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SOIL STABILIZATION BY USING BRICK POWDER

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Abstract

The structures which are constructed over black cotton soil may tend to easy deformations due to its volume change and shrinking tendency. Among various soil deposits in Indian terrain, Black cotton soil is one of the most prevalent constituents. Due to rapid urbanization, constructions over these soils are unavoidable. Development of roads in places having black cotton soil affects strength and durability of the pavement to a large degree. It is vital to increase the soil's bearing capacity & behavior in order for the pavement to endure its load. It is approximately estimated that the building sector in India creates 10 to 12 million metric tons of waste yearly, leading to a significant disposal challenge. These construction and demolition waste can be added in soil which may affect soil properties. For the present study, brick powder from debris has been used as a stabilizer in order to strengthen black cotton soil used in construction of sub grades in pavements. In the current research, it is proposed to determine the optimal proportion of brick powders to be added in black cotton soil or to investigate the properties of BCS. The optimum percentage is fixed by studying the literature. In this study the influence of brick powder with black cotton soil is observed separately. Sieve analysis, Atterberg's Limit, Specific Gravity, Free Swell Index, Modified Proctor, Unconfined Compressive Strength and California Bearing Ratio test were carried out on black cotton soil and 6%, 8%, 10%, 12% brick powder blended soils. The tests were performed using different proportions of brick powder which includes 6%, 8%, 10% and 12%. At the end of all tests with reference to CBR test, the results showed that the maximum strength was obtained when 10% of brick powder was mixed with the BCS. This Shows that the minimum 10% brick powder is to be added in BCS which result in increase in the strength of soil as well as reduction in pavement construction cost as compared to less proportions (6%, 8%) which were tested. Finally, the pavement design for 5%, 6%, 7% CBR is performed and the cost of construction of pavement has been evaluated and it can be reduced for locally available black cotton soil by stabilizing it with wasted brick powder.

Keywords: Sieve Analysis, Atterberg's Limit, Modified Proctor, California Bearing Ratio test, Soil Stabilization, brick powder, Construction and Demolition waste, cost of construction.

1. INTRODUCTION

The stability of soils under pavements determines their long-term durability. Earth materials below pavement do not always meet these requirements. So, there is a need to change these less effective earth materials into sustainable sub grade materials. Stabilizing the poor soil such as black cotton soil with acceptable amount of waste material as stabilizer could be an effective and economic method. Construction and demolition operations create between 0.27 and 5.18 million tons of waste materials annually. Due to the fast expansion of the construction sector, it is appropriate to relate the creation of demolition and building waste to India's economic growth. Therefore, appropriate practices are necessary to control waste from building and destruction in order to propose economic approach. Black cotton (BC) soil, which varies greatly in volume with varying water contents, is the primary cause of structural abnormalities in India, because it comprises around 20% of country geographical area. Over the course of the year, effective approaches have been utilized to stabilize them. However, it is crucial for engineers to evaluate the efficiency and suitability of all stabilizers. Black cotton soil consists of a simple phyllosilicate collection with minerals called as Montmorillonite that precipitate from aqueous solution as minute minerals. Due to the clay mineral's property to swell and contract in response to the addition of water, it may cause a variety of issues on the building site. During the rainy and dry seasons, this soil type expands and compress, causing substantial structural damage.

1.1 Soil Stabilization and Material used for Stabilization:

Before construction, stabilization is the act of altering the physical attributes of a soil to produce permanent increase in strength. When components, design, & construction are carefully examined, stabilized soils outperform as a unstable soil. When the stabilized soil layer is included into the pavement's structural design, succeeding layers may be made thinner, resulting in substantial cost savings. In addition to increasing strength, stabilized soil produces a solid obelisk that limits leakage, which in turn lessens the possibility for shrinking and swelling and the negative consequences of freeze-thaw cycles. In situ, or in their natural form, soils may be improved by soil stabilization, removing the need for costly remove-and-replace procedures. Frequently, construction sites for road, development pads, parking lots, runways, and other surface constructions involve naturally moist, unstable soils. These soils may be pyrolyzed to increase their strength via

stabilization and their engineering qualities, such as their moisture content and flexibility, by alteration. Ex situ, or off-site, soil stabilizing methods are conceivable, although they are often reserved for environmental initiatives as opposed to regular building activities.

Figure No.1 Soil Stabilization

1.2 Black Cotton Soil:

Black cotton soil is indeed very conducive to cotton growing. It is termed black cotton soil because to the prevalence of titaniferous magnetite, which gives it a black hue. Black cotton soil is a clay-rich, calcium-, carbonate-, and potash-rich soil that is mostly developed there in tropics and subtropics. It also retains moisture. In addition to being rich on lime, iron, and magnesium, black cotton soil is deficient in phosphorus, carbon, and organic compounds. Thus, the lowlands are more fruitful than the uplands. Swelling as a result of the enlargement of Black Cotton Soil during monsoon rains, the structure experiences increase the initial and actually creates heave in the fundamentals, plinth beams, ground floors of buildings and canals, road surfaces, etc. During the dry season, cracks form in walls, slabs, plinth safety, floors, etc. Due to a greater clay content, Black cotton soil swells during the wet season. It expands throughout the monsoon rains & shrinks during the summer. The fissures are typically 100 to 150 millimeters broad and 0.5 to 2 meters deep.

Figure No.2 Black Cotton Soil

1.3 Problem Associated with B. C. Soil:

Black Cotton soils is challenging for engineers all over the globe, but especially in tropical nations like India, where vast temperature changes and distinct dry or wet seasons lead to large differences in soil moisture content. The following issues often arise with black cotton soil:

High Compressibility:

When saturated, Black Cotton soils are very flexible and compressible. On such soils, substantial consolidation settlements occur in the footing.

Swelling:

A building constructed during a dry weather, once the groundwater content is low, exhibits differential soil movement during the following rainy season. This results in the lifting and cracking of buildings supported by these expanding soils. Hence, there are limitation on the structure's suitability due to the development of swelling pressures.

Shrinkage:

A building constructed near its end of the rainfall season, so when groundwater sources level is high, BCS exhibits cracking and settling during the ensuing dry season.

1.4 Brick powder from Construction and demolition waste:

Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges, piers, and dams. C&D waste is made up of wood, steel, concrete, gypsum, masonry, plaster, metal, and asphalt. C&D waste is notable because it can contain hazardous materials such as asbestos and lead. Most of the estimates vary, but a commonly accepted estimate is between 15% and 20% of municipal solid waste which comes from construction and demolition projects.

Reusing of brick powder from construction and demolition waste may reduce the demand-supply gap in the construction market. The brick powder from debris can be utilized from the construction and demolition waste for soil stabilization. Brick powder is one of the major components which can get recycled. At the same time aggregate recycling also helps to reduce most of the construction and demolition waste. So that by proper construction and demolition waste recycling it can recycle almost 50 to 60 percent of aggregate, brick powder and some amount of sand, silt and clay also utilized. The brick powder from debris of Construction & demolition waste can be used for the strengthening of subgrade under pavement as well as many other constructions purposes also.

Figure No.3 Construction and Demolition waste

2. LITERATURE REVIEW:

Habiba Afrin (2017) Soil stabilization is indeed the process of boosting the bearing capacity of the soil by increasing its shear strength. When the available construction soil is inappropriate for sustaining structural loads, it must be done. Soils have usually poor engineering characteristics. Soil Stabilization is the process for altering soils in order to improve their physical qualities. Stabilization may raise the shear capacity of a soil and/or regulate its shrink-swell qualities, hence enhancing the sub-ability grades to sustain pavements and foundations. The objective of stabilization of soil is to minimize the flexibility and elastic modulus of the mass of soil in earth constructions and to improve its shear strength. This paper's primary goal is to assess the chemical and physical characteristics of soil in various stabilization procedures. Stabilization and its impact on soil reveal the response mechanism with additives, the influence on its strength, the enhancement and maintenance of soil moisture

content, and building system recommendations. Numerous techniques exist for stabilizing the soil.

Mallikarjun, et.al (2018) It is crucial for engineers to investigate the efficiency and utility of all stabilizers. This research examines the modification of British Columbia (BC) soil with Construction and demolition (C & D) wastes (concrete and plastering debris), resulting in a soil+10% C & D waste ideal mix as determined by a standard proctor test. Additionally, the cohesion (c) & the internal friction angle () were reviewed using the Direct Shear exam, or just the Safe Bearing Capacity (SBC) of soil had been calculated using Tirzah's equation for BC soil without C&D waste, BC soil of 10% C&D waste, BC soil of 12% C&D waste, & BC soil with 14% C&D waste. In the experimental investigations, it was calculated that its optimal addition of C & D waste can effectively contribute to reducing the swelling characteristics of black cotton soil by imparting high bearing capacity and strength, and can be considered a substitute stabilizer that increases the use of construction industry waste product.

A. R. Makegaonkar et.al (2018) The primary source of construction and demolition trash is the two operations of construction and demolition. The garbage generated during construction is referred to as construction waste, whereas the rubbish generated during demolition is referred to as demolition waste. The Destruction trash is produced by the demolition of old buildings, bridges, shopping malls, and roadways. The building industry in India generates around 20 or 32 million tons of trash annually. Therefore, such Untreated wastewater should be adequately handled. The majority of India's building and demolition trash is disposed of in landfills. This could contribute to environmental contamination. The norms and regulations surrounding the disposal of solid waste are not applied correctly. To meet the goal of reusing and recycling building and demolition waste, this article concludes that landfill disposal of construction and demolition waste must be reduced. The purpose of this research is to examine the various C&D garbage reuse and recycling procedures employed by various nations.

Mohd Furkhan, et.al (2018) From a civil engineering construction standpoint, expensive or black cotton soil is one of the most troublesome soils. This research analyses the use of demolition debris to increase the strength of black cotton soil & presents the experimental results on two clay soils, one with high plasticity and the other with low plasticity. The studies were conducted utilizing various percentages of Demolished Waste, including 20%, 40%, and 50%. The conclusion of the experiments revealed that the highest strength was achieved when 50% of destroyed debris was combined with the soil. This indicates that the greater the fraction of destroyed material, the greater the gain in maximum strength relative to the amounts evaluated (20%, 40%).

S.P. Kanniyappan, et.al (2019) The stabilization of subbase and base soil enhances its physical qualities and strength. Red soil is the third biggest soil category in India, and it needs stabilization owing to its weaker strength, porous and fragile structure, and greater swelling capacity than other soils. Red soil stabilization is often achieved by the use of limestone, fly ash, granular blast slag, etc., with construction and demolition debris constituting the majority. This project suggests studying the engineering features of red soil and determining the thickness of the pavement. The debris is added to the soil in varied proportions, and the CBR value is computed. Variation in CBR value might lead to a decrease in pavement thickness.

3. METHODOLOGY:

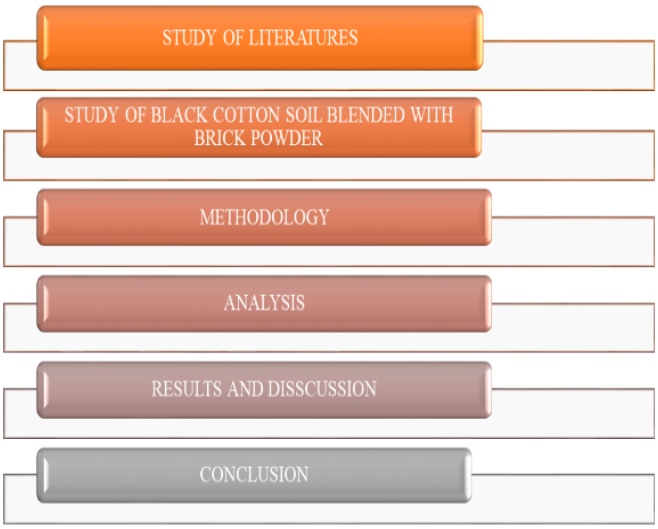


Figure No.3 Methodology flowchart

3.1 Tests performed on soil:

1. Examination for black cotton soil by Sieve.
2. Specific gravity measured by a pycnometer.
3. Free Swell Index
4. Modified Proctor
5. Unconfined Compressive Strength
6. California Bearing Ratio
7. Atterberg's Limit
   a. Liquid Limit
   b. Plastic Limit
   c. Shrinkage Limit

4. RESULTS AND DISCUSSION:

4.1 Properties of Black Cotton Soil:

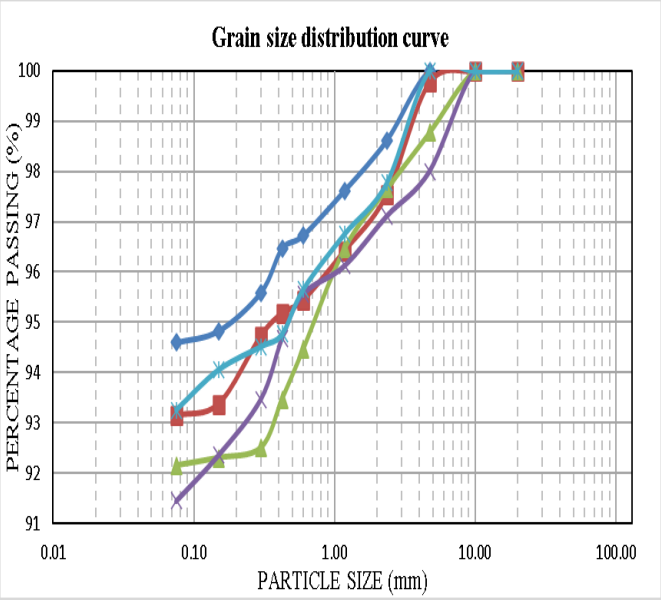
Table No.-1 Properties of Black Cotton Soil

Properties	Black Cotton Soil
Color	Grayish Black
Specific Gravity	2.46
Free Swell Index (%)	95
GRAIN SIZE DISTRIBUTION	
Gravel (%)	0.69
Sand (%)	6.39
Silt / Clay (%)	92.92
IS Classification	CH
ATTERBERG'S LIMIT	
Liquid Limit (%)	72.39
Plastic Limit (%)	33.06

Plasticity Index (%)	39.33
Shrinkage Limit (%)	27.03
COMPACTION CHARACTRISTIC	
Maximum Density (g/cc)	1.38
Optimum Moisture Content (%)	26.41
Unconfined Compressive Strength (Kg/cm^2)	0.445
CALIFORNIA BEARING RATIO (SOAKED)	
2.5 mm penetration (%)	3.90
5 mm penetration (%)	3.08

4.2 Sieve analysis of Pure Black cotton soil:

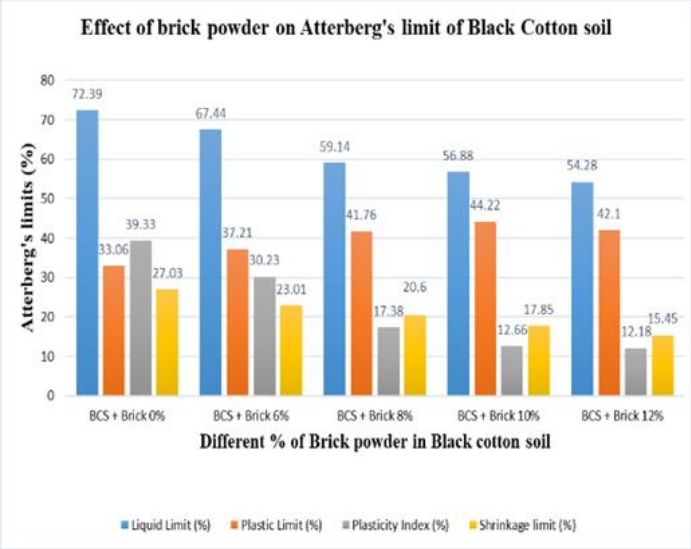
This approach separates soils into distinct fractions based on the particles present in the soil. This Size Analyse test determines the proportion of various grain sizes present in a soil sample. It is also shown in graphical form on a particle size distribution curve. This test was performed 5 times and classification for each test is done and accordingly, Grain size distribution curve is drawn.



Graph No.-01 Grain size distribution curve for Black Cotton Soil

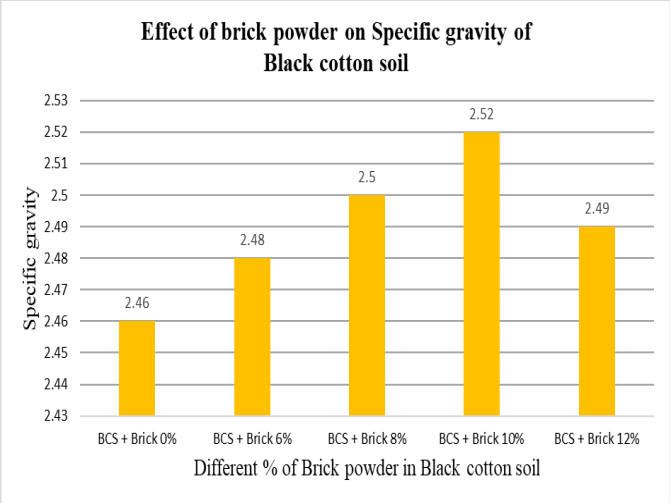
4.3 Atterberg's Limit:

Graph no.-02 compares the findings of Atterberg's Limit of Black Cotton Soil and Black Cotton Soil treated with brick powder (6%, 8%, 10% & 12%). Graph clearly demonstrates a decline in liquid limit of the Black cotton soil sample with a rise in its brick powder content (0%, 6%, 8%, 10% & 12%) from 72.39% to 54.28%. It also shows the increase in Plastic limit from 33.06% (0% brick powder) to 44.22% (10% brick powder). But plastic limit slightly decreased to 42.1% for 12% brick powder content. The graph also depicts a decrease in the plasticity index from 33.06% (0% brick powder) to 12.8% (12% brick powder content). Similarly decrease in Shrinkage limit is seen from 27.03% (0% brick powder) to 15.45% (12% brick powder).



Graph No.-02 Effect of Brick powder on Atterberg's Limit of BCS

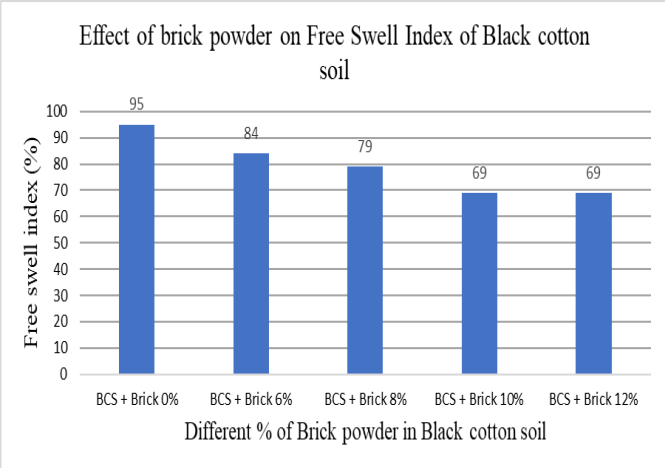
4.4 Specific Gravity:



Graph No.-03 Effect of brick powder on Specific Gravity of BCS

Graph no.-03 shows the comparison of specific gravity of virgin BC soil with BC soil mixed with 6%, 8%, 10% and 10% brick powder. It can be seen that specific gravity of BC soil sample raised marginally when 10% brick powder was added in it. The bars of the virgin BC soil, 6%, 8% and 12% brick powder mixed BC soil are small as compared to the result bar of 10% brick powder mixed BC soil.

4.5 Free Swell Index:

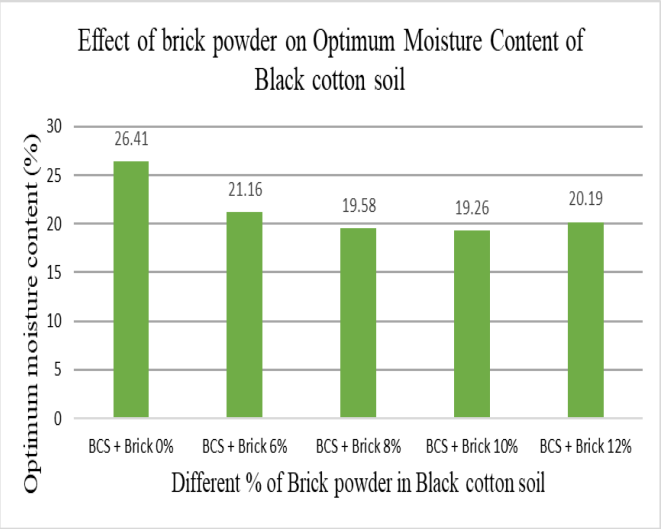


Graph No.-04 Effect of brick powder on Free Swell Index of BCS

In Graph No.-04, the observation from tests done with five different ratios for Free Swelling Index is shown. The first column indicates that, the Free Swell Index for 100% BCS is 95%. The 4th and 5th column represents the same FSI as 69% for 10% and 12% brick powder blended with BCS respectively. This indicates the signifying decrease in FSI as the percent of brick powder in BCS is increased.

4.6 Modified Proctor Test:

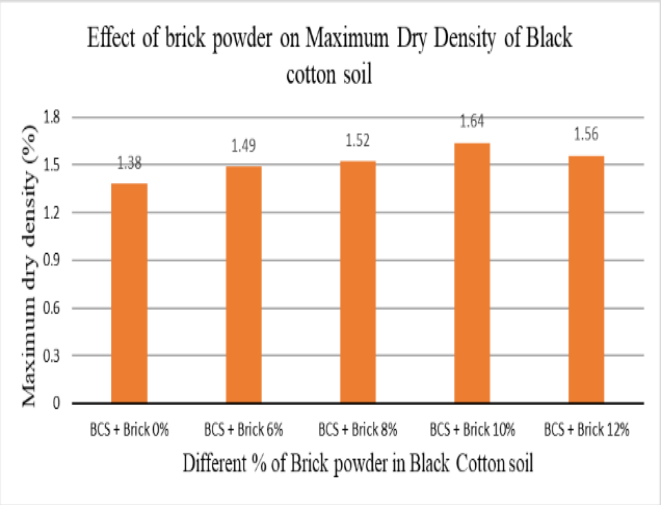
4.6.1. Optimum Moisture Content:



Graph No.-05 Effect of brick powder on Optimum Moisture Content of BCS

Graph no.-05 demonstrates the contrast between the Optimum Moisture Content (OMC) for virgin BC soil and BC soil blended with organic matter 6%, 8%, 10% & 12% brick powder. The optimum brick powder content for stabilization of BC soil is found to be 10% based on compaction test. The optimum moisture content value indicated a declining trend as brick powder content in BC soil was increased up to 10%. It decreased from 26.41% (virgin BCS) to 19.26% (10% brick powder). OMC increased again to 20.19% for 12% brick powder mix.

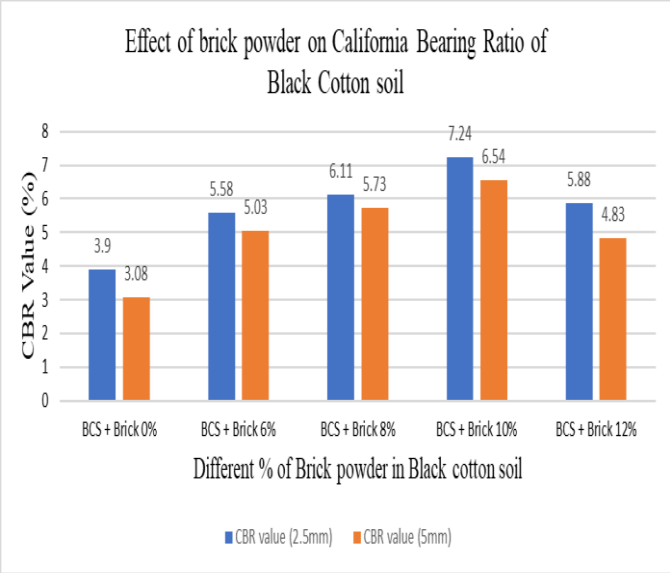
4.6.2. Maximum Dry Density:



Graph No.-06 Effect of brick powder on Maximum Dry Density of BCS

Graph no.-06 represents the observations recorded for Maximum Dry Density for five different proportions of BCS and brick powder. It is observed that up to 10% brick powder addition, MDD goes on increasing whereas when 12% brick powder was mixed with BC soil, MDD of soil is decreased slightly so there was no further scope for addition of brick powder.

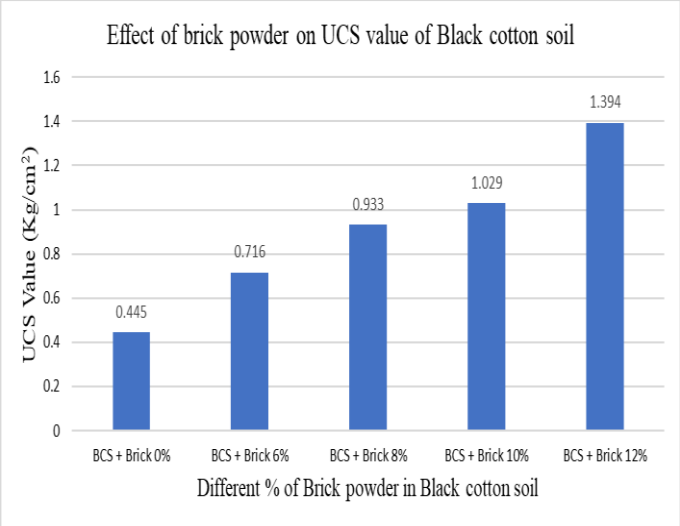
4.7 California Bearing Ratio:



Graph No.-07 Effect of brick powder on California Bearing Ratio of BCS

Graph no.-07 shows the comparison between CBR values of virgin black cotton soil, 6%, 8%, 10%, 12% brick powder added Black Cotton Soil at 2.5 mm & 5 mm penetration. The CBR values at 2.5 mm & 5 mm penetration showed the increasing trend up to 10% brick powder content. It was found that the highest CBR values for penetrations of 2.5 mm & 5 mm were obtained at 10% brick powder content mixed with BCS (7.24% and 6.54% respectively). Then CBR values at both penetrations decreased again significantly when 12% brick powder was blended in BCS.

4.8 Unconfined Compressive Strength:



Graph No.-08 Effect of brick powder on Unconfined Compressive Strength of BCS

Graph no.- 08 demonstrates the comparison between the UCS value of virgin BC Soil and BC soil treated with Brick powder (6%, 8%, 10% & 12%) brick powder. Unconfined compressive strength values showed increasing trend as brick powder content in BC soil was increased up to 12%. It increased from 0.445 kg/cm^2 (virgin BCS) to 1.394 kg/cm^2 (12% brick powder).

5. PAVEMENT DESIGN:

Flexible pavement designs are carried out as per IRC: 37-2018. For CH subgrade soil with soaked CBR more than 5%, pavement designs are performed. The flexible pavement is designed considering the pavement to be double laned with a design life of 15 years and for an initial traffic of 650 CVPD, with annual growth rate of 7.5%. The projected total amount

of standard axles is 20 msa. The thicknesses specified for flexible pavements for the subgrade soils under this study are determined from Design Plates of IRC 37-2018 based on soaked CBR values. From table no.-02, it may be observed that as the CBR value of the BCS increased, the design pavement thickness decreased.

Table No.-2 Pavement design for different % of brick powder + Black Cotton Soil

% of brick powder added in BCS		6%	8%	10%
CBR (%)		5	6	7
Cumulative traffic (msa)		20	20	20
Pavement Composition	Granular Sub Base (mm)	200	200	200
	Wet Mix Macadam (mm)	250	250	250
	Dense Bituminous Macadam (mm)	105	95	100
	Bituminous Concrete (mm)	40	40	30
Total Pavement Thickness (mm)		595	585	580

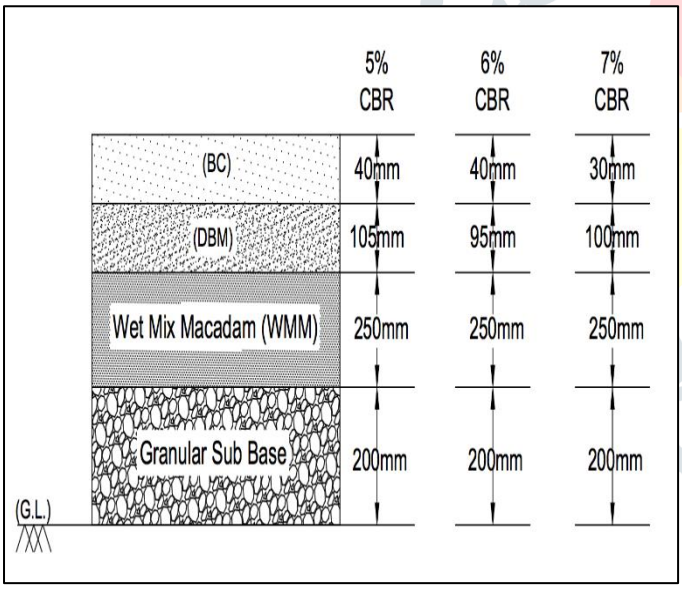


Figure No.4 Pavement composition with thickness of each layer for different CBR values

6. COST EVALUATION OF PAVEMENTS:

For calculating the cost of pavement, rates of each item are taken from Pune Municipal Corporation DSR (2022-23). The cost evaluation is done for 1Km length and 7m width.

The cost analysis of the designed pavements is carried out by considering the pavement to be double lane and by using the Pune Municipal Corporation DSR (2022-23). The costs of pavement sections have been worked out for 1 km length considering width of pavement as 7 m. The details of cost analysis of designed pavement sections are presented in table no.- 3,4 and 5. Cost analysis of flexible pavements indicates that cost of the pavement decreases with augmentation in CBR value of subgrade soil as the thickness of BC, DBM decreases.

Table No.-3 Pavement Cost analysis for 5% CBR

Items of work	Quantity in Meter (m)			Total quantity (Cu.m)	DSR rates (Rs/Cu.m.)	Cost (Rupees)
	Length (m)	Width (m)	Height (m)			
Bituminous Concrete	1000	7	0.04	280	13,139	3678920/-
Dense Bituminous Macadam	1000	7	0.10	700	10,057	7039900/-
Wet Mix Macadam	1000	7	0.25	1750	2,492	4361000/-
Granular Sub Base	1000	7	0.2	1400	2,413	3378200/-
Total cost						18458020/-

Table No.-4 Pavement Cost analysis for 6% CBR

Items of work	Quantity in Meter (m)			Total quantity (Cu.m)	DSR rates (Rs/Cu.m.)	Cost (Rupees)
	Length (m)	Width (m)	Height (m)			
Bituminous Concrete	1000	7	0.04	280	13,139	3678920/-
DBM	1000	7	0.095	665	10,057	6687905/-
Wet Mix Macadam	1000	7	0.25	1750	2,492	4361000/-
Granular Sub Base	1000	7	0.2	1400	2,413	3378200/-
Total cost						18106025/-

Table No.- 5 Pavement Cost analysis for 7% CBR

Items of work	Quantity in Meter (m)			Total quantity (Cu.m)	DSR rates (Rs/Cu.m.)	Cost (Rupees)
	Length (m)	Width (m)	Height (m)			
Bituminous Concrete	1000	7	0.03	210	13,139	2759190/-
Dense Bituminous Macadam	1000	7	0.1	700	10,057	7039900/-
Wet Mix Macadam	1000	7	0.25	1750	2,492	4361000/-
Granular Sub Base	1000	7	0.2	1400	2,413	3378200/-
Total cost						17538290/-

7. CONCLUSION

1. On the basis of research and experimental examinations, it was determined that varying amounts of brick powder increased the qualities of black cotton soil. In this research varying percentage (6%, 8%, 10%, 12%) of brick powder used to stabilize the cotton black soil The conclusions derived from this investigation are provided below:
2. It was discovered that with adding of brick powder in different proportions to black cotton soil, liquid limit showed a decreasing trend from 72.39 % (Virgin BCS) to 54.28 % (12% brick powder + 88% BCS), which is a notifying reduction of 18.11% which leads to improvement in plastic limit.
3. On other hand from plastic limit result it clearly reflects that plastic limit went on increasing up to 44.22 % when 10% brick powder was added to BCS. It showed a great increase of 11.16% from virgin BCS results, which indicates that moisture content goes on reducing with increase in brick powder content up to 10% and plasticity of soil increases.
4. As brick powder is added, the soil's plasticity index reduces between 39.33% to 12.18% once at brick powder concentration of 12%. For augmentation of brick powder there is no little enhancement in soil plasticity.
5. Decreasing of shrinkage limit from 27.03% to 15.45% and free swell index from 95% to 69% with the increase in the percent of brick powder, indicates that shrinking property of BCS decreases with addition of brick powder when it is exposed to water.
6. On addition of brick powder to BCS up to 10%, specific gravity of soil raises to 2.52. For 12% brick powder specific gravity slightly reduced to 2.49.
7. Mixing 10% brick powder to black cotton soil improved the highest dry density of 1.38 g/cc to 1.64 g/cc, which is a signifying increase of 0.26 g/cc for 10% addition of brick powder from virgin BCS. At the same time, optimum moisture content indicated the falling trend from 26.41% to 19.26% until 10% brick powder was added to the BCS. It reflects that pores in BCS were properly filled by the 10% addition of brick powder. Above 10% OMC increased and MDD decreased.
8. An Unconfined Compressive Strength (UCS) graph of the soil with varied brick powder concentration showed an upward pattern. Results indicate that the undrained shear hardness of the soil increases from to 0.45 kg/cm^2 for virgin soil to 1.3 kg/cm^2 for 12% brick powder content.
9. Maximum CBR was determined to be 6.54 percent, which is double the CBR of virgin soil (3.08 percent). This highest CBR value is reached with a 10% brick powder content; hence, a 10% brick powder content is considered the optimal proportion for stabilizing soil. It also showed a sudden decrement in CBR for 12%.
10. As per IRC 37-2018, pavement thickness plate is given for CBR values above 5%. Designing of pavement for soil treated with 6%, 8%, 10% brick powder which are having 5%, 6%, 7% CBR respectively, has found that as CBR value increases simultaneously there is reduction in thickness of bituminous concrete layer and dense bituminous macadam layer by 5-10%.
11. Pavement cost analysis gave a cost of approximately 1.9 Cr, 1.8Cr, 1.7Cr for 6%, 8%, 10% brick powder added BSC respectively. As the brick powder content increases, the CBR also increases. And as the CBR of soil increases cost of Pavement reduces.
12. So, from this study it can be concluded that minimum 10% brick powder content can be adopted for improving the properties of BCS and even this proportion can be opted for economical pavement construction.

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