ENHANCEMENT OF DIFFERENT SOIL PROPERTIES USING STABILIZATION TECHNIQUES BY BASALT FIBER

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Abstract

Soil stabilization is the process of the alteration of the geotechnical properties to satisfy the engineering requirements. Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. A number of stabilizers, such as lime, cement and fly ash, depend on their chemical reactions with the soil elements in the presence of water. This study provides details of advantages and disadvantages of using basalt fiber as soil stabilizer. The organic soils are unsuitable for construction works due to its low shear strength, high swelling potential and poor bearing capacity. These types of soils can be treated by stabilization and compaction methods. In this research, study on effective use of stabilization using basalt fiber in varying proportions and the main objective of this study is to increase the geotechnical properties of soil. The vital role of soil stabilization in modern construction practices and sustainable infrastructure development.

Keywords: - Engineering properties, Basalt fiber, cement, plastic waste and organic soil.

Introduction

Soil stabilization may be defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. Stabilization, in a broad sense, incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance.

Soil stabilization refers to the procedure in which a special soil, cementing material, or other chemical materials are added to a natural soil to improve one or more of its properties. One may achieve stabilization by mechanically mixing the natural soil and stabilizing material together so as to achieve a homogeneous mixture or by adding stabilizing material to an undisturbed soil deposit and obtaining interaction by letting it permeate through soil voids.

Soil stabilizing additives are used to improve the properties of less desirable rood soils. When used these stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion and serve as cementing and water proofing agents.

The high strengths obtained from cement and lime stabilization may not always be required, however, and there is justification for seeking cheaper additives which may be used to alter the soil properties. Lime or calcium carbonate is oldest traditional chemical stabilizer used for soil stabilization. The study provides details of different types of soil stabilizing methods.

Composition of Soil: - Soil is composed of various factors like air, water, minerals, and different living and non-living organic compounds. The entire composition of soil can be classified as biotic and abiotic components; the abiotic component includes the non-living things of soil while the biotic component includes the living organisms. The properties of soil are determined by the composition of the soil, depending on different amounts of biotic and abiotic components. The combinations of these components determine the physical and chemical properties of soil. **of Soils.**

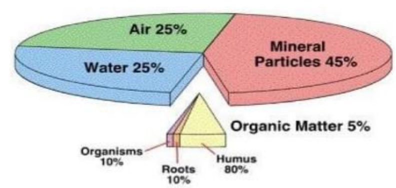


Fig.1 Composition of Soil Properties

Physical Properties: Soil Texture, Structure, Density, Porosity, consistency, Colour.

Chemical properties: Cation exchange capacity (CEC), Soil PH, Soil salinity.

Types of Soil: Sandy soil, Clay soil, Loam soil**,** Black cotton soil.

Statement of the Problem

Construction of buildings in low lands with engineered filling, flexible and rigid pavements for highways/airfields, and embankments for highways/railways are also part of major infrastructural development in addition to construction of tall buildings, bridges/fly overs, major dams and underground structures. A difficult problem in civil engineering works exists when the sub-grade is found to be clay soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase. Many research has been done on the subject of soil stabilization using various additives, the most common methods of soil stabilization of soils. However, there are significant changes in stabilizations techniques with using basalt fiber to increasing of different engineering properties and index properties of the soils.

The Project Objectives

- To analyze the physical characteristics of different soil and with using basalt fiber.
- Comparing basalt fiber with different material.

- To evaluate the bearing capacity and shearing strength of different soil.
- Giving the best result of soil stabilizing with basalt fiber performing different tests.

Literature Review

Gobinath R, Mahesh V, G. Shyamalaand, Adla Rajesh, (2020) "Strength and Settlement studies on basalt fiber reinforced marginal soil": It is made an attempt to study or to analyses the load vs. settlement characteristics of soil and the reinforced soil. Dial gauges are used to take the precise reading and the curve is then made.

Akash Kumar, Mohit Verma (2022) Studied the stabilization of expansive soil using calcium chloride. They used different proportions of calcium chloride and found out the strength and durability properties of the soil. The Free Swell Index of Black Cotton soil decreases with increase in Calcium Chloride content and alternate wet and dry cycles. The Maximum Dry Density increases and the Optimum Moisture Content decreases with increase in Calcium Chloride content. The Unconfined Compressive Strength increases with increase in Calcium Chloride content. Unconfined Compressive Strength increases with increase in number of days of curing and also with increase in alternate wet and dry cycles. The change due to 2% and 3% Calcium chloride are comparable. Hence, 2% Calcium Chloride is recommended from an economical perspective.

Adla Prathyusha, and Mudigonda Harish Kumar,2020 "Experimental Study on the Suitability of Basalt Fiber Reinforced Red Soil for Highway Construction": In this research paper, it is made a try to study of locally available red soil at Telangana for construction of highway, the soil samples prepared at its maximum dry density to its optimum moisture content in the CBR mould to carry out the CBR test. The soil sample was reinforced with basalt fiber.

Mr. Vishal Ghutke 1, Ms. Pranita Bhandari 2, Mr. Vikash Agrawal 3,2018"

Stabilization of soil by using rice husk ash": Black cotton soils are clays of high plasticity, which are having high shrinkage and very low bearing capacity. This study is in black cotton soil and the rice husk ash which is used as a reinforced material in the soil, and stabilization is taking place. The rice husk ash is mixed with soil in different proportions and tests are performed on it.

T. Murali Krishna 1, Sd. Shekun Beedi2, 3 June ,2017 "Soil Stabilization by Groundnut Shell Ash and Waste Fiber Material": This paper gives the study of the utility of groundnut shell ash and waste polypropylene fiber in the geotechnical engineering for the stabilization of soil. Various tests were performed on unreinforced and reinforced soil to study the effect.

Methodology

Materials used

- Basalt Fiber-18mm
- Soils (back cotton soil red soil sandy soil (campus soil))
- Lab equipment's materials

Soil Stabilization Soil stabilization is a method of improving soil properties by blending and mixing other materials. Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of soil. It is required when the soil available for construction is not suitable to carry structural load. Soil stabilization is used to reduce permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Thus, to reduce the settlement of structures. Soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. Soil stabilization is the technique of enhancing the properties, the stability or the bearing capacity of the soil by the utility of controlled compaction, proportioning and by inserting the suitable admixtures, fibres or the stabilizers.

Factors Affecting the Strength of Stabilized Soil

Organic Matter, Sulphates; Sulphides, Compaction, Moisture Content and Temperature.

Methods used for stabilization:

In road construction projects, soil or gravelly material is used as the road main body in pavement layers. To have required strength against tensile stresses and strains spectrum, the soil used for constructing pavement should have special specification. Through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil. Spraying or Spreading, Incorporation in Construction Materials, Soil Injection, Geosynthetic Applications, Hybrid Methods.

Basalt fiber: -

The basalt fiber is a material which is made up of extremely fine fibers of basalt, which contains different minerals like plagioclase, pyroxene, and olivine. It is a byproduct which is manufactured by the melting of the crushed and washed basalt rock at about 1500 ° C. The basic purpose of producing the basalt fiber as it is a naturally occurring material which is obtained by the basalt rock. It is a non- metallic fiber which shows very high performance. It does not contain any other admixture in its production which makes it cost affective and also it is environment friendly.

Table 1. Physical and chemical properties of Basalt.

Physical & Chemical Properties	**Value of Basalt Fiber**
Type of Fiber	Single
Avg. Diameter of Fiber	15 micro meters
Avg. Length of Fiber	13 mm
Tensile strength of fiber	4 GPa
Elastic modulus of fiber	95 GPa
Golden Brown Density	2.6 g/cm^3
Specific Gravity	2.7
Cost	Rs 400/ kg
Melting point	1350 ±100 °C

Applications

Basalt fibre is used in a wide range of possibilities, as basalt plastic reinforcement bars, in heat insulation materials glass and wool etc. now a days basalt fibres are even used as aggregates in concrete, ballast in railways, high quality textile fibres are produced for floor tiles, for heavy industries it is used as acid resistance equipment's.

Experimental tests and Results

The testing program is briefly described sample preparation for various test and test procedures performed in the present work. Materials and combinations are undergone for basic and required tests prior to main tests. Those are liquid Limit, Plastic Limit, Plasticity Index etc., strength characteristic is compaction test (Optimum Moisture Content (OMC), and Maximum Dry Density (MDD), Unconfined Compressive Strength (UCS).

01.ATTERBERG LIMITS

Liquid limits: The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

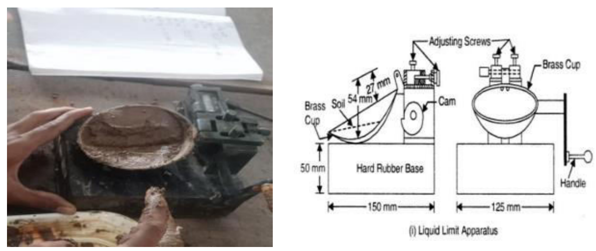


Fig.2 Liquid limit

Plastic limit Soil is used for making bricks, tiles and soil cement blocks in addition to its use as foundation for structures.

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). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.

Fig.3 Performing

Plastic Limit

Plasticity index = liquid limit - plastic limit

Table no.2 Atterberg Limit test results-Black cotton soil

S.No.	Basalt Fiber Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
01	0	74.31	34.05	40.26
02	0.15	49.26	33.14	16.12
03	0.20	45.11	30.02	15.09
04	0.25	43.17	28.11	15.06

Graphs: -

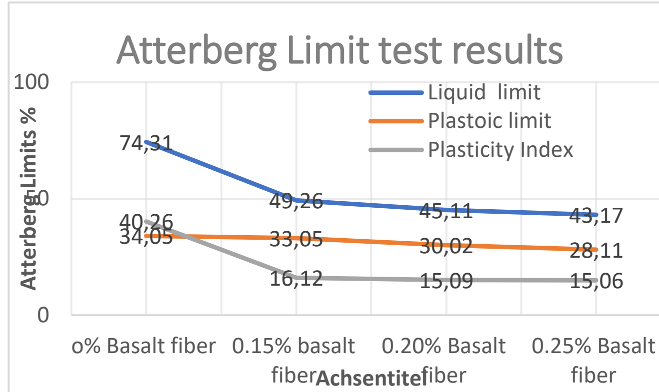


Table No.3 Atterberg Limit test results-Sandy soil (Campus soil)

S.No.	Basalt fiber content (%)	Liquid limit (%)	Plastic Limit (%)	Plasticity Index (%)
01	0	40.12	35.67	4.45
02	0.15	35.34	23.45	11.89
03	0.20	32.10	21.97	10.13
04	0.25	30.18	20.76	9.42

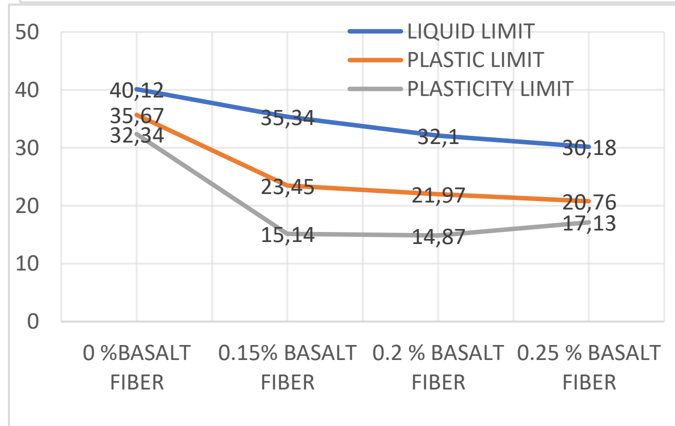
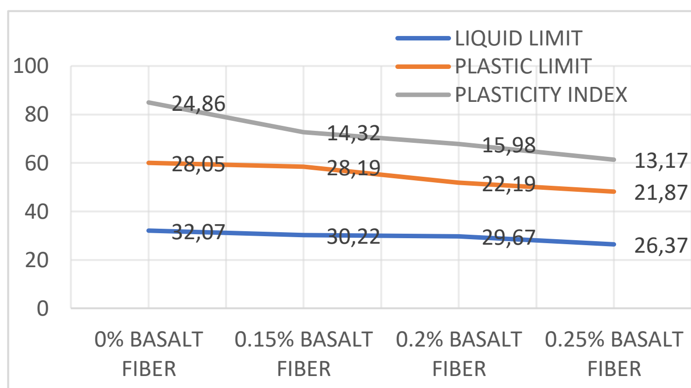


Table No.4 Atterberg Limit test results-Red Soil

S.No.	Basalt Fiber Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
01	0	32.07	28.05	4.02
02	0.15	30.22	28.19	2.03
03	0.20	29.67	22.19	7.48
04	0.25	26.37	21.87	4.5



02.STANDARD PROCTOR TEST

In geotechnical engineering, soil compaction is the process in which a stress applied to a soil causes densification as air is removed from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system). The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density.

NEED &SCOPE: To determine the relationship between moisture content and dry density of soil. This test provides optimum moisture content (OMC) and maximum dry density (MDD) of a given soil, **Fig.4 performing Standard Proctor Test**

which is important for man-made (compacted) earth structures. The results obtained from this test will be helpful in increasing the bearing capacity of foundations, decreasing the undesirable settlement of structures, controlling undesirable volume changes, reducing hydraulic conductivity, increasing the stability of slopes and so on.

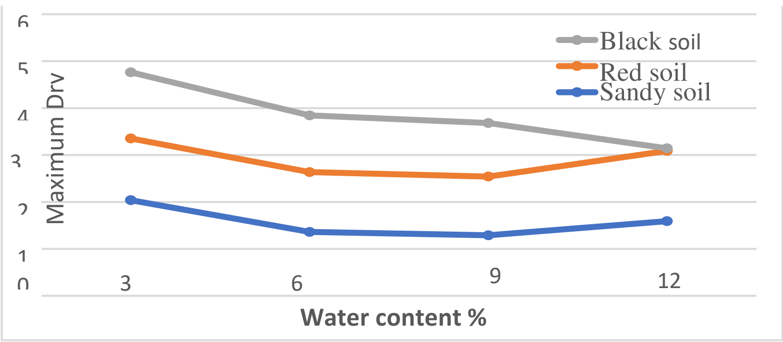
Table.4 Standard Proctor Test Bulk Density -OMC

S.No.	Basalt fiber (%)	Black soil	Red soil	Sandy soil (Clg.soil)
1	0%	1.6	1.55	2.21
2	1%	1.61	1.65	1.82
3	1.5%	1.64	1.63	1.92
4	2%	1.86	2.02	2.10

Table.5 Standard Proctor Test - MDD

S.No.	Basalt fiber (%)	Black soil	Red soil	Sandy soil (Clg.soil)
1	0%	1.410	1.316	2.036
2	1%	1.210	1.275	1.36
3	1.5%	1.142	1.25	1.29
4	2%	0.056	1.496	1.590

Graph: -



03.PERMEABILITY TEST

The rate of flow of water, under laminar flow conditions, through a unit cross sectional are of soil mass, under unit hydraulic gradient, is defined as coefficient of permeability. Permeability of the soil governs the magnitude of excess pore water pressure built-up in the embankment or cuttings, during consolidation process or when the embankment is ponded by water. The excess pore water pressure in-turn significantly influences the stability of the embankments and indicate the need, or otherwise, of need for special measures (e.g. sandwich construction)

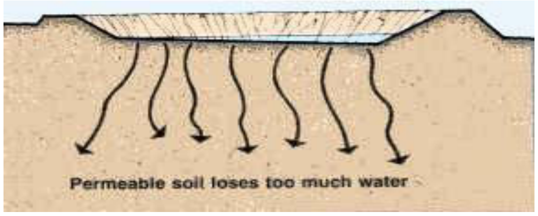


Fig.No.5 Flow of water Soil

to prevent/quickly dissipate excess pore water pressure. Coefficient of permeability is used to assess drainage characteristics of soil, rate of consolidation and to predict rate of settlement of soil bed. The coefficient of permeability is generally determined by two procedures (i.e. Constant Head Method and Falling Head Method).

Table 6. permeability Constant head

S no	Soil type		Volume	Temperature (t)	Kat Temp (cm/min)	µt/µ20	K 20^{0}
1	Campus soil	180	775	23	0.022	0.931	0.0

Fig.No.6 performing Constant Head Permeability Test

2	Black cotton soil	176	776	22	0.044	0.934	0.0
3	Red soil	175	765	22	0.046	0.935	0.0

- **Constant Head Method Permeability** Connect the specimen through top inlet to the constant head reservoir. Open the bottom outlet and when the steady state of flow is established, collect the quantity of flow for a convenient time interval and weight or measure it. Alternatively, the inlet may be at the bottom and collect water from outlet at the top. The collection of water flow for the same time interval shall be repeated thrice.

- **Falling Head Method**

This method, also called the Variable Head Permeability test, is suitable for fine grain soils with intermediate-low permeability such as clays and silts.
In Figure shows a schematic representation of the test which basically works the same as the constant head permeability test, the only difference being that the water head will not be constant but diminishing over time. This test involves the flow of water through a soil sample. At the top of the sample is a standpipe which provides the water head and allows measurement of the volume of water passing through the sample. The diameter of the standpipe depends on the permeability of the soil. This type of test can be carried out in an oedometer cell, or in a specific Falling Head permeability cell.

Table 7. permeability Falling Head

SNO	SOIL TYPE	H_1	H_2	T	Q	T(C)	Kt at Temp. (cm/min)	μt/μ20	K20°C (cm/s)
1	Campus Soil	51.1	24.3	54.1	45.8	21	0.0033	0.976	0.0032
2	Black soil	53.1	25.4	56.4	45.8	21	0.009	0.976	0.008
3	Red soil	54.7	27.7	57.9	45.8	21	0.008	0.976	0.007

04.UNCONFINED COMPRESSION TEST
Object and Scope.
The object of the experiment is to determine the unconfined compressive strength of clayey soil using controlled strain. The purpose of the test is to obtain a quantitative value of compressive and shearing strength of soils in an undrained state. The test may be performed on both undisturbed and remolded soil specimen.

Fig no.7 Unconfined Compression test

Table 10. Results of unconfined compression test-Black cotton Soil

Specimen (Basalt Fiber)	Max.Deviator Stress(kPa)	Axial Strain (%)
Black cotton Soil 0%	450	0.0
18mm fiber 1%	496	11.8
18mm fiber 1.5%	684	30.7
18mm fiber 2%	587	28.5

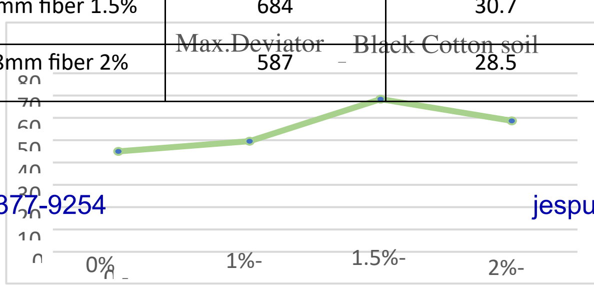


Table 11. Results of unconfined compression test- sandy soil (campus soil).

Specimen (Basalt Fiber)	Max.Deviator Stress(kPa)	Axial Strain (%)
Sandy (Campus) Soil 0%	450	0.0
18mm fiber 1%	519	13.3
18mm fiber 1.5%	746	39.7
18mm fiber 2%	655	31.3

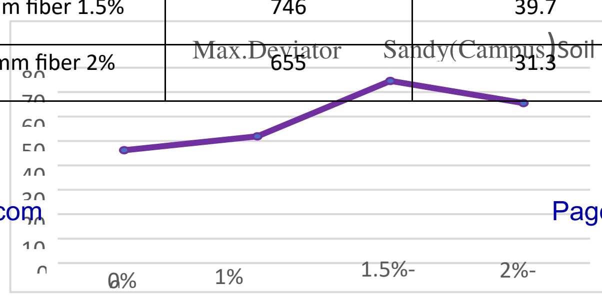
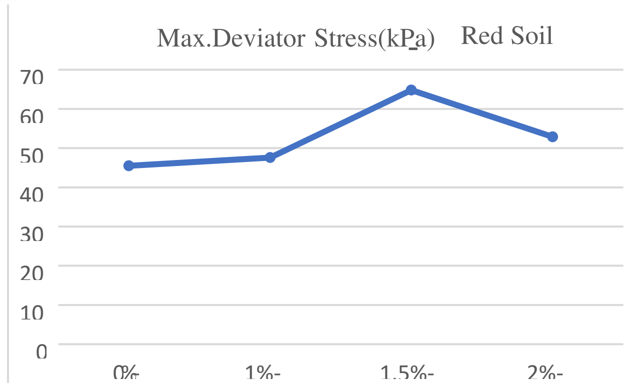


Table 12. Results of unconfined shear test- Red soil

Specimen (Basalt fiber)	Max.Deviator Stress(kPa)	Axial Strain (%)
Red soil 0%	450	0
18mm fiber 1%	476	10.6
18mm 1.5%	648	28.7
18mm 2%	529	26.4

Graph: -



05.DIRECT SHEAR TEST

NEED AND SCOPE

In many engineering problems such as design of foundation, retaining walls, slab bridges, pipes, sheet piling, the value of the angle of internal friction and cohesion of the soil involved are required for the design. Direct shear test is used to predict these parameters quickly. The laboratory report covers the laboratory procedures for determining these values for cohesionless soils.

Fig.No.8 Performing Direct shear test

Table 13. Direct shear test values

Load	Normal stress	Dial reading	Displacement	Corrected area	Proving leading division	Shear force	Shear stress
30	0.04	0	0	0	0	0	0
50	0.04	0.02	0.002	35.9	12.6	1.26	0.035
60	0.04	0.03	0.003	25.96	7	2.94	0.081
90	0.04	0.05	0.005	35.04	9	3.79	0.105
130	0.04	0.06	0.006	35.92	13	5.43	0.152
150	0.04	0.07	0.007	35.91	16	6.73	0.187

CBR TEST

California bearing ratio test is one of the soil strength evaluation tests. In this test, the relative strength of a soil specimen is measured with respect to the standard sample.

The California Bearing Ratio test (CBR test) is a penetration test developed by California State Highway Department (Caltrans) for evaluating the strength of subgrade soil, other paved areas and their used materials. CBR testing is used in the design of flexible pavements and since its development, it has been widely adopted internationally.

CBR=Ps/Pstd. ×100%

Ps=Stress carried by site soil· **Pstd**=Stress carried by standard soil.

Fig No. 9 CBR Test Equipment

Table no.14 Standard loads adopted for different penetrations

Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

Basalt fiber (%)	Sandy soil (campus soil)	Red soil	Black cotton soil
0%	1.42	1.39	1.31
1%	4.7	4.2	3.57
1.5%	6.2	5.8	5.19
2%	7.2	6.6	5.98

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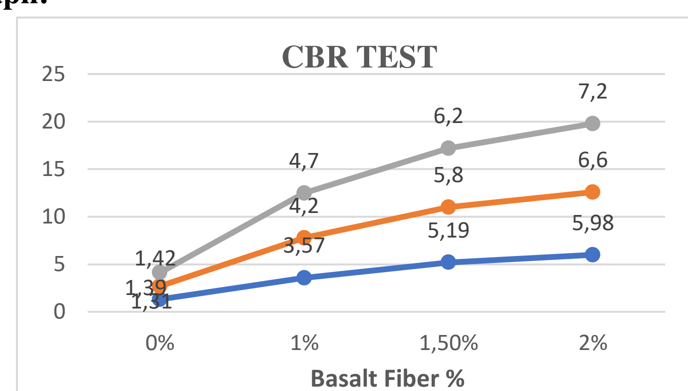

Conclusion

- By incorporating basalt fibers into the soil matrix, several key benefits can be achieved, contributing to improved soil performance and sustainability. Basalt fiber reinforcement effectively enhances soil stability, erosion control, and load-bearing capacity, making it a valuable technique for a wide range of applications, including construction, landscaping, and environmental conservation.
- Additionally, the environmentally friendly nature of basalt fiber underscores its suitability for sustainable soil stabilization practices, aligning with the principles of coconscious land management and infrastructure development.
- As research and practical applications continue to advance, the integration of basalt fiber in soil stabilization strategies holds the potential to foster resilient and environmentally sound solutions for addressing soil-related challenges in diverse contexts.

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