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A LABORATORY STUDY ON EFFECT OF INCLUSION OF SODIUM SILICATE ON STRENGTH BEHAVIOUR OF BLAST FURNACE SLAG TREATED BLACK COTTON SOIL FOR PAVEMENT SUBGRADE

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ABSTRACT:

In order to use the locally available expensive soil as a base course for pavement construction, the engineering properties of the soil need to be enhanced. Hence, the experimental investigation of the expensive soil stabilized with the blast furnace slag and sodium silicate has been conducted.The different level of Blast furnace slag as 3%, 6%, 9% and 12% was utilized to discover the ideal estimation of blast furnace slag. Sodium silicate has been haphazardly included into the blast furnace slag treated soil at four unique rates of fiber content, for example 1%, 2% 3%, and 4% (by weight of soil). The tests, which were done, are Atterberg's Limits, Modified compaction test, California bearing proportion test, unconfined pressure test and tri-hub test. The test outcome shows that quality properties of ideal blend of BC soil-blast furnace slag. Furthermore, the quality of the blended soil increments with increment in days. In addition, Cyclic Plate Load tests were done for the ideal rate got from the above test outcomes and the outcomes were dissected for the appropriateness of sub grade under specific loads in a model test tanks under research facility conditions. It was seen that the by including the various rates of blast furnace slag, the ideal esteem accomplished at the careful level of 6%. Past the variety of any esteem is minimal. In the wake of including, the various rates of Sodium silicate to the blast furnace slag balanced out sweeping soil the ideal estimation of the two blends were 2% Blast furnace slag.

Key words: Cyclic Plate Load Test, Stabilization, Sodium Silicate, Blast Furnace Slag.

1. INTRODUCTION

1.1 Expansive soils:

Expansive soil is one among the problematic soils that has a high potential for shrinking or swelling due to change of moisture content. Expansive soils can be found on almost all the continents on the Earth. Destructive results caused by this type of soils have been reported in many countries. In India, large tracts are covered by expansive soils known as black cotton soils. The major area of their occurrence is the south Vindhyachal range covering almost the entire Deccan Plateau. These soils cover an area of about 200,000 square miles and thus form about 20% of the total

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area of India. The primary problem that arises with regard to expansive soils is that deformations are significantly greater than the elastic deformations and they cannot be predicted by the classical elastic or plastic theory. Movement is usually in an uneven pattern and of such a magnitude to cause extensive damage to the structures resting on them.

In India, the area covered by expansive soil is nearly 20% of the total area. The expansive soils normally spread over a depth of 2 to 20m. In rainy season, they undergo heave and lose weight. In summer, they shrink and gain density and become hard. This alternate swelling and shrinkage damage the structures severely. This is more severe for the light structures.

During summer, polygonal cracks are appear at the surface, which may extend to a depth of about 2m indicating the active zone in which volume change occurs. The depth of active zone defined as the thickness of the soil below the ground surface within which moisture content variations and hence volume changes do take place. Sustained efforts are being made all over the world on highway research field to evolve more promising treatment methods for proper design and construction of pavements running over expansive soil sub grade.

1.2 Characterization of Expansive Soils

Field Identifications:

- Color: May be black, grey, yellow grey.
- During summers, side and deep map type cracking is observed.
- During heavy rains, when such soils get saturated, it would be very difficult to work through these soils because of high stickiness.
- Normally the slope of terrains very flat in the range of 0^0 to 2^0.
- Drainage is very poor.

In India, the vegetation in such area may consist of thorns, bushes, thorny trees (babul) cactus etc. Buildings constructed on such deposits exhibits heaving of floor lifting of columns and walls usually accompanied by cracking. Doors normally jammed during rainy season. In case of canals in embankments, partial cuts or in cutting, bed heaving accompanied by cracking of the bed concrete is observed. Heavy sliding accompanied by progressive failures is observed on the sides. Retaining structure show tilting and distress road get rutted.

2. SOIL STABILISATION

2.1 Definition

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing.

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Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

Soil is one of nature's most abundant construction materials. Almost all constructions is built with or upon soil. When unsuitable construction conditions are encountered, a contractor has 4 options.

(1) Find a new construction site.

(2) Redesign the structure so it can be constructed on the poor soil.

(3) Remove the poor soil and replace it with good soil.

(4) Improve the engineering properties of the site soils.

2.2 Principles of Soil Stabilization:

- Evaluating the soil properties of the area under consideration.
- Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.
- Designing the Stabilized soil mix sample and testing it in the lab for intended Stability and durability values.

2.3 Uses of Soil Stabilization

Traditionally, stable sub-grades, sub-bases andbases have been constructed by using selected, well-graded aggregates, making it fairly easy to predict the load-bearing capacity of the constructed layers. By using select material, the engineer knows that the foundation will be able to support the design loading.

Gradation is an important soil characteristic to understand. A soil is considered either "well-graded" or "uniformly-graded" (also referred to as "poorly-graded"). This is a reference to the sizes of the particles in the materials. Uniformly-graded materials are made up of individual particles of roughly the same size. Well-graded materials are made up of an optimal range of different sized particles. The addition of lime slurry is a form of chemical soil.

2.4 Different Type of Stabilization

i). Mechanical stabilization

ii). Physical stabilization

iii). Chemical stabilization

3. REVIEW LITERATURE

Goodarzi&Salimi, (2015) investigated the use of GGBS and basic oxygen furnace slag (BOFS) on the stabilisation of dispersive soil. The slags were separately incorporated from 2.5% to 30%. The properties of the stabilised soil were indicated by Atterberg limit, UCS, XRD and SEM micrographs. The results indicated that GGBS and BOFS enhanced the performance of the soil and that BOFS has higher activity when compared with GGBS.

Ormila&Preethi, (2014) studied the effect of adding GGBS to expensive soil collected from Palur, Tamil Nadu at various percentages (15%, 20%, and 25%). They indicated that addition of GGBS can improve the unconfined compressive strength of the soil given that 20% GGBS is the optimum content with an increase in strength of 73.79% after curing of 21 days.

ArunPatidar (2014) this paper introduces an experimental study of impact of high thickness polyethylene strands, stone residue and Blast furnace slag on record and building properties of Black Cotton Soils. properties of balanced out soil, for example, compaction qualities, unconfined compressive quality and California bearing proportion were assessed and their varieties with substance of filaments, stone residue and Blast furnace slag are assessed. Different rates of High thickness polyethylene strands (0.5, 1.0, 1.5), stone residue (5,10,15) and Blast furnace slag (3,6,9) have been utilized to improve designing conduct of far reaching dark cotton soil. At last, it is reasoned that relief of dark cotton soils using various added substances may be a powerful strategy in upgrading designing properties of subsoil on which streets and light structures are developed**.**

4. MATERIALS& METHODOLOGY

4.1 Materials

Soil:

The black cotton soil collected from '**Thummalapalli**' village near Amalapuram, East Godavari District in India. The properties of the soil are given in Table

Blast furnace slag:

BFS is by-product materials produced from manufacture of iron. It mainly consists of lime, alumina, and silicate. There are similarity between BFS and ordinary Portland cement in oxides types but not the percentage (Sha and Pereira, 2001; Oner and Akyuz, 2007). During the production of GGBS, its cementitious characteristics increases because molten slag chills rapidly after leaving the furnace.

Figure 1: Blast Furnace Slag

Properties of Blast Furnace Slag

Colour:	**off-white**
Specific gravity:	2.9
Bulk density:	1000 - 1100 kg/m^3 (loose) 1200 - 1300kg/m^3 (vibrated)
Fineness:	>350m^2/kg

Sodium silicate:

Sodium silicates constitute a group of chemicals that possess a wide range of physical and chemical properties. They are used in industry as adhesives, cements, detergents, deflocculants, protective coatings, rust inhibitors, catalyst bases, cleaning compounds, and bleaching agents. Silicates are produced at various alkali, Na20, to silica, Si02, ratios, water contents, and particle sizes depending on their proposed use. They are usually derived from the relatively abundant raw materials of silica, sodium salts, and water. Manufacturers have widely distributed outlets for the products; therefore, sodium silicates are readily available

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and are easily obtained in various packages for commercial use.

Figure 2: Sodium silicate.

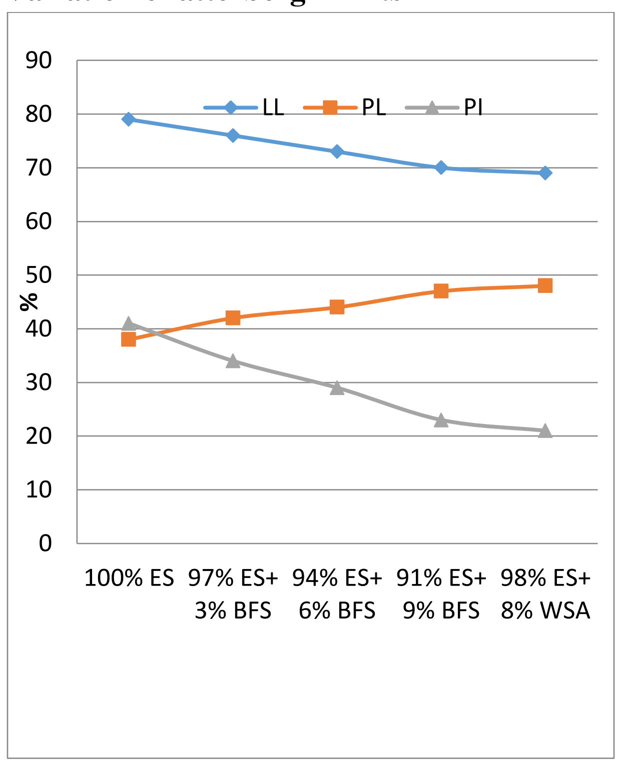
5. DISCUSSION ON TEST RESULTS

5.1 General

In this part, a nitty gritty exchange on the outcomes acquired from different lab tests is displayed.

- Proctor compaction (MDD&OMC) attributes of the dirt.
- California Bearing Ratio (CBR) attributes of the dirt.
- Variation of compaction esteems (MDD&OMC) with differing in level of Blast Furnace slagContent.
- Variation of California Bearing Ratio (CBR) with differing in level of Blast Furnace slag content.
- Variation of UCS with shifting in level of Blast Furnace slagcontent.
- Variation of compaction esteems (MDD&OMC) with Optimum level of Blast Furnace slagcontent alongside differing in level of Sodium silicate content.
- Variation of California Bearing Ratio (CBR) with Optimum level of Blast Furnace slagcontent alongside differing in level of Sodium silicate content.
- Variation of UCS with Optimum level of Blast Furnace slagcontent alongside changing in level of Sodium silicate content
- Variation of Ultimate Cyclic Pressure and Settlement for Untreated Expansive soil subgrade with Model Flexible asphalt.
- Variation of Ultimate Cyclic Pressure and Settlement for Expansive soil subgrade treated with ideal rates of Blast Furnace slagand Sodium silicate for Model Flexible asphalt.

Variation of atterberg Limits



Graph 1: Variation of atterberg Limits of ES with different % of Blast Furnace slag

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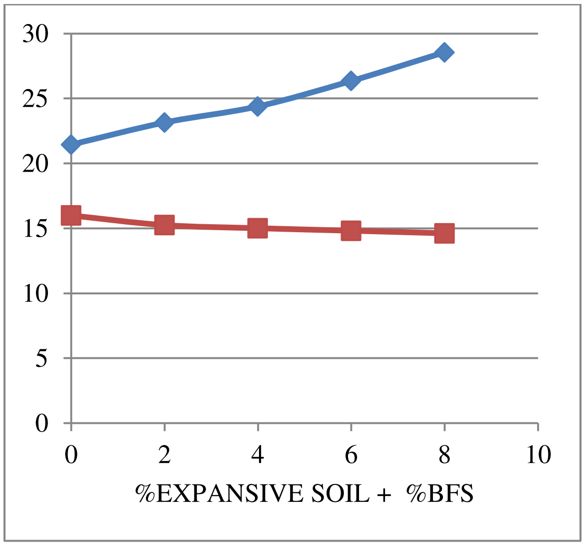
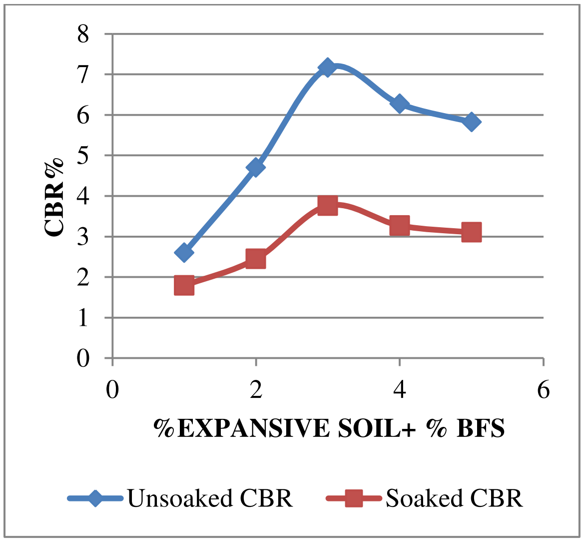
Variations of OMC and MDD for ES with different % of Blast Furnace slag



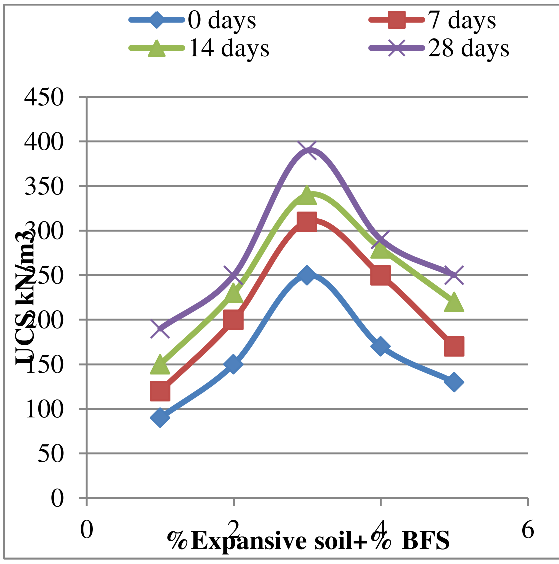
Graph 2: Variations of OMC and MDD for ES with different % of Blast Furnace slag

Variation of Un-Soaked and Soaked CBR for % ES with different % ofBlast Furnace slag



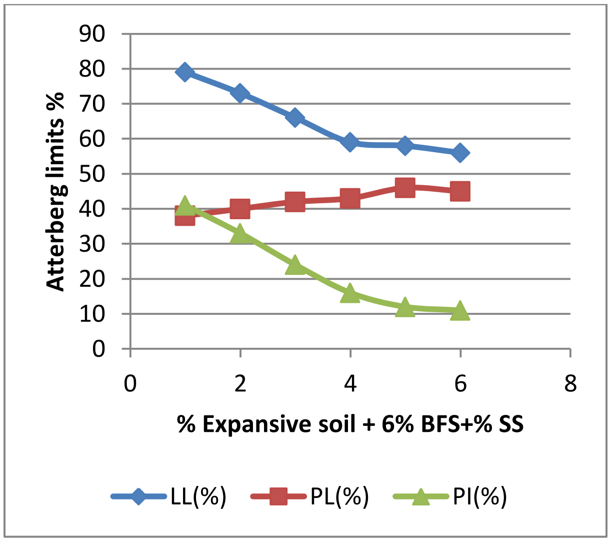
Graph 3: Variation of Un-Soaked and Soaked CBR for % ES with different % ofBlast Furnace slag

Variation of UCS for ES with different % of Blast Furnace slag



Graph 4: Variation of UCS for ES with different % of Blast Furnace slag

Variation of Atterberg Limits of 6% Blast Furnace slagtreated Expansive soil treated and inclusion with Different percentages of Sodium silicate



Graph 5: Variation of Atterberg Limits of 6% Blast Furnace slagtreated Expansive soil treated and inclusion with Different percentages of Sodium silicate

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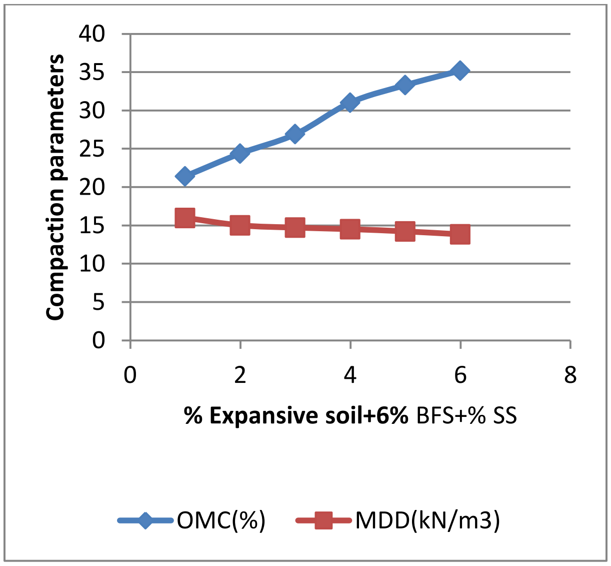
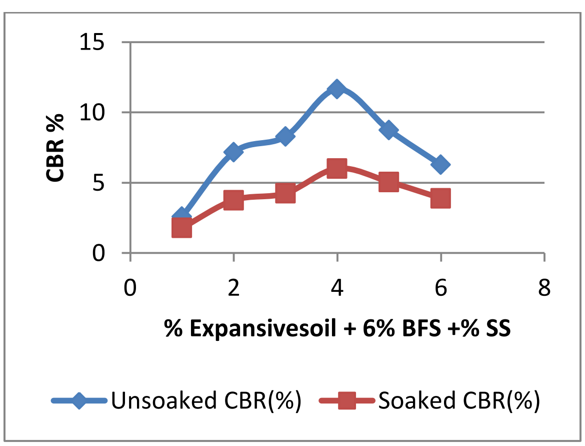
Expansive soil treated and inclusion with Different percentages of Sodium silicate



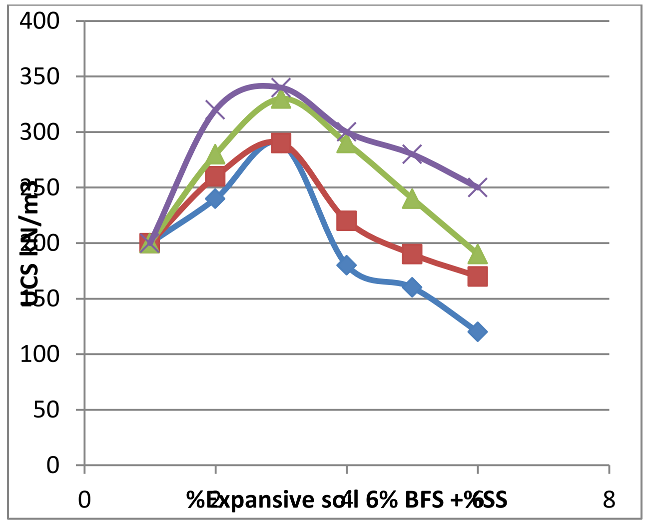
Graph 6: Expansive soil treated and inclusion with Different percentages of Sodium silicate

Variation of CBR (Un-Soaked&Soaked) of 6% Blast Furnace slag treated Expansive soil treated and inclusion with Different percentages of Sodium silicate

Graph 7: Variation of CBR (Un-Soaked&Soaked) of 6% Blast Furnace slag treated Expansive soil treated and inclusion with Different percentages of Sodium silicate

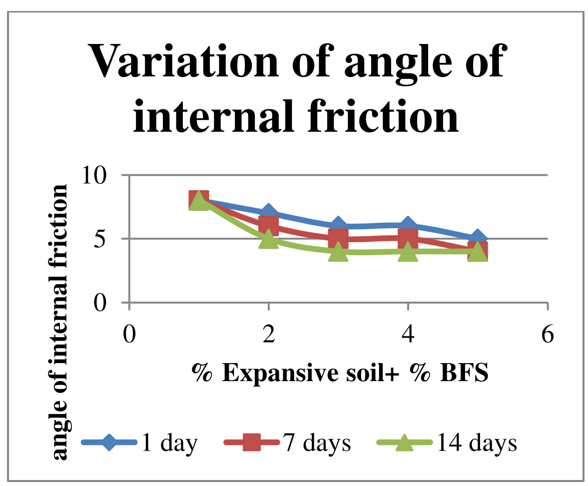


Variation of UCS of 6% blast furnace slag treated Expansive soil treated and inclusion with Different percentages of Sodium silicate



Graph 8: Variation of UCS of 6% blast furnace slag treated Expansive soil treated and inclusion with Different percentages of Calcium chloride

The variation of cohesion of expansive soil stabilized with different percentages of sodium silicate



Graph 10: The variation of angle of internal friction expansive soil stabilized with different percentages of Blast furnace slag

6. CONCLUSIONS

Based on *results* presented in this paper, *following* conclusions are drawn.

- Blast furnace slag treated BC soil strengthened with 1% Sodium silicateexpands quality and lessens weak conduct of soil example, where as different rates of strands utilized demonstrates a minimal increment.
- This paper assessed impact of Sodium silicate on quality and compaction attributes of Blast furnace slag treated dark cotton soil. A progression of tests were performed to think about impacts of Blast furnace slag on quality attributes of dark cotton soil.
- For a given Sodium silicate rate substance in compaction tests, greatest dry thickness of balanced out soil diminished and ideal dampness substance expanded. most extreme dry thickness of Sodium silicate fortified with 4%Blast furnace slag treated soil diminished thickness esteem and OMC esteem.
- Expansion of different rates of Blast furnace slag to dark cotton soil gives expanded an incentive in unconfined compressive quality upto4% and expansion of Blast furnace slag with Sodium silicate likewise gave increment in compressive quality upto1.0% Sodium silicate.
- relieving time frame with expansion of Blast furnace slag and Sodium silicate gave higher quality qualities. Consequently, 4% of Blast furnace slag substance and 1.0% of Sodium silicate is considered as ideal rates for dark cotton soil.
- Expansion of different rates of Blast furnace slag to dark cotton soil gave expanded an incentive in CBR upto4% as we can see in chart. At that point expansion of Sodium silicate gave expanded estimation of CBR for 1.0Sodium silicate.
- Mix of 4% Blast furnace slag and 1.0% Sodium silicate gives more expanded an incentive than expansion of Blast furnace slag and Sodium silicate. Subsequently, 4 of Blast furnace slag substance and 1.0% of Sodium silicate can be considered as ideal rates for dark cotton soil to build CBR esteem.
- Expansion of Blast furnace slag has appeared in fluid point of confinement from 79% to 73% and improvement in plastic farthest point from 38% to 44% and versatility record decline from 41% to 29% when Blast furnace slag substance fluctuates from 0% to 8% with an addition of 2% blended in far reaching soil because of cation particles from Blast furnace slag which decreases volumetric changes.
- With expansion of differing level of Sodium silicatewith ideal estimation of Blast furnace slag, as far as possible esteem diminishes to 79% to 59%, plastic limit increments to 38% to 48

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- Expansion of Blast furnace slagto dark cotton soil results declines MDD valuefrom 15.99 KN/m3 to 15.11 KN/m3 while OMC increments from 21.42% to 24.30% at 4% of Blast furnace slag.
- Compaction qualities of treated far reaching soil-Blast furnace slag blend at ideal 4% of Blast furnace slag, OMC expanding from 24.39% to 31.40% and MDD diminishing from15.01 KN/m3 to 14.51KN/m3 with expansion of various rates of filaments ranges from 0.5 to 2 with an augmentation of 0.5% of Sodium silicate.
- On looking at CBR esteems it is discovered that we showed signs of improvement CBR esteem when dirt is treated with both Blast furnace slag and Sodium silicate than untreated soil.
- Expansion of Blast furnace slag to far reaching soil, Unsoaked CBR esteems increments from 2.6% to 7.16% up to 4% of Blast furnace slag and past esteem diminishes. Subsequently, ideal level of Blast furnace slag is 4%.
- Expansion of Blast furnace slag to far reaching soil, Soaked CBR esteems increments from 1.79% to 3.76% up to 4% of Blast furnace slag and past esteem diminishes. Henceforth, ideal level of Blast furnace slag is 4%.
- Unsoaked CBR esteem goes expanding from 7.16% to 11.65% up to addition of 1% fiber to Blast furnace slag treated soil, past it is diminished with further expansion fibber. Henceforth, ideal level of fiber is 1%.
- Doused CBR esteem goes expanding from 3.76% to 11.65% up to addition of 1% fiber to Blast furnace slag treated soil, past it is diminished with further expansion fibber. Henceforth, ideal level of fiber is 1%.
- From UCS test, it is acquired that unconfined compressive quality of far reaching soil is expanding with ideal of Blast furnace slag i.e.4% and expansion of Sodium silicate up to 1% and past it is diminished.
- At 0 Days, Unconfined compressive quality esteem increments from 350KN/m2 of dark cotton soil to 780 KN/m2 at 4% of Blast furnace slag and came to 1110 KN/m2 at 1% Sodium silicate with Blast furnace slag mixed soil. From it is reasoned that 1% Sodium silicate is ideal.
- At 7 Days, Unconfined compressive quality esteem increments from 420KN/m2 of dark cotton soil to 910 KN/m2 at 4% of Blast furnace slag and came to 1370 KN/m2 at 1% Sodium silicate with Blast furnace slag mixed soil. From it is presumed that 1% Sodium silicate is ideal.
- At 14 Days, Unconfined compressive quality esteem increments from 480KN/m2 of dark cotton soil to 1020 KN/m2 at 4% of

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Blast furnace slag and came to 1560 KN/m2 at 1% Sodium silicate with Blast furnace slag mixed soil. From it is reasoned that 1% Sodium silicate is ideal.

- At 28 Days, Unconfined compressive quality esteem increments from 500KN/m2 of dark cotton soil to 1180 KN/m2 at 4% of Blast furnace slag and came to 1690 KN/m2 at 1% Sodium silicate with Blast furnace slag mixed soil. From it is presumed that 1% Sodium silicate is ideal.
- It is seen from research facility test after effects of cyclic plate burden test that a definitive weight of treated Expansive soil sub level adaptable asphalt has been expanded by 225% regarding untreated Expansive soil sub level adaptable asphalts.
- It is seen from research center test consequences of cyclic plate burden test that Ultimate weight of treated Expansive soil sub level adaptable Pavement with separately fortified among subgrade and base coarse has been improved by 266.66% regarding untreated Expansive soil sub level adaptable asphalts.
- above perceptions give a lucidity that utilization of Blast furnace slag and strands in soil adjustment can improve quality attributes impressively.
- At 1, 7, 14 Days, Shear quality qualities increments from 0.56Kg/cm2 to 0.89Kg/cm2, 0.56Kg/cm2 to 1.28Kg/cm2, 0.56Kg/cm2 to 1.39Kg/cm2 of dark cotton soil at 4% of Blast furnace slag and at 1% Sodium silicate with Blast furnace slag mixed soil. From it is reasoned that 1% Sodium silicate is ideal.
- Generally speaking it very well may be reasoned that Blast furnace slag and fiber settled soil can be viewed as great ground improvement strategy particularly in building ventures on frail soils from monetary thought.

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