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Pavement Subgrade Soil Stabilization using Stone Quarry Dust

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ABSTRACT

In order to increase the strength of subgrade soil and to reduce the construction cost of road and airfield pavement by making best use of the locally available materials, mechanical stabilization technique is one of the vital solution. But, in the past few years, utilization of stone quarry dust has been the focus of few researches. Therefore, in this investigation an attempt is made to stabilize clayey soil using stone quarry dust to analyze the index properties and subgrade strength properties of soil, which includes Atterberg's limits, Compaction Characteristics, California Bearing Ratio and Consolidated Undrained Tri-Axial Compression tests. It was concluded that addition of 30% stone quarry dust had increased maximum dry density, California bearing ratio value, angle of internal friction and decreased the optimum moisture content which made the soil-quarry dust mixes durable.

Introduction

Subgrade soil is an essential part of the pavement structure as it provides support to the pavement from bottom. The properties of subgrade soil are significant in the design of pavement thickness. Subgrade soil is generally made up of locally available natural soils and sometimes to improve the performance of soil they are stabilized or modified. Thus, the process of stabilization in a broad sense, includes the various techniques used for modifying the properties of a soil to enhance its engineering properties. Stabilization is mainly used in the construction of road and airfield pavement where the main objective is to increase the strength of soil and to reduce the construction cost by making best use of the locally available materials [1].

Several methods of soil stabilization are available in recent time with their own advantages and disadvantages [2]. However, stabilization methods can be broadly classified into two main groups, viz. mechanical and chemical process. Mechanical stabilization is the most in-expensive method and suitable for most varieties of soil groups consisting of two procedures for altering the soil properties, viz. the rearranging the soil particles for improving the soil gradation and modification of soil structure. Particle rearrangement is accomplished by blending different soils, and modification of soil structure is achieved by densification through compaction.

Stone quarry dust, also known as stone screenings, is the finest of the types of crushed stone. It is the by-product fine grained material generated in the crushing plant during crushing of gravel and rock. Besides, the water used for cooling up the cutting saw flows out carrying very fine suspended particles as high viscous liquid known as stone slurry [3]. The stone slurry is also oven dried, ground and sieved for obtaining stone quarry dust. Quarry dust can be used in very large quantity for soil stabilization and reducing the over-all cost of construction.

In addition to this various environmental issues can be addressed with stone quarry dust. In recent years researchers [3-11] have focused on utilizing the stone quarry dust for soil stabilization.

Soosan et al. [4] evaluated that quarry dust exhibits high shear strength which is highly beneficial for its use as a geotechnical material and also it has a good permeability and variation in water content does not completely affect its desirable properties. Later, Soosan et al. [5] evaluated that quarry dust can be used as a substitute for sand to improve the properties of lateritic soil. Sridharan et al. [6] studied the effect of quarry dust on the geotechnical properties of soil used in highway construction and concluded that the CBR value steadily increased with increase in percentage of quarry dust. Further, Sridharan et al. [7] studied the shear strength of soil-quarry dust mixtures and the results showed that the quarry dust proved to be a promising substitute for sand and can be used to improve the engineering properties of soils, even the dry density increased with the addition of quarry dust with consequent decrease in the optimum moisture content (OMC). Onyelowe et.al [8] evaluated the qualities and applications of quarry dust as admixture during soil improvement and for a more economic approach. Al-Joulani [3] investigate the effect of stone powder and lime on the strength, compaction and CBR properties of fine grained soil. Results indicate that 30% stone powder has increased the angle of internal friction (φ) by about 50% and reduced cohesion by about 64%, the maximum dry density and optimum moisture content decreased slightly, the CBR values have increased from 5.2 to 16 and 18 and the thicknesses of flexible pavement based on the CBR values and assumed daily traffic volume and found to be reduced from 38 cm for soil without additives to 20 cm. Biradar et al. [9] evaluated the performance of industrial waste admixtures (crusher dust, fly ash and steel slag) in improving weak clayey soil through mechanical stabilization and results of the laboratory tests on index and engineering properties indicates

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that steel slag is proven to be effective over other types, but maximum decrease in optimum moisture content takes place in the presence of quarry dust. Sarvade and Nayak [10] studied the utilization of quarry dust to improve the geotechnical properties (consolidation, permeability) of lithomargic clay and the results showed that the geotechnical properties (consolidation, permeability) of lithomargic clay and the results showed that the geotechnical parameters of the lithomargic clay are improved substantially by the addition of quarry dust. Venkateswarlu et al. [11] experimented the variation of index and engineering properties (liquid limit, plastic limit, plasticity index, compaction characteristics, California Bearing Ratio and shear strength) of expansive soil mixed with different percentages (0%, 5%, 10% and 15%) of Quarry dust and the results were found that up to the addition of 10% of stone dust there is an increase in strength parameters beyond it is not effective.

The main objective of this investigation is to utilize stone quarry dust industrial waste in the field of geotechnical-transportation engineering for enhancing the strength of subgrade layer in pavement structure. In this investigation an attempt is made to stabilize clayey soil using stone quarry dust to analyze the index properties and subgrade strength properties of soil, which includes Atterberg's limits, Compaction Characteristics, California Bearing Ratio and Consolidated Undrained Tri-Axial Compression tests.

Materials Characterization

Soil

The soil sample used for this study is collected near BIET Building, Suri (Birbhum), at a depth of 1.0-1.5 m beneath the ground surface. Initially, the soil sample is allowed to dry for 2 days and then the sample is dried in oven at 110°C for 24 hours. After completely drying, the dried soil is thoroughly grinded. The grinded soil is allowed to pass through 4.75mm IS sieve and the passed soil is used for the current study. The results from grain size analysis of the soil as per IS: 2720 (Part IV)-1985 [12] is shown in Figure. 1.

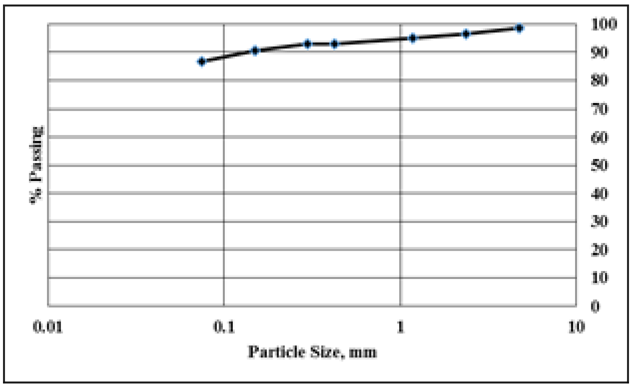

Figure 1.Grain Size Analysis of Soil Sample

Stone Quarry Dust.

The stone quarry dust used was collected from a local quarry near Md. Bazar, Birbhum District, West Bengal. Experiments were conducted on the samples blended with waste materials at different percentages. The stone quarry dust were added at an increment of 5% from 15% to 30%. The specific gravity value of the quarry dust sample is obtained as 2.57.

Experimental Details

In this research the index properties (Atterberg's limits) and subgrade strength properties of soil (Compaction Characteristics, California Bearing Ratio and Consolidated Undrained Tri-Axial Compression tests)mechanically stabilized with stone quarry dust were evaluated.

Liquid Limit and Plastic Limit

Soil passing through 425 microns sieve is used for Atterberg limit tests, where the liquid limit (L.L) and plastic limit (P.L) of soil and mixes at different percentages is determined as per IS: 2720 (Part V)-1985 [13]. The liquid limit was determined in the laboratory by the help of standard Casagrande apparatus and the plastic limit was determined by rolling out a thread of 3mm dia. of the fine portion of a soil on a flat, non-porous surface.

Plasticity Index

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI =LL-PL).

Standard Proctor Compaction Test

For any type of soil, an "optimum water content" exists at which it will achieve its maximum dry density where the peak dry unit weight is called the "maximum dry density (MDD)". At very high moisture contents, the maximum dry density is achieved when the soil is being compacted to nearly saturation where almost all the air is to be driven out. The compaction tests on the selected soil sample is conducted at different moisture contents by applying Light compaction effort as per IS 2720 (Part VII)-1980 [14]. In the Standard Proctor Test, the soil is compacted by a 2.6 kg rammer falling a distance of 310 mm into a soil filled mould. The mould is filled with three equal layers of soil, and each layer is subjected to 25 drops of the rammer. Finally, dry density and corresponding moisture content are evaluated and from the calculated values compaction curve is being plotted for determining the relationship.

California Bearing Ratio Test

The primary purpose of the California Bearing Ratio test is to determine the bearing capacity and the mechanical strength of road sub-base and sub-grade. The CBR test denotes the measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The CBR test is carried out on a compacted soil in a CBR mould 150 mm in diameter and 175 mm in height, provided with detachable collar of 50 mm and a detachable perforated base plate as per IS 2720 (Part XVI)-1987 [15]. The CBR values are usually calculated for penetrations of 2.5 mm and 5mm. Generally the CBR values at 2.5mm penetration will be greater than 5mm penetration and in such a case the former is taken as the CBR value for design purposes. Again, if the CBR value corresponding to a penetration of 5mm exceeds that for 2.5mm, the test is repeated and if identical results follow, the bearing ratio corresponding to 5mm penetration is taken for design.

Tri-Axial Test

A triaxial shear test is a common method to measure the mechanical properties deformable soil and other granular materials. In this test method as per ASTM D4767-11 [16], the shear characteristics are measured under undrained conditions and is applicable to field conditions where soils that have been fully consolidated under one set of stresses are subjected to a change in stress without time for further consolidation to take place (undrained condition). The height of the specimen should be equal to twice of its diameter and compressive force is applied at a constant rate of axial compression such that failure is produced in a period of approximately 5 to 15 minutes. Finally, the deviator stress, strain and stress ratio is determined.

Results and Discussion

The index and subgrade strength properties of unmodified soil were presented in Table: 1, and further experiments were conducted on the samples blended with varying percentages of stone quarry dust to determine the index properties (Table: 2 and Figure 2), OMC, MDD properties and CBR value (Table: 3, 4 and Figure 3) and consolidated undrained tri-axial compression tests properties (Table: 5 and Figure 4) of the modified soil.

Table 1. Index and Sub-grade strength properties of unmodified soil.

Liquid Limit (%)	45.30
Plastic Limit (%)	25.15
Plasticity Index	19.15
OMC (%)	15.70
MDD (g/cc)	1.59
CBR (unsoaked)	34.21
CBR(soaked)	5.36
Cohesion Value (C), kg/cm^2	0.17
Angle of internal friction, Φ°	9°
Major Principle Stress (σ_1), kg/cm^2	2.44
Minor Principle Stress (σ_3), kg/cm^2	1.5
Major Principle Stress (σ_1), kg/cm^2	3.12
Minor Principle Stress (σ_3), kg/cm^2	2.0

Table 2.Variations in Index properties for Soil+Stone quarry dust mixes.

Soil+Stone quarry dust (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index
100+0	45.30	25.15	20.15
85+15	43.23	24.74	18.49
80+20	41.75	24.50	17.25
75+25	40.30	23.52	16.78
70+30	38.40	23.04	15.36

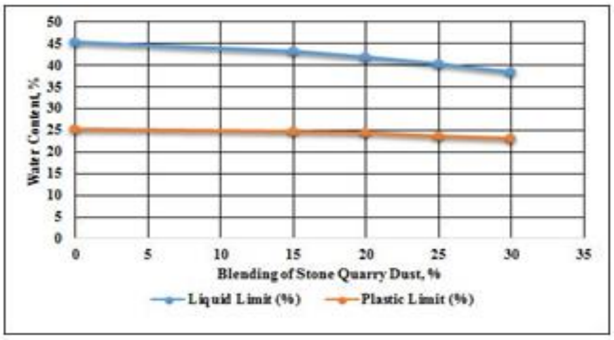

Figure 2.Index properties for Stone quarry dust mixes.

Considerable reductions in plasticity index occurred with the addition of stone quarry dust stabilizer. The maximum decrease in plasticity index with the addition of 30% stone dust is 23.71%, while in the range of 25% to 30% addition of stone dust the maximum variation occurred to be of 8.46%.

Table 3.Variations in OMC and MDD for Soil+ Stone quarry dust mixes.

Soil + Stone quarry dust (%)	OMC (%)	MDD (g/cc)
100+0	15.70	1.59
85+15	18.58	1.55
80+20	16.70	1.57
75+25	16.20	1.58
70+30	15.38	1.62

Table 4.Variations in Soaked CBR value for Soil + Stone quarry dust mixes.

Soil + Stone quarry dust (%)	Soaked CBR (%)
100+0	5.36
85+15	5.12
80+20	5.40
5+25	5.69
70+30	5.95

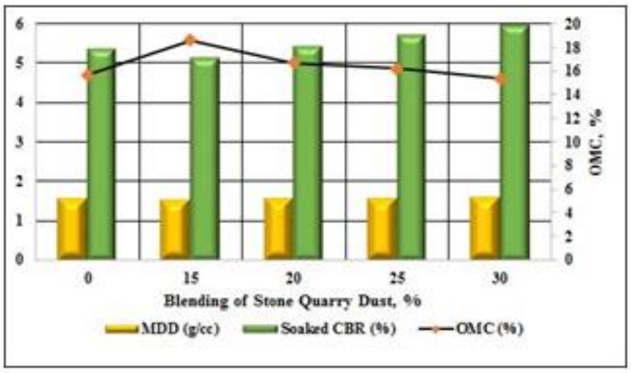

Figure 3.Variations in MDD and CBR value with varying OMC (%) for Stone quarry dust mixes.

OMC of the samples generally decreases by following a similar trend but with the initial addition of 15% stone dust, OMC (%) value suddenly increases by 18.34% and correspondingly MMD (g/cc) also decreases by 2.51%. Even, the soaked CBR (%) value decreases by 4.47% with the addition of 15% stone dust. Overall, addition of 30% stone dust gives enhanced result.

Table 5.Variations in consolidated undrained tri-axial compression tests properties for Soil + Stone quarry dust mixes.

Soil + Stone quarry dust (%)	C (kg/cm^2)	Φ°	Cell Pressure 1.0kg/cm^2	Cell Pressure 1.5kg/cm^2
			σ_1(kg/cm^2)	σ_1(kg/cm^2)
100+0	0.17	9	2.44	3.12
85+15	0.17	13	1.99	2.77
80+20	0.20	23	2.32	3.48
75+25	0.27	10	2.03	2.73
70+30	0.25	10	1.98	2.68

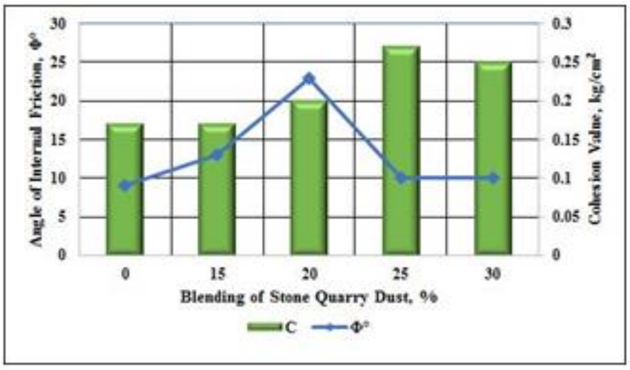

Figure 4.Variations in C and Φ value for Stone quarry dust mixes.

Conclusion

In this study, the suitability of stone quarry dust as stabilizer for sub-grade soil was studied. According to test results, the following outcomes can be summarized:

1) The addition of the Quarry dust to the soil reduces the clay content and thus increases in the percentage of coarser particles, reduces the Liquid limit by 15.23% and plastic limit by 8.39% of unmodified soil.

2) Optimum moisture content of soil is decreased by 2.04%, with increase in Percentages of Quarry dust.

3) Maximum dry density of soil is increased by 1.88% by addition of (30%) Quarry dust.

4) It is also identified that addition of (30%) Quarry dust yield high CBR value by 11%.

5) The addition of quarry dust increases the angle of internal friction up to 25% addition of stone dust and decreases with further increase in dust content.

For best stabilization effect, the optimum proportion of Soil: Stone quarry dust was found to be 70:30.Thus it can be remarked that waste material from industry is well identified for improving soft sub-grade characteristics.

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