the case study, and 10% is the ideal dosage.
Keywords: Expansive soil, Stabilization, Rock dust, Subgrade, Geotechnical properties, Environmental Psychology, Risk Perception

INTRODUCTION

On this planet, soil is a plentiful naturally occurring substance. It is the least expensive building material on the market. However, the substance is also highly complicated. Naturally occurring factors affect how the soil behaves [1]. Compared to rocks, they have a lower shear strength, which decreases even more when wet. Soil engineers are primarily concerned with the volume stability, strength, permeability, and durability of soil. They can expand when wet, contract clay with certain minerals, and be plastic and compressible [2]. When the moisture content is increased, these soft clayey soils with high plastic characteristics inflate, reflecting the clay ratio in the soil and the presence of clay minerals on the qualitative value of the plasticity index [3-5]. The shift in the composition of the soil structure, in particular, led to a number of technical issues in engineering constructions such parking lots, buildings, roadways, and airports [6].
Natural deposits that have not been subjected to drying are soft, clayey, and have mottled colors in various parts of the world. When their unique qualities are adequately identified, lateralized soil performs well in pavement

construction [7]. According to research, rock dust can be utilized as building stones, sub-grades, sub-base material, base material, fill material for road and building foundations, an embankment for dams, etc. [8]. By using locally accessible materials and soils, the cost of building stabilized soil roads can be significantly reduced. Soil stabilization can be used to improve the locally available soil if it is extremely poor and cannot support the anticipated traffic wheel loads [9].

Constructing road bases and surface courses using materials that are already stable, such concrete, crushed rock, etc., is typically not seen as falling under the aforementioned criterion [10]. Combining soils in a way that, when compacted under certain circumstances and to a certain degree would undergo a material change in its properties and remain in its stable compacted state without changing under the effects of exposure to traffic is known as soil stabilization. Additionally, it can generate some income, thus it is no longer considered waste [11]. Ground soil compaction will therefore aid in lowering the void ratio and enhancing soil strength parameters such as cohesion (©) and angle of internal friction (·). In certain situations, the geotechnical engineer must stabilize the soil in order to improve its characteristics and avoid issues. Less desirable soils can have their qualities improved with the use of soil stabilizing chemicals. When applied, these stabilizing chemicals can increase soil particle cohesion, improve and maintain soil moisture content, and act as cementing and waterproofing agents [12–16].

Rock dust, also known as quarry dust, is a concentrated material used as fine aggregates that are released during the cutting and crushing of rock and aggregate. It is a cementation byproduct. When a mountain explodes, a rock is broken into tiny pieces, and throughout the process, particles known as quarry dust are created, which are disposed of as garbage. The disposal of these massive amounts of quarry dust poses a major risk to human health and the environment. Utilizing these waste resources is mandatory [17]. Large amounts of quarry dust can be used, which not only solves an environmental issue but also lowers the overall cost of building. High shear strength has been found in quarry dust, which is advantageous for its application as a geotechnical material. Through a series of CBR experiments, the strength characteristics of compacted crusher dust and crushed stone mix are also investigated by varying the crusher dust. According to their findings, fly ash and stone dust work well together to strengthen expansive soil and lessen swelling. Rock dust has several geotechnical uses, including large-scale subbase and embankment backfill [18, 19]. Its excellent qualities are not significantly affected by variations in water content, and it has good permeability.

With the addition of quarry dust, or rock dust, the specific study aims to analyze the engineering properties to stabilize the loose clayey soil. Its effects can be quantified by comparing the soil's characteristics with and without the rock dust, as well as by determining the precise amount of the addictive substance (rock dust) needed to stabilize the specific clayey soil under monitoring.

People's perceptions of safety, the environment, and community well-being are significantly influenced by infrastructure reliability in addition to engineering performance. Pavement failures, such as differential settlement and subgrade deformation, are frequently associated with increased public concern, diminished trust in local infrastructure, and increased cognitive stress for nearby communities. According to environmental and cognitive psychology views, the use of sustainable materials, such rock dust, may affect stakeholder attitudes toward construction projects, perceived environmental stewardship, and acceptance of novel geotechnical techniques. This study uses a psychological framing to show how engineering modifications in soft clayey soils relate to broader human perceptions of risk, sustainability, and urban livability.

The following are the study's goals.

- To investigate how certain soils on Taru Road in Mardan City, Pakistan, are affected by additions (rock dust) in terms of stability and increased bearing capacity.
- To determine whether employing rock dust as a soil stabilizing agent is appropriate.
- To look into how using rock dust affects the native soil's engineering qualities.

One of the biggest issues is dealing with soft subgrade. This scenario is likely to arise in geotechnical engineering, roads, or highway building [20]. Finding strategies for soil enhancement procedures to meet the demands is essential because there are fewer places available for construction development. The most popular or standard method for stabilizing soft subgrade was to remove the soft soil first. It will then be replaced with stronger materials, such crushed rock. Due to the expensive expense of replacing the materials, numerous studies have been conducted to identify alternative solutions to this issue. The soil must be altered for one or more qualities in order to produce a better soil material with the required engineering properties [21]. This technique is known as soil stabilization and can be carried either mechanically or chemically. Sand can be replaced with quarry dust to enhance lateritic soil's qualities. The CBR value increased steadily as the percentage of quarry dust increased, and the improvement in CBR value can be linked to the notable improvement in angle of shearing resistance, according to research on the impact of quarry dust on the geotechnical characteristics of soil used in highway construction. The potential of soil-quarry dust mixes as a sub foundation for flexible pavement is increased by higher CBR values [22]. For weak soil deposits, quarry dusts are regarded as one of the widely used and reasonably priced ground improvement techniques. They serve the main purposes of drainage and reinforcing, which enhances the deformation properties and strength of weak soil deposits. The shear strength of soil-quarry dust combinations was studied by researchers. The findings demonstrated that quarry dust can be utilized to enhance the engineering qualities of soils and has shown promise as a sand substitute. When quarry dust was added, the dry density rose and the ideal moisture content decreased. Any effort to use this trash in developing initiatives is pertinent in this context. Quarry dust has several geotechnical uses, including backfills, embankments, and sub-base. By combining with quarry dust, issues related to building roads over clayey subgrade can be greatly minimized [23].

MATERIALS AND METHOD

The soils were taken from a 3x3-foot trial pit on Taru Road in Mardan, Pakistan. Samples were taken from four trial pits, and all of the samples utilized in this study were molded in a lab using normal operating techniques. Rock dust was taken into consideration as a potential stabilizer to treat and stabilize soil for the laboratory testing procedure. The characteristics of soil were examined utilizing locally accessible materials (rock dust) in order to achieve the goals of the study. Rock dust was gathered from nearby quarries. The percentage of dry soil content would change. Rock makes up 5%, 10%, and 15% of the weight of dry soil that is categorized as type A, type B, type C, and type D. By comparing and contrasting the findings with the ASTM standards, conclusions were reached after the geotechnical parameters were examined. A soil/additive performance-based specification would be very helpful in examining the relative performance predicted from each soil/additive combination supported by a variety of soil testing methodologies to make the selection process easier.

Soil Preparation

The soil was broken up to fit through the 3/8" sieve after being air-dried in big pans for the entire night. To get rid of the bigger particles, soil samples were wetly sieved in accordance with ASTM D 2216 over a #40 sieve. Since the Atterberg restrictions demand material smaller than the #40 sieve, the #40 sieve was utilized rather than the #10 sieve. The material was utilized for testing such as Atterberg Limits and sieve analysis after it had been broken up.

Based on the percentage of mix rockdust applied by dry soil weight, the soil utilized for research is divided into four groups.

- Type A: Pure Soil Sample.
- Type B: Rockdust as 5% by weight of dry soil.
- Type C: Rockdust as 10% by weight of dry soil.
- Type D: Rockdust as 15 by weight of dry soil.

Native Soil

The purpose of collecting the soil sample was to evaluate the admixture. According to the Unified Soil Classification System (USCS), CL-ML is the soil used to stabilize substandard subgrade soil.

Additive

Rock dust is one of the additives utilized in the stability and modification study. Additives that were expected to improve the engineering qualities of the soils were combined with them. The natural soil was combined with additives at weight percentages of 0%, 5%, 10%, and 15%.

Psychological Component and Theoretical Framework

Despite the study's experimental focus, a theoretical examination of risk perception, sustainability attitudes, and human-factor concerns related to soil stabilization contains a psychological component. This entails investigating the potential effects on worker safety perceptions, community trust in infrastructure, and public acceptance of sustainable building materials of improvements in soil performance, such as increased carrying capacity and decreased flexibility. Concepts from environmental psychology and risk-perception research were used to frame the engineering findings' possible human repercussions rather than collecting direct psychological data.

RESULTS AND DISCUSSIONS

Locally accessible materials were used to investigate the characteristics of the rock dust soil mix. The local quarry site at Landaki Swat, where stones were crushed and processed, provided the rock dust. The rock dust that was extracted from the quarry site was extensively mixed with dry soil in different weight percentages.

In this section, materials used in the experimental program along with the procedures followed for testing soil mixes are discussed.

Sieve Analysis

Sieve Analysis of pure soil sample

The result is shown in the figure.

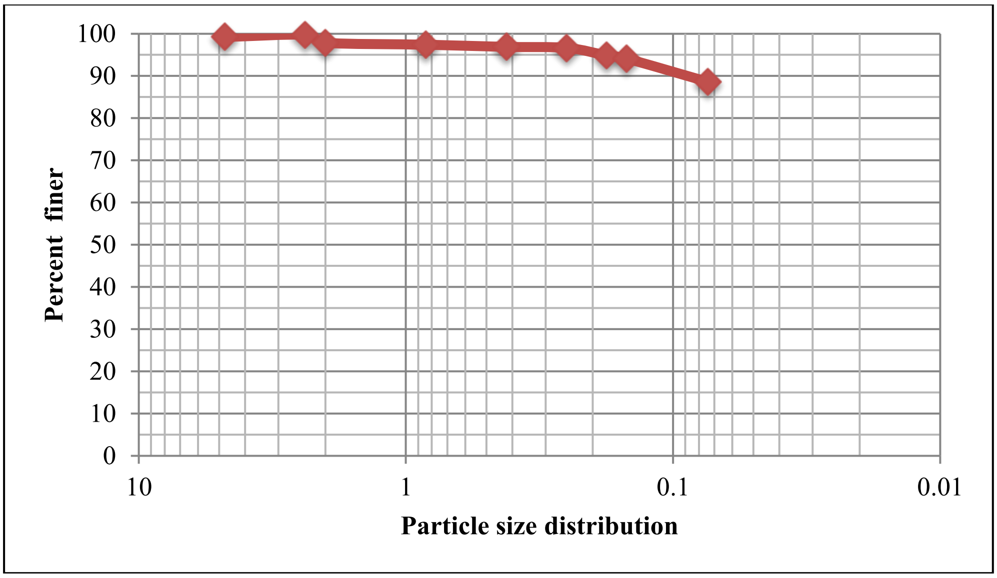

Figure: Gradation Curve for Soil Sample

DISCUSSION:

Gradation curve of soil sample is shown in the figure. The soil sample is essentially a fine grained material and is classified as CL-ML according to unified soil classification system (USCS).

Modified Proctor Test

Modified proctor test of pure soil sample

The results are shown in table and figures.

Table: Modified Proctor Test of Pure Soil Sample

S. No.	Soil Type	Optimum Moisture Content (OMC)	Maximum Dry Density (MDD)
1	Pure (0%)	8.9	2.272
2	A (5%)	9.35	2.332
3	B (10%)	8.1	2.346
4	C (15%)	8.9	2.313

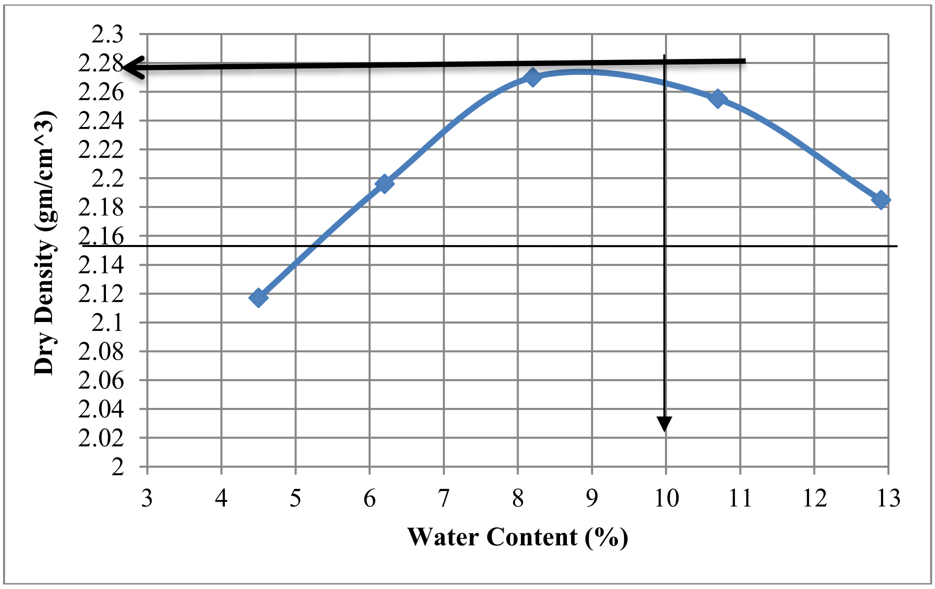

Figure: Plot of Water Content (%) Vs. Dry Density for the Maximum Dry density for pure soil sample

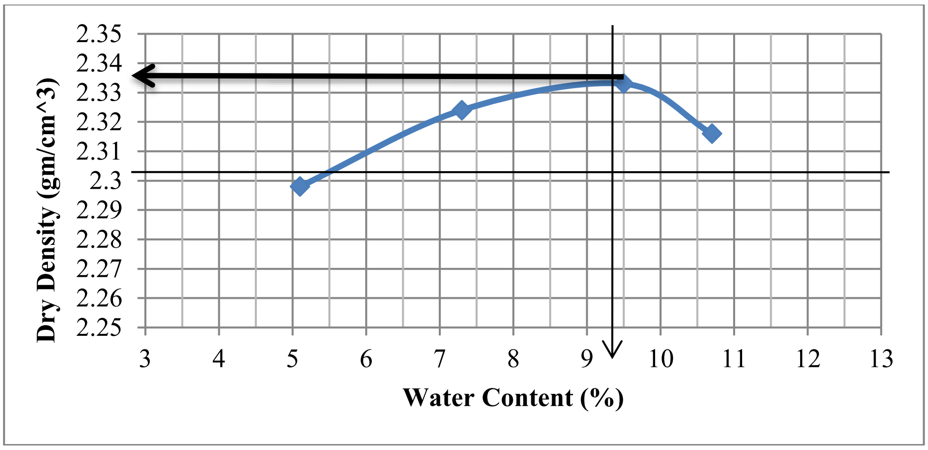

Figure: Plot of Water Content (%) Vs. Dry Density for the Maximum Dry Density at 5% Rock dust

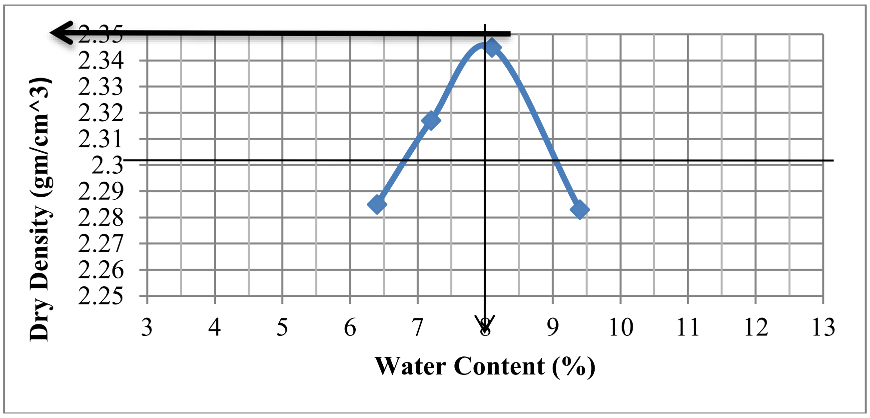

Figure: Plot of Water Content (%) Vs. Dry Density for the Maximum Dry density at 10% Rock dust

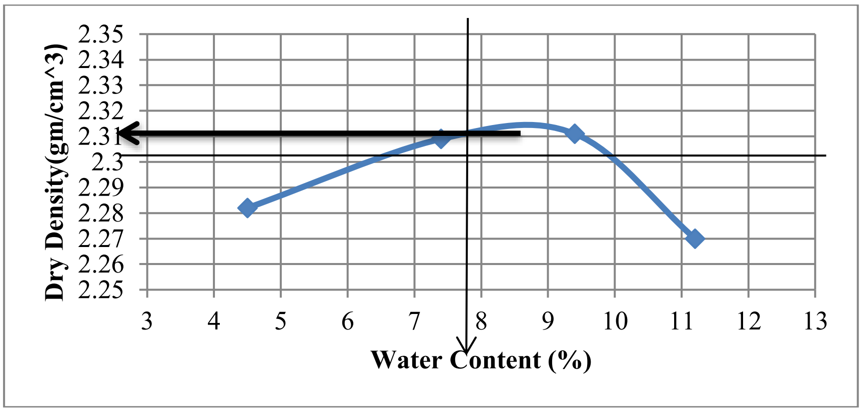

Figure: Plot of Water Content (%) Vs. Dry Density for the Maximum Dry Density at 15% Rock dust

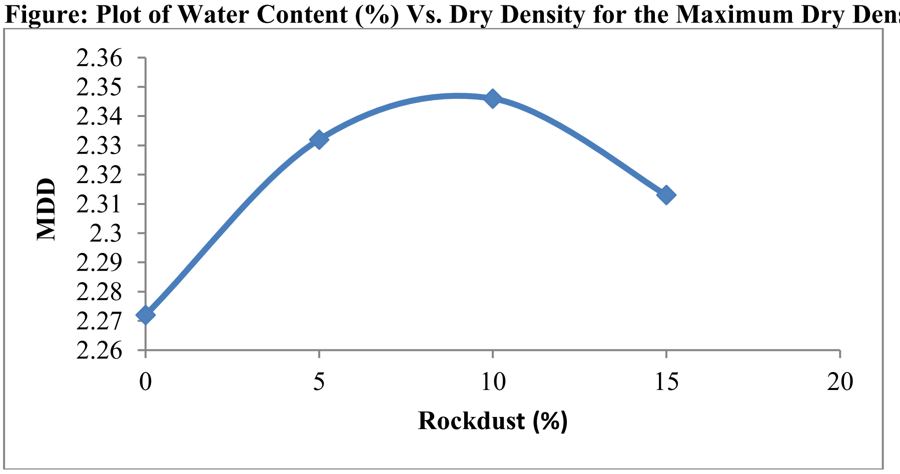

Figure: Variation of Graph between MDD and Rock dust

Discussion: The maximum dry density of soil was found to increases from to 2.346gm/cc from 2.272gm/cc up to addition of 10% rock dust; beyond it decreases as shown in figure.

Liquid Limit Test Results

Pure soil sample

The results are shown in table and figures.

Table: Liquid Limit for Pure Soil Sample

Serial No.	Soil Type (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (PI)
1	Pure (0%)	32.96	30.71	2.25
2	A (5%)	30.54	28.63	1.91
3	B (10%)	29.16	27.40	1.76
4	C (15%)	27.34	26.37	1.04

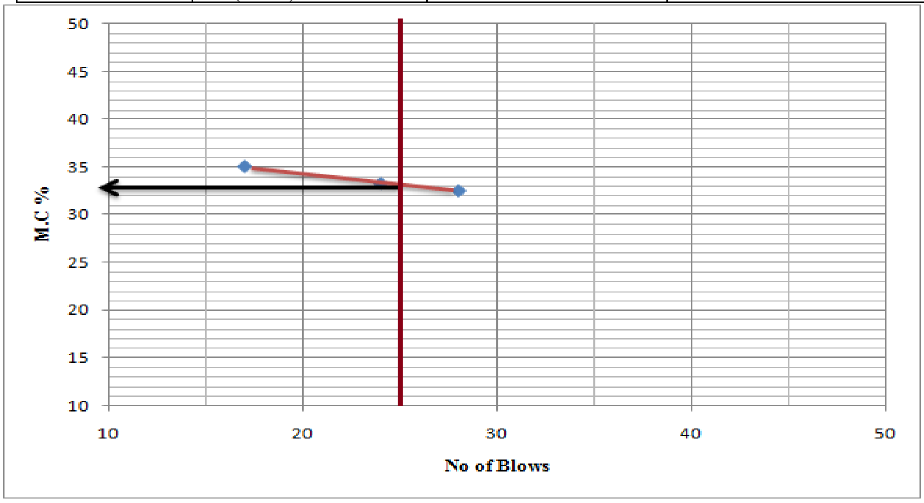

Figure: Plot of Moisture Content (%) vs. Number of blows for the Liquid limit test

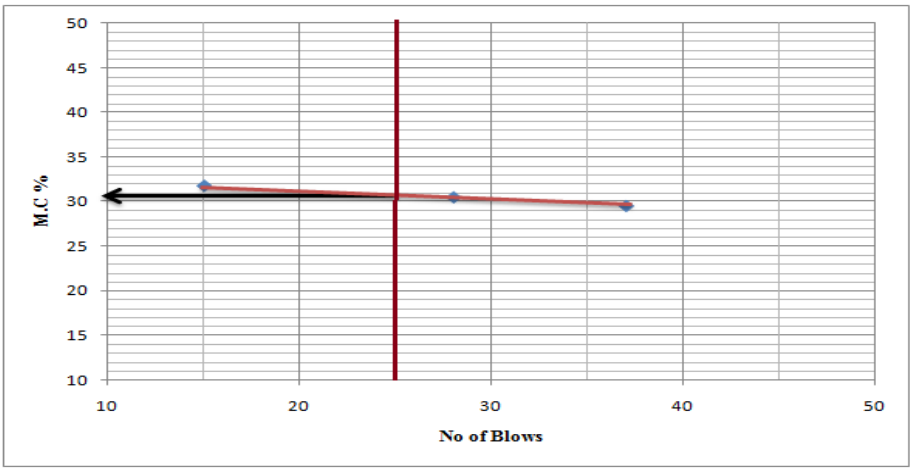

Figure: Plot of Moisture Content (%) Vs. Number of Blows for the Liquid Limit Test

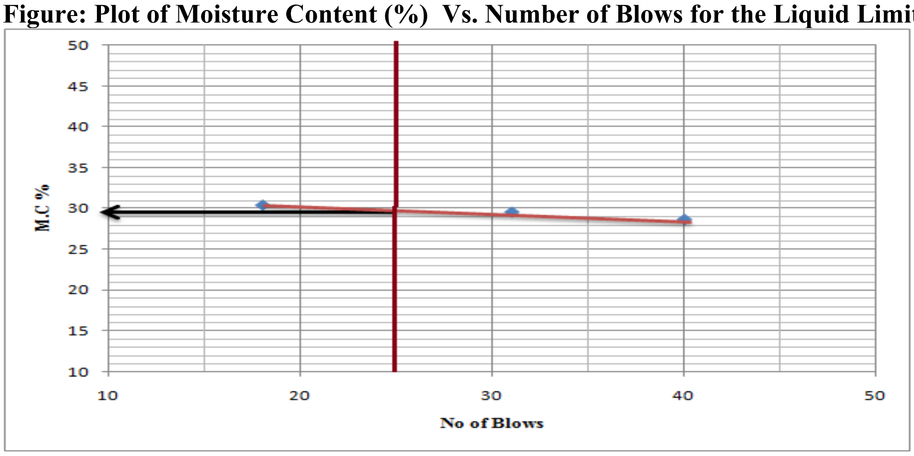

Figure: Plot of Moisture Content (%) Vs. Number of Blows for the Liquid Limit Test

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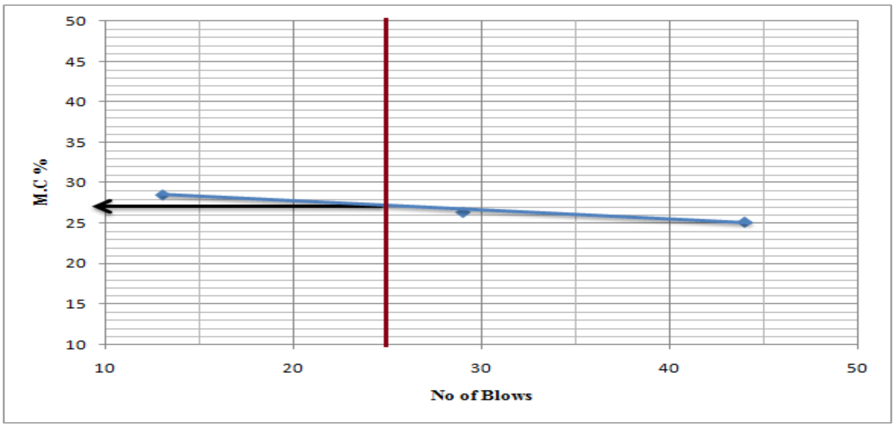

Figure: Plot of Moisture Content (%) Vs. Number of Blows for the Liquid Limit Test

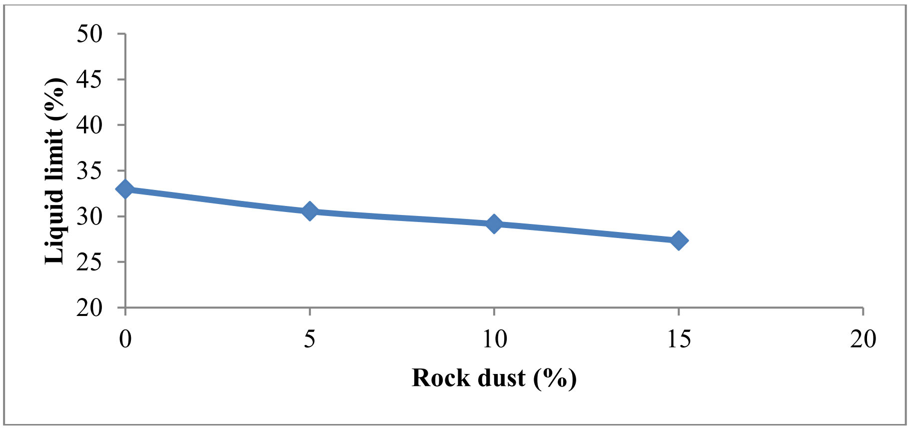

Figure: Variation of Graph between Liquid Limit with the Percentage of Rock dust

Discussion: The Percentage of variation of liquid limit to the admixture. It is observed that as the percentage of admixture (Rock dust) increases, the liquid limit decreases.

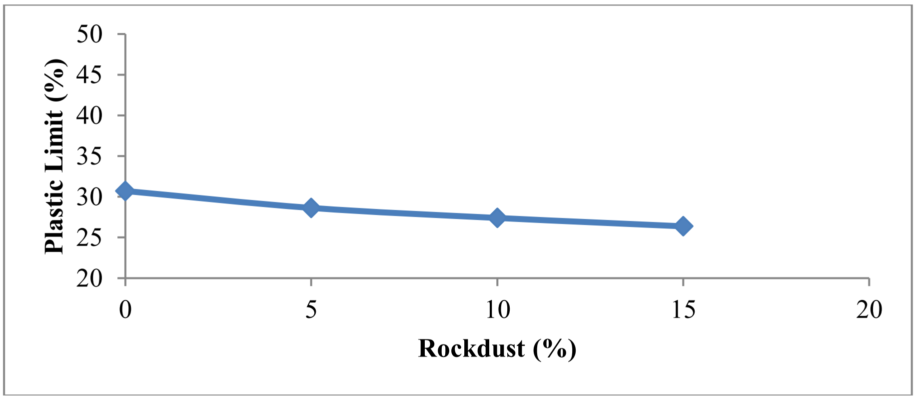

Figure: Variation of Graph between Plastic Limit with the Percentage of Rock dust

Discussion: The Percentage of variation of Plastic limit to the admixture. It is observed that as the percentage of admixture (Rock dust) increases, the plastic limit decreases.

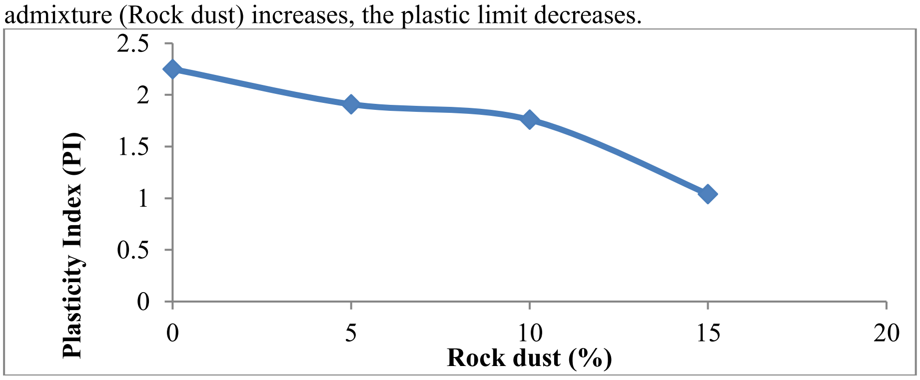

Figure: Variation of Graph between Plasticity Index with the Percentage of Rock dust

Discussion: The Percentage of variation of Plasticity index to the admixture is given in fig 4.13. It is observed that as the percentage of admixture (rock dust) increases, the plasticity index decreases.

Specific Gravity

The results are shown in table and figures.

Table: Specific Gravity Test for Pure Soil Sample

Serial No.	Soil Type	Specific Gravity
1	Pure (0%)	2.7226
2	A (5%)	2.6231
3	B (10%)	2.6498
4	C (15%)	2.7086

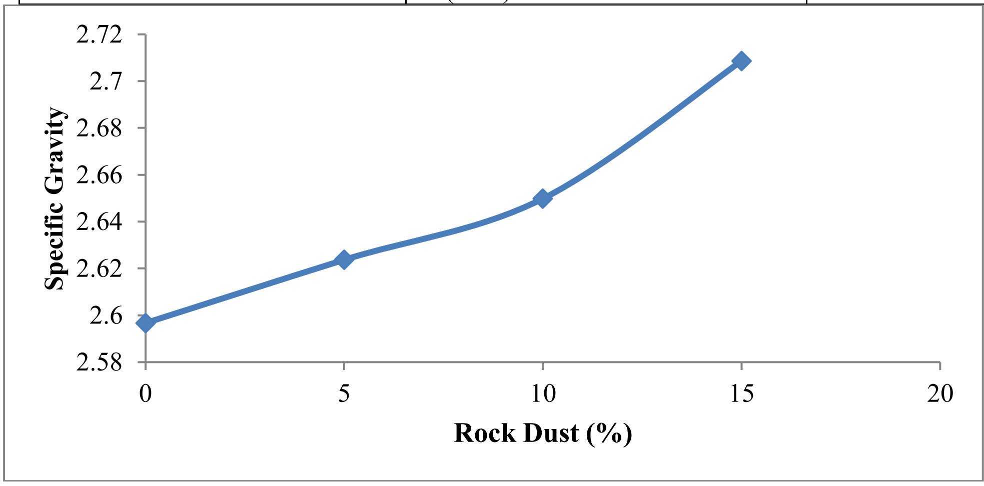

Figure: Variation of Graph between Specific Gravity with the Percentage of Rock dust

Discussion: The Percentage of variation of specific gravity to the admixture is given in figure. It is observed that as the percentage of admixture (Rock dust) increases, the specific gravity increases.

Direct Shear Test

The results are shown in figures.

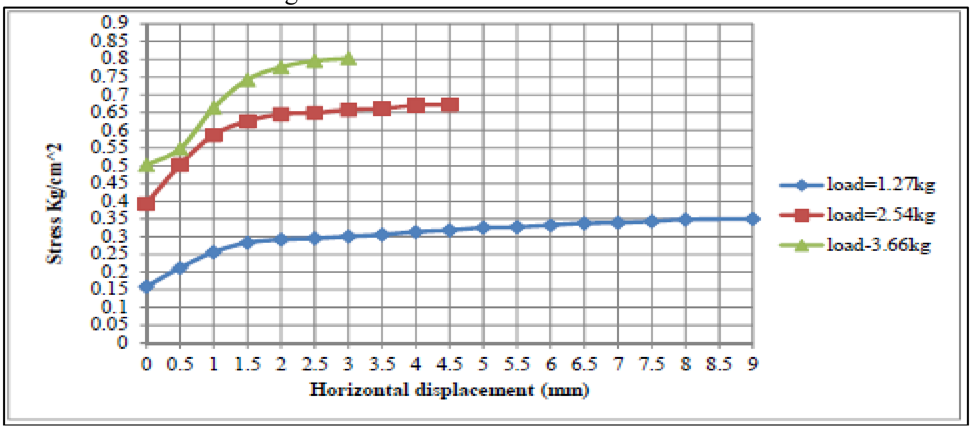

Figure: Variation of Graph between Shear Stress and Horizontal Displacement for Pure Soil Sample

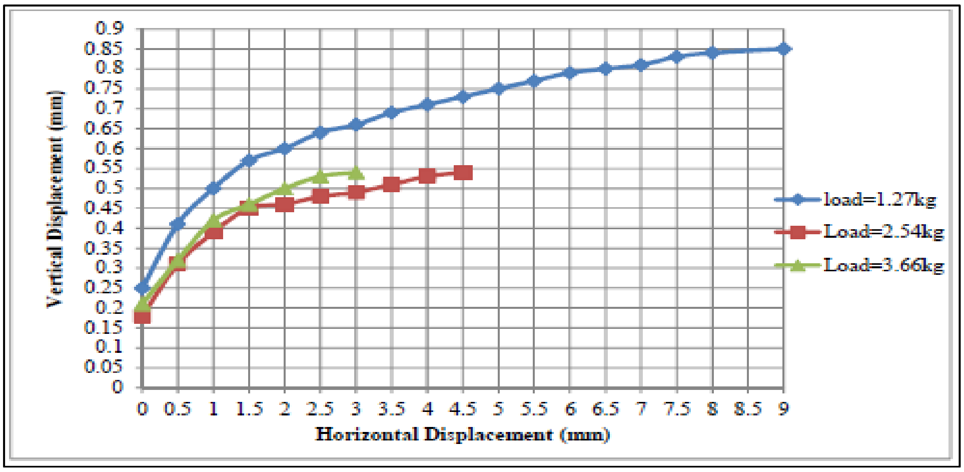

Figure: Variation of Graph between Vertical Displacement and Horizontal Displacement for Pure Soil Sample

Direct Shear Test (4% Rock dust)
The results are shown in figures.

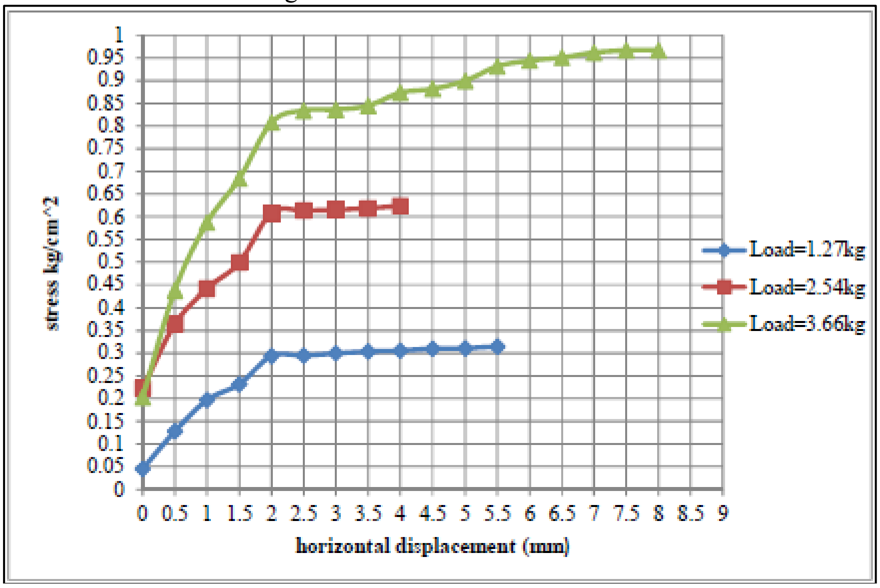

Figure: Variation of Graph between Shear Stress and Horizontal Displacement for 5% Rock dust

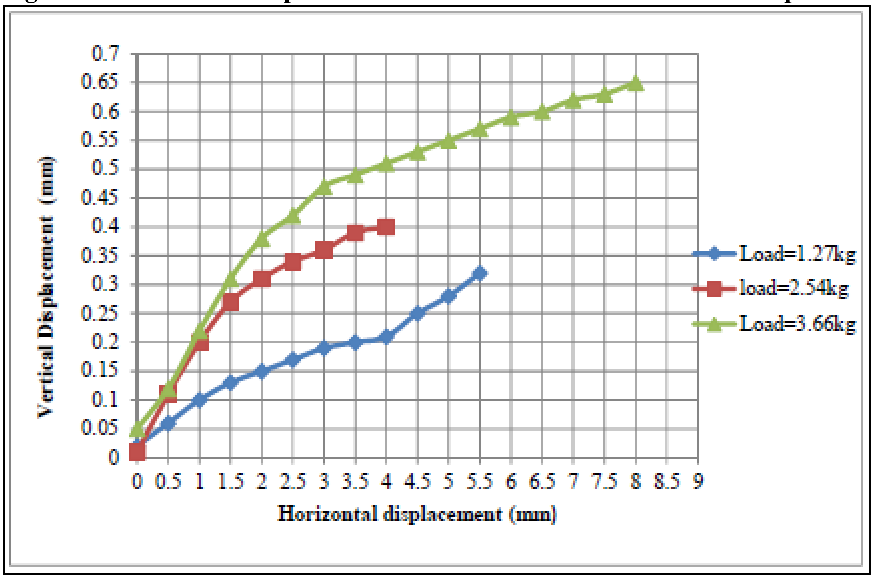

Figure: Variation of Graph between Vertical Displacement and Horizontal Displacement for 5% Rock dust

Direct Shear Test at 10% of Rock dust
The results are shown in figures.

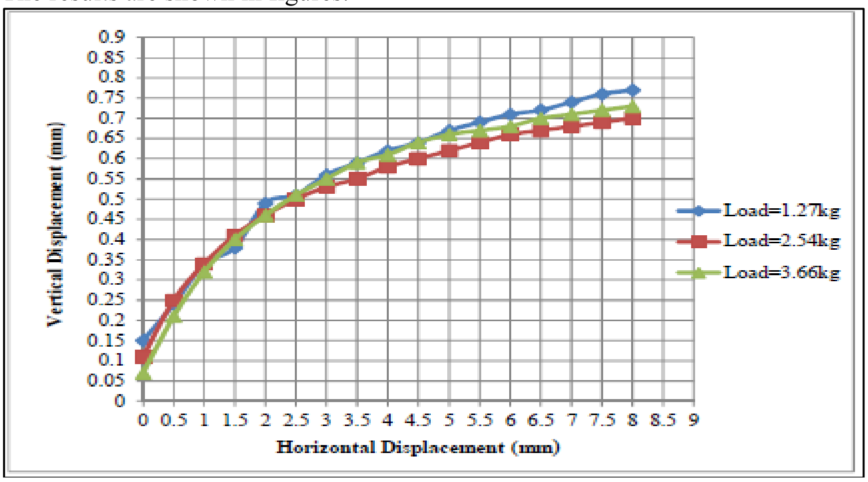

Figure: Variation of Graph between Shear Stress and Horizontal Displacement for 10% Rock dust

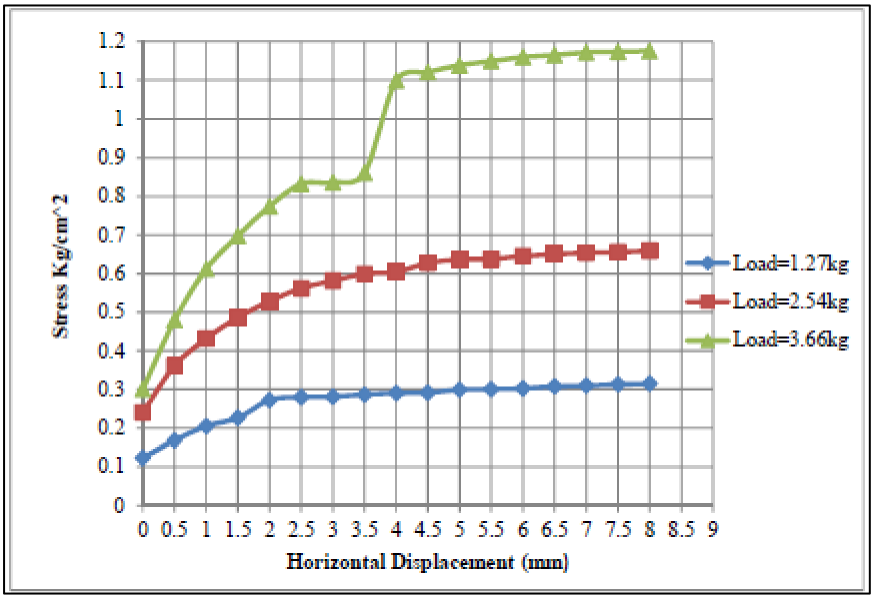

Figure: Variation of Graph between Vertical Displacement and Horizontal Displacement for 10% Rock dust

Direct Shear Test at 15% Rock dust

The results are shown in figures

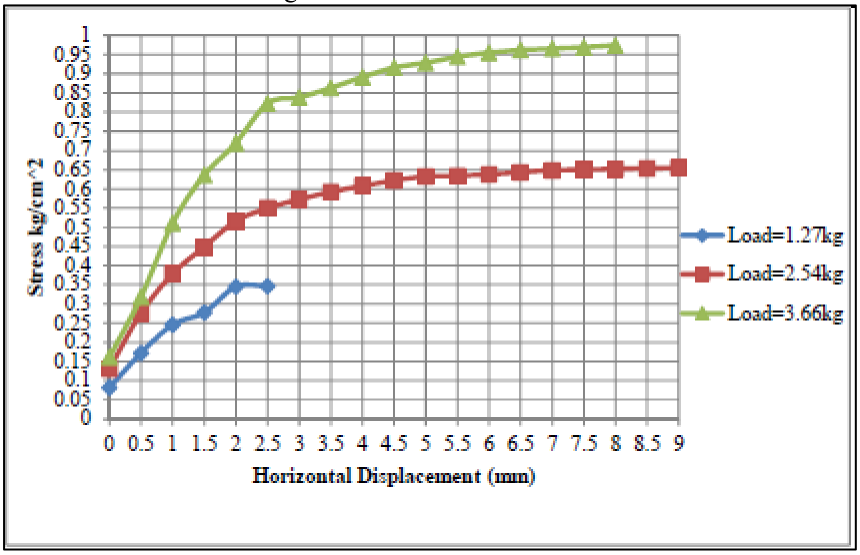

Figure: Variation of Graph between Shear Stress and Horizontal Displacement for 15% Rock dust

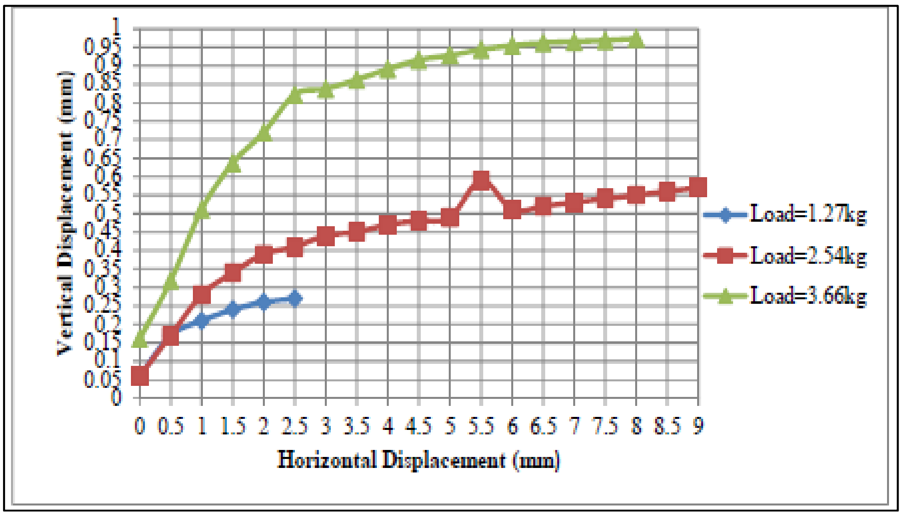

Figure: Variation of Graph between Vertical Displacement and Horizontal Displacement for 15% Rock dust

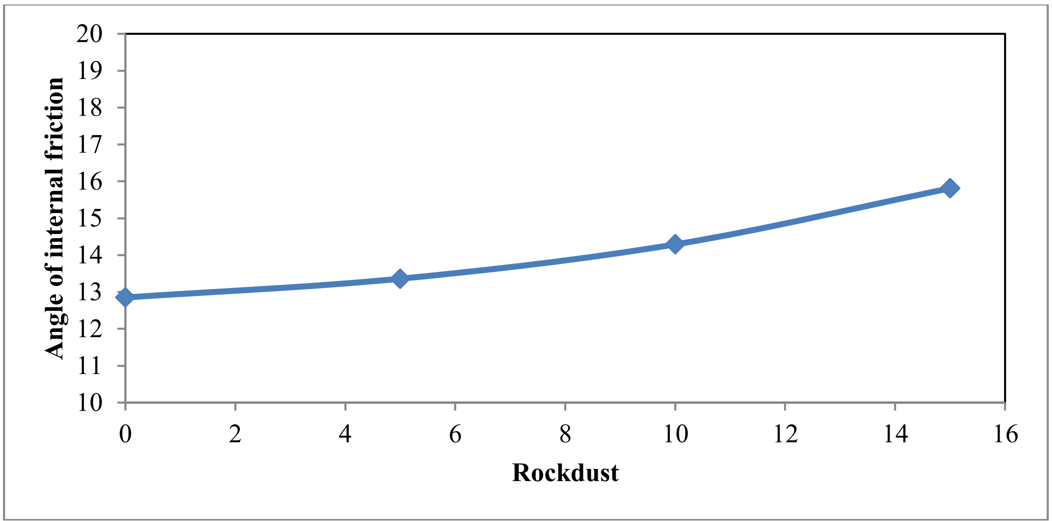

Figure: Variation of Graph between Angle of Internal Friction with the Percentage of Rock dust

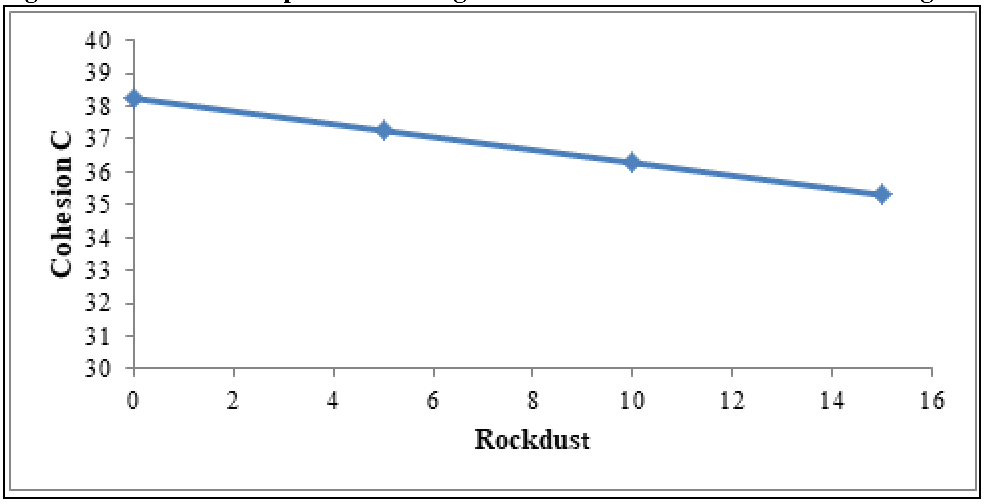

Figure: Variation of Graph between Cohesion C with the Percentage of Rock dust

Discussion: The variation of shear strength parameters is shown in figures. With the addition of admixture (rock dust), the cohesion of soil decreases while the angle of internal friction increases. The reason behind is the replacement of cohesive soil with rock dust which have very low cohesion value and high angle of internal friction.

California Bearing Ratio (CBR)

The results are shown in figures.

Serial No.	Soil Type	CBR
1	Pure (0%)	45.11
2	A (5%)	47.63
3	B (10%)	48.5
4	C (15%)	50.2

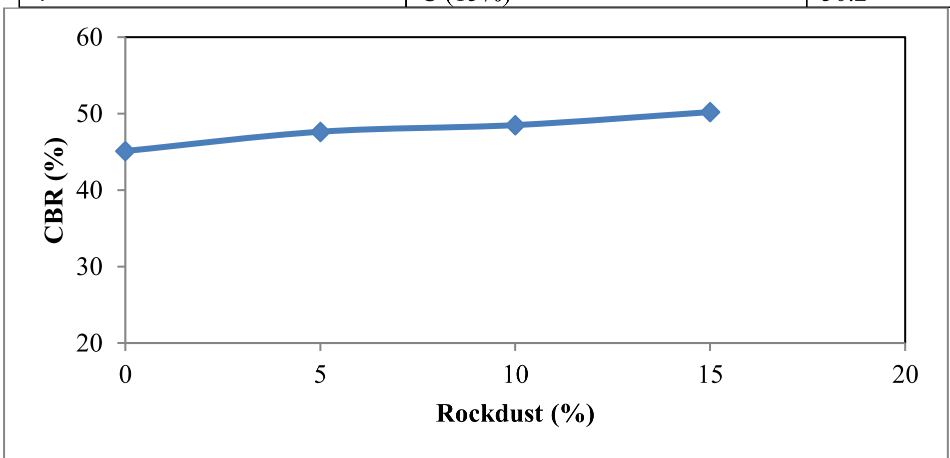

Figure: Variation of Graph between CBR with the Percentage of Rock dust

Discussion: The California bearing ratio value was found to be increases with increase with the percentage of rock dust as shown in figure. The improvement in CBR value can be attributed to significant improvement in in angle of shearing resistance.

OVERALL RESULTS DISCUSSION

Beyond engineering efficacy, the dramatic changes in soil behavior brought about by rock dust stabilization have repercussions. Increased load-bearing capacity and reduced deformation potential may boost maintenance and construction workers' perceptions of safety because unstable soils are often associated with operational stress. In a similar vein, populations that frequently suffer from pavement may feel more at ease when sustainable geotechnical solutions demonstrate dependability and long-term performance. Successful soil stabilization enhances both physical infrastructure and human well-being by affecting perceptions of safety, environmental responsibility, and trust in urban development processes. Incorporating psychological perspectives strengthens this.

Psychological Implications of Findings

The geotechnical developments mentioned have secondary psychological effects, particularly the increases in bearing capacity and reductions in flexibility. Because construction workers often associate unstable ground with operational hazard and occupational stress, improved soil performance increases their perceptions of safety. Similarly, residents in areas susceptible to pavement deterioration or differential settlement may feel more at ease when stabilization measures demonstrate sustainability and reliability. The finding that 10% rock dust produces the best results supports not only engineering efficiency but may also encourage greater public acceptance by striking a balance between performance, cost-effectiveness, and environmental friendliness factors known to affect behavioral responses and community attitudes toward infrastructure interventions.

CONCLUSION AND SUGGESTION FOR FUTURE WORK

Following are the points of conclusion and recommendations for this research article under consideration.

Conclusion

Following conclusions are drawn from this research work;

- The Liquid Limit, Plastic Limit and Plasticity Index are on decreasing with addition of Rock dust in different percentages.
- The Specific gravity are increasing by increasing the percentage of quarry dust
- The Maximum Dry Density (MDD) is on increases up to 10% rock dust, then further decreases at 15%.
- From direct shear test, the angle of internal friction increases by increasing the percentage of quarry dust, which cohesion c decreases with the addition of percentage of rock dust.
- The California bearing ratio is found to be increase with increase in the percentage of rock dust.
- Rock dust has high specific gravity and the soaked CBR value for standard compaction is more. This indicates that stone dust can be used as an embankment material, backfill material for the lower layer of sub base.
- Alongside the scientific findings, the investigation stresses how rock-dust-based stabilization can improve public perception by increasing trust in the durability of infrastructure and supporting ecologically beneficial building approaches. These psychological factors emphasize the significance of sustainable geotechnical solutions in urban settings, where community attitudes, perceived safety and long-term trust in infrastructure are increasingly recognized as critical components of growth.

Recommendation

The followings are suggestion to the crushed stone industry regarding the use of Rock dusts in soil stabilization. Before use of stabilized quarry dusts as a base material, it must be determined whether it can perform under durability restraints of freeze, thaw, shrinkage, moisture etc.

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