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Effects Of Rockdust As A Soil Stabilizing Agent On Poor Subgrade Soil

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Abstract
Pavement failures are usually associated with the lateral displacement of subgrade as a result of pavement absorbing water and excessive deflection and differential settlement of material underneath the pavement. The aim of the research is to study the effect of the additives (rockdust) on the stability and the increase of bearing capacity of selected soils in Sabah. The physical, chemical and engineering properties of soil were studied, and the soils were treated with additives (rockdust) for the purpose of stabilising the native soil. The stabilisation of soil is carried out by addition of Rock dust to soils in the range of 0 to 85% by the percentage increase of 5%,10%, and 15 % respectively. The Results showed that the gradation of soil is narrow from the particle size analysis. Plasticity index (P.I.) and Liquid limit (L.L), and plastic limit (P.L.) were decreased with the addition of Rock dust. It was concluded that the value of the Maximum dry density increased with the addition of Rock dust, and the highest value was obtained when adding 10% Rock dust, and beyond 10%, it shows a decrease in their content. It was found that the value of cohesion c decreased, the angle of internal friction and the California bearing ratio(C.B.R) was improved with the addition of Rock dust. The study showed that the best stabilizer for the case study is the Rock dust and the optimum dose is 10 %.
Keywords: *Rockdust, stabilization, CBR, Atterberg limit, Standard compaction test, Quarry clay, Soil stabilisation.*

1 INTRODUCTION:

The Soil is abundantly accessible normally happening material on this earth. It is the least expensive accessible development material. But in the meantime, it is extremely complicated material too. The conduct of the soil differs with normally happening conditions. They exhibit low shear strength as compared with rocks which reduce further upon wetting. The primary Function of soil with which the geotechnical engineer is concerned are about its strength, permeability, steadiness and durability.

Dealing with delicate subgrade or poor subsoil is one of most real issues. This circumstance most likely may happen in roadways development [3]. Since there is diminishment in locales for development advancement, it is pivotal to discover routes for soil modification to react to the requests [4] that were stronger, such as crushed rock then will be used to replace it. The cost involved for replacing the materials was quite high, thus it leads to various researches to find another methods in order to encounter this problem [9]. Soil Stabilization alludes to the methodology in which a special soil, an establishing material, or other chemical or nonchemical materials are added to a natural soil to enhance at least one of its properties. The method of soil stabilization is generally endorse with the reason for rendering plastic soils coherent to the standards and requirements of engineering projects. Rock dust, a none cementations added substance, discharges from the cutting and pulverizing procedure of boulder and stones which is a concentrated material to use as fine totals. By detonating mountain, a stone will be squashed to little size stones and alongside this fine fragments type particles called rock dust will be formed during the process which is going as waste. scrapping of these extensive amounts of rock dust delivers a serious issue in environment and wellbeing risk. There is a necessity to use these waste materials. Rock dust can be utilized as a part of extensive amount, lessening the cost of development and contribute a solution to environmental hazards.

Rock dust show high shear quality and is gainful for its utilization as a geotechnical material [1]. The quality attributes of compacted crusher Stone dust blend through a progression of CBR tests by fluctuating the crusher dust [2]. The mix of fly ash remains and rock dust observed to be reasonable to diminish swelling and increment the quality of extensive soil. The qualities and uses of rockdust as stabilizing agent and for a more prudent approach. Rock dust show high shear strength(friction point high as 44 degrees) which is exceptionally gainful for its utilization in geotechnical material [10].

LITERATURE REVIEW

The stability of the subgrade soil plays an important role in longevity and performance of the pavements and other structural units. The expansive and weak subgrade soils cause te structural failures like rutting, settlement and cracking. Thus, to address the issues, different soil stabilization techniques are explored that include the use of the quarry and industrial by products. Among these quarry dust and rock dust gas received the creasing attention because of abundance , environmental sustainability and cost effectiveness. This literature review explores prior research on the use of rock dust and related stabilizing agents like fly ash and cement for improving poor subgrade soils.

1. Soil Stabilization with Cementitious and Pozzolanic Additives

Several researchers investigated about the impact of cementitious materials like Portland cement and pozzolanic substances like fly ash on weak soils. This is studied by the Cristelo et al. [2], the performance f society soils treated with Portland cement and alkaline activated fly ash. This research further indicated that significant improvement in unconfined compressive strength, long term durability and stiffness. The addition of fly ash help in improving the pozzolanic reaction, bonded particles, and reduced the plasticity index of the soil. These findings indicate the potential of industrial by products in stabilizing problematic sills like clayey subgrades. The different fly ashes for stabilization of the soft subgrades can help in enabling the durability and strength of the Class F fly ash [9]. This mechanism of stabilization is because eof the pozzolanic reaction that Class C flsyah perfo,ed better in enahing the strength and durability tas compared to Class F fly ash. The stabilization mechanim was because of the pozzolanic recation to form cementitious compouns like calcium silicate hydrate that cause binding the soil particles and reuction permeability. Thus, flash is different chemically from rock dust and play a role as the mineral fillers and hep in improving soil graduation as well as mechanical behaviour.

2. Rock dust and Quarry Dust as Stabilizers

Research focus on the quarry dust or rock dust that is the finely crushes stone waste produced because of the quarrying operations. As compared to fly ash that is the combustion reside, quarry dust is intent material that is rich in minerals like silicates. This is justified by Sridharan et al. [7] that shear strength studies on soil quarry dust mixtures and observed the improved shear parameters based on the angle of internal friction. The study indicates the addition of quarry dust altered the grain size distribution and reduction in plasticity that enhance the bearing capacity and strength of subgrade soils. The studies examined the use of quarry waste in ground improvement and sub base construction [10]. They found the blessing of quarry dust with silty or clayey soil improved graduation, increased in maximum dry density and decreased optimum moisture content. The compaction characteristics of the soil improved that is important for achieving desired pavement performance. The comprehensive review on geotechnical use of quarry dust as a soil admixture [9]. The further review has been given by the geotechnical use of quarry dust indicated the nature of the soil admixture. The authors concluded that material can be used in an effective manner for stabilisation of the expansive soils and improving strength properties when used in combination with lime and alone [8]. The review focus on the sustainability and cost effectiveness in using the quarry dust in road construction in development of countries where access in traditional stabilisers is limited.

3. Performance in High Plastic Soils

The performance of rock dust in high plasticity subgrade soils also has been tested under the different condition. The performance often crusher dust for stabilisation of the high plastic gravel sills. They found that the addition of crusher dust significantly reduced the plasticity and improve strength and California Bearing Ratio (CBR) values [14]. This improvement is based on the better particle interlocking reduction in moisture susceptibility and improved compaction. Thus, authors of the study indicated the use of the low-cost alternative to chemical stabilizer in low volume and rural road [12]. Thus, the noticeable increase in unconfined compressive strength (UCS) and shear strength parameters like clay rich so is. This study indicate that granular nature and high fineness of rock dust contribute in better mechanical performance of subgrade soils by enhancing interparticle friction and reduction of water absorption capacity.

4. Environmental and Sustainability Considerations

Based on the performance , the sustainability aspect of using quarry dust is important to consider in soil stabilisation. The sustainable corporate performance is aligned with triple bottom line of environment, economic and social dimensions to meet the demand of the civil infrastructure projects adopt materials and practice to minimise the environmental harm [11] Quarry dust is based on the waste product, that help in promotion of the resource recovery and reduction of demand for the virgin materials. By the use of the quarry dust also contribute in carbon footprint reduction in construction when it replaced Portland cement that is energy intensive for production [3]. The quarry dust contributes in carbon footprint in construction like when it replaces the Portland cement that is energy incentive in production. This rational is helpful in analysing the stability of rock dust in road and infrastructure projects like regions striving for sustainable development.

5. Limitations and Future Research Directions

Despite of certain challenges like limitation to widespread use of rock dust as a soil stabiliser. One of the issues is the inconsistency in material properties like quarry dust composition may vary on depending the parent rock. Thus, as compared to cement and lime quarry dust lacks the ceiling bonding potential that rely on the mechanical improvements.

3. Materials

The materials used in this study include soil samples collected from Sabah and rock dust sourced from a local quarry. The geotechnical properties of the soil and the effects of blending it with varying percentages of rock dust were analysed to assess improvements in compaction, stability, and load-bearing capacity for construction applications.

2.1 Soil

The soil samples in this study were collected from various locations in Sabah through which representative analysis was performed to obtain geotechnical properties of this region.

Table 1: Geotechanical Properties of soil sample:

Moisture Content (%)	19.16%
Liquid Limit (%)	32.96
Plastic Limit (%)	46.71
Plasticity Index	24.25
Specific Gravity	2.59
Maximum Dry Density	2.5
Optimum Moisture Content	17.9
USCS Classification	CL
CBR Unsoaked	45

The geotechnical properties of soil samples collected from Sabah are presented in Table 1. The moisture content of the soil is 19.16%, indicating the level of water present at the time of sampling. The liquid limit, at 32.96%, and plastic limit of 46.71% show the soil's consistency and plasticity range, while the plasticity index of 24.25% highlights its potential for deformation under stress. The specific gravity of 2.59 suggests a typical density for clay soils. The maximum dry density of 2.5 g/cm^3 and optimum moisture content of 17.9% represent values achieved during compaction testing, essential for construction suitability assessments. Classified as "CL" under the Unified Soil Classification System (USCS), the soil falls into the category of lean clays with low plasticity. The California Bearing Ratio (CBR) test yielded an unsoaked value of 45, signifying moderate strength and load-bearing capacity suitable for foundational and subgrade construction.

2.2 Rockdust

The rockdust were collected from local quarry site of Sabah where Rocks are crushed down. The specific gravity was found to be 2.59. The material's properties make it suitable for blending with soil to improve structural and geotechnical characteristics. Experimental investigations were carried out by mixing the soil samples with varying percentages of rock dust to assess its influence on the geotechnical behaviour of the soil. The addition of rock dust is typically intended to enhance the soil's compaction, stability, and load-bearing capacity while reducing plasticity and swelling characteristics. Such modifications are critical for improving the performance of subgrades and other foundation layers in civil engineering projects. The study aims to optimise the proportion of rock dust for achieving favourable properties suitable for construction applications.

3. RESULTS AND DISCUSSIONS

Experiments were carried out on soil samples blended with varying percentages of rock dust, specifically 5%, 10%, and 15%, to evaluate the engineering properties of the modified soils. The geotechnical parameters of these samples were determined following the guidelines and testing procedures outlined by ASTM standards to ensure accuracy and reliability of the results.

3.1 Gradation Test

The gradation curve of the soil sample, as illustrated in Figure 1, represents the particle size distribution and highlights the composition of the material. The soil predominantly consists of fine-grained particles, indicating a high percentage of silt and clay fractions with minimal coarse material.

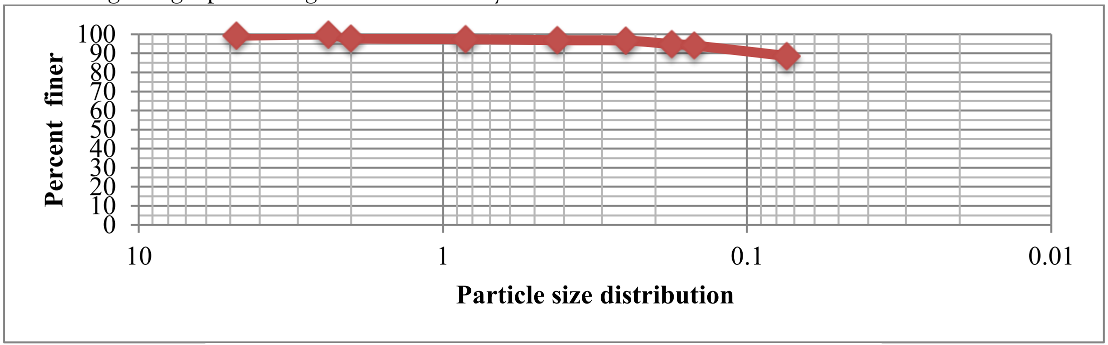

Figure 1: Gradation Curve for Soil Sample

The distribution indicates that the material primarily consists of fine-grained particles, as evidenced by the high percentage of finer particles retained in the silt and clay size ranges. The curve shows minimal coarser material, highlighting a uniform gradation typical of cohesive soils. Based on these characteristics and classification according to the Unified Soil Classification System (USCS), the soil is categorised as "CL," representing lean clays with low to medium plasticity. Such soils typically exhibit moderate compressibility and fair load-bearing capacity, making them suitable for specific construction applications with proper treatment or stabilisation. The gradation data helps assess the suitability of the soil for engineering purposes, such as subgrade construction, and is essential for determining compaction properties and predicting soil behaviour under load.

3.2 Compaction Characteristics

The moisture content-dry density relationship of a given soil is determined by Modified proctor test.

Table 3: Variation of MDD and OMC with the percentage of Rockdust

Soil + Rockdust (%)	MDD (%)	OMC (%)
100 + 0	1.272	17.9
95 + 5	1.332	16.5
90 + 10	1.346	16.0
85 + 15	1.313	14.75

The compaction characteristics of the soil mixed with varying percentages of rock dust were evaluated using the Modified Proctor test. Table 3 presents the relationship between the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) as the percentage of rock dust increases from 0% to 15%. For the untreated soil sample (100% soil), the MDD is 1.272 g/cm^3, and the OMC is 17.9%. As 5% rock dust is added, the MDD increases to 1.332 g/cm^3, while the OMC decreases to 16.5%. Further addition of 10% rock dust raises the MDD to 1.346 g/cm^3 and reduces the OMC to 16.0%. However, when the rock dust content reaches 15%, the MDD slightly decreases to 1.313 g/cm^3, with the OMC dropping further to 14.75%. The initial increase in MDD and decrease in OMC indicate that rock dust improves soil compaction by filling voids and reducing water demand. The slight decline in MDD at higher percentages suggests a potential limit beyond which rock dust addition may reduce compaction efficiency.

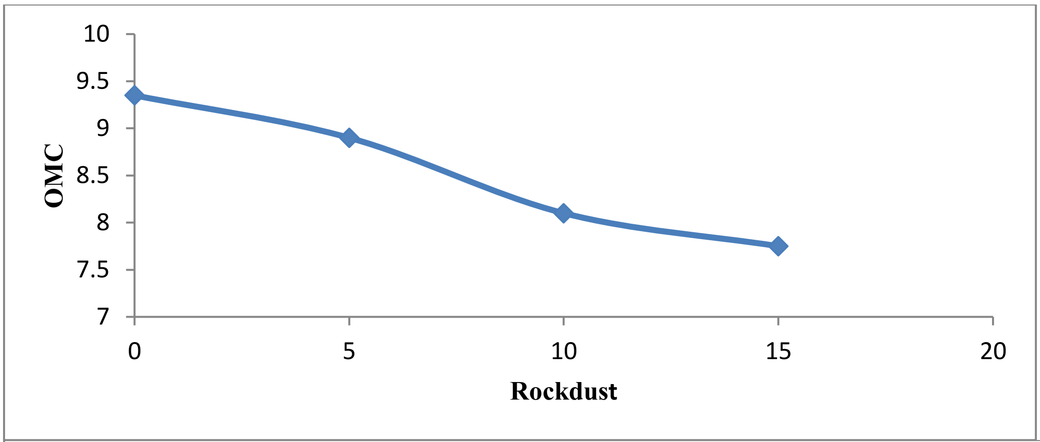

Figure 2: Plot of curve between OMC with the Percentage of Rockdust

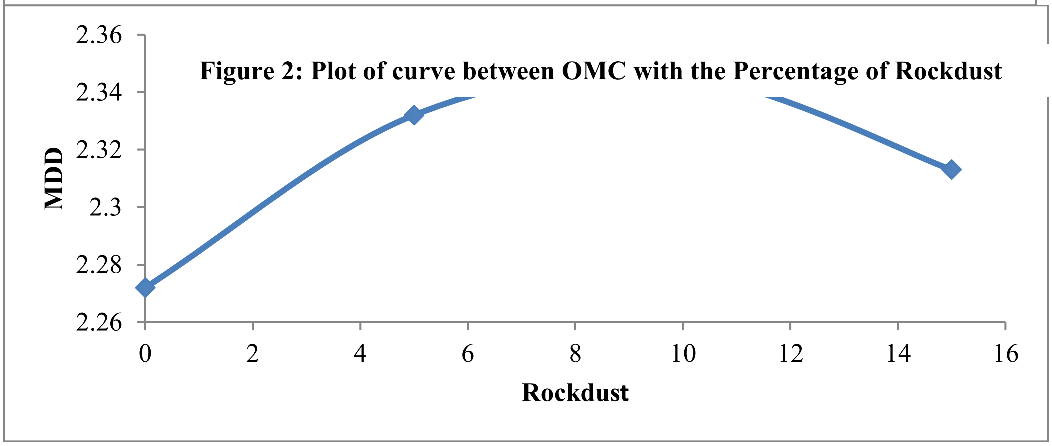

Figure 3: Variation of graph between MDD with different percentage of Rockdust

The maximum dry density of soil was found to increases to 1.346gm/cc from 2.272gm/cc up to addation of 10% rock dust, beyond it decreases. While in case of OMC, the graph shows variations. The max OMC obtained at 5% Rockdust as shown in fig 3.

3.3 Atterberg Limits Test:

The Atterberg limits test provides information about the plasticity of the soil in terms of Liquid Limit (L.L), Plastic Limit (P.L), and Plasticity Index (P.I) for a particular soil mass across the limits of moisture content that can be defined in terms of its state. Table 4 shows the changes in these parameters as the percentage of rock dust as an admixture increased. The liquid limit reduces from 32.96 % at 0% rock dust to 27.34 % at 15% rock dust. The plastic limit is also lowered from 30.71% to 26.37%, and the plasticity index, which shows the range of water content at which the soil behaves plastically, decreases from 2.25 to 1.04. The decrease in these values means that the soil's plasticity reduces with the inclusion of rock dust. This change happens because fine, clayey soil particles with high water retentive capacity and remaining plastic at different conditions are substituted by coarser rock dust particles, reducing the mix's holding capacity. Since the rock dust particles are non-cohesive and increase the friction rather than the cohesion of the soil, the free expansion, contraction or deformation with fluctuations in the moisture content of the soil is minimised. This change reduces the shrinkage and swelling potential of the soil. It increases the stability of the soil for engineering uses such as road subgrades and constructions where minimal deformation is required. As Figure 6 shows, the plasticity index curve decreases as the rock dust content increases, which further supports that the soil-rock dust mixture has better workability, lower compressibility, and higher load-carrying capacity.

Table 4: Variations of L.L, P.L and P.I for Soil+Rockdust Mixes

Soil + Rockdust (%)	Liquid Limit	Plastic Limit	Plasticity Index
100 + 0	32.96	30.71	2.25
95 + 5	30.54	28.63	1.91
90 + 10	29.16	27.40	1.76
85 + 15	27.34	26.37	1.04

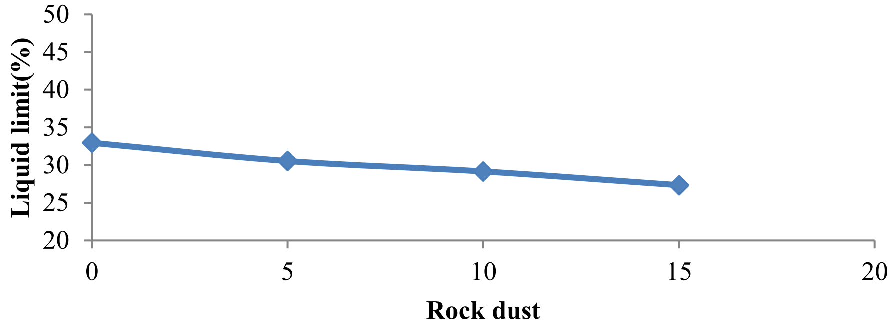

Figure 4: Plot of curve between Liquid Limit with different percentage of Rockdust

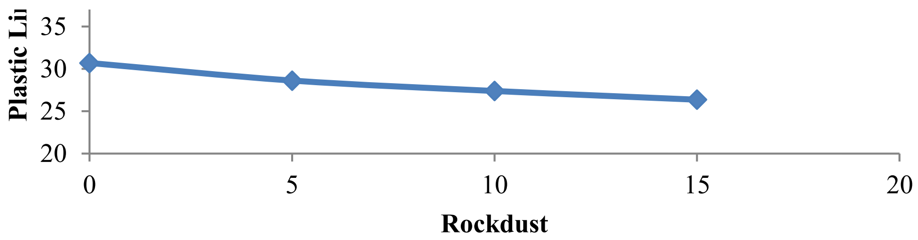

Figure 5: Plot of curve between Plastic Limit with different percentage of Rockdust

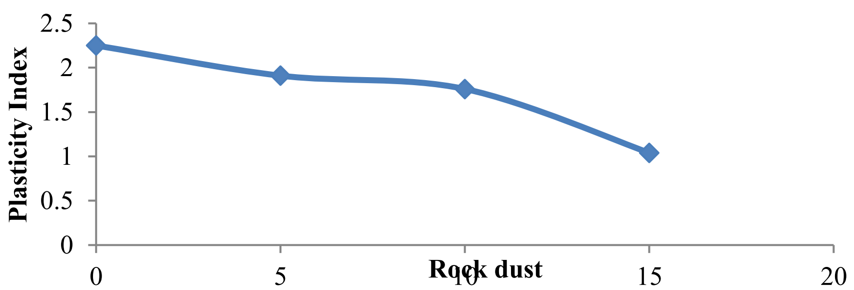

Figure 6: Plot of curve between Plasticity index with different percentage of Rockdust

The Percentage of variation of liquid limit, plastic Limit and Plasticity index to the admixture is shown in figures. It is observed that as the percentage of admixture (Rockdust) increases, the liquid limit, plastic limit and plasticity index goes on decreasing.

3.4 Specific Gravity:

The specific gravity of a soil sample is defined as an essential characteristic that points to the soil's mineralogy, density and structural stability. It helps in comparing the density of the solid particles in the sample with that of water. Table 5 below shows the specific gravity of mix proportions of the soil-rock dust: The specific gravity of soil-rock dust mix at different proportions. The specific gravity also increases from 2.597 at 0% rock dust to 2.709 at 15% rock dust. This trend shows that rock dust particles play an important role in determining the mass of the soil sample. The increase in specific gravity may be due to the increased density of rock dust compared to the original soil particles of clay and silt, which have less density and more cohesiveness. Rock dust is mainly made of granules of minerals with a higher specific gravity than sand because of their crystalline nature. The rock dust added to the soil occupies the interstitial pores. It improves the packing of the soil particles, decreasing the porosity of the newly formed mix and increasing the density. This leads to an increase in the soil's density and, thus, enhances the soil's bearing capacity against applied loads. The improved packing and strength characteristics make the soil-rock dust blend more suitable in construction practices such as subgrade layers, embankments, and retaining structures where high stability and strength are desirable. As the percentage of rock dust increases, Figure 7 shows how specific gravity increases in a linear trend. This supports the finding that more significant percentages of rock dust render the soil mix more stable and less susceptible to erosion.

Table 5: Variations of Specific Gravity with different percentage of Soil+Rockdust

Soil + Rockdust (%)	Specific gravity
100 + 0	2.597
95 + 5	2.623
90 + 10	2.650
85 + 15	2.709

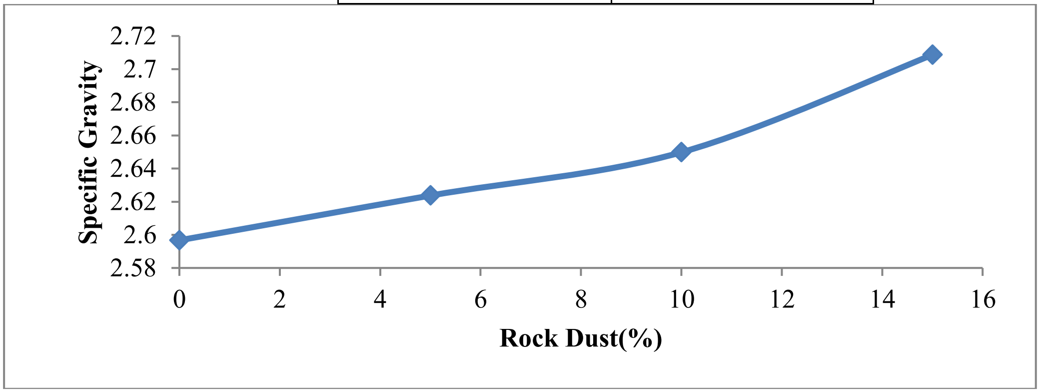

Figure 7: Plot of curve between specific gravity with different percentage of Rockdust

The Percentage of variation of specific gravity to the admixture is shown in fig 7. It is observed that as the percentage of admixture(Rockdust) increases, the specific gravity increases.

3.5 Direct Shear Test:

The direct shear test measures the shear strength parameters, including cohesion (C) and the angle of internal friction (Ø). Table 6 shows the variations in these parameters with different percentages of rock dust. The soil cohesion decreases from 26.24 kPa to 22.30 kPa as rock dust content increases, while the angle of internal friction increases from 21.85° to 25.81°. The reduction in cohesion occurs because rock dust particles, which have minimal cohesive properties, replace the finer, more cohesive soil particles. However, the increase in the angle of internal friction is due to the angular nature of rock dust particles, which enhances interlocking between particles and provides more excellent resistance to shearing forces. This improved internal friction angle signifies increased shear strength, making the soil-rock dust mix more suitable for load-bearing structures and slopes where stability is crucial. These changes result in a more stable material with improved performance in resisting shear deformation.

Table 6: Variations of Cohesion C and angle of internal friction with different percentage of Soil+Rockdust

Soil + Rockdust (%)	Cohesion C	Angle of internal Friction (Ø)
100 + 0	26.24	21.85
95 + 5	24.36	23.36
90 + 10	23.28	24.29
85 + 15	22.30	25.81

The variation of shear strength parameters 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.

3.4 California Bearing Ratio:

The California Bearing Ratio (CBR) test is a penetration test used to evaluate the subgrade strength of soils for road and pavement construction. Table 7 presents the CBR values for different soil and rock dust mixture percentages. The CBR value increases from 43.1% at 0% rock dust to 48.2% at 15% rock dust. This increase in CBR value indicates that adding rock dust improves the soil's load-bearing capacity. The improvement is attributed to the enhanced particle interlock and reduced plasticity due to the inclusion of coarser rock dust particles. The higher angle of internal friction observed in the direct shear test correlates with the higher CBR values, as a stronger soil structure resists penetration more effectively. The improvement in CBR is significant for the design of subgrade and base layers, as it implies reduced deformation under traffic loads. Figure 10 illustrates the positive trend of increasing CBR values with the percentage of rock dust, showcasing the effectiveness of rock dust as an admixture for enhancing subgrade strength and durability. The findings highlight the potential of rock dust as an economical and efficient soil stabiliser, particularly in improving the structural properties required for various civil engineering applications.

Table 6: Variations of CBR with different percentage of Soil+Rockdust

Soil + Rockdust (%)	CBR
100 + 0	43.1
95 + 5	45.6
90 + 10	46.5
85 + 15	48.2

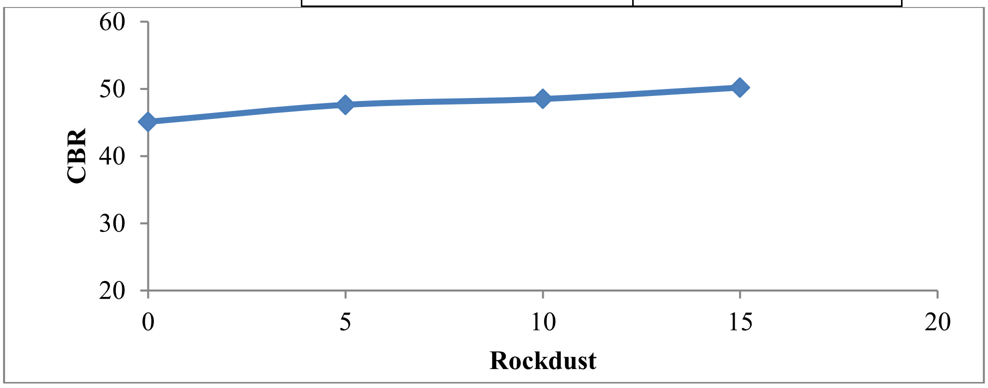

Figure 10: Plot of curve between CBR with different percentage of Rockdust

The California bearing ratio value was found to be increases with increase with the percentage of rockdust as shown fig 10. The improvement in CBR value can be attributed to significant improvement in angle of shearing resistance.

4 Conclusions:

- 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 upto 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 Rockdust.
- The California bearing ratio is found to be increase with increase in the percentage of Rockdust.
- Rock dust has high specific gravity and the soaked CBR value for standard compaction is more. This indicates that Rockdust can be used as an embankment material, backfill material for the lower layer of sub base

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