Experimental Investigation of Expansive Soil Properties Stabilized by using Fly Ash, Waste Cement Bag Fiber, and Lime

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Abstract: The qualities of the soil on which the structure is made are primarily answerable for its instability. As an example, if the soil has poor index properties, cracking and settlement are possible. The structure of any road or pavement involves a variety of layers such as subgrade, subbase, base, and wearing course. The subgrade is critical in road construction. The current study is concerned with the improvement of soil properties by the accumulation of fly ash, waste cement bag fiber, and lime. Various proportions are 40% fly ash, 0.4% to 1.2% of waste cement bag fiber within the increment of 0.4%, and lime 0.9% to 2.7% within the increment of 0.9% by dry weight of soil sample to arrange the soil samples for stabilization. The tests which are Atterberg's limit, Plasticity index, Specific gravity, Compaction test, California bearing ratio test, and unconfined compressive strength are performed to recognize the modifications within the properties of soil.

Keywords: *Expansive Soil; Flyash; Waste Cement Bag Fiber; Lime; CBR Test; UCS Test*

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I. INTRODUCTION

Expansive soil is one of the troublesome soils, causing damage to many civil engineering structures due to its swelling and shrinking potential when exposed to water. This soil has changed significantly in volume due to the addition or removal of water. (1) Their physical properties are characterized primarily by low bearing capacity, low shear strength, and high water absorbability. Expansive soil's limited bearing capacity causes issues in civil engineering structures. So, the procedure of stabilization is adopted to enhance the engineering properties of expansive soil. Soil stabilization is the process of blending and combining materials within the soil in order to improve the soil's quality. Stabilization is required to strengthen the base layer, on which the base course gravel layer can be laid. (2)Stabilization is used in a variety of engineering jobs, the most prevalent of which is the construction of pavements such as road and airfield pavements, with the purpose of boosting soil carrying capacity and strength while also minimizing development costs. The pavement is supported by subgrade soil, which helps the foundation to carry weight. A suitable value of California bearing ratio (CBR) for subgrade soil is essential for this purpose to ensure the required strength to support the load from traffic despite adverse conditions such as excessive rainfall and flooding. Some subgrade soils are unable to meet these requirements.(3,4) Stabilization has been accomplished using a variety of approaches, including chemical substances such as Portland cement, lime, fly ash, calcium or sodium chloride, and viscoelastic materials such as bitumen. Many waste materials, including jute, palm fiber, nylon fiber, synthetic fiber, iron residue, fly ash, and coal, can be utilized to stabilize expansive soils. Furthermore, recycled waste materials are utilized to stabilize expansive soils, which is the most essential technique to save money and prevent pollution. These compounds improve the soil's strength and durability. It was also discovered to greatly boost crack reduction due to the enhanced tensile strength of the soil, therefore the current study is concerned with the enhancement of soil qualities by the addition of fly ash, waste cement bag fiber, and lime in different proportions. Waste cement bag fibers are polypropylene and polyethylene fibers used to make cloth for packing cement that has high strength and is used to grow soil stability.(5)There are two reasons why these synthetic fibers are used in the subgrade. The first is to increase the bearing capacity of the subgrade, and the second is to improve drainage efficiency. The primary reason for incorporating these materials into the soil is that the fabric reinforcement must remain in the soil for the duration of the development. The following material is Fly ash that is produced by coal-fired electric and steam-generating plants. (6) Typically, coal is crushed and pushed into the boiler's combustion chamber with air, where it quickly burns, producing heat and a molten mineral residue. Heat is extracted from the boiler via boiler tubes, which cools the flue gas and causes the molten mineral residue to harden and create ash. Coarse ash particles, known as bottom ash or slag, settle at the bottom of the combustion chamber, while finer ash particles, known as fly ash, rise to the top. Over 68 million tons of fly ash were produced in 2001. Currently, 22 million tons of fly ash are used annually

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in a variety of engineering applications. Portland cement concrete (PCC), soil and road foundation stabilization, grouts, structural fill, and asphalt filler are examples of common highway engineering applications. However, to achieve sustainable construction, many governments have urged the reuse of specific types of waste. As a result, utilizing fly ash as a binding additive enhances soil engineering properties while also reducing energy consumption and greenhouse gas emissions. The shear strength and bearing capacity of the soil can be enhanced by stabilizing it with fly ash. (4,5) On the other hand, the current study uses lime to change and stabilize soil beneath highways and similar construction projects. It is an inorganic calcium-containing substance made mostly of oxides and hydroxides, typically calcium oxide and calcium hydroxide. Before the invention of portland cement, lime was used as the chief cementing material in the construction industry. Today, the use of lime has become very limited and is sometimes used in places where lime is locally available and the availability of portland cement is scarce. Lime is not available in nature in its free state, as it reacts with CO2 to form calcium carbonate. It is used as a stabilizer to decrease plasticity, swell, and increase stability. The ideal water content increases, while the maximum compacted density decreases, and soil strength and durability improve. The study is mainly concentrated in the mixture of waste cement bag fiber of 0.4%, 0.8%, and 1.2% with 40% fly ash and 0.9%, 1.8%, and 2.7% of lime. Make the blend of these three materials in definite proportions within the soil and identify the influence of maximum dry density, optimum moisture content and California bearing ratio test, and unconfined compressive strength test for soil stabilization.

II. LITERATURE REVIEW

A few researchers investigated the effects of mixing soil with various polymer composites, epoxy resins, copolymers, polypropylene fiber material, fly ash, and lime. A great deal of work has been done by several researchers, some of whom are included below:

K. tharani et.al (2021) [1] Researchers focused on boosting soil strength through the use of fiber, lime, and other elements. In this study, black cotton soils were subjected to a variety of tests, including Atterberg's Limits, Compaction test, Unconfined Compressive Strength, California Bearing Ratio, and Shear test with varying percentages of polypropylene fiber (i.e., 0.5%, 1%, 1.5%, and 2%), and constant percentages of basalt fiber and lime (4% and 6%). The inclusion of fibers and lime lowers the optimal water content and swelling ability while improving strength and dry density.

B. Priyadarshini et.al (2021) [2] studied the influence of fiber addition on the parameters of the collected finer soil is demonstrated in this experimental investigation. The following is the conclusion based on the findings: Standard proctor compaction test results were obtained by putting fibers in fine-grained soil during tests. When using natural fibers, the optimum moisture content is decreased to 2%, and when using artificial fibers, it is reduced to 2.8 percent as compared to untreated soil, and the maximum dry density increases with the accumulation of fibers. The CBR values of soil with stabilized samples and soil without stabilized samples demonstrate that the bearing capacity of the soil has increased, making it appropriate for pavement.

Ayani tasaduq et.al (June 2020) [3] studied the composite of lime, fly ash, and fiber on compaction of subgrade so, initially, the clay soil was subjected to the addition of fly ash. The optimal moisture content increased while the maximum dry density decreased. CBR's worth has also risen. With the addition of fiber, OMC increased while MDD dropped. The CBR value increased within the fiber as well. As a result, the strength and other qualities of clay soil have significantly improved, making it appropriate for subgrade and other buildings.

Shiva Prashanth Kr kodicherla (2019) [4] paper deliberates the stabilization with coir fiber and fly ash with expansive soil to construct the subgrade. The tests like plastic limit and liquid limit test, gradation test, unconfined compressive strength, and CBR test are performed so, they conclude that 20% flyash+1% fiber mixed with soil shows the percentage increase in strength and bearing ratio of soil for subgrade.

➢ *Research Gap*

Expansive soil is self very poor in bearing capacity and has negligible shear strength and a very large void ratio. That's the key reason to do research work on the stabilization of expansive soil because the expansive soil changes its volume when it comes in contact with moisture or water content. From the previous research work, it is found that different fibers (natural fibers and artificial fibers) and also different varieties of materials (sawdust, rice husk ash, fly ash, lime, cement, marble dust, etc) were used in different proportions to improve the strength of soil so the soil can carry more load before failure. It is also observed that doing all those stabilization methods shows improvement in soil bearing capacity. So here is what I found interesting in soil stabilization and choose to enhance and improve the strength of expansive soil, that's why improved soil can carry more load.

➢ *Objective of the Study*

- To evaluate the fundamental engineering properties of the natural soil sample without any additives. This includes determining specific gravity, grain size distribution (gradation test), Atterberg limits, optimum moisture content (OMC), maximum dry density (MDD), unconfined compressive strength (UCS), and California bearing ratio (CBR).
- To assess the effects of adding fly ash (40%), waste cement bag fibers (0.4%, 0.8%, and 1.2%), and lime (0.9%, 1.8%, and 2.7%) to the soil by measuring changes in plasticity index, MDD, OMC, CBR, and strength. The goal is to identify the optimum combination of these additives.

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- To determine the most effective soil stabilization method, compare the performance of the untreated soil sample with the improved samples containing the optimum proportions of admixtures.

III. MATERIALS USED

➢ *Soil*

The expansive soil used in this investigation came from G.T ROAD in Amritsar, Punjab (India). It was examined for its liquid limit, plastic limit, particle size distribution, and other parameters using sieve analysis, compaction test, Unconfined compressive strength (UCS), California bearing ratio (CBR), and other methods.

➢ *Waste Cement Bag Fiber*

Threads were extracted from a waste cement bag comprised of robust and flexible cast polypropylene. Unfilled waste cement bags were cleaned with water and dehydrated at room temperature before being cut into 5cm in length of threads for various experiments. The cement bag threads were determined to be 0.03 mm thick. Fiber ratios of 0.4% to 1.2% within the increment of 0.4% were used.

➢ *Fly Ash*

The fly ash calm from the thermal power plant located at the new telephone exchange, Albert street, Amritsar (Punjab). To remove foreign materials, it is sieved through a 2.36mm sieve. The soil samples for this study were prepared with a constant 40% fly ash content.

➢ *Lime*

A 5kg bag of lime, well-known as quick lime, was received from the market. At room temperature, lime is a white, caustic, and alkaline crystalline solid. Lime frequently includes MgO, SiO, and trace amounts of aluminium oxide and iron oxide. The soil was blended with 0.9% to 2.7% lime in 0.9% increments.

IV. RESULT AND OBSERVATIONS

According to the experimental program, several tests were executed on soil with various percentages of fly ash(40%), waste cement bag fiber(0.4%,0.8%,1.2%), and lime(0.9%,1.8%,2.7%) within the soil. The results are presented below in Table .

Table 1 Different Properties of Soil (7-12)

Parameters	value
Specific gravity	2.38
Grain size distribution:	
Gravel %	10
Sand %	43
Silt and clay %	47
Degree of cohesiveness	Cohesive
Classification	CL
Liquid limit LL%	13.7
Plastic limit PL%	3.12
Plasticity index PI%	10.58
Maximum dry density (g/cc)	1.781
Optimum moisture content (%)	10
California bearing ratio (%)	2.29
Unconfined compressive strength (N/sq.cm)	4.7

➢ *Effects of Flyash, Waste Cement Bag Fiber, and Lime*

The soil used in this study was combined with 40% fly ash, 0.9%,1.8%, and 2.7% of lime, and 5cm in length waste synthetic fiber threads in proportions of 0.4%,0.8%, and 1.2%. Various experiments were undertaken to increase the soil's carrying capacity and strength, and the findings are listed below as shown in Fig (a,b,c)

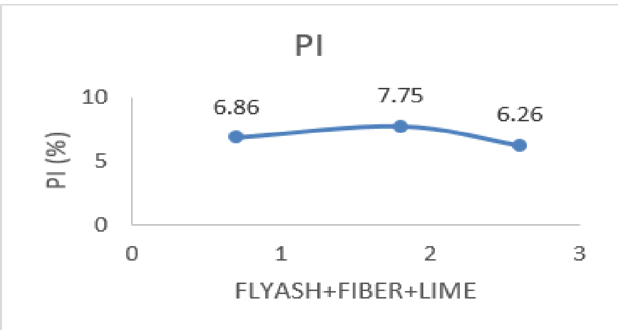

Fig 1 (a) Soil+0.4%Fiber+40%fa+Lime%

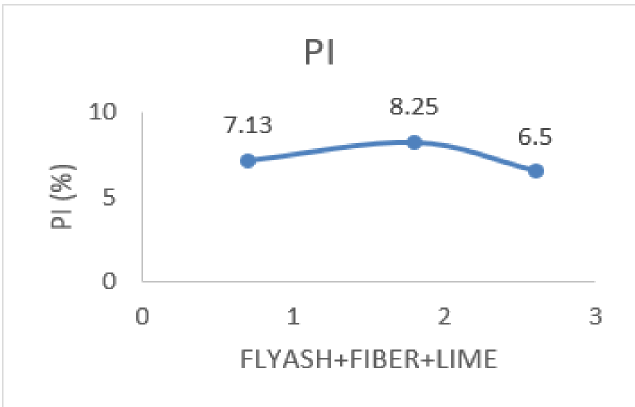

Fig 1 (b) Soil+0.8%Fiber+40%fa+Lime%

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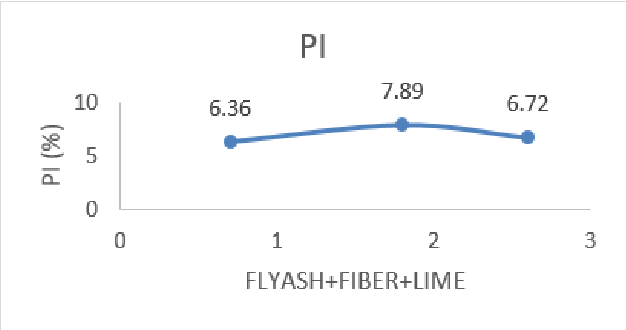

Fig 1 (c) Soil+1.2%Fiber+40%fa+Lime%

In the Fig of plasticity index, a blend of soil sample with 40%flyash with 0.4%,0.8%, and 1.2% of fiber increase the plasticity of the soil. In this mix of soil, 40%flyash with 0.4% fiber shows a plasticity of 7.75% at 1.8% proportion of lime also in the case of 0.8% and 1.2% of fiber shows the 8.25% and 7.89% plasticity index. At last, the maximum increment in the plasticity index in the proportion of 40%flyash with 0.8%waste cement bag fiber and 1.8% lime within the soil.

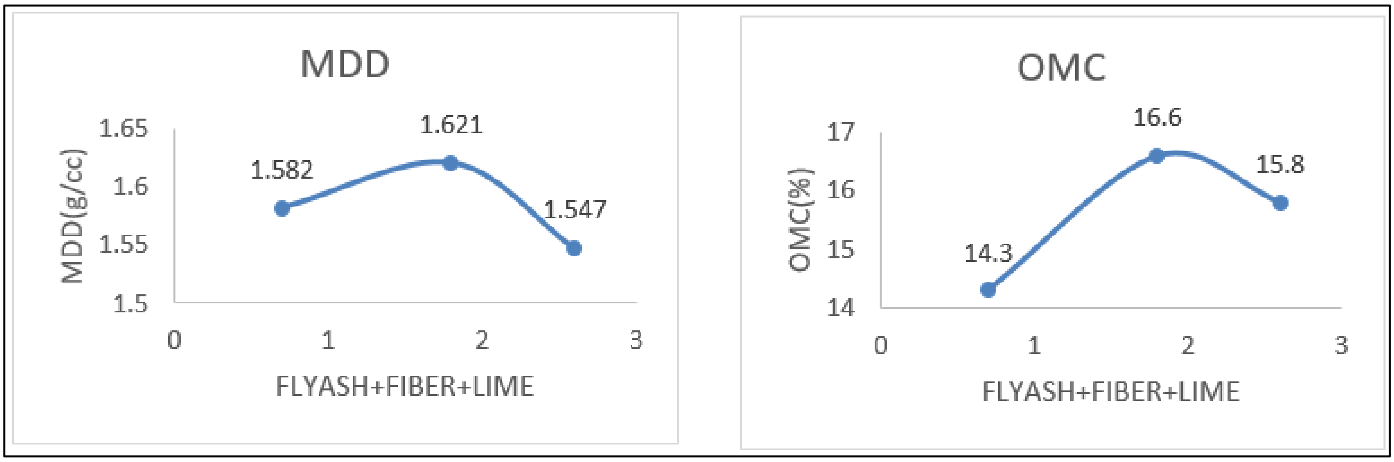

Fig 2 (a)and(b) Soil+0.4%Fiber+40%fa+Lime%

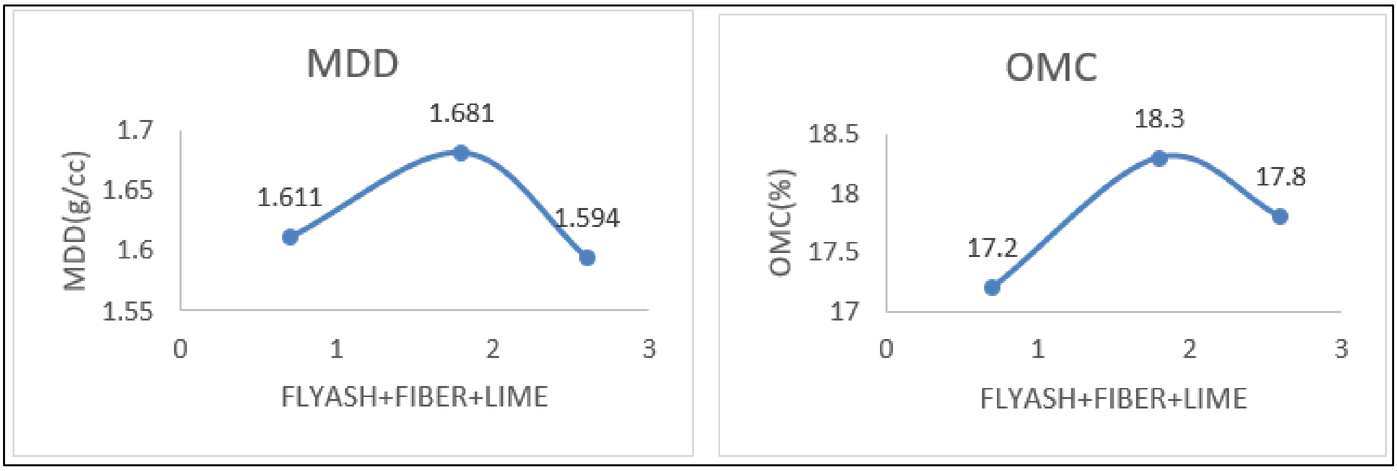

Fig 3 (a)and(b) Soil+0.8%Fiber+40%fa+Lime%

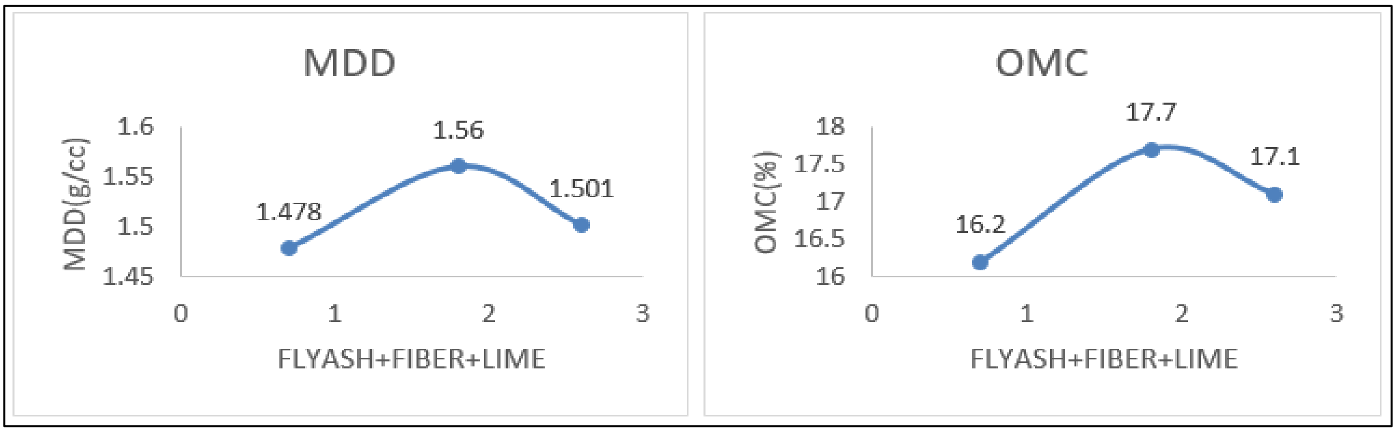

Fig 4 (a)and(b) Soil+1.2%Fiber+40%fa+Lime%

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In the proctor compacting experiment needs to find the maximum dry density of soil and the optimum moisture content or water content that is obtained when the density attains its higher value. In this case, the result displays the maximum dry density of soil with 40%flyash, 0.4%,0.8%,1.2% of waste cement bag fiber at the proportion of 1.8% lime is 1.621g/cc, 1.681g/cc, 1.56g/cc at 16.6%, 18.3%. 17.7% optimum moisture content respectively. In the end, the proportion is 40%flyash,0.8% waste cement bag fiber with 1.8% of lime showing the maximum dry density that is 1.681g/cc at 18.3% moisture content as shown in **Error! Reference source not found.**Fig Fig .

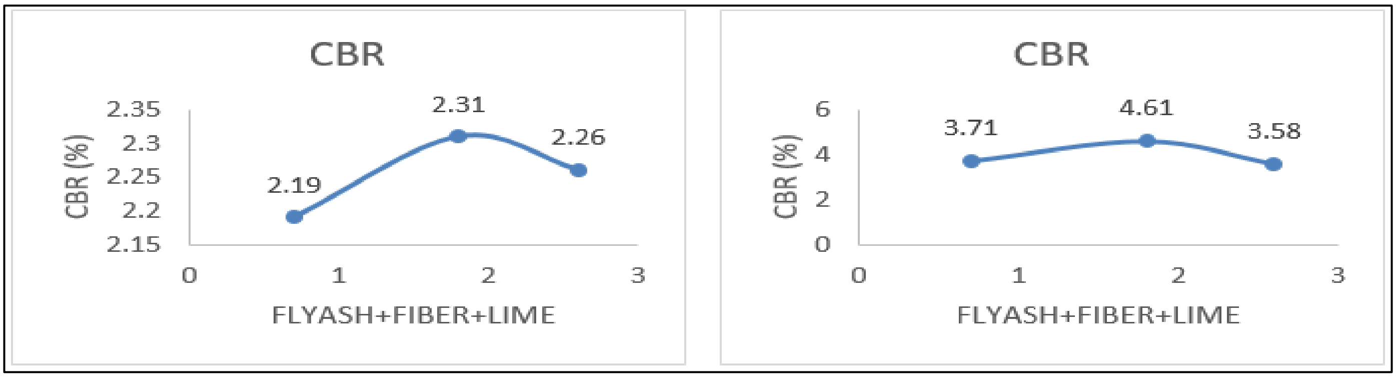

Fig 5 (a) Soil+0.4%Fiber+40%fa+Lime% ; (b) Soil+0.8%Fiber+40%fa+Lime%

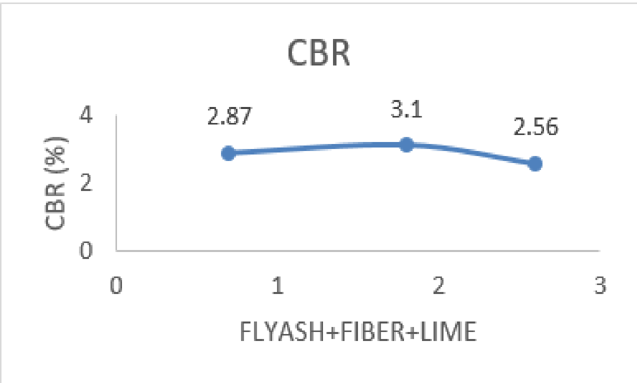

Fig 6 soil+1.2%fiber+40%fa+lime%

As shown in Fig,FigThe California bearing ratio test is conducted to check the capacity of the bearing ratio of the treated or untreated soil sample, where a gradual load is put on the soil sample. In this bearing ratio is going to increase at 40%flyash+0.4%,0.8%,1.2% waste cement bag fiber with 0.9%,1.8%,2.7% of lime. Still, in the case of 0.8% waste cement bag fiber, the bearing ratio is going to increase at 4.61% as compared to the proportion of 0.4% and 1.2% of fiber. On the other hand, when adding 1.8% of lime with 40%flyash and 0.8% of waste cement bag fiber is also showing an increment in the bearing ratio so the optimum proportion of 40% flyash+1.8 % lime+0.8 % waste cement bag fiber helps to increase the bearing capacity of soil and carry more load before failure.

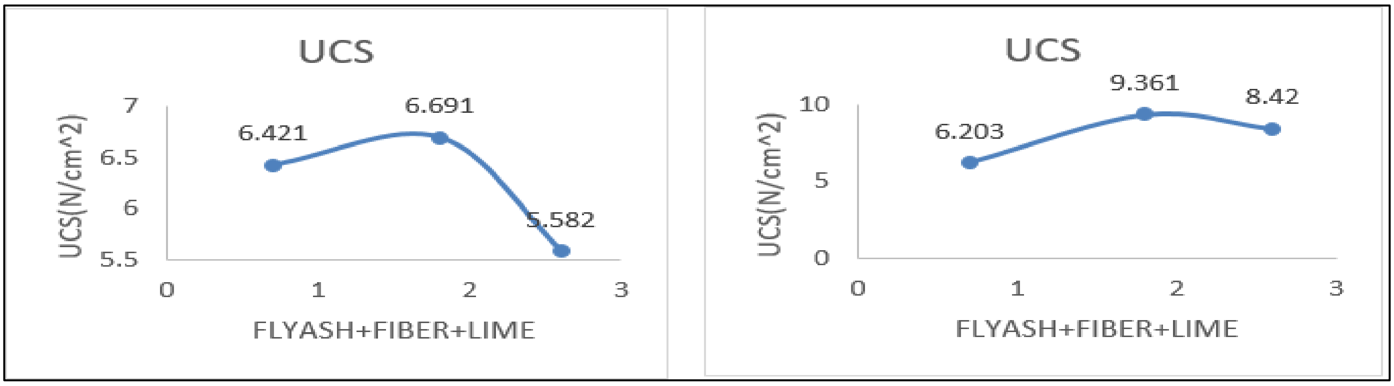

Fig 7 (a) Soil+0.4%Fiber+40%fa+Lime% ; (b) Soil+0.8%Fiber+40%fa+Lime%

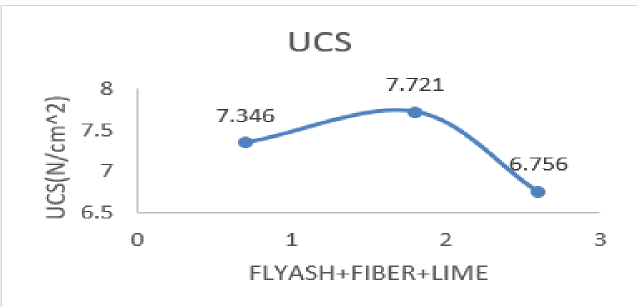

Fig 8 Soil+1.2%Fiber+40%fa+Lime%

As shown in Fig, FigThe unconfined compressive strength is going to increase with increases in the percentage of lime and waste cement bag fiber but at 40%flyash, 1.8%lime and 0.8% waste cement bag fiber reach the higher value of unconfined compressive strength when applying the axial load on the soil sample assorted with the optimum proportion of flyash, lime, and waste cement bag fiber. Similar results can be seen in (13-20)

V. CONCLUSION

➤ *Key Findings based on Experimental Results:*

- Various proportions of waste cement bag fiber (0.4%, 0.8%, 1.2%), fly ash (40%), and lime (0.9%, 1.8%, 2.7%) were used to enhance the engineering properties of soil.
- The plasticity index of soil decreased with the addition of fly ash, lime, and varying percentages of waste cement bag fiber.
- The optimum moisture content (OMC) increased with the addition of 40% fly ash and lime (0.9%, 1.8%, 2.7%).
- The combination of 0.8% waste cement bag fiber + 40% fly ash + 1.8% lime achieved the highest OMC.
- The maximum dry density (MDD) of soil decreased with the addition of the above admixtures.
- The blend of 0.8% fiber + 40% fly ash + 1.8% lime resulted in the highest California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS), outperforming untreated soil.
- The optimum mix for soil stabilization was determined to be 0.8% waste cement bag fiber + 40% fly ash + 1.8% lime.
- The use of waste cement bag fibers helps in reducing synthetic waste, contributing to environmental protection.
- This study promotes the utilization of waste materials in construction, offering sustainable and eco-friendly solutions.
- The fiber threads from waste cement bags form a bonding matrix with soil, making the stabilized soil particularly suitable for sub-base and base course construction.

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