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A Review Paper on Effect of Curing On Cement Stabilized Black Cotton Soil

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ABSTRACT

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This Black cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the Black cotton soils (BC soils) have been a challenge to the highway engineers. It is observed that on drying, the black cotton soil develops cracks of varying depth. As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. Black cotton soil (BC soil) is a highly clayey soil. It is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This poses serious problems as regards to subsequent performance of the road. Moreover, the softened sub grade has a tendency to up heave into the upper layers of the pavement, especially when the sub-base consists of stone soling with lot of voids. Gradual intrusion of wet Black cotton soil (BC soil) invariably leads to failure of the road. Cement or hydrated lime in the range of 3 to 5 percent. This technology has been found 20-30% cheaper than conventional WBM construction.

Keywords: *Compressibility, Shrinkage, Settlement, Black Cotton.*

INTRODUCTION

Black cotton soils are inorganic clays of medium to high compressibility and form a major soil group in India. They are characterized by high shrinkage and swelling properties. This Black cotton soils occurs mostly in the central and western parts and covers approximately 20% of the total area of India. Because of its high swelling and shrinkage characteristics, the Black cotton soil (BC soils) has been a challenge to the highway engineers. The Black cotton soils is very hard when dry, but loses its strength completely when in wet condition It is observed that on drying, the black cotton soil develops cracks of varying depth As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. This article covers highway construction in Black cotton soils (BC soils) and also describes a case history of highway construction in highway construction in Black cotton soils. Rich proportion of montmorillonite is found in Black cotton soil from mineralogical analysis. High percentage of montmorillonite renders high degree of expansiveness. These property results cracks in soil without any warning. These cracks may sometimes extent to severe limit like ½” wide and 12” deep. So building to be founded on this soil may suffer severe damage with the change of atmospheric conditions. Black cotton soil (BC soil) is a highly clayey soil. It is so hard that the clods cannot be easily pulverized for treatment for its use in road construction. This poses serious problems as regards to subsequent performance of the road. Moreover, the softened sub grade has a tendency to up heave into the upper layers of the pavement, especially when the sub-base consists of stone soling with lot of voids. Gradual intrusion of wet Black cotton soil (BC soil) invariably leads to failure of road.

The roads laid on Black cotton soil (BC soil) bases develop undulations at the road surface due to loss of strength of the sub grade through softening during monsoon. The black color in Black cotton soil (BC soil) is due to the presence of titanium oxide in small concentration. The Black cotton soil (BC soil) has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in color. The physical properties of Black cotton soil (BC soil) vary from place to place. Its engineering properties are given in Table 1.40 to 60% of the Black cotton soil (BC soil) has a size less than 0.001 mm. At the liquid limit, the volume change is of the order of 200 to 300% and results in swelling pressure as high as 8 kg/cm^2/ to 10 kg/cm^2. As such Black cotton soil (BC soil) has very low bearing capacity and high swelling and shrinkage characteristics. Due to its peculiar characteristics, it forms a very poor foundation material for road construction. Soaked laboratory CBR values of Black Cotton soils are generally found in the range of 2 to 4%. Due to very low CBR values of Black cotton soil (BC soil), excessive pavement thickness is required for designing for flexible pavement. Research & Development (R&D) efforts have been made to improve the strength characteristics of Black cotton soil (BC soil) with new technologies.

APPLICATIONS

Soil stabilization is used in many sectors of the construction industry. Roads parking lots, airport runways, building sites, landfills, back fills, embankments and soil remediation all use some form of soil stabilization. Other applications include waterway management, mining, and agriculture.

Soil Type

This refers primarily to the particle size distribution and the chemical composition of the soil.

Particle Size Distribution Limits

Maximum size 3 inches.

Passing 3/16 inch BS sieve >50%

Passing 0.425 mm BS sieve >15%

Passing 0.075 mm BS sieve <15%

BS Plasticity Test Limits

Liquid limit <40%

Plasticity index <18%

- Soils that have been successfully stabilized in this country range from materials with clay contents up to 30%, requiring 12-15% of cement, to sand-clay mixtures giving high strength and durability with cement contents from 5 to 8%.
- The soil should be low in organic matter for successful stabilization since this constituent tends to reduce the strength of soil-cement. Apart from organic matter, the chemical composition of the soil is believed to be of importance only if appreciable quantities of deleterious salts are present. The harmful of these compounds is thought to be due not to a reaction affecting the setting of the cement.

METHODOLOGY

Materials Used

- Black Cotton Soil
- Cement

Soil Used

The soil was collected from Gudur and laboratory study was carried out for salient Geotechnical characteristics of soil like grading, Atterberg limits, compaction, strength and CBR.

Engineering Properties

Compaction Test

The relationship between the dry unit weight and moisture content of unreinforced and reinforced soil specimens was investigated using the procedure described in

These are two types

- IS Light Compaction
- IS Heavy Compaction

This can done according to IS 2720(part 8).In IS light compaction, the compaction mould should be filled with soil in 3 layers, for each layer 25 blows are given with 2.6kg hammer at a drop of 310mm.In IS heavy compaction, the compaction mould should be filled with soil in 5 layers, for each layer we are giving 25 blows with 4.89kg hammer at a drop of 450mm.

Need and Scope

It is a quantitative test. Proctor developed this test in 1933. In situ density of the soil has to be known before the bearing capacity or settlement characteristics are worked out. Similarly in case of earth dams and embankments, whether the soil has been compacted to a specified value of dry density or not has to be known for further continuation of work. Distinctly two different unit weights or densities are often referred in soil mechanics. The total or bulk unit weight is the ratio of weight of soil including water to the total volume which includes the air volume as well. The dry unit weight is the ratio of solids to the total volume plus volume of air, as water is not present.

Unconfined Compression Test

The unconfined compressive strength is defined as the ratio of failure load to cross section area of the soil sample if it is not subjected to any lateral pressure. The samples were prepared by static compaction method to achieve maximum dry density at optimum water content. The mould consists of steel device with an internal diameter of 38 mm and height of 76 mm. This is the simplest quickest test for determining cohesion and shear strength of cohesive soils. These values are used for checking the short term stability of foundation and slopes, where rate of loading is fast but drainage is very slow Soil consistency can easily be known from the value of unconfined compressive strength. The test was conducted using unconfined compression test apparatus at a strain rate of 1.25 mm/min. The specimen to be tested was placed centrally in between the lower and upper platform of the testing machine. The proving ring readings were noted for each 50 divisions on a deformation dial gauge. The loading was continued until three or more consecutive reading of the load dial showed a decreasing or a constant load or a strain of 20 % had been reached. Unconfined compressive test at OMC is conducted as per IS:2720 (part - x).

California Bearing Ratio

The California Bearing Ratio test is conducted for evaluating suitability of the sub grade and the materials used in sub-base and base of a flexible pavement. The plunger in the CBR test penetrates the specimen in the mould at the rate of 1.25 mm per minute. The loads required for a penetration of 2.5mm and 5mm are determined. The penetration load is expressed as a percentage of the standard loads at the respective penetration level of 2.5mm or 5mm.

$$CBR = \frac{Penetration\,load}{Standard\,load} \times 100$$

The CBR Value is determined corresponding to both penetration levels. The greater of these values is used for the design of the pavements.

RESULTS AND DISCUSSION

Soil Properties

The soil used for current study has been taken from Gudur. It is collected from a depth of 1.5m. Tests are conducted to determine the Index properties, engineering properties as per Indian standard.

Table1. *Engineering properties of soil*

Property	Values
Gravel (%)	8.61
Sand (%)	14.35
Fines (%)	77.04
Liquid Limit (%)	49
Plastic Limit (%)	33.33
I.S Classification	CI
Specific gravity	2.04
Modified Procter test	
(OMC) (%)	14
(MDD) (g/cc)	1.385
Unconfined compression strength (kPa)	14.22
Cohesion (C)	7.11
Angle of internal friction (Ø)	16
California Bearing Ratio	3.705

Cement Properties

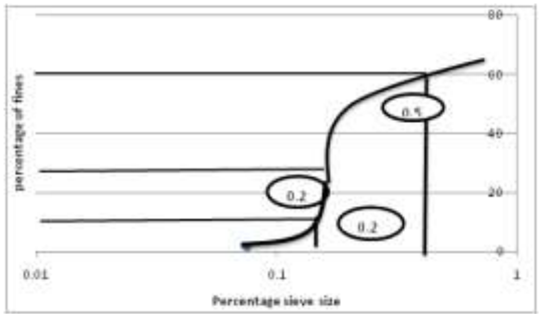
Table4.2. *Properties of Cement*

Normal Consistency	35%
Initial Setting Time	30min
Final Setting Time	420min
Specific Gravity	3.20
Fineness	7.75%

Test Results

Grain Size Distribution Curve

The Grain size distribution is carried out by conducting wet Sieve Analysis. The test was carried out according to IS: 2720(part-IV). The set of sieves according to IS: 2720 are 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.425mm, 0.3, 0.15mm and 0.075mm.From the analysis the values are plotted in the grain size distribution curve, shown in the fig 4.4.1From the graph we find that the soil is uniform graded soil.

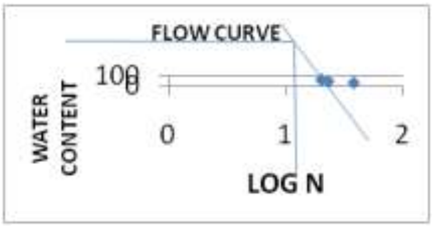


Graph 4.3.1 Grain size distribution curve

Liquid Limit and IS Classification of Soil

Liquid limit depends up on the clay content, stronger the surface charge & thinner the particle, the greater will the amount of adsorbed water and therefore higher is the liquid limit.

This is conducted as per IS: 2720 (PART V).And classify the soil as perIS: 1498- 1970 using plasticity chart. A graph plotted from this experiment is shown in figure below.



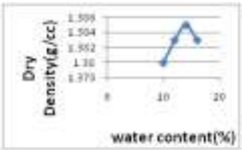
Graph 4.3.2 Flow curve

Effect on Compaction Characteristics

IS light compaction tests were carried out on black cotton soil with varying cement content in order to study variation in optimum moisture content and maximum dry density. The cement were mixed in the soil by hand till uniform mixing was obtained. The cement were mixed in varying proportions of3%, 6%,9% and 12% of dry weight of the soil. The relationship between moisture content and dry density was obtained for soil specimens with cement contents of 3%,6%, 9% and 12%. This is represented in Fig 4.1.From figure Fig.4.1 it is observed that there is no significant effect on moisture content. The variation of OMC with % cement is depicted in Fig.4.2. The variation of MDD with % cement is given in Figure 4.3. The results for OMC and MDD with cement % are given in Table 4.3 and Table 4.4

Table4.3. 3. *Variation of compaction characteristics*

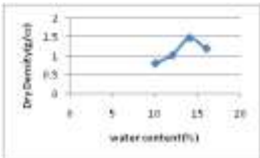
Water Content	Dry Density
10	1.38
12	1.383
14	1.385
16	1.383



OMC & MDD of B.C from Modified Proctor Test

Table4.3.4. *Variation of compaction characteristics with 3% cement.*

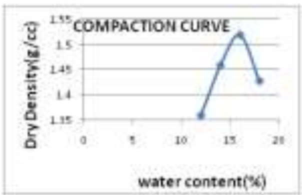
3% Cement	
Water Content	**Dry Density**
0	0.81
2	1.02
4	1.468
16	1.196



4.3.5 OMC &MDD for 3% cement graph

Table4.3.5. *Variation of compaction characteristics with 6% cement*

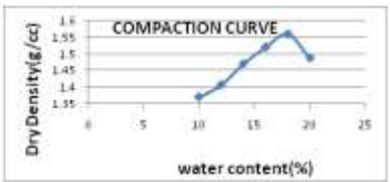
6% Cement	
Water Content	**Dry Density**
12	1.36
14	1.45
16	1.519
18	1.428



4.4.3.3 OMC &MDD for 6% cement graph

Table6. *Variation of compaction characteristics with 9% cement*

9% Cement	
Water Content	**Dry Density**
10	1.37
12	1.407
14	1.471
16	1.521
18	1.561
20	1.488

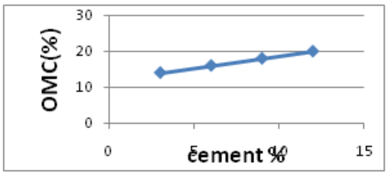


OMC &MDD for 9% cement

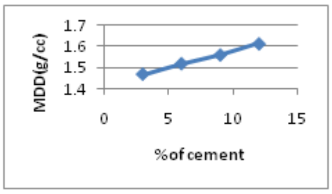
Table7. *Variation of compaction characteristics with 12% cement.*

12% Cement	
Water Content	**Dry Density**
14	**1.412**
16	**1.446**
18	**1.521**
20	**1.615**
22	**1.58**

Graph 4.4.3.5 OMC & MDD for 12% cement



Graph 4.4.4 *Variation of OMCs' with different percentages of cement*



Graph 4.4.5 *Variation of MDDs' with different percentages of cement*

As from the above tables and figures, the MDD values of soil cement mixes increase significantly with increasing cement content from 1.385 g/cc to 1.615 g/cc, and OMC values increase with increase in cement percentage from 14 to 20%. As cement content increases more water is needed for the hydration process.

Unconfined Compressive Strength (Kg/Cm2)

Specimen Preparation

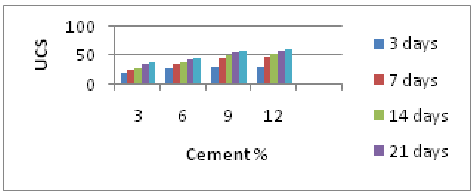
Cylindrical samples of 38 mm diameter and 76 mm height were prepared by static compaction method at their maximum dry density and optimum moisture contents. All the prepared samples were cured for 3 day, 7 days, 14 days, 21 days and 28 days by maintaining 100% humidity. Unconfined compressive strength test were conducted after completion of their curing period at a strain rate of 1.25 mm/min.

Figure.4.5. Unconfined Compressive Strength

4.6.1 Specimens of 38mm diameter and 76mm height were prepared at OMC for different percentages of cement for 3 day, 7 days, 14 days ,21days and 28 days and are tested for UCS.These are tabulated as shown below.

Table8. *Variation of UCS with different percentage of cement*

% Cement @ OMC	**Curing Period (days)**				
	3	7	14	21	28
3	18	24	27	33	38
6	26	35	38	42	46
9	29	45	51	56	58
12	30	48	52	58	61

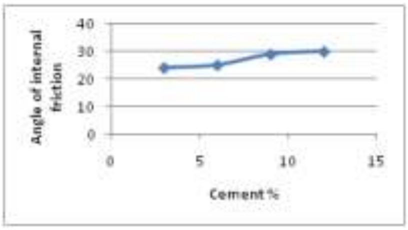


Graph 4.6.1 *Variation of UCS with different percentage of cement*

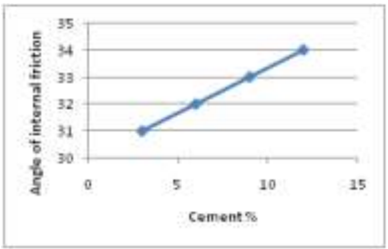
From table No:8 and fig no:4.5.1, It is noticed that the UCS values of the mixes increases with increasing cement content and curing periods.The maximum UCS value is 61 kg/cm^2 at for 12% cement at 28 days curing .From the table no:8 and fig no:4.5.1 show that variations of UCS values with percentage of cement and curing periods. Addition of cement increases UCS values. Increase in curing periods also increases UCS values. The steady increases in UCS values were obtained up to 6% and a rapid increase up to 9% was observed. Beyond 9% that increase was not rapid as earlier percentages. Similarly a steady increase in UCS values was observed up to 3 days and rapid increase was observed from 3 to 7 days and this continues beyond 7 days. Maximum values were obtained at 28 days curing. From the data it is observed that up to 6% of cement 50% values are 3 days, 70-80% values for 7 days with respect to 28 days were obtained.

After 6%, 40% values decrease for 3 days, 70% for 7 days were obtained. It shows at lower percentages of cement higher values were obtained at early days and at high percentages of cement more time is required to mobilize pozzolanic action under hydration.

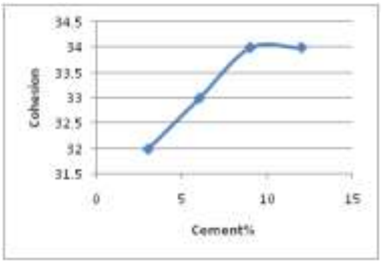
Graph 4.6.2. *Variation of cohesion with different percentages of cement*



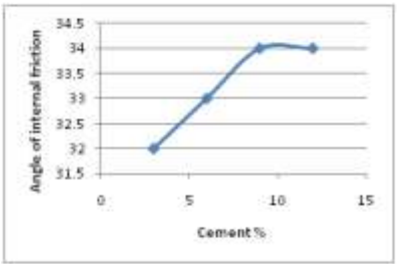
Graph 4.6.3 *Variation of angle of internal friction with different% of cement*



Graph 4.6.4 Variation of angle of internal friction with different % of cement



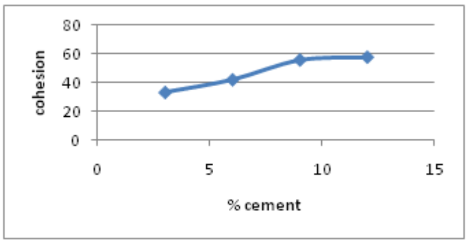
Graph 4.6.5. Variation of cohesion with different percentages of cement



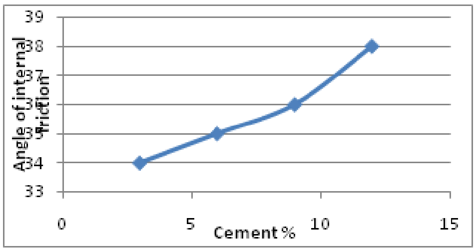
Graph 4.6.7 *Variation of angle of internal friction with different % of cement*

Table12. *Variation of cohesion values and friction angle with percentage of cement and 21 days curing*

Percentage of cement	cohesion	Angle of friction
3	33	34
6	42	35
9	56	36
2	58	38



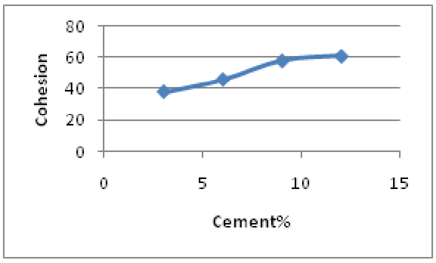
Graph 4.6.8 *Variation of cohesion with different percentages of cement*



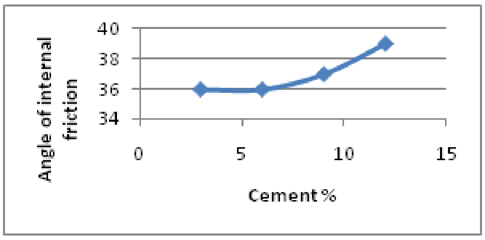
Graph 4.6.9 variation of angle of internal friction with different % of cement

Table13. *Variation of cohesion values and friction angle with percentage of cement and 28days curing*

Percentage of cement	cohesion	Angle of friction
3	38	36
6	46	36
9	58	37
2	61	39



Graph 4.6.10 *Variation of cohesion with different percentages of cement*



Graph 4.6.11 *Variation of angle of internal friction with different % of cement*

CONCLUSION

Based on the results presented in this study, the following conclusions are drawn:

- Addition of cement to black cotton soil increases the MDD
- OMC values increased with increase in cement content
- The Unconfined Compressive Strength of cement stabilized black cotton soil increased with increase of percentage of cement.
- Addition of cement to black cotton soil increases the angle of internal friction.
- The cohesion of cement stabilized black cotton soil increased with increase of percentage of cement.
- The shear strength of soil increased with addition of cement.

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