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Stabilization of Expansion Soil Using Brick Dust

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Abstract: The black cotton soil is known as expansive type of soil which expands suddenly and starts swelling when it comes in contact with moisture. Due to this property of soil the strength and other properties of soil are very poor. To improve its properties, it is necessary to stabilize he soil by different stabilizers. Expansive type of soil shows unpredictable behavior with different kind of stabilizers. Soil stabilization is a process to treat a soil to maintain, alter or improve the performance of soil. In this study, the potential of burnt brick dust as stabilizing additive to expansive soil is evaluated for the improving engineering properties of expansive soil. The evaluation involves the determination of the swelling potential, linear shrinkage, atterberg's limits, & compaction test of expansive soil in its natural state as well as when mixed with varying proportion of burnt brick dust (from 30 to 50%). The practices have been performed on three proportions 30%, 40%, and 50% with expansive soil. The research result shows considerable reduction in swelling of expansive soil. With increasing amount of stabilizer swelling decreases. Maximum decrement in swelling has been noted in 50% of replacement of soil by brick dust. Also, by increasing stabilizing content linear shrinkage reduces. Maximum decrement in shrinkage has been noted in 50% replacement of soil by stabilizer. Maximum dry density of soil is improving and optimum moisture content is decreasing with increasing stabilizing content. For increasing content of stabilizing agent brick dust atterberg's limit values are also decreasing.

Key Words: Soil stabilization, Brick dust, CBR, Atterberg's limits, Sieve analysis, Specific gravity.

INTRODUCTION

For any land-based structure, the foundation is very important and has to be strong enough to support the structure. Structures or roadways needs a stable foundation to ensure the best construction and durability. The foundation itself must rest on a strong soil that is able to transfer the entire load of the building adequately. If the soil is weak, over time it will compact and begin to swell. The soil around the foundation will plays a very crucial role. The strength of the soil will depend on the composition of the soil particles and the amount of water in the soil. If the stability of the soil is not adequate then failure of structure occurs in form of settlements, cracks etc.

Expansive soils are the types of soils that shows a significant change in volume when they come in contact with moisture. They expand when exposed to excess moisture content and shrinks in hot weather conditions. These soils can be easily identified in the field during dry seasons as they show deep cracks of polygonal pattern. This behaviour of swelling and shrinking of expansive soil in turn effects the stability of structure that is built over these soils causing a serious hazard.

Civil engineers face difficult problems while base soil is found to be clay soil. Soil that has more clay content generally have tendency to swell more when their moisture content is allowed to increase. There is much research has been done to improve soil properties by soil stabilization methods using various additives. In most cases, clay soil in pavement work is cement and lime stabilization.

Black cotton soil is a major soil group in India. The black cotton soil looks dark in colour. The Black cotton soil has a high percentage of clay. Chemically black cotton soils consist of lime, iron, magnesium, alumina and potash but they lack in nitrogen, phosphorus and organic matter. Because of their capacity to hold water, they are suitable for the cultivation of cotton. Hence the name black cotton soil.

Here, in this present study Brick dust have been used for stabilization of Black cotto n soil. Detailed laboratory tests were carried out to ascertain the benefits in terms of engineering properties..

HISTORY AND BACKGROUND

Black cotton soil, is a cohesive soil, formed by the weathering or breaking of igneous rocks and also by the cooling and solidification of lava from the volcano eruption. It is considered a problematic soil for civil engineers. It has characteristics of swelling during rainy season and shrinking during summer season. In both the conditions, it poses problems. This is due to presence of

montmorillonite mineral in it, which has ability to undergo large swelling & shrinkage.

Fig : Black cotton soil

We can see the cracks in many lands having black soil, this is because during the dry season they form the crack for the circulation of the air. When the upper soil water loss for evaporating the water content at below soil has no marked change, as a result, the upper and below soil shrinkage is inhomogeneous and the soil crack appears. The inhomogeneous shrinkage many times lead to the crack of expansive soil produced.

Fig : Cracks in expansive soil

Availability of Expansive soil or Black Cotton soil:

Expansive soils also called as Black soils or Black cotton soils and Regular soils are mainly found over the Deccan lava tract (Deccan Trap) including Maharashtra, Madhya Pradesh, Gujarat, and Andhra Pradesh and in some parts of Odisha, in the Indian sub-continent. Black cotton soils are also found in river valley of Tape, Krishna, Godavari and Narmada. In the north western part of Deccan Plateau and in the upper parts of Krishna and Godavari, the depth of black soil is very large. Basically, these soils are residual soils left at the place of their formation after chemical decomposition of the rocks such as basalt and trap. Also, these types of soils are formed due to the weathering of igneous rocks and the cooling of lava after a volcanic eruption. These soils are rich in lime, iron, magnesia and alumina but lack in the phosphorus, nitrogen and organic matter.

Nature of black cotton soil:

Those soils which tend to swell and shrink with the variation in moisture content. As a result of which significant distress in the soil occurs, causing severe damage to the overlying structure. During monsoon's, these soils imbibe water, swell, Expansive soils also known as swelling soils or shrink-swell soils are the terms applied to become soft and their capacity to bear water is reduced, while in drier seasons, these soils shrink and become harder due to evaporation of water. These types of soils are generally found in arid and semi- arid regions of the world and are considered as a potential natural hazard, which if not treated well can cause extensive damages to not only to the structures built upon them but also can cause loss of human life. Soils containing the clay minerals montmorillonite generally exhibit these properties.

Problems Associated with black cotton soil:

Expansive soil has low shrinkage limit and high optimum moisture content. It is highly sensitive to moisture changes & highly compressible sub grade material. It is having low shear strength, further upon wetting or other physical disturbances it reduces further. The wetting and drying process of a sub grade layer of black cotton soil results into failure of pavements in the form of settlement and cracking. Black cotton soil is one of the most prevalent causes of damage to buildings and roads. The following damages occur to change in volume of black cotton soil

SOIL STABILIZATION

Soil Stabilization is the alteration of soils to enhance their engineering properties. Shear strength, permeability, compressibility, durability, and plasticity are the examples these properties. Stabilization can increase the shear strength of a soil and control the shrinkage and swelling properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil serves as the basis for any

construction project, whether it be a structure, a road, or an air field. Furthermore, soil is a construction material. Soil stabilization including the mixing of special soil, cementing material, or other chemical materials that are added to natural soil to improve one or more of its properties. It can also be done by mechanically mixing stabilizing agents and natural soil together so as to achieve a homogeneous mixture or by adding stabilizing material to the soil deposit. Soil stabilizing methods is used to improve the properties of road base soil. These soil stabilizing agents can improve and maintain soil moisture content, increase soil particle cohesion, and acts as cementing and waterproofing agents.

Objectives of soil stabilization:

To improve the undesirable properties of soil such as excessive swelling or shrinkage.

- To reduce compressibility and there by settlements.
- It is also used to provide more stability to the soil in slopes or other such places.
- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- To create a strong working platform for the foundation of structures.
- To reduce the plasticity of the soil.

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

Specific Objectives:

- Optimization of Fly Ash Content:To determine the ideal percentage of fly ash replacement (e.g., 10%, 20%, 30%, etc.) that provides the best balance between strength, durability, and workability.
- Mechanical Properties Analysis:To evaluate the compressive, tensile, and flexural strength of fly ash-based concrete at different curing ages (7, 14, 28 days).
- Durability Assessment:To study the resistance of fly ash concrete to sulfate attack, chloride penetration, water absorption, and acid exposure.
- Workability and Setting Time Evaluation:To analyze the slump value, flowability, and initial and final setting time of fly ash concrete compared to conventional concrete.
- Environmental Impact Analysis:To quantify the reduction in CO_2 emissions and natural resource consumption by replacing cement with fly ash.
- Economic Feasibility Study:To compare the cost-effectiveness of fly ash concrete with traditional concrete by assessing material costs, availability, and potential savings.
- Long-Term Performance Study:To investigate the structural integrity and durability of fly ash concrete under real-life exposure conditions.
- Standardization and Practical Implementation:To develop guidelines and recommendations for the safe and effective use of fly ash as a cement substitute, ensuring compliance with industry standards such as IS codes, ASTM, and ACI guidelines.

SCOPE OF THE STUDY

The study on the partial replacement of cement with fly ash in concrete focuses on evaluating its effects on the material's properties and sustainability. The scope of this experiment includes:

1.Material Selection:

- Use of Ordinary Portland Cement (OPC) as the primary binder.
- Utilization of Class F or Class C fly ash as a partial replacement for cement.
- Inclusion of aggregates, water, and admixtures (if necessary) for concrete mix preparation.

2.Replacement Levels:

Experimenting with different replacement percentages (e.g., 10%, 20%, 30%, and higher if applicable) to analyze the impact on concrete performance.

3.Concrete Properties Analyzed:

- Fresh Properties: Workability, setting time, and slump test.
- Mechanical Properties: Compressive strength, tensile strength, and flexural strength at different curing periods (7,14 and 28 days).
- Durability Properties: Water absorption, sulfate resistance, alkali-silica reaction, and permeability tests.

4.Testing Methods:

- Standardized tests as per ASTM, IS, or other relevant codes.
- Comparison of fly ash-based concrete with conventional concrete.

5.Environmental and Economic Assessment:

- Evaluation of CO_2 reduction and sustainability benefits.
- Cost comparison between conventional concrete and fly ash-modified concrete.

6.Applications:

- Suitability for different construction projects such as pavements, buildings, bridges, and precast concrete elements

1. Soil Stabilization Methods:

Mechanical Stabilization:

Improves soil properties by changing its particle size distribution (gradation).

Involves mixing different soils, adding coarse particles, or removing fine particles.

Also includes compaction and densification using rollers, rammers, and vibration.

Cement Stabilization:

Mixes pulverized soil with Portland cement and water.

Creates "soil cement," a hard and durable material as cement hydrates.

Requires cement to coat soil particles for effective bonding.

Lime Stabilization:

Adds lime (various types) to soil to improve density and bearing capacity.

Typical lime addition is 5% to 10% of the soil's weight.

Fly Ash Stabilization:

Uses fly ash, a byproduct of coal-fired power plants.

Cost-effective and relatively fast.

Fly ash has some cementitious properties, but less than cement or lime.

Chemical Stabilization:

Adds chemicals (e.g., sodium chloride, calcium chloride) to alter soil properties.

Relies on chemical reactions between the stabilizer and soil minerals.

Geotextile and Fabric Stabilization:

Uses porous synthetic materials (geotextiles) like polyethylene and polyester.

Improves soil stability, controls erosion, and aids drainage.

Reinforces soil.

MATERIALS

General:

The main objective of this study is to investigate the change in the behaviour of soil when black cotton soil

and Hypo sludge and glass fibres at varying percentages was mixed in clayey soil through the various geotechnical tests conducted in the laboratory.

Black cotton soil:

Black Cotton Soil procured from "Pasarlapudi" village near Amalapuram, Kona Seema district in Andhra Pradesh. It is used as a representative soil sample in the present study. This soil is collected from an open excavation, at a depth of 1 to 1.5m below the natural ground surface.

Fig: Black cotton soil

Properties of Soil Sample:

This soil is classified according to I.S classification as well graded gravel (GW)

S.NO.	Laboratory Test	Symbol	Results	Relevant IS Codes
1	Different Free Swell	DFS	79%	IS 2720 PART XI
2	Atterberg's limits			
	Liquid Limit	WL	68%	IS 2720 PART V
	Plastic Limit	WP	27%	IS 2720 PART V
	Plasticity Index	PI	40%	IS 2720 PART V
3	Specific Gravity	G	3%	IS 270 PART III
4	Compaction parameters (Modified Proctor test)			
	Optimum Moisture content	OMC	17.54%	IS 2720 PART VIII
	Maximum Dry density	MDD	1.55 %	IS 2720 PART VIII
5	California Bearing ratio (Un soaked)	CBR	2.74	% IS 2720 PART XVI

BRICK DUST:

Brick dust occurs from loading or unloading, construction sites and brick kilns. This dust is used in dumping and filling. There are thousands Ton of brick waste generated each year around the world which goes in unplanned way. Pozzolanic materials such as brick dust and other ceramics powder has been used in concrete since ancient times. In ancient times the brick dust was used according to experiences and experiments as they were unaware of the properties of brick dust.

Bricks are made up of different types of clays and other materials like sand. Clay composed up of 20-30% Alumina, 50-60% Silica and other carbonates and oxides. Clay is responsible for the pozzolanic behavior of brick. Clay itself has no pozzolanic properties but when fired together with lime during brick making process it gains pozzolanic nature.

Fig Brick dust

Brick dust is lavish material which on dumping not only occupy land but also it has environmental problems which is hazardous to livings. This waste is generated in brick kilns, brick masonry construction sites and during transportation. By recycling brick dust the problem could be solved up to some extent.

Preparation process of waste burnt brick powder (WBBP):

(a) collection site of waste bricks

(b) collected bricks are crushed into smaller size and washed to remove dirt

(c) the wet pieces of waste bricks are dried under sunlight for 1 day

(d) The sun-dried sample is converted into powder using the ball milling.

CHEMICAL PROPERTIES OF BRICK DUST:

Table: Chemical properties of Brick dust:

Chemical Properties	Brick dust
Silicon Dioxide(SiO2)	62.21%
Calcium Oxide (Cao)	0.42%
Magnesium Oxide (MgO)	1.00%
Sodium Oxide (Na2 O)	1.09%
Aluminium Oxide (Al2O3)	16.31%
Ferric Oxide (Fe2O3)	6.00%
Potassium oxide (K2O)	2.73%

Loss of Ignition	8.13%

PHYSICAL PROPERTIES OF BRICK DUST:

Table: Physical properties of Brick dust

Physical properties	Brick-dust
Specific gravity	2.54
Fineness module	2.07
Moisture content	4.60%
Color	dark, subdued, Merlot red with an oaky undertone.

Particle size distribution:

The particle size distribution of the brick powder with grains of less than 1 mm in diameter d10 = 2.094 µm, d50 = 18.750 µm, and d90 = 302.256 µm. The brick powder was sorted into 5 fractions: 0–90 µm, 0–125 µm, 0–250 µm, 0–500 µm and 0–1000 µm.

RESULTSAND DISCUSSION

Introduction:

Details of the laboratory experimentation carried-out with Brick dust have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory were presented.

Laboratory Test Results on Black Cotton Soil:

The soil sample used in investigation is a local clayey soil. The soil sample was collected by excavating the ground surface and from physical observation, it was found that, this soil is classified according to I.S classification as well graded gravel (GW).

Table: Physical properties of black cotton soil

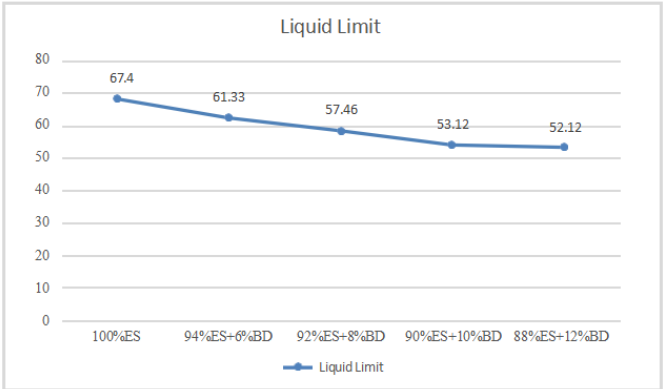
S.NO	Laboratory Test	Symbol	Result
1	Differential Free Swell	DFS	79%
Atterberg's Limits			
2	**Liquid Limit**	**WL**	**68%**
	Plastic Limit	**WP**	**27%**
	Plasticity index	**PI**	**40%**
3	**Specific Gravity**	**G**	**2.55**
Compaction Parameter (Modified Procter Test)			
4	**Optimum Moisture Content**	**OMC**	**17.54%**
	Maximum Dry Density	**MDD**	**1.55%**
5	**California Bearing Ratio (Un-soaked)**	**CBR**	**2.74%**

Index properties:

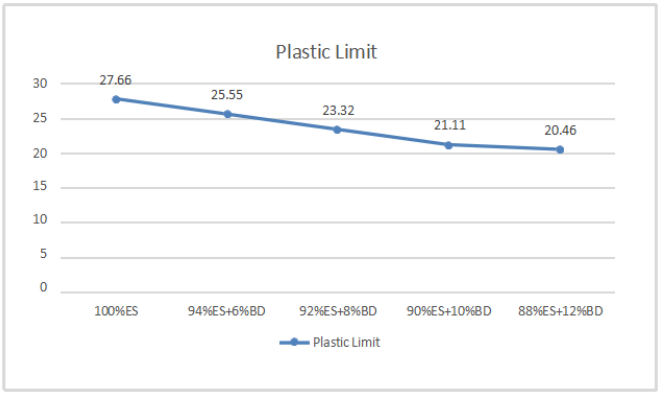
Finding the Index properties of black cotton soil Liquid Limit and Plastic Limit of the samples tried in this investigation. The results of Liquid Limit tests on expansive soil treated with different percentages of Brick dust can be seen that with increase in percentage of Br ick dust the liquid limit of soil goes on decreasing from 67. 4 % to 52.12% when Brick dust is increased from 0 to 12%. The results of plastic Limit tests on expansive soil treated with different percentages Brick dust can be seen that with increase in percentage of Brick dust the plastic limit of soil goes on decreasing from 27.66% to 20.46% when Brick dust is increased from 0 to 12%.

Table: Variation of index properties in expansive soil with different percentages of Brick dust:

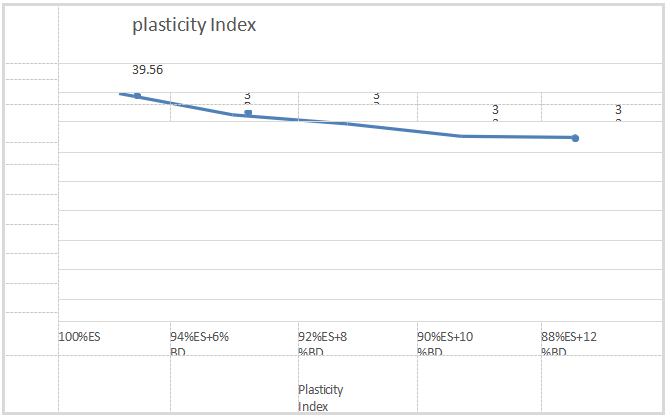
S.NO	Sample	Liquid Limit (%)	Plastic Limit (%)	Plasticity index (%)
1	100%ES	67.4	27.66	39.56
2	94%ES+6%BD	61.33	25.55	36.57
3	92%ES+8%BD	57.46	23.32	35.03
4	90%ES+10%BD	53.12	21.11	32.89
5	88%ES+12%BD	52.12	20.46	32.46



Graph: % of Expansive soil + % of Brick dust



Graph Brick dust of Expansive soil + % of Brick dust



Graph: Variation of Plasticity index in ES with different % of Brick dust

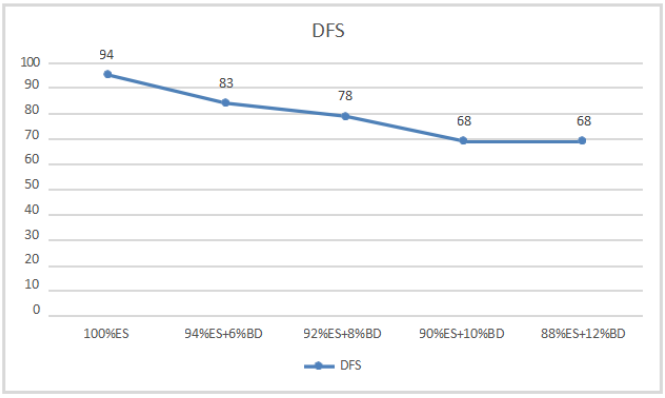
Differential free swell Index test results:

Various percentages of Brick dust are added in soil to know the effect on differential free swell index properties. Results are shown in the below table.

Free Swell Index	Degree of Expansiveness	LL	PL	SL
<20	Low	0.5	0-35%	>17%
20-35	Moderate	40-60%	25-50%	8-18%
35-50	High	50-75%	35-65%	6-12%
>50	Very high	>60%	>45%	<10%

Table: Variation of DFS in expansive soil with different percentages of Brick dust

S.NO	Samples	DFS (%)
1	100%ES	94%
2	94%ES+6%BD	83%
3	92%ES+8%BD	78%
4	90%ES+10%BD	68%
5	88%ES+12%BD	68%

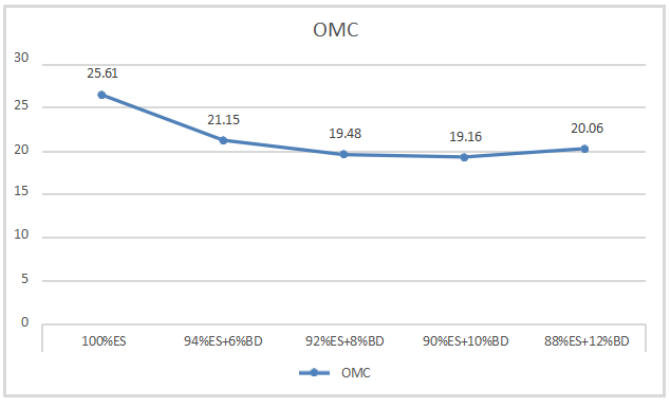


Graph: Variation of DFS in ES with different %Brick dust

COMPACTION TEST RESULTS:

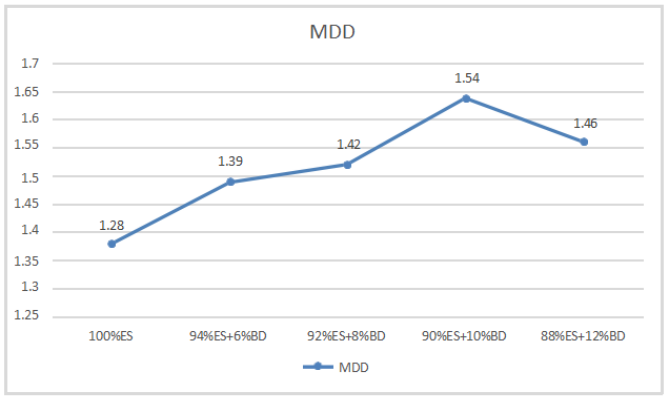
Modified proctor compaction tests are conducted on expansive soil. First compaction tests are carried for expansive soil with different percentages of Brick dust and later with optimum value of brick dust mixed with soil. Graph are drawn between water content and dry density for each percentage increment of brick dust to the expansive soil, from these results Optimum Moisture Content and Maximum Dry Density values are derived. The results and graph from these tests are presented below table.

S.NO	Sample	OMC (%)	MDD(g/cc)
1	100%ES	25.61	1.28
2	94%ES+6%BD	21.15	1.39
3	92%ES+8%BD	19.48	1.42
4	90%ES+10%BD	19.16	1.54
5	88%ES+12%BD	20.06	1.46



% of Expansive soil + % of Brick dust

Graph: Variation of OMC in ES with different % of Brick dust



% of Expansive soil + % of Brick dust

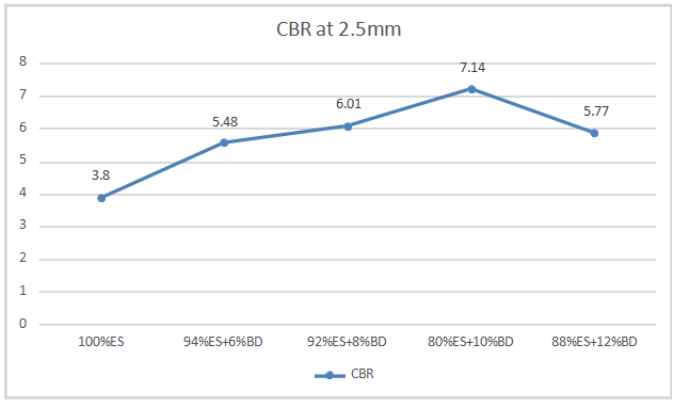
Graph: Variations of MDD in ES with different % of Brick dust

CALIFORNIA BEARING RATIO (CBR) TEST

Compares the CBR value of black cotton soil. 6%,8%,10% and 12% brick powder mixed with black cotton soil at 2.5mm and 5mm penetration. The CBR values at 2.5mm and 5mm penetration showed the increasing trend up to 10% brick content. It was found that the highest CBR values at 2.5 mm and 5mm penetrations were obtained for 10% brick powder content mixed with BCS (7.14% and 6.44%). Then CBR values at both penetrations decreased again significantly when 12% brick powder was blended in BCS.

California bearing ratio (CBR) test results at 2.5mm penetration:

Compares the CBR value of black cotton soil. 6%,8%,10% and 12% brick powder mixed with black cotton soil at 2.5mm penetration. The CBR values at 2.5mm and penetration showed the increasing trend up to 10% brick content. It was found that the highest CBR values at 2.5 mm penetration were obtained for 10% brick powder content mixed with BCS (7.14% and 6.44%). Then CBR values at both penetrations decreased again significantly when 12% brick powder was blended in BCS..



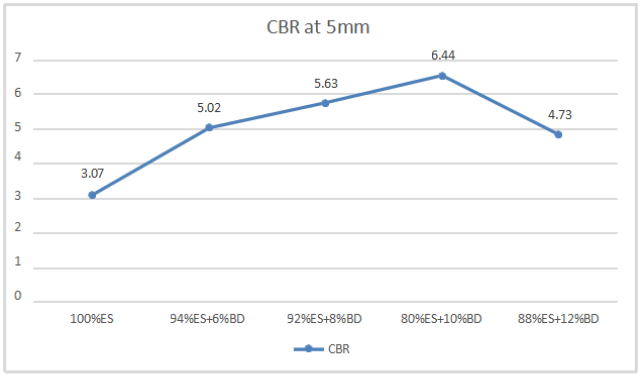
% of Expansive soil + % of Brick dust

Figure Variation of dust CBR in % ES with different % of Brick at 2.5mm penetration

California bearing ratio (CBR) test results at 5mm penetration:

Compares the CBR value of black cotton soil. 6%,8%,10% and 12% brick powder mixed with black cotton soil at 5mm penetration. The CBR values at 5mm and penetration showed the increasing trend up to 10% brick content. It was found that the highest CBR values at 5 mm penetration were obtained for 10% brick powder content mixed with BCS (7.14% and 6.44%). Then CBR values at both penetrations decreased again significantly when 12% brick powder was blended in BCS

S.NO	Samples	CBR (%) at 5mm
1	100%ES	3.07
2	94%ES+6%BD	5.02
3	92%ES+8%BD	5.63
4	80%ES+10%BD	6.44
5	88%ES+12%BD	4.73



% of Expansive soil + % of Brick dust

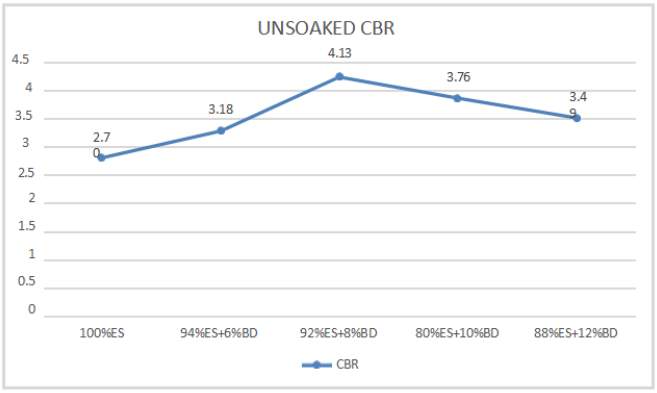
Graph : Variation of dust CBR in % ES with different % of Brick at 5mm penetration

Variation of Unsoaked CBR values in Black cotton soil with different percentage of Brick dust:

The stabilized soil with optimum percentage of brick dust is mixed with black cotton soil in the presence of causing a cylindrical plunger of 50mm diameter to penetrate a pavement component material at 1.25mm/minute.

Table: Variation of Unsoaked CBR values in black cotton soil with different percentage of Brick dust.

S.NO	Samples	CBR (%)
1	100%ES	2.7
2	94%ES+6%BD	3.18
3	92%ES+8%BD	4.13
4	80%ES+10%BD	3.76
5	88%ES+12%BD	3.49



Graph: Variation of Unsoaked CBR %ES with different %of Brick dust.

CONCLUSION

The following conclusions are drawn based on the laboratory studies carried out in this investigation The optimum value of brick dust is adding with different percentage mixed with the soil for strengthening its stability is being studied. The following observations are being made after performing several experiments:

Addition of Brick dust has shown decrement in liquid limit from 68.4% to 53.12% and also decrement in plastic limit from 27.77% to 20.56% and plasticity index decrease from 40.63% to 32.56% when the Brick dust content varies from 6% to 12% with an increment of 2% mixed in expansive soil.

Addition of Brick dust has shown decrement in Differential free swell index from 95% to 69%.

Optimum moisture content (OMC) and maximum dry density (MDD) increases up to the addition of 10% of brick dust & further increment of brick dust beyond that 10% OMC and MDD decreases. When 10 % of the soil is being replaced with Brick dust maximum values of optimum moisture content (OMC) 26.41% and maximum dry density (MDD) 1.64 gm/cc is obtained.

California bearing ratio (CBR) value has been increases up to the addition of 10% Brick dust & further increment of brick dust beyond that 1 0 % CBR value decreases. The optimum CBR value 7.24% is obtained at 10% of soil replaced with Brick dust.

From the experiments performed, it is established that the optimum value of Brick dust with the soil is 10% and 1.0% respectively. Such kind of findings is valuable in the consideration of economy and cost.

From the study it is concluded that, the Brick dust is suitable to be used as a suitable stabilizing agent for the purpose of admixture with the soft clay soil..

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