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# SOIL STABILIZATION 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 major constituents. Due to rapid urbanization, constructions over these soils are unavoidable. Development of roads in places having black cotton soil affects the strength and durability of the pavement to a great extent. In order to withstand the load of the pavement, it is essential to improve bearing capacity and behavior of the soil. It is estimated that the construction industry in India generates about 10-12 million tons of waste annually which leads to the disposal problem of such waste on large basis. 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 for improving the strength of black cotton soil used in construction of sub grades in pavements. In the present study it is proposed to find optimum percentage of brick powder to be added in black cotton soil and study the properties of the 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, 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.***

***Keywords: Aspect Ratio, Slenderness, Hopper, Eccentric Discharge***

## 1. INTRODUCTION

Long term durability of pavement structures depends on the stability of the soils beneath. 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 waste material as stabilizer could be an effective and economic method. The quantity of waste materials generated per annum from construction and demolition activities ranges from 0.27 to 5.18 million tons. Due to the rapid growth in the construction industry, it will be suitable to link construction and demolition waste generation with the Indian economic development. Therefore, appropriate practices are necessary to control construction and demolition (C&D) waste in order to propose an economic approach. Black cotton (BC) soil that change significantly in volume with change in water content is the major cause of distortions to structures in India since, it covers around 20% of land area. Over the year's successful methods have been used to stabilize them. However, it is found very important for engineers to judge the effectiveness and appropriateness of all stabilizers. Black cotton soil constitutes of a too easy phyllosilicate collection of minerals that procedure when they involve from water solution as microscopic minerals known as Montmorillonite. Clay mineral that have susceptibility to change volume with application of moisture into it which in turn create various problems during construction on site due to swelling and shrinkage behavior. The expansive soils encounters swelling and shrinkage during different wet and dry seasons causing considerable damage to structures.

### 1.1 Soil Stabilization Methods and Materials

**Figure No.1 Soil Stabilization**

Soil stabilization is a process by which the physical properties of a soil are transformed to provide permanent strength gains before construction. Stabilized soils outperform non-stabilized soils when materials, design, and construction are properly considered. When the stabilized soil layer is incorporated into the structural design of the pavement, the subsequent layers can be thinner, resulting in sizable cost savings. In addition to adding strength, stabilized soil forms a solid monolith that decreases permeability, which in turn reduces the shrink/swell potential and the harmful effects of freeze thaw cycles. Soil stabilization can improve in situ, or natural state, soils eliminating the need for expensive remove-and-replace operations. Often job sites where roads, building pads, parking lots, runways or other pavement structures need to be built contain naturally wet, weak soils. Those soils can be chemically treated to add strength through stabilization and improve engineering properties including moisture content and plasticity, through modification. Ex situ, or off site, soil stabilization processes are possible but are usually reserved for environmental projects rather than typical construction operations.

### 1.2 Black cotton soil

Black cotton soil is very favorable for the cultivation of cotton. It is called black cotton soil because it is black in colour formed by the presence of titaniferous magnetite. Black cotton soil is clay-rich soil i.e., it contains calcium, carbonate, potash, and holds moisture and is mainly formed in the tropics and subtropics region. Black cotton soil is also rich in lime, iron, and magnesium but contains a low amount of phosphorous, nitrogen, and organic matter. So, it is more fertile in low lands than on the uplands.

Swelling caused in Black Cotton Soil during the rainy season, the structure has uplift pressure and generates heave in the foundations, plinth beams, ground floors of the buildings and canals, roads surfaces, etc and on shrinkage in the summer season, cracks created in walls, slabs, plinth protection, floors, etc.

In the rainy season, Black cotton soil swells due to a higher percentage of clay. It swells during the rainy season and cracks in summer due to shrinkage. The cracks are generally in the range of 100 mm to 150 mm wide and 0.5m to 2m deep.

### 1.3 Problem Associated with B. C. Soil:

Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil -

**High Compressibility:**

Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude.

**Swelling:**

A structure built in a dry season, when the natural water content is low shows, differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on having developed swelling pressures making the structure suitable.

**Shrinkage:**

A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

## 2. LITERATURE REVIEW

**Habiba Afrin (2017)** Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of soil. It is required when the soil available for construction is not suitable to carry structural load. Soils exhibit generally undesirable engineering properties. Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil stabilization is used to reduce permeability and compressibility of the soil mass in earth structures and to increase its shear strength. The main objective of this paper is to determine the physical and chemical properties of soil in different types of stabilization methods. Stabilization and its effect on soil indicate the reaction mechanism with additives, effect on its strength, improve and maintain soil moisture content and suggestion for construction systems. Soil stabilization can be accomplished by several methods.

**Mallikarjun, et.al (2018)** It is of great importance for engineers to study the effectiveness and usefulness of all stabilizers. The present work deals with the alteration of BC soil using Construction and Demolition (C & D) waste (concrete and plastering debris) which resulted in soil+10% C & D waste optimum mix obtained through standard proctor test. Further, the cohesion (c) and angle of internal friction ($\phi$) were evaluated using Direct Shear test and the Safe Bearing Capacity (SBC) of soil was calculated using Tirzah's equation for BC soil alone, BC+10 % C & D, BC + 12 % C & D and BC + 14 % C & D waste respectively. In the experimental studies carried out it can be seen that optimum addition of C & D waste can efficiently contribute in decreasing the swelling characteristics of black cotton soil by transmitting high bearing capacity and strength and can be contemplated as a substitute stabilizer which enhances the use of waste product obtained from construction industry

**A. R. Makegaonkar et.al (2018)** The construction and demolition waste are the waste mainly generated from the two activities i.e., from the construction activity and demolition activity. The waste which is produced during construction activities are called as construction waste and the waste produced during demolition activities are called as demolition waste. The Demolition waste is generated from the demolition of old structures like buildings, bridges, malls and roads. Construction industry in India generates about 20-32 million Tons of waste annually. So, this C&D waste should be managed properly. Most of the construction and demolition waste in India is getting disposed into the landfills. This may lead to the environmental pollution. The rules and regulations regarding to the land filling disposal are not implemented properly. So, this paper gives finding that to reduce the landfill disposal of the construction and demolition waste and to achieve the aim of reuse and recycle of that construction and demolition waste. The objective of this paper is to study the various strategies of the reusing and recycling of the C&D waste adopted by different countries.

**Mohd Furkhan, et.al (2018)** Expensive soil or black cotton soil are one of the most problematic soils from civil engineering construction perspective. So findings from this paper is that it investigates the use of demolition waste to improve the strength of black cotton soil and summarizes the results of experiment on two clay soils one with high plasticity as well as low plasticity. The tests were performed using different proportions of Demolished Waste which includes 20%, 40%, 50%. At the end tests the results showed that the maximum strength was obtained when 50% of demolished waste was mixed with the soil. This Shows that the maximum the amount of demolished proportion will result in increase in maximum strength compared to less proportions (20% ,40%) which were tested.

**S.P. Kanniyappan, et.al (2019)** Stabilization of sub-base and base soil improves its properties and strength. Red soil is the third largest soil group in India and it possess lower strength compared to other soil due to its porous and fragile structure and it has a higher swelling capacity, thereby it requires stabilization. Red soil stabilization is usually done using lime, fly ash, granulated blast slag etc., of which construction & demolition waste is the major factor. This project gives an idea to study the engineering properties of red soil & to determine the pavement thickness. The debris is added in varying percentage to the soil & the CBR value is calculated. The variation in CBR value may result in the reduction of pavement thickness.

## 3. METHODOLOGY

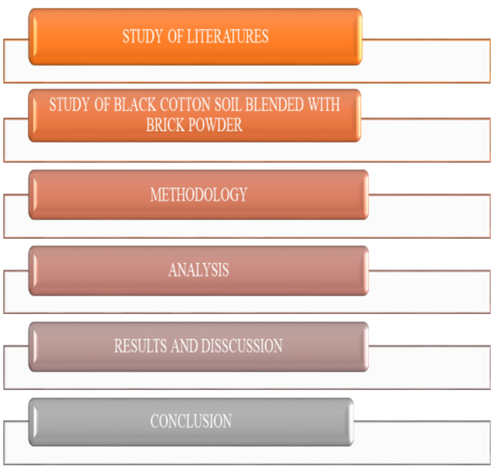



**Figure No.2 flowchart**

### 3.1 Tests performed on soil:

1. Sieve Analysis of black cotton soil.
2. Specific gravity by pycnometer.
3. Atterberg's limit
   a. Liquid Limit
   b. Plastic Limit
   c. Shrinkage limit
4. Standard proctor test
5. Unconfined compression test

## 5. RESULTS AND DISCUSSION

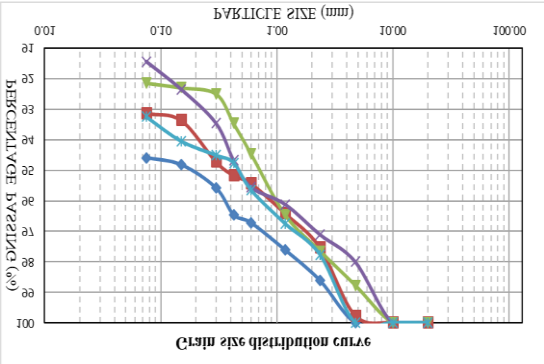
### 5.1 Properties of black cotton soil

**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)** | |
| 2.5mm penetration (%) | 3.90 |
| 5mm penetration (%) | 3.08 |

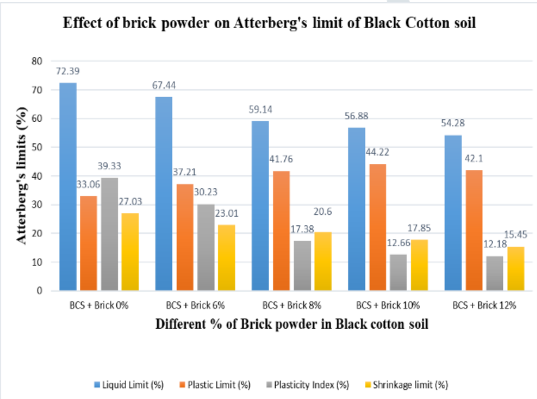
### 5.2 Sieve analysis of Pure Black cotton soil:

This is method of separation of soils into different fractions on the basis of particles present into soils. This Particle Size Analysis test is performed to determine the percentage of different grain sizes present within 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 shown in table no.-02 and accordingly Grain size distribution curve is drawn.




**Graph No.-01 Grain size distribution curve for black cotton soil**

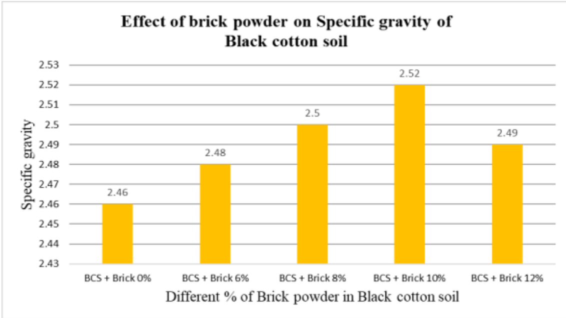
### 5.3 Atterberg's Limit




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

compares the results of Atterberg's limits of the black cotton soil and black cotton soil treated with brick powder (6%, 8%, 10% & 12%). Graph below clearly shows the decrease in liquid limit of the Black cotton soil sample with increase 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. Decrease in corresponding plasticity index is also seen in the graph 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).

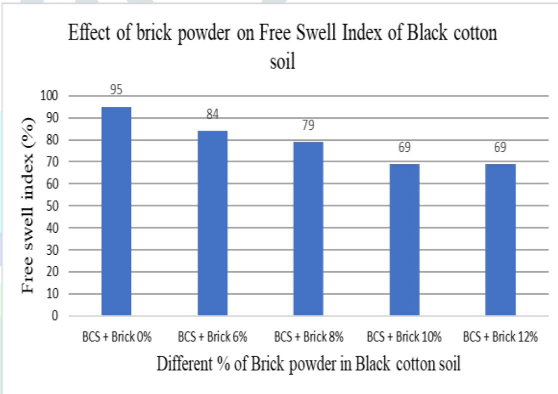
### 5.4 Specific Gravity




**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.

### 5.5 Free swell Index

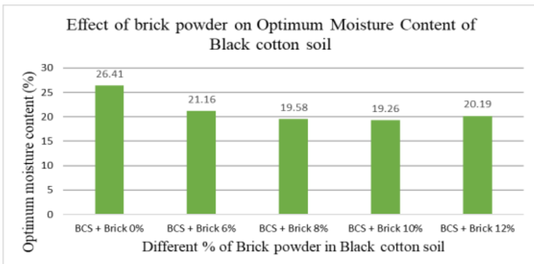



**Graph No.-04 Effect of brick powder on Free swell index of BCS**

In Graph no.-04 the representation of observations from the tests conducted using five different proportions for Free Swell Index is manifested. The 1st column signifies the FSI of 100% BCS to be having 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 was increased.

### 5.6 Modified Proctor Test

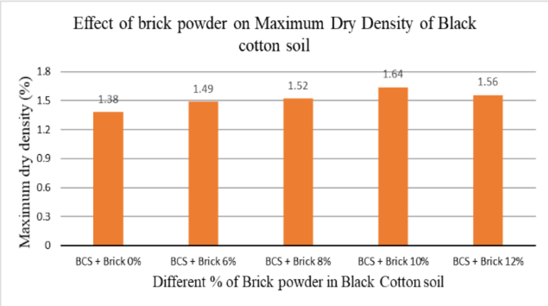
#### 1. Optimum Moisture Content




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

Graph no.-04 shows the comparison of OMC of virgin BC soil with BC soil mixed with 6%, 8%, 10% and 12% brick powder. The optimum brick powder content for stabilization of BC soil was found to be 10% based on compaction test. Optimum moisture content value showed a decreasing 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.

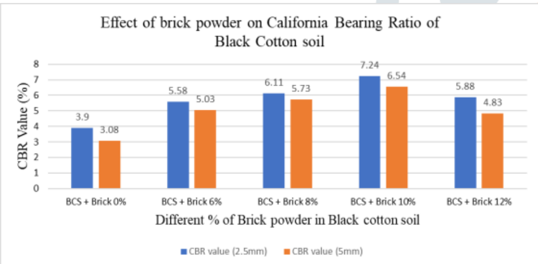
### 2. Maximum dry density




**Graph No.-06 Effect of brick powder on Maximum dry density of BCS**

Graph no.-06 represents the observations recorded of Maximum Dry Density for five different proportions. 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.

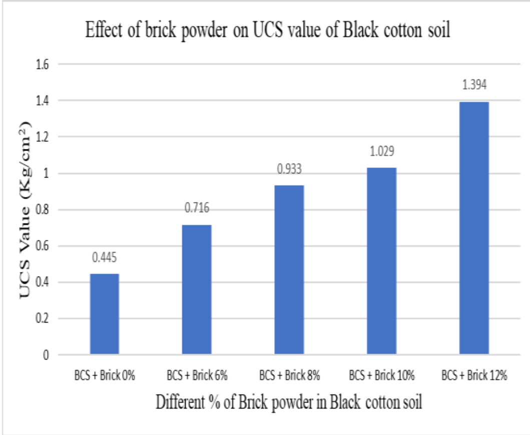
### 5.7 California Bearing Ratio




**Graph No.-07 Effect of brick powder on California bearing ratio of BCS**

Graph no.-07 compares the CBR values of virgin black cotton soil, 6%, 8%, 10%, 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 powder content. It was found that the highest CBR values at 2.5 mm and 5 mm penetrations were obtained for 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.

### 5.8 Unconfined Compressive Strength




**Graph No.-08 Effect of brick powder on Unconfined compressive strength of BCS**

Graph no.- 08 shows the comparison of UCS value of virgin BC soil with BC soil mixed with 6%, 8%, 10% and 10% 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).

## 6. 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 cumulative number of standard axles is estimated as 20 msa. The design thicknesses of 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.-10, 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 |

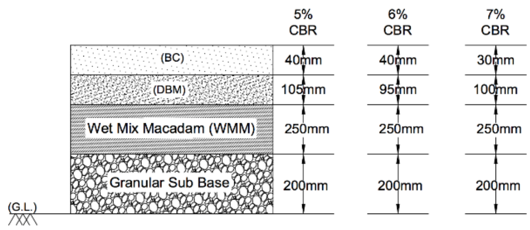



**Figure No.3 Pavement composition with thickness of each layer for Different CBR values**

## 8. Cost evaluation of pavements

### 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/- |

## 9. CONCLUSION

**1.** On the basis of study and experimental investigations it was observed that the properties of black cotton soil effectively improved by adding different percentages of brick powder content. In this research varying percentage (6%, 8%, 10%, 12%) of brick powder was used to stabilize the black cotton soil. Conclusions which were drawn from this study are listed below:

2. It was observed that on addition 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. With increase in addition of brick powder the plasticity index of soil decreases from 39.33% to 12.18% at brick powder percentage of 12%. For further increase in brick powder there is no marginal improvement 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 comes in contact with 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 maximum dry density from 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. The Unconfined Compressive Strength (UCS) of the soil with varying brick powder content indicated an increasing graph. Results shows that there is an increase in the unconfined compressive strength of the soil from 0.45 kg/cm$^2$ for virgin soil to 1.3 kg/cm$^2$ for 12% brick powder content.
9. The maximum CBR value was obtained as 6.54%, 2 times the CBR value of the virgin soil (3.08%). This maximum CBR value is obtained with 10% brick powder content and hence 10% brick powder content is taken as the optimum percentage of brick powder for stabilizing the 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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