# AN EXPERIMENTAL STUDY ON STABILIZATION OF BLACK COTTON SOIL USING HDPE WASTAGE FIBRES, STONE DUST & LIME

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## ABSTRACT

An experimental investigation is carried out to study the effect of high density polyethylene fibres, stone dust and lime on index and engineering properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics, unconfined compressive strength and California bearing ratio were evaluated and their variations with content of fibres, stone dust and lime are evaluated. Various percentages of High density polyethylene fibres (0.5, 1.0, 1.5), stone dust (5,10,15) and lime (3,6,9) have been used to improve the engineering behaviour of expansive black cotton soil. One ingredient at a time has been mixed with soil and index as well as engineering properties have been determined. The optimum content of each ingredient has been determined. The optimum content of each ingredient has been mixed to greater and the same properties have been evaluated.

It has been concluded that liquid limit & plastic limit of the soil is reduced by adding of any ingredient individually. However the improvement in shrinkage limit is not suggestions. The standard proctor parameters are influenced negatively i.e. the optimum moisture content increases for 18% to 21% using HDPE and lime content while at 15% stone dust it reduced to 15% the maximum dry density is reduced for 1.71 to 1.55 gm/cm$^3$, The free swell index is reduced from 30% to 17% while swelling pressure is reduced from 0.096kg/cm$^2$ to 0.062kg/cm$^2$, The cohesion value is reduced from 0.8kg/cm$^2$ to 0.3kg/cm$^2$ while angle of internal friction is increased from 19’ to 27’. The coefficient of permeability is increased from $3.4\times10^{-07}$ m/sec to $4.72\times10^{-07}$m/sec. It is increased by increase in % of all ingredients except lime where it reduces the UCS value increases with increase in % of all ingredients. the soaked CBR value is increased for 1.53% to 7% using different ingredients individually while the same value reaches to 12% when combinations of all such ingredients at their optimum dose is mixed.

Thus, it can be concluded that stabilization of expansive black cotton soil using HDPE fibre, stone dust & lime is a good way of improving then engineering behaviour f expansive soil. Moreover it cost effective also as the cost of pavement is reduced flexible pavement.

**Keywords:** HDPE Wastage Fibre , Stone Dust and Lime.

## 1. INTRODUCTION

### 1.1 General

Foundations in expansive soils (popularly known as black cotton soils) in our country undergo alternate swelling and shrinkage upon wetting and drying due to seasonal moisture fluctuations. Usually moisture and water vapour migrates from the high temperature zones around the pavement. The difference in water contents between the interior and the exterior zones of the pavements causes uplift of the interior portion and results in mound – shaped heave of the pavement. This induces hogging moments, which are more detrimental to the safety of the pavement than sagging moments. Severe cracking might result in the pavement of the layers as a consequence. In India, about one-fifth of the land area, mostly in and around the Deccan plateau, is covered with these soils. The pockets include the states of Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Rajasthan, Gujarat, Maharashtra, Karnataka and Tamilnadu. Design of problem-free and economical foundations in these soils continues to pose challenge to civil engineers. Black cotton soils are clays of high plasticity. They contain essentially the clay mineral montmorillonite. The soils have high shrinkage and swelling characteristics. The shearing strength of the soils is extremely low. The soils are highly compressible and have very low bearing capacity. It is extremely difficult to work with such soils.

## 1.2 Black cotton soil mineralogy

Soil is defined as sediments or other accumulation of mineral particles produced by the physical or chemical disintegration of rocks plus the air, water, organic matter and other substances that may be included. Soil is typically a non homogeneous, porous, earthen material whose engineering behavior is influenced by changes on moisture content and density. Black Cotton soil is clayey soil grayish to blackish in color. Some clayey soil contains montmorillonite clay mineral which has high expansive characteristics. Montmorillonite is the most common of all the clay minerals in expansive clay soils. The mineral made up of sheet like units.

## 1.3 Problems related to 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.

- Severe structural damage,
- Disruption of pipelines and sewer lines.
- Heaving of roads and highway structures,
- Condemnation of buildings.
- Cracked driveways, sidewalks and basement floors.

Therefore, prior to construction of a road on such sub grade, it is important either to remove the existing soil and replace it with a non-expansive soil or to improve the engineering properties of the existing soil by stabilization.

## 1.4 Soil Stabilization

Soil stabilization is the process of improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest senses, stabilization includes compaction, preconsolidation, drainage and many other such processes. However, the term stabilization is generally restricted to the processes which alter the soil material itself for improvement of its properties.

Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. Soil stabilization is required to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for the construction of highways and airfields. The principles of soil stabilization are used for controlling the grading of soil and aggregates in the construction of bases and sub- bases of the highways and airfields.

The term soil stabilization means the improvement in the properties of poor soils by the use of controlled compaction; proportioning and the addition of suitable admixtures or stabilizers. Soil stabilization deals with mechanical, physic-chemical and chemical methods to make the stabilized soil serve its purpose. The stabilization process, essentially involve excavation of the in-situ soil, treatment to the in-situ soil and compacting the treated soil. As the stabilization process involve excavation of the in-situ soil, this technique is ideal for improvement of soil in shallow depths such as pavements.

## 2. EXPERIMENTAL PROGRAM

## Material Used

### 2.1 Black Cotton Soil

Soil stabilization is carried out for weak soils having low strength and poor engineering properties, the mostly available black cotton soil has low strength and stability to resist load coming on it and also it has high settlement characteristics. For our project work we collected Black cotton soil sample from SGSITS campus, Indore region. About 175 Kg soil sample was brought by us to soil mechanics lab for carrying out our project work.

**Table 2.1 Physical Properties of Black Cotton Soil**

| TESTS | PROPERTIES |
|---|---|
| OMC | 18% |
| MDD | 1.71gm/cc |
| CBR(Unsoaked) | 3.00 |
| CBR(Soaked) | 1.53 |
| UCS | 2.41kg/cm$^2$ |
| Free Swell Index | 30% |
| Swelling Pressure | 0.096kg/cm$^2$ |
| Liquid Limit | 55% |
| Plastic Limit | 32% |
| Shrinkage Limit | 12.10% |

### 2.2 High Density Polyethylene Wastage Fibres

In recent years the uses of fibres in various fields have gained much importance. Several researches on soil reinforced fibres have been reported. The research on fibre-reinforced soils demonstrated that this material might be a practical and cost effective technique for reinforcement of sub grade soils in flexible pavements. Fibres are used to evaluate a methodology for preventing crack developments in clays due to desiccation by the use of short polymeric fibres. Such elements are available as short polyethylene fibres.

An investigation was conducted and from the results obtained, there is potential for the use of fibre reinforcing in clays as it is increasing the strength of the clay by reducing desiccation cracking. It is suggested that the reinforcing fibre concept might be improved if longer fibres with a different texture or surface coating were used. Fibers are also used as reinforcement for water contaminant soil liners.

**Table 2.2 Physical Properties of Fiber.**

| Component | Weight (%) |
|---|---|
| Silica | 70.74 |
| Aluminium Dioxide | 20.67 |
| Ferric Oxide | 2.28 |
| Magnesium Oxide | 1.57 |

### 2.3 Stone Dust

Pulverized stone used in the construction of walkways or other stable surfaces. The dust is mixed with soil and compacted or used with gravel to fill spaces between irregular stones. Stone dust is a by-product of stone crushing operations.

The building stones are obtained from rocks. These rocks have a distinct plane of division along which stones can easily split. The plane is known as the natural bed of stone and it thus indicates the plane or bed on which the sedimentary stone was originally deposited. The natural bed of stone need not necessarily be horizontal. For sedimentary rocks, it is easy to observe and locate the natural bed as it lies along the plane of stratification. For igneous rocks, the natural bed is of little significance or importance and it is also difficult to determine.

**Table 2.3 Chemical Properties of Stone Dust**

| Component | Weight (%) |
|---|---|
| Cao | 3.5 – 40 |
| $Al_20_3$ | 0.5-40 |
| Mgo | 2.5-25 |
| $Si0_2$ | 1-12 |
| $S0_3$ | 0.23-3 |
| Available Alkalis | 0-4 |

## 2.4 Lime

Hydrated lime was used as stabilizing agent in this research. Major chemical constituent of lime is calcium hydroxides [$Ca(OH)_2$]. Lime stabilisation is done by adding lime to a soil. It is useful for stabilisation of clayey soils, When lime reacts with soil, there is exchange of cations in the adsorbed water layer and a decrease in plasticity of the soil occurs. The resulting material is more friable than the original clay, and is, therefore, more suitable as subgrade. Lime is produced by burning of lime stone in kilns. The quality of lime obtained depends upon the parent material and the production process.

**Table 2.4 Chemical Properties of Lime.**

| TEST | PROPERTIES |
|---|---|
| Tensile Strength | 553-759 mpa |
| Young's Modulus | 3450 mpa |
| Specific Gravity | 0.9 |
| Melting Point | 160-170 $^{0C}$ |
| U V Resistance | Poor |
| Acid Resistance | Very Good |
| Alkali Resistance | Good |
| Dispersion | Good |

## 3. OBJECTIVES OF STUDY

- To analyze property of soil such as Atterberg's Limits, standard proctor Compaction, Free Swell Index, swelling pressure, shear parameters, permeability, UCS and CBR.
- To analyze the effectiveness of optimum value of ingredients as an admixture to stabilize the Black Cotton soil for the sub-base.

- Design the pavement thickness compositions for untreated black cotton soil and treated black cotton soil with optimum value of ingredients.
- To analyze the costs of pavement for untreated black cotton soil and treated black cotton soil with optimum value of ingredients.

## 4. RESULTS AND DISCUSSIONS

Fibre is mixed in various percentage of 0.5,1.0,1.5 with plain soil, stone dust is mixed in various percentage of 5,10,15 with plain soil, and Lime is mixed in various percentage of 3,6,9 with plain soil. There tests on find out optimum value of all the materials and mixed with combination of fibre(1%) ,stone dust(10%) and Lime(6%) with plain soil.

laboratory tests were conducted on Black cotton soil and stabilized soil such as show in below

- Standard proctor compaction.
- California Bearing Ratio.
- Unconfined Compressive Strength.
- Atterberg's limits.
- Free swell index
- Swelling pressure.
- Direct shear parameters.
- Permeability.

### 4.1 STANDARD PROCTOR COMPACTION

compaction tests were conducted on the fibres, stone dust and lime mixes on plain soil of varying percentage and evaluated to the maximum dry density (MDD) values and optimum moisture content (OMC) values.

### 4.2 CALIFORNIA BEARING RATIO

The CBR tests were conducted on the fibre ,stone dust and lime mixes on black cotton soil samples. It is noted that CBR value of the fibres, stone dust and lime in various proportions has increased gradually from 1.53 to 12. and materials combinations is optimum percentages of CBR value is find out. It should have CBR value 12 is considered .

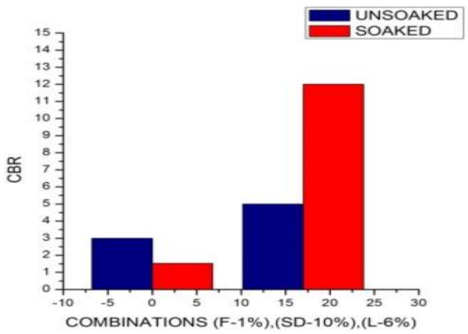


**Fig4.1 Material Comination of optimum percentage**

## 4.3 UNCONFINED COMPRESSION TEST

The UCS tests were conducted on the fibre ,stone dust and lime mixes on black cotton soil samples. It is noted that UCS value of the fibres, stone dust and lime in various proportions has increased gradually from 1.41kg/cm$^2$ to 5.82kg/cm$^2$ and materials combinations is optimum percentages of UCS value is find out. It should have UCS value 5.82 kg/cm$^2$ is considered.

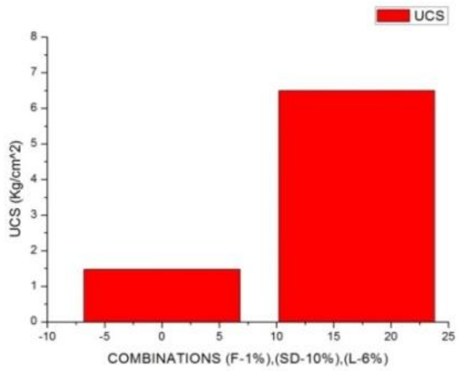


**Fig4.2 Material Comination of optimum percentages**

## 4.4 ATTEERBERG'S LIMITS

Liquid limit, plastic limit and shrinkage limit tests were conducted on the varying percentage of fibres, stone dust and lime mixes in plain soil and evaluated of the plasticity index.

## 4.5 FREE SWELL INDEX

The Free swell index tests were conducted on the fibre ,stone dust and lime mixes on black cotton soil samples. It is noted that values of the fibres, stone dust and lime in various proportions has decreased gradually and materials combinations is optimum percentages of value is find out.

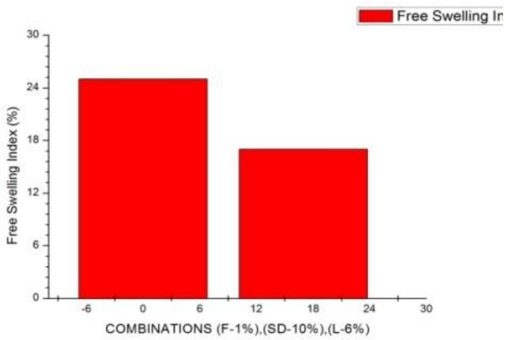


**Fig4.3 Material Comination of optimum percentages**

## 4.6 SWELLING PRESSURE

Swelling pressure were conducted on the varying percentage of fibres, stone dust and lime mixes on plain soil and evaluated to the swelling pressure of the materials.

## 4.7 PERMEABILITY

Permeability test were conducted on the varying percentages of fibres, stone dust and lime mixes on plain soil and evaluated to the permeability of the optimum percentage materials.

**Table4.1 The test results of treated and untreated soil.**

| MATERIALS | COMPACTION | | CBR | | UCS | ATTERBERG'S LIMITS | | | DIRECT SHEAR | | PERMEABI-LITY |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | OMC % | MDD gm/cc | UN SOAKED | SOAKED | $kg/cm^2$ | LL % | PL % | SL % | C $kg/cm^2$ | Φ degree | $\times 10^{-07}$ cm/sec |
| PLAIN SOIL | 18 | 1.71 | 3 | 1.53 | 1.41 | 55 | 32 | 12 | 0.8 | 19’ | 3.40 |
| 0.5% FIBER | 21 | 1.57 | 3.12 | 1.71 | 2.82 | 53 | 30 | 12 | 0.6 | 19’ | 4.72 |
| 1.0% FIBER | 21 | 1.6 | 3.53 | 1.93 | 3.48 | 52 | 28 | 11 | 0.45 | 21’ | 4.63 |
| 1.5%FIBER | 21 | 1.59 | 3.64 | 1.86 | 3.39 | 48 | 27 | 12 | 0.7 | 18’ | 4.10 |
| 5% STONE DUST | 21 | 1.64 | 3.54 | 1.74 | 4.85 | 52 | 25 | 12 | 0.5 | 20’ | 4.54 |
| 10% STONE DUST | 18 | 1.67 | 3.71 | 1.85 | 5.52 | 50 | 24 | 11 | 0.4 | 24’ | 4.34 |
| 15% STONE DUST | 15 | 1.7 | 3.60 | 1.60 | 5.37 | 49 | 24 | 11 | 0.6 | 21’ | 3.80 |
| 3%LIME | 21 | 1.59 | 3.88 | 3.30 | 3.71 | 50 | 26 | 11 | 0.5 | 22’ | 3.10 |
| 6%LIME | 18 | 1.63 | 4.27 | 5.40 | 4.95 | 45 | 28 | 11 | 0.3 | 26’ | 3.15 |
| 9%LIME | 21 | 1.55 | 4.78 | 6.99 | 4.11 | 40 | 18 | 10 | 0.4 | 27’ | 2.90 |
| 17% COMMON | **18** | **1.58** | **5.99** | **12** | **5.82** | **46** | **29** | **17** | **0.6** | **22’** | **3.11** |

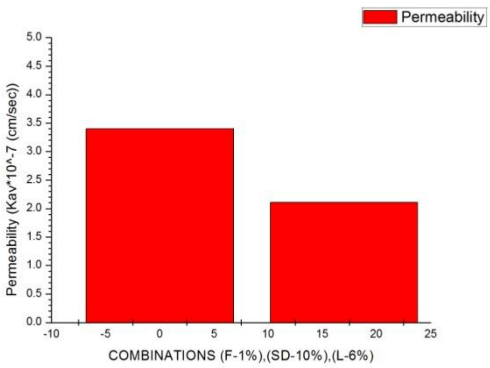


**Fig4.4 Material Comination of optimum percentages**

## 4.8 DIRECT SHEAR PARAMETERS

The Direct shear tests were conducted on the fibre ,stone dust and lime mixes on black cotton soil samples. It is noted that various proportions of materials of cohesion and internal friction are determine. Materials combinations is optimum percentages of optimum value is find out. It should have Direct shear cohesion is 0.6 $kg/cm^2$ and Internal friction angle 22’ is considered

## 5. PAVEMENT THICKNESS AND COST ANALYSIS

Pavement thickness on untreated sub-base layer is 460 mm and thickness on treated soil with optimum combination of fibre (1%), stone dust(10%) and Lime (6%) sub-base layer is 200 mm. Pavement Thickness is reduces so as cost also decrease of CBR value increases in this experiment. Composition thickness Comparisons on treated and untreated soil.

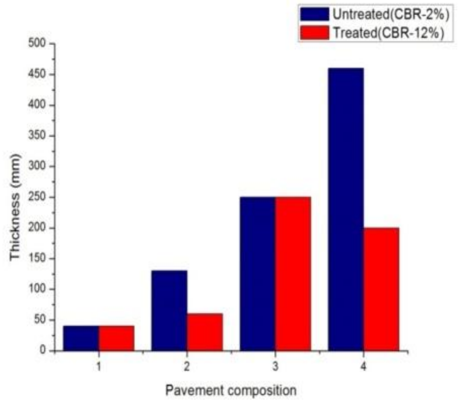


**Fig5.1 Pavement Composition Thickness Comparison**

## 6. CONCLUSIONS

A number of tests were conducted on the expansive soil mixed with different ingredients. After the analysis of test results following are the conclusions

1) Liquid limit and plastic limit of Black Cotton soil decrease with increasing % Lime. But Liquid limit and plastic limit of Black Cotton soil increase with increasing % stone dust and % fibre.

2) CBR value of Black Cotton soil is maximum with combination of fibre(1%) ,stone dust(10%) and Lime (6%).

3) UCS value of Black Cotton soil increase with varying % of fibre, stone dust and lime.

4) Permeability of Black Cotton soil decreases with increasing % of stone dust and lime.

5) By designing the two lane road treated with combination of fibre (1%), stone dust (10%) and lime (6%) having 12% CBR, it is found that reduction in sub-base layer thickness is of the order of 40% and the overall cost of 22 lacks pavement reduced.

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