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Stabilization of Black Cotton Soil by Using Stone Dust

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Abstract: *The soil above which a civil engineering structure rests must have adequate shear strength and bearing capacity if it is to be secure and stable. When the soil on the site is unsuitable, it can be improved using the soil stabilization method. Black Cotton Soil is a soil with low bearing capacity, swelling and Shrinkage characteristics. Through this project, we are trying to study the improvements in the properties of soil by adding stone dust of varying percentages. Use of waste material and natural materials for improving soil property is advantageous because they are cheap, locally available and eco-friendly. Effectiveness of using natural wastes is rapidly increasing. Keeping this in view an experimental study is conducted on locally available black cotton soil mixed with varying percentage of stone dust. In order to achieve the objectives detailed laboratory tests were conducted on virgin sample and stone dust reinforced clay. Tests are performed by varying the stone dust content in different proportions so as to achieve optimum stone dust content ensuring maximum increase in bearing capacity of the soil. The soil sample selected for the study is the Jalgaon Region's Black Cotton soil. The basic properties of virgin soil like specific gravity, Atterberg's limits, compaction characteristics were Studied. Further the black cotton soil is mixed with varying percentage of stone dust by dry weight of soil such as 0.5 %, 0.75% and 1 %.*

Keywords: Black Cotton Soil, Stone dust, Stabilization, Optimum Moisture Content (OMC), Maximum dry density (MDD), Stone dust, Stabilization, Waste Material, Soil property, Eco-friendly.

I. INTRODUCTION

Soil is basic material of construction. It transfer load coming from superstructure in buildings, while in case of roads it take load from the base course and sub base course but soil on various locations may not suitable for construction due to poor or low bearing capacity such as expansive or collapsible soil. Stabilization is a technique which introduce several years before with the purpose to make soil capable. Many additives like cement, lime, and other additives like fly ash, gypsum, silica fume, rice husk ash, coconut fiber powder have been used. Countries like India has produced in large quantity of industrials and agricultural wastes like fly ash or rice husk ash, coconut fiber powder, stone dust which has low cost value. Countries like US followed the concept of no wastes and used these materials for development of new material through value addition. Stabilization improve soil properties and it is necessary due rise of land cost and huge demand for high rice buildings. Improving properties of soil by using cost effective materials like Stone dust. These materials have cementitious property. Soil like clay, its properties like low shear strength can be improved by using stabilization technique. These material increases its strength. Most advantageous application of natural material in comparison with metal and polymer materials is that they are pollution free, easily available and cost effective.The soil above which a civil engineering structure rests must have adequate shear strength and bearing capacity if it is to be secure and stable. When the soil on the site is unsuitable, it can be improved using the soil stabilization method. Urbanization in recent decades demands to take up construction of civil engineering projects even in weak soil due to land constraints. Black cotton soil is one such soil which lacks engineering properties such as shear strength and bearing capacity. In India, Black soil covers about 30% of land area and is found majorly in states of Andhra Pradesh, Karnataka, Maharashtra, Gujarat, Rajasthan, Uttar Pradesh, Madhya Pradesh and Tamil Nadu. Therefore such soils are

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to be stabilized before taking up construction works. Stabilization is a process of fundamentally changing the properties of soft soils by adding binders or stabilizers, to increase the strength and stiffness of the weak soils. Stabilization by using waste products or by products can reduce this cost and also finds the solution for waste disposal.

II. LITERATURE REVIEW

[1]Surabhi Chawda (2014) The effect of crusher dust on the engineering characteristics of Black Cotton soil is presented in this paper. The soil Sample used is stabilized with 5% lime. A laboratory study was undertaken to evaluate the effect of crusher dust as a soil stabilizer. The result showed the CBR value increased from 1.7% to 7.15%, the optimum moisture content has been reduced from 22% to 14.3% and the maximum dry density have been increased from 1.58 g/cc to 1.88 g/cc.

[2] Sabat (2012) conducted series of tests and concluded that addition of quarry dust decreases Liquid limit, Plastic limit, Plasticity index, Optimum moisture content, Cohesion and increases shrinkage limit, Maximum dry density, Angle of internal friction of expansive soil.

[3]Suresh. K, Padmavathi.V (2009) to study the effect of stone dust and Polypropylene fibers on engineering and strength properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics, unconfined compressive strength and California bearing ratio were evaluated and their variations with content of stone dust and fibers are evaluated. Addition of either Optimum percentage of stone dust (3%) and Optimum Percentage of fibers (0.6%) or Optimum percentage of its combination to the Black Cotton Soil has improved the strength characteristics of sub grade.

[4] Ali and Koranne (2011) had added fly ash and stone dust in the proportion of 1:1 up to 50% to an expansive soil, liquid limit, plastic limit, IS heavy compaction, unconfined compressive strength (UCS), free swell index and soaked CBR tests were conducted on these samples and found a lot improvement in strength and swelling behavior of the soil along with improvement in other engineering properties.

[5]Muntohar et.al (2013) Conducted laboratory tests to evaluate the engineering properties of silty soil stabilized with lime, waste plastic fibers and rice husk ash. They have conducted CBR, UCS shear strength test to find out the strength of stabilized soil. From the test results, they have concluded that the proposed methodology is very effective for improving the engineering properties the clayey soil.

III. DATABASE AND METHODOLOGY

3.1 What is Stabilization of Black Cotton Soil:

Soil stabilization is the process of improving the physical and engineering properties of soil to enhance its strength, durability, and load-bearing capacity. Black cotton soil, being highly expansive, poses significant challenges for construction due to its swelling and shrinkage behavior. Stabilization methods include mechanical stabilization (blending with granular materials), chemical stabilization (using lime, cement, or fly ash), and waste material stabilization (such asstone dust). These methods help reduce plasticity, increase compaction, and enhance strength, making the soil suitable for construction purposes.

3.1.1 Properties of Black Cotton Soil :

1. High Swelling and Shrinkage – Expands during the rainy season and shrinks in dry conditions, leading to structural damage.

2. Poor Load-Bearing Capacity – Weak shear strength and high compressibility make it unsuitable for construction.

3. High Plasticity – Possesses high liquid and plastic limits, making it difficult to compact.

4. Cracking and Volume Changes – Develops deep cracks in dry conditions, affecting pavement and foundation stability.

3.1.2 Introduction of stone dust :

Stone dust, also known as quarry dust, crushed stone powder, or rock dust, is a fine granular material generated as a by-product during the crushing and screening of hard stones in stone crushers. It is typically produced during the

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manufacturing of coarse aggregates, where stones are broken down into smaller particles. The fine particles that pass through the smallest screens are collected as stone dust. This material is generally gray in color, non-plastic in nature, and has a texture similar to that of natural sand.In the past, stone dust was considered a waste product with limited application and was often discarded in landfills or dumped near quarry sites, causing environmental issues such as dust pollution and land degradation. However, ongoing research in material engineering has revealed that stone dust has valuable engineering properties that make it suitable as a construction material. Due to its uniform gradation, angular particle shape, and excellent compaction characteristics, stone dust is now being widely utilized as a soil stabilizer, sand replacement, and filler material in concrete and asphalt mixes.

When incorporated into soil, stone dust significantly alters its gradation and texture. It reduces the plasticity of clayey soils, enhances their workability, and contributes to increased bearing strength. For expansive soils like black cotton soil, the addition of stone dust can help mitigate swelling and shrinkage behavior by improving the overall stability of the soil matrix. These advantages make stone dust an effective and economical solution for soil improvement, especially in areas where it is readily available as a quarry by-product.

3.1.3 Production of Stone dust :

Stone dust is produced during the mechanical crushing of large stones such as granite, basalt, limestone, and other igneous or sedimentary rocks in crushing plants. The process involves feeding the raw stones into crushers where they are broken down into various sizes of coarse and fine aggregates. During this process, the finer particles that are not suitable for coarse aggregate are collected as stone dust. This dust is typically passed through sieves to ensure uniformity and may be stockpiled for reuse.

In regions like Jalgaon, where stone crushing units are prevalent, stone dust is generated in substantial quantities. Earlier considered a nuisance or waste, it is now being recognized as a valuable resource. The widespread availability of stone dust in such areas makes it a practical and sustainable material for construction and geotechnical applications. Its utilization not only addresses the problem of industrial waste management but also reduces the dependence on natural sand and other non-renewable resources.The growing scarcity and environmental restrictions on the extraction of river sand have further accelerated the demand for alternative materials like stone dust. By efficiently collecting and processing stone dust, industries can reduce the environmental footprint of their operations while simultaneously supplying a reliable material for infrastructure development. The use of stone dust for stabilizing soils is a step toward achieving more sustainable and resilient construction practices, especially in regions with expansive soils and increasing infrastructure demands.

3.1.4 Application in Civil Engineering:

Stone dust has found wide-ranging applications in civil engineering, owing to its favorable physical and chemical properties. In construction, it is often used as a partial or full replacement for sand in concrete and mortar mixes. Its angular and fine texture provides good binding characteristics, which improve the strength and durability of construction materials. Stone dust is also used in the production of paver blocks, precast units, and road base layers, where it contributes to improved interlocking, compaction, and load distribution. In geotechnical engineering, stone dust is increasingly utilized for soil stabilization purposes. When mixed with weak or expansive soils, it improves compaction characteristics, reduces plasticity, and enhances bearing capacity. This is particularly beneficial in road construction, foundation engineering, and embankment development. The addition of stone dust to black cotton soil helps mitigate volumetric changes due to moisture variations, thus increasing the longevity and performance of the constructed structure. Furthermore, its high availability and low cost make it a preferred choice in large-scale infrastructure projects, especially in areas with limited access to conventional construction materials.

3.2 Objectives:

1. To find the properties of black cotton soil for treated (Stabilized) condition and untreated condition.
2. The objective of the project is to using the waste material from natural by products, here we added Stone dust for improve the soil. The different ratio of Stone dust mix with soil where the properties of soil was compared.

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3.The black cotton soil is mixed with varying percentage of Stone dust by dry weight ofsoil such as 0.5 %, 0.75 and 1 %. The change in properties of stabilized black cotton soil are studied, optimum fiber percentage are determined.
4.The effect of stone dust waste on black cotton soil has been studied.
5.To evaluate the performance of stone dust as additive material in improving properties of soil.

3.3 Need of the Study:

1.For improving engineering properties of black cotton soil.
2.For improving soil strength, stability to improve bearing capacity of soil.
3.For Stabilization by using by products can reduce this cost and also find best solution for waste disposal.
4.Use of wastes that will reduce construction cost as well as environmental hazards.
5.Use of Stone dust as stabilizing material, is cheap as well as eco-friendly method of soil stabilization, which will solve the economic problems as well as enhances soil properties.

3.4 Scope of the Work :

This study will contribute in improvement of soil properties by using Stone dust. As soil and waste is variable material in characteristics from place to place, this experimental research work will be applicable for particular type of soil. For different area's soil, we can have different optimum percentage of stone dust which will enhance soil properties. Use of stone dust as stabilizing material, is Cheap as well as eco-friendly method of soil stabilization, which will solve the economic problems as well as enhances soil properties.

The experimental work consists of the following steps:

1.Determination of Nature Moisture content of the soil.
2.Determination of soil index properties (Atterberg‟s Limits)- i. Liquid limit
ii. Plastic limit
iii.Shrinkage limit
3.Determination of Specific gravity of soil.
4.Particle size distribution by Sieve Analysis.
5.Determination of the Maximum Dry Density (MDD) and the corresponding Optimum Moisture Content (OMC) of the soil by Proctor compaction test.(Standard Proctor test).

IV. METHODOLOGY

Soil stabilization is a crucial aspect of geotechnical engineering, aimed at improving the strength, durability, and load-bearing capacity of problematic soils. Black cotton soil, a highly expansive clayey soil, presents significant challenges in construction due to its high shrink-swell characteristics, low shear strength, and poor load-bearing capacity. These properties make it unsuitable for infrastructure development without proper treatment.This study focuses on the stabilization of black cotton soil using stone dust, an industrial by-product commonly generated from stone crushing operations. Stone dust is known for its fine gradation and pozzolanic properties, which can enhance soil performance by reducing plasticity and increasing strength. The research aims to assess the effectiveness of stone dust as a stabilizing agent by conducting a series of laboratory tests to evaluate changes in soil properties.
The laboratory tests conducted in this study include:
Grain Size Distribution – Determines the particle size composition of the soil.
Liquid Limit, Plastic Limit, and Plasticity Index – Assess the soil's consistency and plasticity characteristics.
Specific Gravity – Helps in understanding the density and mineral composition of the soil.
Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) – Evaluate the soil's compaction properties.
California Bearing Ratio (CBR) – Measures the soil's strength and load-bearing capacity.

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4.1 Experimental Work

Consistency Limits: Soil consistency is the strength with which soil materials are held together or the resistance of soils to deformation and rupture. Soil consistency is measured for wet, moist and dry soil samples. For wet soils, it is expressed as both stickiness and plasticity, as defined below. Soil consistency may be estimated in the field using simple tests or may be measured more accurately in the laboratory.

- **Liquid Limit:** The liquid limit is defined as the moisture content at which soil begins to behave as a liquid material and begins to flow. The liquid limit is determined in the lab as the moisture content at which the two sides of a groove formed in soil come together and touch for a distance of 2 inch after 25 blows.
- **Plastic Limit:** The plastic limit of a soil is the water content of the soil below which it ceases to be plastic. It beginning crumble when rolled into threads of 3mm diameter.
- **Standard Proctor Test:** In geotechnical engineering, soil compaction is the process in which a stress applied to a soil causes densification as air is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil. The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become densest and achieve its maximum dry density.
- **CBR Test (California Bearing Ratio Test):** California Bearing Ratio (CBR) is defined as the ratio expressed in percentage of force per unit area required penetrating a soil mass with a circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. Tests are performed out on natural or compacted soils in water soaked or unsoaked conditions and the results so obtained are compared with the curves of standard test.

Parameter	Values
Liquid limit	54.00 %
Plastic limit	23.00 %
Plasticity Index	31.00 %
Specific Gravity	2.65
UCS	1.07 kg/ cm^2
Unsoaked CBR	5.36%
MDD	1.90 g/cm3
OMC	12.48 %

Table 1.Testing parameters of Black cotton soil

4.2 Experimental Analysis

Various laboratory tests have been conducted to determine the properties of the natural soil and soil mixed with different proportions of stone dust (0 %, 10%, 20% and 30%). In order to justify the properties of stabilized black cotton soil, the different tests have been performed. Those tests are Standard Proctor test, Atterberg's limit test, unconfined compressive strength test, CBR test,Standard Proctor Compaction Tests is conducted on soil with 0 %, 10%, 20%, and 30%,stone dust to determine the optimum moisture content and maximum dry density of soil with different stone dust content. The following are the compaction values obtained from the standard proctor compaction tests.

California Bearing Ratio Tests are conducted on soil samples prepared under Light compaction to determine CBR value of soil with different stone dust content in soaked and unsoaked both conditions. The test is conducted on soil samples with 0 % ,10 %, 20 %,and 30 % stone dust to determine the optimum dust content in percentage

Following IS: Codes were used for the conduction of the test are as follows:-

1. IS: 2720 (Part 7) – 1980 Standard proctor test
2. IS: 2720 (Part 10) – 1991 Unconfined compressive strength (UCS) test
3. IS: 2720 (Part 16) - 1987 CBR test (California Bearing Ratio) test
4. IS: 2720 (Part 5) - 1985 Atterberg Limit test for liquids and plastics

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5. IS: 2720 (Part 3) – 1980 Specific gravity test of soil using pycnometer

V. RESULTS AND DISCUSSION

5.1 properties and classification of Soil :

After performing various experiment following properties of soil were observed

1. Moisture content of black cotton soil by using oven dry method = 16.56 %
2. Plastic limit = 23.00 %
3.Liquid Limit = 54.00 %
4. Plasticity Index (PI) = LL-PL
= (54.00 – 23.00) = 31%

Liquid limit > 50 %, so that soil is HIGHLY compressible (H) on the basis of compressibility.

5. According to plasticity chart value of Ip from equation of A line = 0.73(WL-20)
= 0.73(54.00-20)
= 24.82

As Ip (31.00) > Value of Ip from A line & liquid limit > 50.

• Hence, Soil is CH soil (clay of High Compressibility) Based on the above results, the soil was classified as Clay of High Compressibility.

5.1.1 Standard proctor test :

Stone dust Proportion (%)	Maximum Dry Density (g/cm3)	OptimumMoisture Content (%)
0	1.82	24.74
0.50	1.85	18.32
0.75	1.87	15.22
1	1.90	12.48

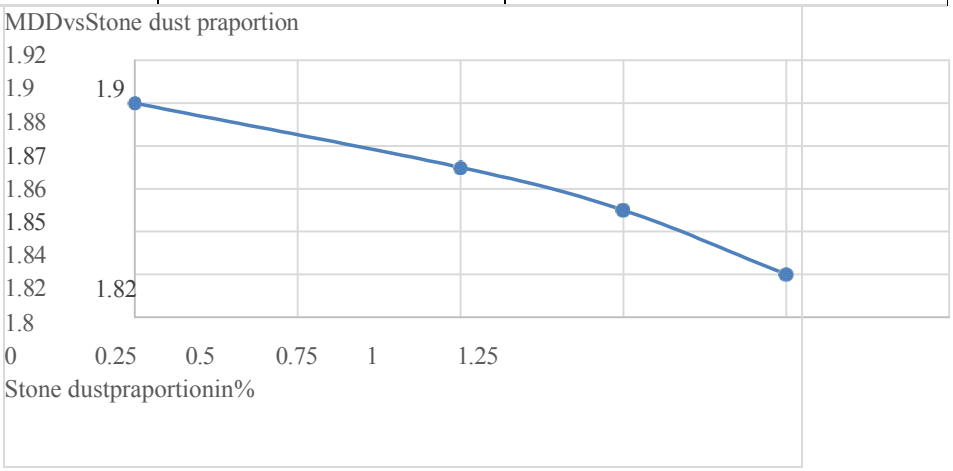

Figure 1: Effect of Stone dust on MDD

VI. CONCLUSION

As per the data and results obtained from the experimental work on the soil stability investigation on Black Cotton soil with different proportion of stone dust i.e. (0 %,0.50% , 0.75% and 1%) as a reinforcing material, following conclusion can be drawn:

1. The soil sample selected for the study is from the Jalgaon Region with specific gravity of 2.65 and has optimum moisture content and maximum dry density 12.48% and 1.90 g/cm3 respectively. The soil according to Indian Standard Classification is clay of High compressibility (CH) soil.

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2.As soil is variable material in characteristics from place to place, this experimental work is only applicable to Jalgaon region Black cotton soil. For different area's soil, there will be chances of different Optimum percentage of Stone dust which will enhance soil properties.

3. From figure 1, it was observed that on increasing Stone dust proportion from 0% to 0.50%. MDD value increased from 1.87 g/cm3 to 1.90 g/cm3 respectively. On further increment in Stone dust proportion from 0.5% to 0.75% the MDD value increased from 1.85 g/cm3 to 1.87 g/cm3. Again further increment in Stone dust proportion from 0.75% to 1 %, the MDD value increased from 1.87 g/cm3 to 1.90g/cm3

4.It was observed that OMC decreased from 24.74 % to 18.32 % when proportion of Stone dust increases from 0 to 0.50 % after that OMC decreases to 18.32 % and 15.22 % when coir fiber proportion increases from 0.50 % to 0.75 %.Again further increment in Stone dust proportion from 0.75% to 1 %, OMC decreases to 15.22 % and 12.48 %.

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LISTS OF INDIAN STANDARD CODES

IS: 2720 (Part 1)–1983: Method of test for soils: Preparation of dry soil samples for varioustests (Second rev). A publication of Bureau of Indian Standards, Manak Bhawan, New Delhi.

IS: 2720 (Part 3/Sec 1)–1980: Methods of test for soils: Determination of specific gravity, Section 1: Fine grained soils. A publication of Bureau of Indian Standards, Manak Bhawan,New Delhi.

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IS: 2720 (Part 5)–1985: Method of test for soils: Determination of liquid and plastic limit.
IS: 2720 (Part 7)–1980: Method of test for soils: Determination of water content-dry density Relation