# Stabilization of Black Cotton Soil using Fly Ash and Nylon Fibre

**Pallavi[1], Pradeep Tiwari[2], Dr P D Poorey[3]**

[1]*M.E.Student, Patel college of technology, Bhopal, M.P., India*
[2] *Technical Manager, Krishna Digital Material testing Laboratory, Bhopal, M.P., India*
[3]*Director, Patel institute of technology, Bhopal, M.P., India*

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**Abstract -** *Stabilization of black cotton soils with various additives has also attained lot of success and due to rapid industrialization throughout the world; the production of huge quantity of produced waste materials creates not only the environmental problem but also the disposal hazards. Many procedures have been developed to improve the mechanical properties of soil by incorporating a wide range of stabilizing agents, additives. In this paper, an attempt had been made to utilize industrial wastes such as fly ash and Nylon fibres as stabilizing agents. The effect of fly ash and Nylon fibres on certain properties of soil such as Liquid Limit, Plastic Limit, Plasticity Index, Dry density, OMC, CBR (Soaked) of clayey soil had been studied. Study the effect of varying percentage of fly ash (10%, 20%, 30%,40% ) and varying percentage of Nylon Fibre (0.25, 0.50, 0.75, 1, 1.25, 1.50) at varying aspect ratios (20,40,60,80) on properties of Black Cotton Soil and then study the combined effect of varying percentage of optimum quantity of fly ash and optimum quantity of Nylon fibre at various aspect ratio on properties of Black Cotton Soil. Results from various test determine optimum percentage quantity of fly ash and optimum value of fibre aspect ratio and fibre content and also determine the effect of optimum nylon fibre and fly ash on varying depth of sub grade. in soil with appropriate proportion improved strength*

*Keywords: Black Cotton Soil, Stabilization, Fly ash, Nylon Fibre, CBR.*

## 1.INTRODUCTION

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. The roads laid on BC soil bases develop undulations at the road surface due to loss of strength of the sub grade through softening during monsoon. Soaked laboratory CBR values of Black Cotton soils are generally found in the range of 2 to 4%. Due to very low CBR values on sub grade BC soil, excessive pavement thickness is required for designing for flexible pavement. Research & Development (R&D) efforts have been made for a long time to improve the strength characteristics of BC soil with new technologies During last 25 years, much work has been done on strength deformation behaviour of fly ash and fibre reinforced soil and it has been established beyond doubt that addition of fibre and fly ash in soil improves the overall engineering performance of soil

## 2. Objectives of the study

The present study was under taken with the following objectives:

a) To study the effect of varying percentage of fly ash on properties of Black Cotton Soil.

b) To study the effect of varying percentage of Nylon Fibre at varying aspect ratios on properties of Black Cotton Soil.

c) To study the combined effect of varying percentage of optimum quantity of fly ash and optimum quantity of Nylon fibre at various aspect ratio on properties of Black Cotton Soil.

d) To study the variation of Liquid Limit, Plastic Limit, Plasticity Index, Dry density, OMC, CBR (Soaked) of clayey soil with and without fly ash with different fibre concentration and aspect ratio.

e) To determine optimum percentage quantity of fly ash and optimum value of fibre aspect ratio and fibre content.

f) To determine the effect of optimum nylon fibre and fly ash on varying depth of sub grade.

## 3. Characteristics of B.C. Soil

Black cotton soils are generally reddish brown to black in color and occur from 0.5m to 10m deep and have high compressibility. The generally observed characteristics of black cotton soils are recorded in table below -

Table 1: Characteristics Raw soil sample of Black Cotton Soils

| | |
|---|---|
| Specific Gravity | 2.55 |
| Grain Size Distribution | |
| Sand (%) | 7.80 |
| Silt and Clay (%) | 92.20 |
| Maximum Dry Density (gm/cm3) | 1.57 |
| O.M.C. (%) | 18.20 |
| Liquid Limit (%) | 71.20 |
| Plastic Limit (%) | 30.50 |
| Plasticity Index (%) | 40.70 |
| CBR (%) | 1.71 (Soaked) |
| IS Classification | CH |

## 4. LITERATURE REVIEW

M. Bagra (Aug 2013) In this experimental study was conducted on locally available (Doimukh, Itanagar, Arunachal Pradesh, India) soil stabilized with Jute fiber. In this study the soil samples were prepared at its MDD corresponding to its OMC in the CBR mould with and without reinforcement. The percentage of Jute fiber by dry weight of soil was carried as 0.25%, 0.5%, 0.75% and 1%. In the present investigation the lengths of fiber was carried as 30 mm, 60 mm and 90 mm and two various diameters, 1 mm and 2 mm were considered for each fiber length. Tests result shows that CBR value of soil increases with the increase in fiber content. It was also observed that increasing the length and diameter of fiber further increases the CBR value of reinforced soil and this increase is substantial at fiber content of 1 % for 90 mm fiber length having diameter 2 mm.Thus there is significant increase in CBR value of soil reinforced with Jute fiber and increase in CBR value will substantially reduce the thickness of pavement subgrade.

H.P. Singh (Oct 2012) Studied soil reinforcement with jute geotextile layers. The Jute Geotextile layers are arranged within the soil sample in different combination such as 1 layer, 2 layers, 3 layers, 4 layers etc. and laoratory CBR values were determined in both soaked and unsoaked conditions corresponding to each combination of reinforcing layer .Further, these test results were compared with that of unreinforced soil. It was observed that inclusion of Jute Geotextile layer increases the CBR value of soil and this increase is maximum corresponding to 4 layers of Jute Geotextile layers. Hence there is a significant increase in CBR value of soil due to inclusion of Jute Geotextile layers as a reinforcement.

A K Choudhary et al (Dec 2010) In this study disposal of an industrial waste like fly ash formed from burning of coals in thermal power stations requires a large land area. The decreasing availability of good construction site has led to the increased use of low lying areas filled up with industrial wastes whose bearing capacity is low. In-situ treatment of such industrial waste fills; in order to improve their bearing capacity with reinforcements is a good repacement to other conventional methods of stabilization. In comparison with systematically reinforced soil, randomly distributed discrete fibre reinforced soil mimics soil stabilization by admixture and exhibit some advantages.

## 5. Methodology adopted

The literature survey of previous studies is done to find out the factors that should be considered for modeling of fiber reinforced subgrade with flyash. The experimental program will be planned to carryout various tests on subgrade soils.

Table 2 – Steps carried out for the experimental work showing different combinations of materials and the tests conducted

| Material | Tests conducted |
|---|---|
| Raw soil or Black Cotton soil only | Specific Gravity<br>Consistency Indices<br>Modified Proctor's<br>CBR Test |
| Black Cotton Soil with Fly ash | |
| Black Cotton Soil with 10 % Fly ash<br>Black Cotton Soil with 20 % Fly ash<br>Black Cotton Soil with | Specific Gravity<br>Consistency Indices<br>Modified Proctor's<br>CBR Test |
| From the results of above performed tests, the Optimum flyash percentage having the maximum CBR value is selected for next step of the experiment. | |
| Black Cotton Soil with Optimum Quantity of Fly ash and Randomly Distributed Nylon Fiber % with Aspect ratio (L/D) of 20, 40, 60 and 80. | |
| Aspect Ratio (L/D) – 20 | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.25 percent Nylon Fiber | Modified Proctor's Test<br>CBR Test<br>(Soaked) |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.50 percent Nylon Fiber | |

| | |
|---|---|
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.75 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.00 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.25 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.50 percent Nylon Fiber | |
| Aspect Ratio (L/D) – 40 | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.25 percent Nylon Fiber | Modified Proctor's Test CBR Test |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.50 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.75 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and | |
| 1.00 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.25 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.50 percent Nylon Fiber | |
| Aspect Ratio (L/D) – 60 | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.25 percent Nylon Fiber | Modified Proctor's Test CBR Test |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.50 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.75 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.00 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.25 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.50 percent Nylon Fiber | |
| Aspect Ratio (L/D) – 80 | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.25 percent Nylon Fiber | Modified Proctor's Test CBR Test |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.50 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 0.75 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.00 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.25 percent Nylon Fiber | |
| Black Cotton Soil with Optimum Quantity of Fly ash and 1.50 percent Nylon Fiber | |

### 6. Material Used

The different materials used in the present investigation are described as follows:

#### 1. Soil:-

Soil is an accumulation or deposit of earth material, derived naturally from the disintegration of rocks or decay of vegetation that can be excavated readily with power equipment in the field or disintegrated by gentle mechanical means in the laboratory. The supporting soil beneath pavement and its special under courses is called sub grade. Undisturbed soil beneath the pavement is called natural sub grade. Compacted sub grade is the soil compacted by controlled movement of heavy compactors.

The desirable properties of sub grade soil as a highway material are

- Stability
- Incompressibility
- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- Good drainage, and
- Ease of compaction

The soil used in this investigation is an expansive clay, one type of most problematic soil for sub grade constructions is used in this research work which is locally available Black Cotton Soil collected from Bhopal (M.P.)

### 2. Fly ash:-

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal bearing rock strata. The fly ash used in this research work is collected from Sarni Thermal Power Plant, M.P. India.

### 3. Fibre:-

The synthetic fiber using in the present investigation is Nylon fiber. A manufactured fiber in which the fiber forming substance is a long-chain synthetic polyamide in which less than 85% of the amide-linkages are attached directly (-CO-NH-) to two aliphatic groups.

Characteristics:-

- ✓ Variation of luster: nylon has the ability to be very lustrous, semi lustrous or dull.
- ✓ Durability: its high tenacity fibers are used for seatbelts, tire cords, ballistic cloth and other uses.
- ✓ High elongation, excellent abrasion resistance, highly resilient (nylon fabrics are heat-set)

### 7. RESULTS AND DISCUSSIONS

In the present study, Specific Gravity Test, Consistency Indices (Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI)), Modified Proctor's Test, and California Bearing Ratio (CBR) Tests were conducted on the Black Cotton Soil (Highly Clayey Soil) first by mixing with varying percentage of fly ash to stabilize the soil and then the varying percent of fly ash at which the maximum CBR is gained is selected for the next step of the experiment. The optimum percentage of fly ash at which maximum CBR is achieved is then selected and gets reinforced with varying percentage of synthetic Nylon fiber. Among these varying percentages of the reinforcement the optimum quantity of fiber required to get maximum strength is known. After that the depth of reinforcement is varied on premix fly ash and Black cotton soil mix and the changes in engineering properties are determined. For better understanding of the experiment the results are presented in the graphical form and where possible in tabular forms.

Table 3 Combined results for Clayey Soil (B.C. Soil) and B.C. Soil with varying Percentages of fly ash

| Properties | B.C. Soil | 10% fly ash+ B.C. Soil | 20% Fly ash+ B.C. Soil | 30% fly ash+ B.C. Soil | 40% fly ash+ B.C. Soil |
|---|---|---|---|---|---|
| Specific Gravity | 2.55 | 2.48 | 2.42 | 2.33 | 2.22 |
| MDD (gm/cc) | 1.57 | 1.83 | 1.90 | 1.86 | 1.85 |
| O.M.C. (%) | 18.20 | 16.70 | 17.38 | 17.52 | 17.93 |
| Liquid Limit(%) | 71.20 | 54.30 | 49.40 | 48.50 | 46.00 |
| Plastic Limit(%) | 30.50 | 28.20 | 26.00 | 23.70 | 22.50 |
| Plasticity Index (%) | 40.70 | 26.30 | 23.40 | 24.80 | 23.50 |
| CBR % Soaked | 1.71 | 4.50 | 4.95 | 3.55 | 3.38 |

From Table-3, it is cleared that with the gradual addition of fly ash in soil the properties of the soil is regularly changing and the change is high up to 20 percent addition of fly ash and after that the change is not so remarkable and starts reducing. The change in Plasticity index of value is regularly noted with the fly ash addition and PI value reduced up to 21.90 % at 40 percent fly ash mix. The maximum value of CBR achieved with varying percentages of fly ash is at 20 percent addition of fly ash is 4.95, which is 2.89 times more than the initial CBR of the Black Cotton Soil. That percentage of 20 % fly ash is taken for the next step of the experiment at which these samples undergoes tests with varying concentration of nylon fiber at different aspect ratio.

Table 4 Combined results for varying fiber concentration with 20 percent fly ash and Clayey Soil at fiber aspect ratio (L/D) of 40.

| Properties | 20% Fly ash + B.C. Soil + ( )Nylon Fiber % | | | | | |
|---|---|---|---|---|---|---|
| | 0.25 % Fiber | 0.50% Fiber | 0.75 % Fiber | 1.00 % Fiber | 1.25% Fiber | 1.50% Fiber |
| M.D.D. (gm/cc) | 1.94 | 1.97 | 1.99 | 1.97 | 1.95 | 1.90 |
| O.M.C. (%) | 17.22 | 16.82 | 16.70 | 16.88 | 16.50 | 16.90 |
| CBR (%) (Soaked) | 6.64 | 6.95 | 7.18 | 6.40 | 6.38 | 6.25 |

After the analysis of Table -4, it is concluded that the maximum favorable changes in the engineering properties of fly ash – fiber – soil mix is achieved at fiber concentration of 0.75 percent by weight of the sample at an aspect ratio of 40. The change in CBR value is remarkable which increased from 1.71 to 7.18, which are about more than 4.20 times greater than the initial CBR of the B.C. Soil. Taking the optimum combination of 0.75 % Nylon fiber with 20 % fly ash and remaining B.C. Soil, one more experiment is carried out to study the effect of providing this combination at certain depth only and remaining depth is of Soil and 20 percent fly ash mix without fiber. For that purpose the depth is divided in to 5 equal parts and each of depth 1/5 and then the variation in properties is studied. The results are also shown in tabular form in Table- 5

Table 5 Combined results for 0.75 percent Nylon Fiber with 20 percent fly ash and Black Cotton Soil at varying depth.

| Properties | (0.75 %Nylon fiber +20 % Fly ash + B.C. Soil ) | | | | | |
|---|---|---|---|---|---|---|
| | Full Depth | 4/5 Depth | 3/5 Depth | 2.5/5 Depth | 2/5 Depth | 1/5 Depth |
| MDD (gm/cc) | 1.98 | 1.82 | 1.85 | 1.88 | 1.91 | 1.92 |
| O.M.C. (%) | 16.72 | 16.78 | 16.75 | 16.70 | 16.67 | 16.66 |
| CBR (%) (Soaked) | 7.18 | 6.95 | 6.48 | 6.18 | 5.85 | 5.25 |

## 9. CONCLUSIONS AND RECOMMENDATIONS

General

In the present research work, which is described in Chapters 3 and 4, black cotton soil of Bhopal which is highly compressible in nature is mixed with the varying percentages of fly ash (taken from Sarni Power Plant, M.P.) ranging from 10 % to 40 % by weight of soil and changes on behavior of soil is studied including soaked CBR. The combination of soil and fly ash that gave maximum CBR value is regarded as the optimum percentage of fly ash i.e. less than or more than this percentage of fly ash addition in soil, reduces the CBR value. Now, this optimum percentage of fly ash mixed soil is added with varying percentage of nylon fibre of 0.40 mm diameter. The percentage of fibre content varied from 0.25 % to 1.50 % on different aspect ratios of 20, 40, 60 and 80 and soaked CBR value in each case was determined. The percentage of fiber giving maximum strength at specific aspect ratio is identified and termed as optimum percentage of nylon fiber.

5.2 Conclusions

The conclusions drawn from these studies are as follows:-

1. The consistency indices value of the black cotton soil reduces with mixing of fly ash. Initially the LL, PL and PI values of raw soil are 71.20%, 30.50 % and 40.70 % respectively which on mixing fly ash in ranges from 10 % to 40 % gradually decreased. With 40 % addition of fly ash to the soil, the LL, Pl and PI values are obtained as 45.50%, 23.60 % 21.90 % respectively. Thus, the soil plasticity is reduced on mixing of fly ash and the soil became less problematic.

2. The mixing of fly ash has pronounced effect on compaction characteristics also. In Modified Proctor's Compaction Test, the MDD value of raw soil is achieved as 1.57 gm/cc at OMC of 18.20 %. It got increased to 1.90 gm/cc at OMC of 17.38 % on 20% addition of fly ash. However, further addition of fly ash causes reduction in MDD.

3. The soaked CBR value of the raw soil is 1.71 and after mixing of fly ash in the soil, there is remarkable change in CBR value. The addition of 20 % fly ash increased the CBR value from 1.71 to 4.95, but further addition of fly ash caused decrease in CBR value.Thus, the optimum quantity of fly ash i.e., after which the CBR value starts decreasing, is 20 %.

4.When the soil is mixed with optimum quantity of fly ash and Nylon Fibre of 0.40 mm diameter at different aspect ratio and fibre content the results obtained are-

i. At aspect ratio of 40 with 0.75 % fibre content in 20 % fly ash mixed soil, the maximum value of CBR is achieved which is 7.18. It is 4.20 times greater than the CBR value of raw soil.

ii.Irrespective of the aspect ratio, the soaked CBR value of the fly ash mixed soil increases up to 0.75 % fiber content and after this value it starts decreasing.

5. Thus for the black cotton soil used in the present study, the optimum quantity of fly ash and Nylon Fibre are 20 % and 0.75 % (at aspect ratio of 40) respectively for achieving maximum soaked CBR.

6. CBR tests were also carried out for the combination of fly ash mixed soil and the fly ash nylon fibre mixed soil. The Top portion of mould was filled with the optimum mix of Nylon Fibre, fly ash and soil and bottom is filled with only optimum percentage of fly ash and the soil. It is found that a combination of ½: ½ gave CBR as 6.18 which is an impressive value as the CBR of raw soil is only 1.71. Thus mixing of fibers only in the top portion of fly ash mixed soil would be an economical proposition in construction of road in poor black cotton spoil areas.

5.3 Recommendations for further study

The present study was carried out on Black cotton soil of low compressibility and optimum value of Nylon fiber and fly ash is calculated. Further study may be taken up on other weak soils like silt etc. and other fibers may be used to study the effect of them on the properties of soils. Combined effect of other admixtures like lime, bitumen, chemicals etc. with different type of fibers can be studied.

## REFERENCES

[1] S Murugesan. "A Study of Fibres as Reinforcement for Subgrade of Flexible Pavement".

[2] Dean, R. Freitag. (1986), "Soil Randomly Reinforced with Fibers", Journal of Geo- technical Engineering, ASCS, Vol.112, pp.823-826..

[3] Donald, H.G., and Ohashi, H., (1983), "Mechanics of Fiber Reinforced in Sand", Journal of Geo-technical Engineering, ASCS, Vol.109, pp.335-353..

[4] Zachary G. Thomas (2002), "Engineering Properties of Soil-Fly Ash Subgrade Mixtures", Graduate Research Report, Lowa State University, Ames, Lowa.