DETERMINATION OF STRENGTH OF SOIL AND ITS STABILITY USING NON DESTRUCTIVE TESTS

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ABSRACT

The alteration or modification of one or more soil properties to enhance a soil's engineering qualities and performance is known as soil stabilization. A practical and environmentally responsible way for improving soils is to use industrial waste products. Ultrasonic testing is used in this study to determine density. This technique can offer a quick and easy way to ascertain the properties of compacted stabilized soil. As an alternative to currently utilized methods for analyzing laboratory or field compacted soils, this non-destructive technique can be applied. The compaction parameters of stabilized soil are identified in this work using measurements of ultrasonic velocity.

Analysis was doneon how the density and water content of compacted stabilized soils affected the ultrasonic velocityvariation. The effects of soil type and velocity-dependent compaction conditions were examined.

Keywords: *soil stabilization, Ultrasonic Pulse Velocity, NDT method*

1. INTRODUCTION

Compaction characteristics of soil may be determined by analyzing the connection between soil's dry density (unit weight) and water content. Proctor compaction tests (ASTM D 698) are often used in laboratories to evaluate how changes in dry density with water content. The connection between the soil's dry density and water content is depicted by a compaction curve. The compaction characteristics of field soils and those of soils tested in a lab are compared to determine if building methods are effective. The use of in-situ methods necessitates more time. The ultrasonic pulse velocity method is an alternative strategy that this study effort tries to show. Ultrasonic testing makes it simple and rapid to identify the traits of compacted soils. This non-destructive technique can be used in place of the current ones to assess soils that have been compacted in a lab or in the field.

Following the completion of standard tests on soil samples with varied degrees of plasticity, such as black soil, an ultrasonic pulse velocity test was carried out on the samples, and a graph illustrating the link between density and velocity and water content was produced. An ultrasonic pulse velocity test brought the results to a conclusion after the association was established by extrapolating the results of prior conventional investigations. The standard values are acquired during the course of the laboratory tests, and the outcomes are then verified using the data from the ultrasonic pulse velocity measurement.

2. SCOPE AND OBJECTIVES OF PRESENT STUDY

To carry out standard quality control in the field, the methods ask for core-cutting pavement samples to be gathered for later laboratory testing. This procedure cannot be used to fix mistakes found while laying and compacting soil sub grade in the field since it is too time-consuming, expensive, and valuable solely for official records. In order to manage the soil sub grade of the pavement layer, fast on-the-spot measurements are necessary. The development of the ultrasonic pulse velocity method is influenced by these elements. Using an alternative in-situ testing technique termed ultrasonic testing, the research's goal is to evaluate the physical features of black soil and the stabilization of black soil by stabilizers.

The main objectives of the study are:-

- Researching how stabilizers alter Black soil's engineering performance and determining ifthey canbe employed as soil stabilizers are the study's key goals.
- The strength and stiffness of the soil specimen will increase if the soil stabilizer has good volumestability and durability.

- To determine the volume stability and durability of the soil specimen using the informationfrom theultrasonic pulse velocity test.

- In order to avoid causing damage, it is important to analyze the project specimen using non-destructive procedures.

3. METHODOLOGY

In order to break up any lumps, the earth was dug up 1.5 meters below the surface of the ground, rammed, and then dried in the open air. Black soil was mixed with stabilizer that had been oven-dried. Several different soil and stabilizer combinations were used to determine the compaction and strength properties of mixes made in compliance with IS. In total, three of these mixtures were made, and the laboratory assessed the mixes strength and compaction properties. Two transducer arrangements—onefor transmitting and the other for receiving—were employed in the ultrasonic experiments conducted for this work in order to estimate the P-wave velocity in the test compacted stabilized soil.

- **Ultrasonic Pulse Velocity Test [2]**

An on-site, non-destructive test termed ultrasonic pulse velocity testing (UPV) is used to determine the quality of soil and concrete. By monitoring the ultrasonic pulse velocity through concrete structures or soil formations, this test analyses the quality and strength of concrete or soil. The concrete being tested undergoes exposure to an ultrasonic pulse, and the duration of time it takes for the pulse to pass through thestructure is recorded. Slower speeds indicate more cracks and cavities in the concrete or soil whereas higherspeeds show greater material quality and continuity. An electrical circuit that creates pulses, a pulse production circuit, and a conversion device that turns those electronic pulses into mechanical pulses makeup an ultrasonic fault detector. The fundamental premise of this test is that the square root of the relationship between a material's density (ρ) and elasticity modulus (E), or the ratio E/ρ, determines the sound velocity (V) in that material (V). The equation in Polish notation is as follows:

$E = V^2 . \rho$

By calculating the elasticity modulus using this relationship, the quality of the soil can be established.

- **About the equipment**

  - P-wave transducers,
  - Pulse-receiver, and
  - Data acquisition system.

Two transducers are used for the measurements; one emits the ultrasonic waves and the other receivesthem after the test sample. The transducers are turned on by a pulse receiver, which is a part of the data-collecting system for digitizing data.

The travel time for both test techniques is obtained by using ultrasonic measurements at the receiving transducer at the time of their initial arrival. The initial arrival time was calculated as the interval between when the transmitting transducer applied the pulse and when the waveform entered the receiving transducer. Data collection started when the pulse was administered thanks to synchronization between the digital data board and the pulse receiver. Along withtheir journey time, the waves' velocities as they go across the compacted soil from the transmitter to the receiver are also calculated.

The information gatheredis useful in assessing the effects of soil propertiesand compaction conditions on velocity.

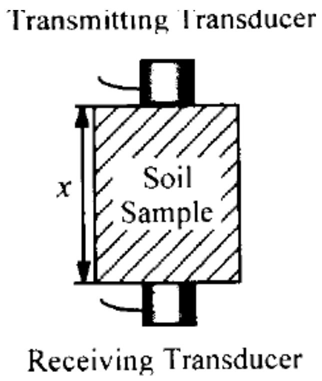


Fig-1: UPV machine working

Comparisons were made between conventional compaction plots (dry density vs. water content) and compaction plots produced via ultrasonic measurements (velocity vs. water content). The soil that has been stabilised with stabilizer to an increasing proportion is compacted with different water contents using standard and modified Proctor efforts. The compacted soil mass is used for the ultrasonic pulse velocity test. During tests using the through-transmission test method, samples were used to evaluate density, water content, and P-wave velocity. The velocity of each sample used to evaluate the compaction characteristics of the soils was calculated. Compaction plots were made using dry density vs. water content and velocity vs. water content.

4. EXPERIMENT DETAILS

- **Material**

- **Soil**

Black soil, sometimes known as regular soil or just black soil, is a prevalent kind of soil in many parts of India, especially on the Deccan Plateau. Its name comes from its dark tint, which is the result ofa significant amount of organic matter and clay minerals. Black cotton soil is created by the weatheringof volcanic rocks, basaltic lava flows, and sediments left behind by rivers. Because clay minerals like montmorillonite make up the majority of its constituents, it exhibits peculiar characteristics. Due to its abundance in organic matter and nutrients, the soil is effective for farming.

- **Stabilizers**

1. Marble slag works well as a soil stabiliser because of its binding properties. When coupled with soil, it improves the mechanical properties of the soil, such as greater stability, decreased flexibility, and improved load-bearing capacity. It can therefore be utilised in a range of applications relating to construction. The alkaline nature of marble slag helps to balance acidic soils. Using marble slag as a soil stabiliser is an economical alternative to conventional soil stabilizing methods. Byproducts like marble slag are readily available for little to no cost, lowering overall project expenditures. Due to its ability to improve soil stability, pH levels, and load-bearing capacity, it is suitable for a range of uses in road construction, building foundations, landscaping, and land rehabilitation.

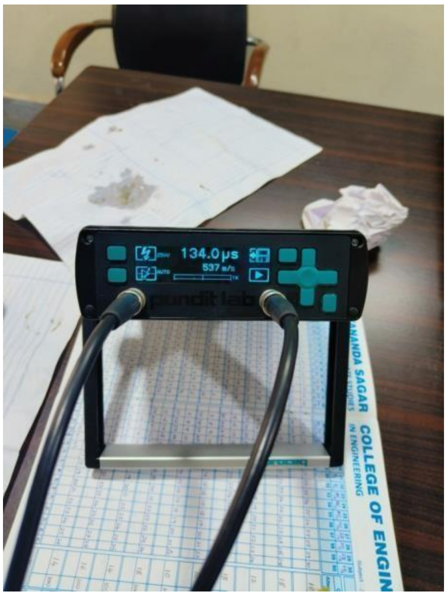


Fig-2: UPV machine showing reading

2. The fibrous husk of coconuts is used to create coconut coir, which is now known to be an effective soil stabilizer. This paper aims to provide a comprehensive overview of the properties, benefits, and applications of coconut coir as a soil stabilizer. Due to its unique characteristics and environmentally friendly supply, coconut coir presents a more environmentally responsible option for soil stabilisation. Coconut coir is the term for the fibrous substance that is removed from the coconut husk's outer layer. Pith, lingo-cellulosic fibres, and other organic materials make up its composition. The coir fibres provide the structure strength, while the pith acts as a medium for retainingmoisture. The pH of coconut coir typically ranges from 5.5 to 6.8, from slightlyacidic to neutral.

Sample preparation

The soil sample collected on-site is dried outside in the open air. The clods were broken up using a wooden mallet to hasten drying. Any organic matter, such as tree roots and bark slivers, is removed from the sample. Shells are one more kind of non-oil materials that are separated from the main soilmass, much like oil is.

Shells, roots, and other foreign objects are not removed when samples are taken for estimating organic content or lime content, and these removals are documented along with their percentage ofthe overall soil sample.

Laboratory Tests to be conducted:

a. Specific Gravity test of soil

b. Light compaction to determine the OMC

c. UCS

d. Ultrasonic Pulse Velocity test

e. DATA ACQUISITION

The physical and chemical properties of the specimen (soil) are given below,

S.NO	PROPERTY	SOIL
1	Specific Gravity	2.8066
2	Grain sizeanalysis	Passed through a 4.75mm sieve
3	Atterberg'slimits	

	Liquid limit	63
	Plastic limit	30
4	Plasticity index	33
5	Soil classification	Coarse grained soil
6	Compaction characterstics	
	Max. dry density(kN/m^3)	17.45
	Optimum moisture content(OMC)%	17.2%

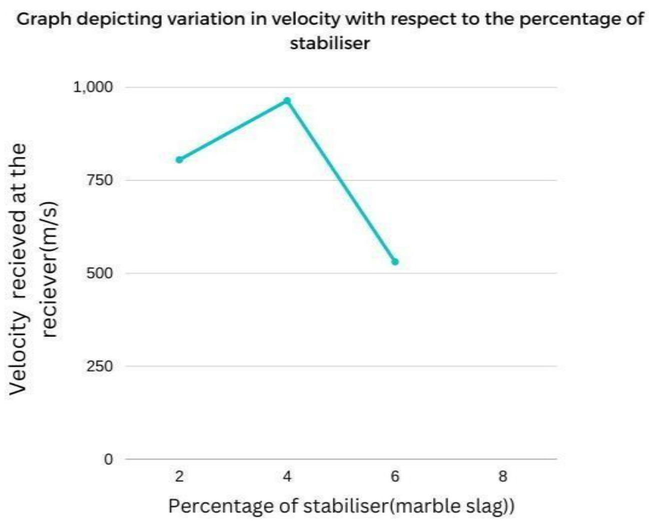
TABLE- 1 Physical properties of soil

The results of the various tests to be conducted in the laboratory were also taken into account while doing the analysis and drawing out the conclusions for the experiment.

f. DATA ANALYSIS

Through various tests that are conducted throughout the whole project, the effect on the variousproperties of the soil with the influence of stabilizer at different percentages are obtained by evaluation and generating the relation between various parameters of stabilized soil.

The results are depicted using the nature of the graphs derived from data from various experiments,

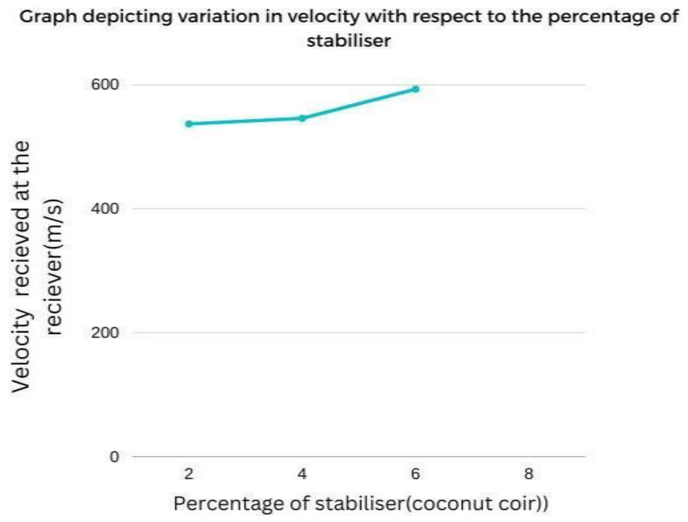


Graph-1: Variation in readings with percentage

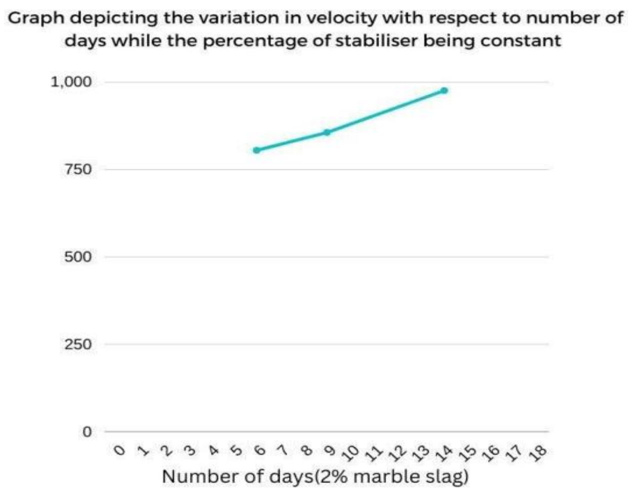
Here we can see through the graph that as the percentage of the stabilizer(here marble slag) is increased there is asubsequent increase in the velocity readings of the UPV test as well indicating that the increase inpercentage of the slag lead to better soil quality and in turn better stabilization.

Here too we can see through the graph that as the percentage of the stabilizer(here coconut coir) is increased there is a subsequent increase in the velocity readings of the UPV test as well indicating that the increase in percentage of the slaglead to better soil quality and in turn better stabilization. Here we should keep in note that theUPV tests conducted on the specimen were done after 7 days ofthe specimen being made.

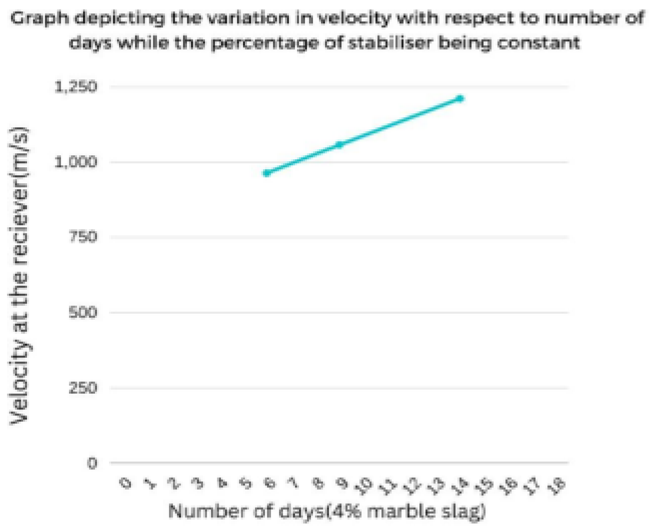
Now we shall see the velocity returnsof the UPV test when we keep the percentage of the stabilizerconstant and test it on different days,



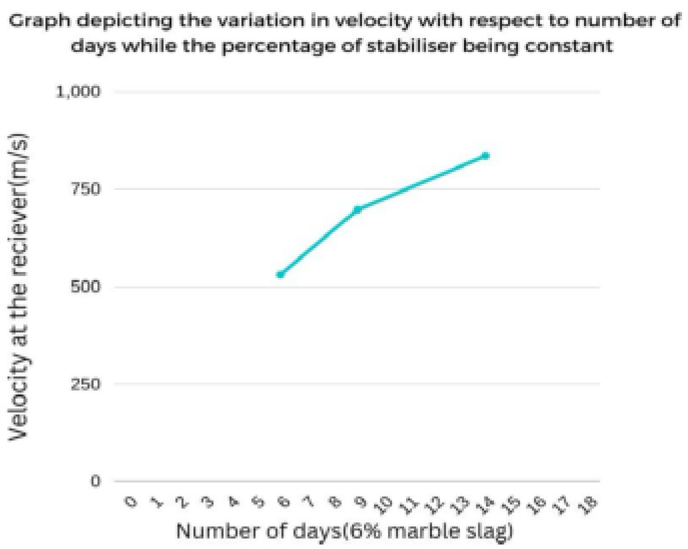
Graph-2: Variation in readings with percentage



Graph-3: variation in readings with passage of days (2%MS)

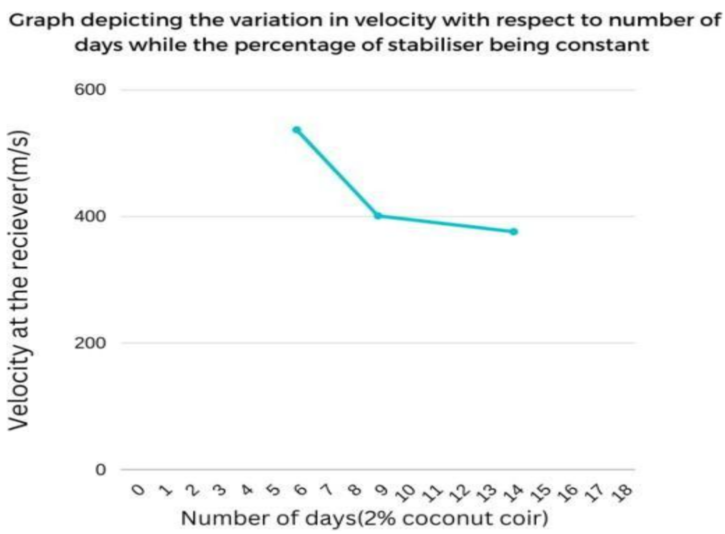


Graph-4: variation in readings with passage of days(4%MS)

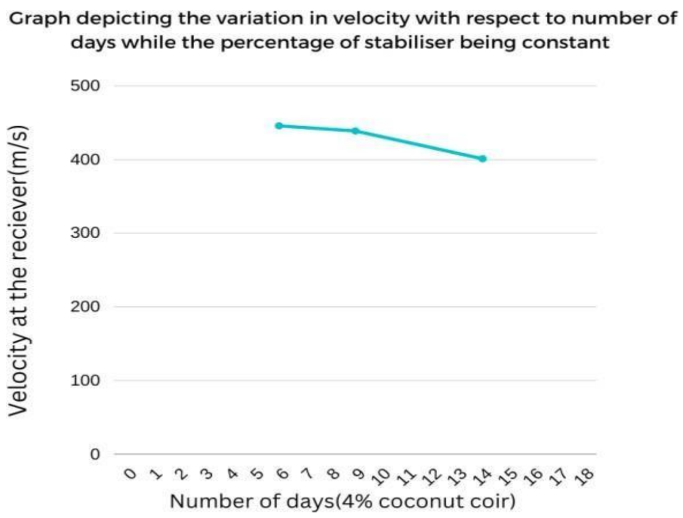


Graph-5: variation in readings with passage of days (6%MS)

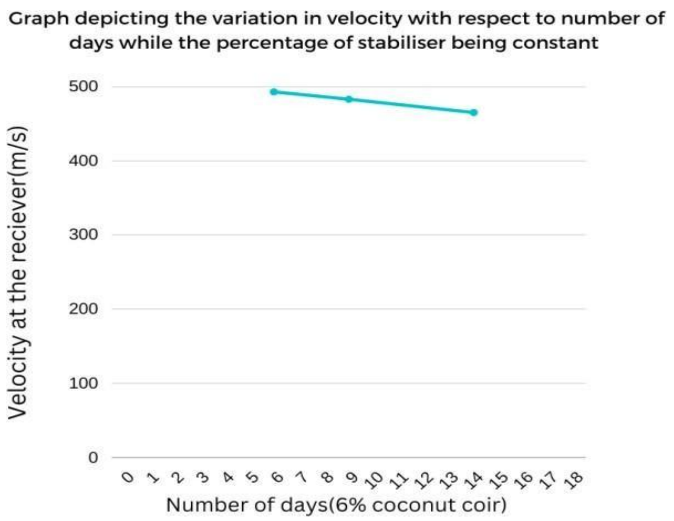
As we can see through the graph thatthere is an increase in the velocity of the Ultrasonic Pulse waves as the specimen mould(made up of soil and stabilizer) is kept preserved through the days. The graph is not perfectly linear but one can estimate the values to a close approximation for the later daysusing thegraph.



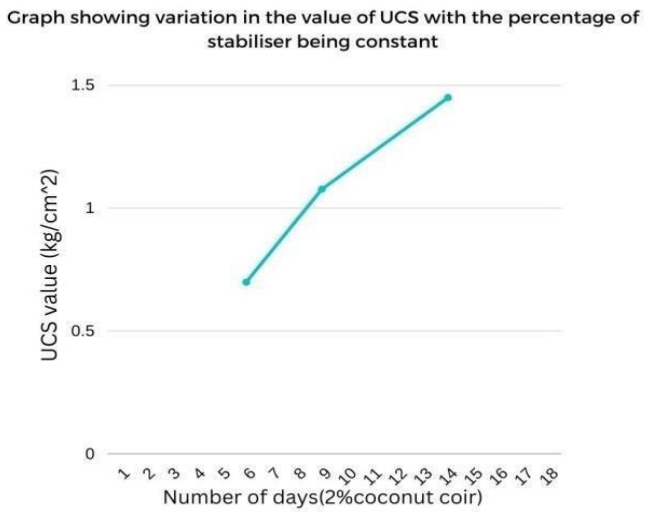
Graph-6: variation in readings with passage of days (2%CC)



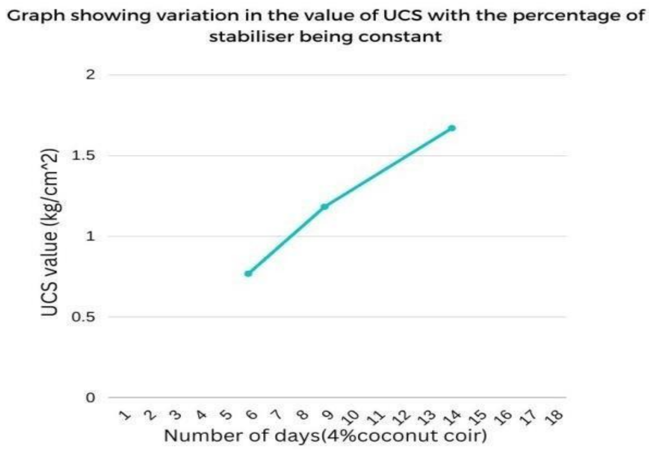
Graph-7: variation in readings with passage of days (4%CC)



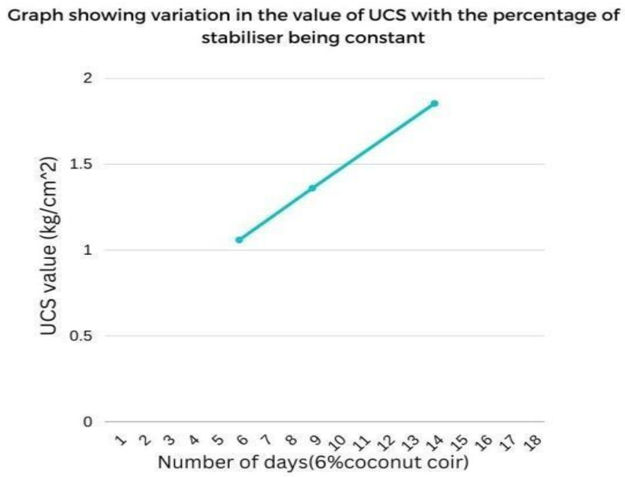
Graph-8: variation in readings with passage of days (6%CC)



Graph-9: variation in readings with passage of days (2%CC)(UCS)



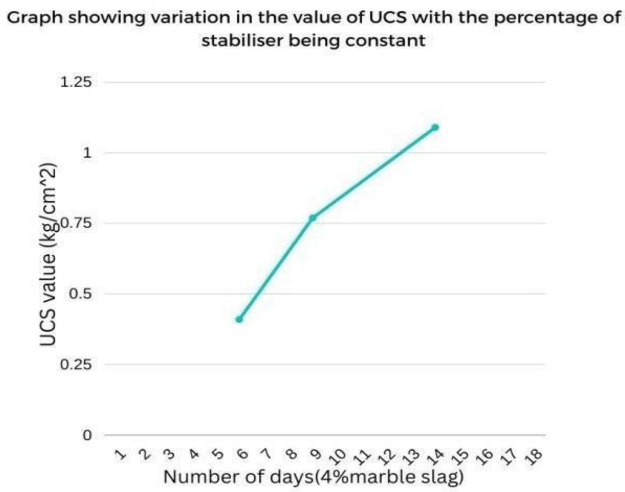
Graph-10: variation in readings with passage of days (4%CC)(UCS)



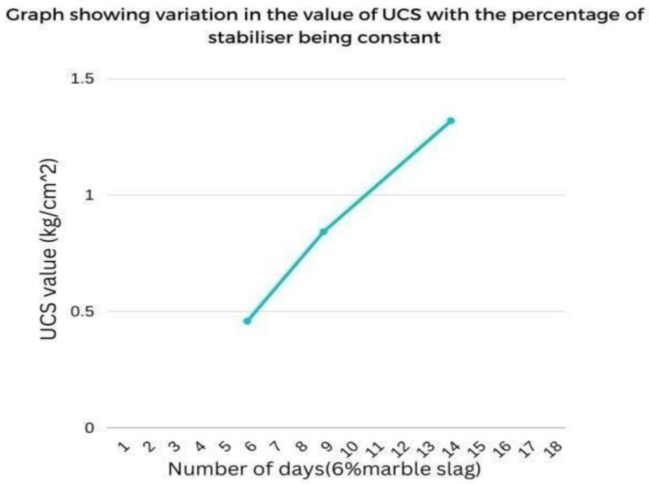
Graph-11: variation in readings with passage of days (6%CC)(UCS)

In the above graphs we can see the UCS value of the sample containing different percentagesof coconut coir and test it on different days.

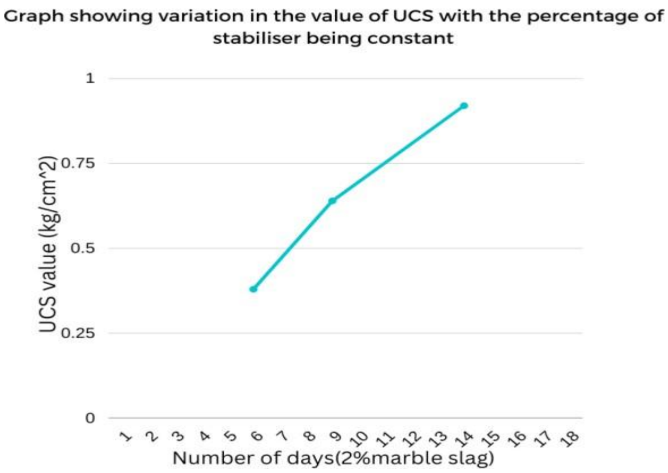
In the below graphs we can see the UCS value of the sample containing different percentagesof marble slag and test it on different days.



Graph-12: variation in readings with passage of days (4%MS)(UCS)



Graph-13: variation in readings with passage of days (6%MS)(UCS)



Graph-14: variation in readings with passage of days (2%MS)(UCS)

Type of Stabilizer	Coconut Coir		
Percentage of Stabilizer	2	4	6
UPV(m/s)	434.3.	432.3	475.33
UCS(kg/cm^2)	0.89	0.95	1.21
Time(µs)	156.8	161.2	148.5

TABLE-2: Upv, Ucs and time readings for Coconut coir

Marble Slag		
2	4	6
865	1036.3	662
0.51	0.59	0.65
89.4	74.7	135.7

TABLE-3: Upv, Ucs and time readings marble

Mix Stabilizer [Marble Slag+Coconut Coir]		
(1+1)	(2+2)	(3+3)
308	545	389
1.543	1.701	1.82
234	132.2	185

TABLE-4: Upv, Ucs and time readings for mixed stabiliser

CONCLUSION

From the obtained analyzed results, thefollowing conclusions were drawn:

- Stabiliser can be used to stabilise the soil because it has significantly enhanced thegeotechnical properties of soil.
- Stabiliser enhanced soil's maximum dry density while lowering its optimal moisture content.
- The soil's propensity to expandhas greatly diminished.
- In order to investigate the compaction characteristics of soil with stabiliser added, ultrasonictechnology was used.
- Plastic limit, liquid limit, and plasticity index all decrease as stabiliser percentage rises. Using ultrasonic measurements, the p-wave velocity in the stabilised soil is determined.
- It was discovered that there was no difference in the variation of either velocity or density forthe same water content.
- It was determined that high solidcontents, low water and air voids, and low solid contents and high water and air contents, respectively, result in an increase invelocities of the compacted soil mass.
- The rate of velocity rises with density was higher for varied proportions of stabilisers supplied to the soil at various percentages.
- The combined soil meets MORTH's (Ministry of Road Transport andHighways) subgraderequirements.

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