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A STUDY ON STRENGTH CHARACTERISTICS OF SOIL REPLACED WITH PONDASH AND REINFORCED WITH COIR FIBRE

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ABSTRACT

Over the last few years, the construction of highways and roads has taken a boost. This requires a huge amount of natural soil to excavated or to be deposited which is an environmental issue and economical too. These issues motivates in development of alternative methods and thus leads to the reuse of suitable industrial by products. Pond ash is one such by product. Expansive nature of black cotton soil generates lot many problems in pavement construction. Thus for good performance and long life of road it is important to improve the properties of black cotton soil. This study deals with improving the properties of black cotton soil through addition of Pond ash and naturally available coir fibre which is an environmental friendly option. During this work, a series of tests such as CBR test, compaction test and Unconfined compression test were carried out . Percentage of pondash varied from 20, 40, 60 and 80 % whereas percentage of fibre varied from 0.50, 0.75, 1 and 1.5%. Results of laboratory investigation revealed that 60% pondash, and 1% of fibre were optimum for the improvement of strength characteristics of soil stabilization. Flexible Pavement design are also done for both stabilized and non stabilized soil subgrade and the results were compared.

KEYWORDS: Pondash, Black cotton soil, Coir fibre, Pavement design

INTRODUCTION

Soils with low-bearing capacity can be strengthened economically for building purposes through the process of “soil stabilization” using different types of stabilizers. Soil bed should bear all generated stresses transmitted by shallows or piles. The soil often is weak and has no enough stability in heavy loading. In this regard, it is necessary to reinforce and or stabilize the soil. With the increased global demand for energy and increasing local demand for aggregates, it has become expensive from a material cost and energy use standpoint to remove inferior soils and replace them with choice, well-graded aggregates. One way to reduce the amount of select material needed for base construction is to improve the existing soil enough to provide strength and conform to engineering standards. This is where soil stabilization has become a cost-effective alternative.

Over the last few years, environmental and economical issues have stimulated interest in the development of alternative materials and reuse of industrial waste/by-products that can fulfill specification. A material such as pond ash is a residue collected from ash pond near thermal power plants. Pond ash is a non-plastic and lightweight material having the specific gravity relatively lower than that of the similar graded conventional earth material. Massive generation of pond ash by thermal power plants has become a major cause of concern for people living in and around thermal power plants. The current rate of generation of coal ash in India has reached 130 million tons per annum with about 75,000 acres of precious land under the cover of abandoned ash ponds. It is estimated that the generation of pond ash from coal fired generation units in India will reach 170 million tons per annum by the year 2012 whereas, the current rate of utilization of ash is about 35%. This leads to an ever increasing ponding area for storing ash and related environmental issues. On the other hand, the construction of highways and roads in India, which has taken a boom in the recent years, requires a huge amount of natural soil and aggregates. To meet this demand ruthless exploitation of fertile soil and natural aggregate is being adopted. This has brought the situation to an alarming state. To address these problems pond ash has been tried in the low lying areas as structural fills and

embankment construction for highways. However, due to lack of sufficient knowledge and confidence its use has not taken momentum.
In order to minimize the cost of fibre reinforced soil, locally available fibres should be considered in design. But at the same time stability and life of structure should be given prime importance. Treatment of soils with natural product offers economical, ecological and environmental benefits. For the advantages, coir fibre is a versatile product, available abundantly throughout the country, produced at cheaper costs, it is, as such a sure and economical answer. The coir fibre also has strong characteristic and durable, making it suitable for use in the cementitious matrix for high performances structural element. Flexural properties are very important for construction materials, especially when their intended applications are in area such as country road or pavement. The advantages of using natural fibre as reinforcements to improved bending strength, post crack load bearing capacity and much higher energy absorption.
In our project we economically and effectively use coir fibre as reinforcement in stabilizing expansive soil. Usage of Stabilizing agents like pondash and coir fibre, not only improves the engineering properties of black cotton soil, but also highlights an economical waste management solution. Stabilized expansive soil will considerably reduce the thickness of pavement subgrade , hence the wastage of fertile cotton soil can be minimised

OBJECTIVES

- To study the basic engineering properties of the Black Cotton Soil and Pondash.
- To know whether the industrial waste pondash can be effectively used as a stabilizing material.
- To find the optimum percentage of pondash and coir fibre .
- To study the influence of pondash content and coir fibre on OMC and maximum dry density.
- To evaluate the strength characteristics of black cotton soil replaced with pond ash and reinforced with coir fibre using UCC and CBR value.
- To design the thickness of subgrade and hence compare the thickness of both treated and untreated soil.

SCOPE OF THE PROJECT

- Almost all the researches have concentrated on utilization of fly ash but that of pond ash is scarce.
- Effective utilization of pond ash in structural fills, levees and bunds to reduce the environmental problems and to preserve the valuable top soil.
- Naturally available coir is an environmental friendly option for reinforcement.
- Using of pondash which is a waste product solves the disposal problems and towards the green environmentally without disposal materials.
- As pondash is an industrial waste the optimum usage of this material in subgrade soil stabilization will bring down the construction cost of the pavements

MATERIALS AND METHODS

The materials used for this study are blackcotton soil, pond ash and coir fibers. Fly ash and bottom ash were collected from Hindustan News Print Limited, Kottayam and coir fibres were purchased from a small scale coir unit in Kaniyapuram, Trivandrum. Blackcotton soils were collected from palakkad. Pond ash was prepared by mixing both fly ash and bottom ash in equal proportion.The coir fibre that has been used is a coconut coir fibre. The length of coir fibre taken is 12 mm and the fibre content is 0.5%, 0.75%, 1% and 1.5% by raw of sample.
The following experimental tests are done.
1. Determination Of Index Properties
1.1 *Determination of Specific Gravity* :The specific gravity of soil and pondash is to be determined by density bottle method according to IS 1720 (Part – 3/sec – 1) 1980

1.2. *Determination of Grain Size Distribution :* Grain size analysis is mainly carried out to determine the percentage of different particles in the blackcotton soil and pondash. Sieve analysis was done on the samples which passes through 4.75mm sieve and retained on 75 micron IS sieve. Hydrometer analysis were done on samples which is passing 75 micron IS sieve. Tests were done according to the IS 2720 (Part 4) – 1985

1.3. *Determination of Atterberg's limits* : Atterberg's limits for the blackcotton soil were determined by using test procedures according to IS 2720 (Part -5) 1985. The liquid limit, plastic limit and plasticity index should found as per the standards

2. Determination Of Engineering Properties

2.1.*Compaction test :* The maximum dry density and the optimum moisture content for the different soil samples are obtain by conducting the Standard Proctor compaction test. The test was carried out according to IS 2720 (Part VII) 1985

2.2.*Unconfined compressive strength tests :* Unconfined compressive strength is the load per unit area at which an unconfined cylindrical specimen of soil will fail in a simple compression test. All the specimens were of 76mm height and 38mm diameter

2.3. *California Bearing Ratio Test :* The california bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement

RESULTS AND DISCUSSION

3. Properties Of Soil Sample

To determine the general properties of the soil sample, the above mentioned tests were conducted on the soil and results are tabulated in Table :1

Table 1: Properties of Blackcotton soil

Property	Value
Specific Gravity	2.35
Atterberg Limits	
Liquid limit	53%
Plastic limit	32.7%
Particle Size Distribution	
Gravel (%)	0
Sand (%)	10.06%
Silt (%)	38.22%
Clay (%)	51.72%
Unconfined Compressive Strength (KN/m^2)	8.7
Compaction characteristics	
Optimum moisture content (%)	22%

Maximum dry density (g/cc)	1.7
California Bearing Ratio	2.7%
Permeability (cm/sec)	$4.3x10^{-4}$

The particle size distribution of blackcotton soil is shown in figure 1

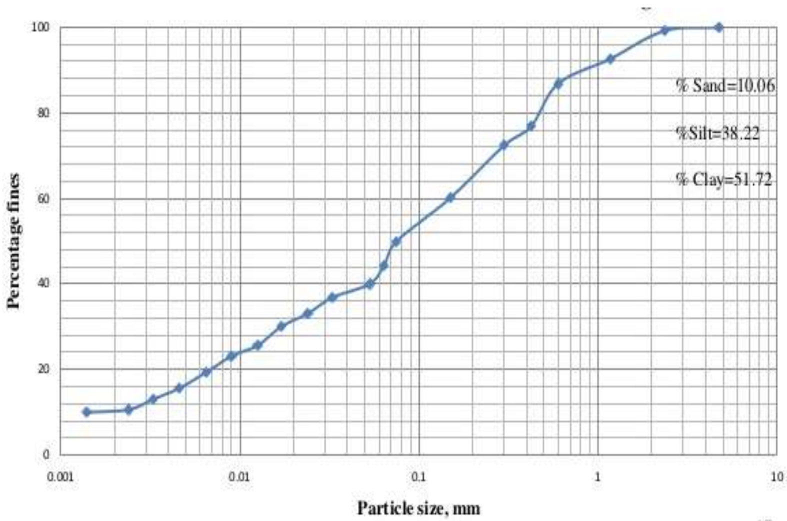

Figure 1: Particle size distribution of Black cotton soil

4. Properties Of Pond Ash

To determine the general properties of the pondash, the above mentioned tests were conducted on the pondash and results are tabulated in Table 2

Table 2: Properties of Pond ash

Property	**Value**
Specific Gravity	2.38
Atterberg Limits	
Liquid limit	-
Plastic limit	Non-Plastic
Particle Size Distribution	
Gravel (%)	0
Sand (%)	95
Silt (%)	5

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Clay (%)	0
Compaction characteristics Optimum moisture content (%) Maximum dry density (g/cc)	18% 1.82

The particle size distribution of pond ash is shown in figure 2.

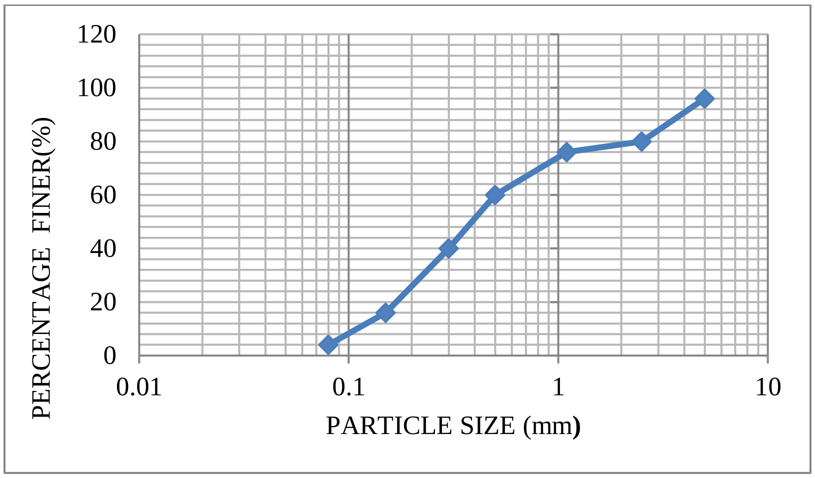

Figure 2: Particle size distribution of Pond ash

The results of Unconfined compressive strength, Compaction and CBR tests with pond ash replaced with soil at different percentage and pond ash reinforced with coir fibers are discussed in this chapter. Coir fibers are added to optimum percentage of pond ash in various fiber contents such as 0.25%, 0.5%, 0.75% and 1%.

5.U.C.C Test Results

The test was conducted with reference to IS 2720 Part10-1973. The variation in UCS with varying percentage of pondash was plotted as shown in Fig 3

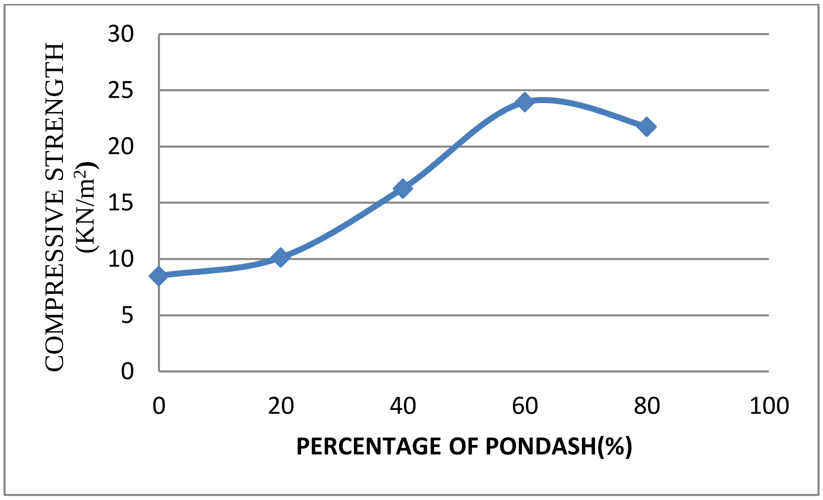

Figure 3: UCS Curve 1

By increasing the percentage of pondash, the UCS of soil goes on increasing up to 60% addition of pondash. Further addition of pondash, decreases the UCS of the expansive soil. The UCS of stabilised soil increases to 23.95 KN/m^2 from 8.7 KN/m^2 of untreated soil, when 60% pondash was replaced with soil . There is a 15 % increase in UCS of the untreated soil by the effect of pondash

The optimum percentage of pondash was fixed as 60% and the unconfined compressive strength of the expansive soil was determined at optimum pondash content and varying percentages of coir fibre. The variation of unconfined compressive strength with varying fiber contents on optimum percentage of pondash on blackcotton soil are shown in figure 4

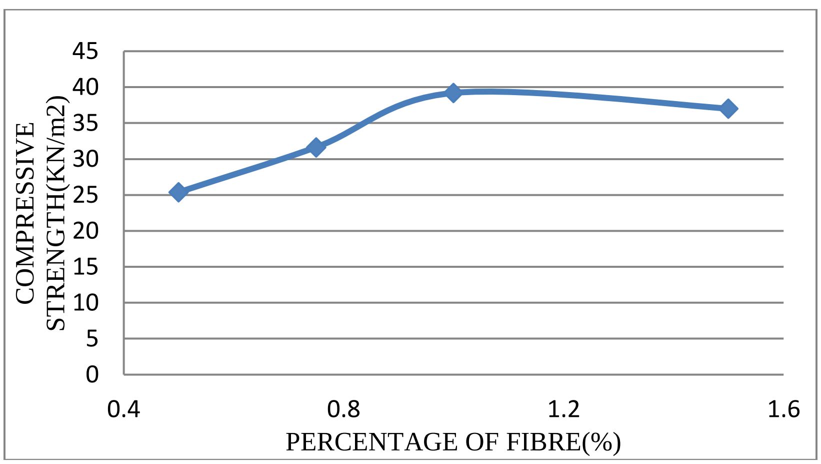

Figure 4: UCS Curve 2

It is observed that by addition of 1% of fibre, the UCS of soil increases to 39.2kN/m^2 from 23.95kN/m^2. The UCS had the highest value when the percentage of fibre was 1%. There is a 15 % increase in UCS of the untreated soil by the combined effect of pondash and coir fibre

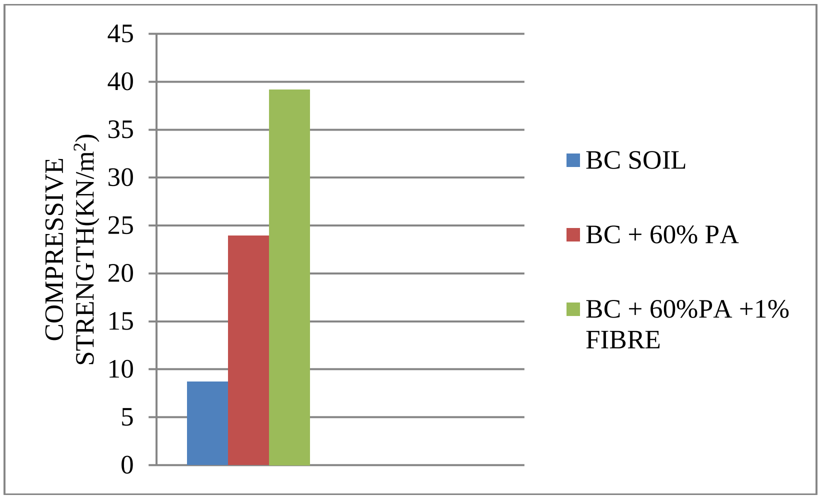

Figure 5: Comparison of UCC Values

Thus the optimum percentage of pondash was selected as 60% and that of fibre was selected as 1%.

6. Compaction Characteristics

The Optimum moisture content and dry density was determined by performing the standard proctor test as per IS: 2720(part VII) 1965. Dry density and water content for pure soil sample and reinforced sample was determined and compaction curve was plotted.

Results for compaction tests of blackcotton soil replaced with different percentage of pondash are shown in shown in Table: 3. The variation in dry density and optimum moisture content with varying percentage of pondash was plotted as shown in Fig 6

Table 3: Results of compaction of soil with different percentage of pondash

Soil Sample	Maximum Dry Density(gm/cc)	Optimum Moisture Content(%)
B.C Soil	1.87	22
B.C.Soil+20% pondash	1.95	16.9
B.C.Soil+40% pondash	1.83	19.1
B.C.Soil+60% pondash	1.76	20.79
B.C.Soil+80% pondash	1.73	23.12

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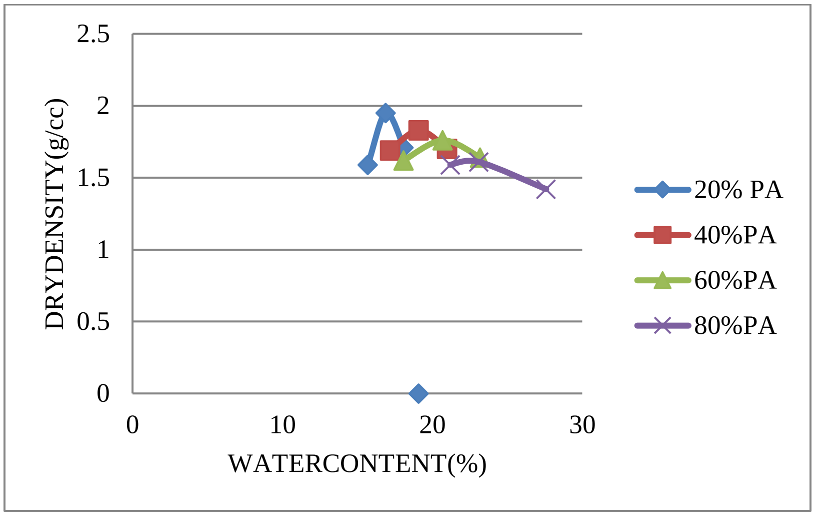

Figure 6: Drydensity Vs Watercontent graph of compacted soil with different percentage of pondash

A decrease in MDD and increase in OMC with addition of pond ash content has been obtained from the Figure 6 respectively.

The optimum percentage of pondash was fixed as 60% and the compaction tests of the expansive soil with varying fiber contents was conducted. Results for compaction tests are shown in Table:4. The variation in drydensity and optimum moisture content with varying fiber contents on optimum percentage of pondash on blackcotton soi was plotted as shown in Fig 7

Table 4: Results of compacted soil with different percentage of fibre at optimum pondash

Soil Sample	Maximum Dry Density(gm/cc)	Optimum Moisture Content(%)
B.C Soil + 60% pondash	1.76	20.79
B.C.Soil+60% pondash + 0.5% fibre	1.87	21.8
B.C.Soil+60% pondash + 0.75% fibre	1.89	20.2
B.C.Soil+60% pondash +1% fibre	1.92	19.6
B.C.Soil+60% pondash + 1.5% fibre	1.96	17.4

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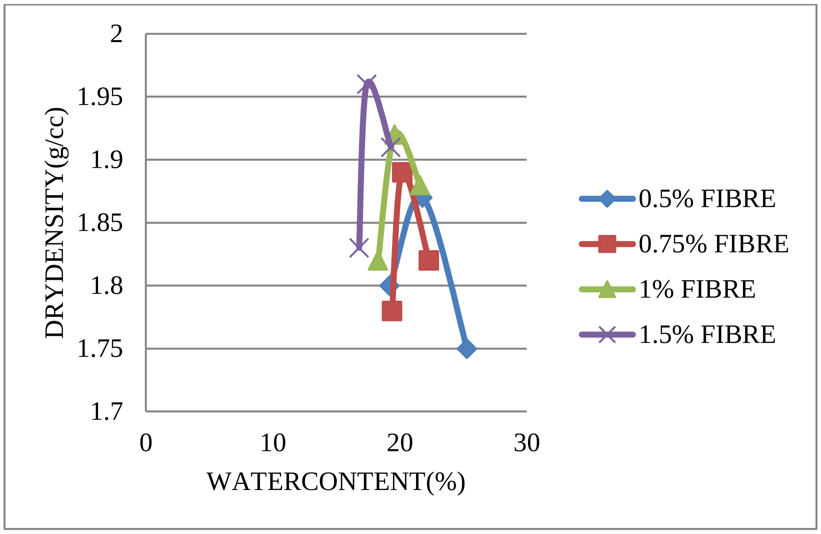

Figure 7: Drydensity Vs Watercontent graph of compacted soil different percentage of fibre at optimum pondash

The results shows that optimum moisture content decreases as percentage of fibre increases and dry density increases.. This is due to the surface texture of coir fibers. At the same time, maximum dry density increases when fiber content increases. This is due to the low density of coir fibers

7. California Bearing Ratio Test

The California Bearing Ratio is determined by performing the CBR test as per IS: 2720 (part XVI) 1979. The Unsoaked and soaked CBR tests were carried out. CBR test were most important test because as per IRC 37 the pavement thickness depends upon CBR value of soil. The test was conducted on black cotton soil and in reinforced black cotton soil (i.e. B.C. soil + 60% pondash + 1% fibre). The variation in CBR value with varying percentage of pondash was plotted as shown in Fig 8

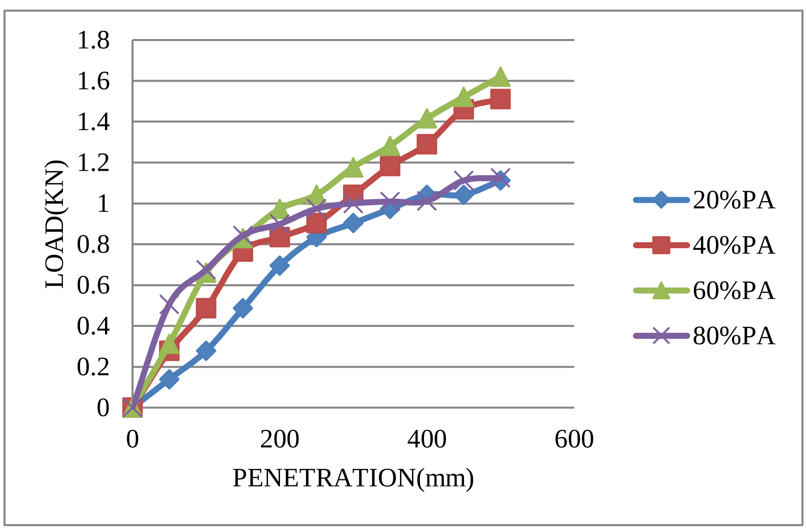

Figure 8: Load - Penetration graph of compacted soil at different percentage of pondash

The gradation of soil changes after addition of Pond ash due to which gap between soil particles is reduced. The soil particles comes closer to each other & compact effectively due to which CBR value of soil increases, result in to stability of soil increases. After addition of Pond ash up to 60 % CBR value goes on increasing, after that with further addition of Pond ash the value of CBR goes on decreasing due to change in gradation of soil particles. Hence the optimum composition of pondash to be considered is 60% by its weight.

The optimum percentage of pondash was fixed as 60% and the CBR value of the expansive soil was determined at optimum pondash content and varying percentages of coir fibre. The variation of CBR value with varying fiber contents on optimum percentage of pondash on blackcotton soil are shown in figure 9

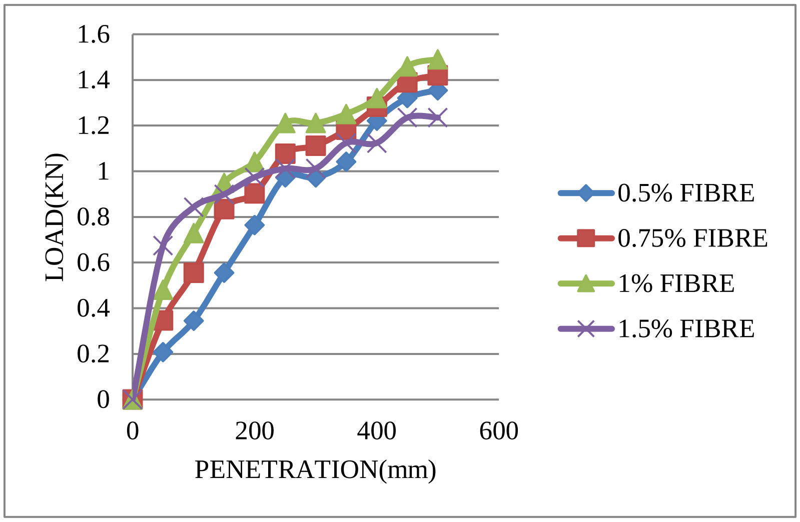

Figure 9: Load - Penetration graph of soil at different percentage of fibre with optimum pondash

The Load – Penetration graph of soaked normal black cotton soil , blackcotton soil replaced with 60% pondash and reinforced with 1% fibre are shown in figure 10.

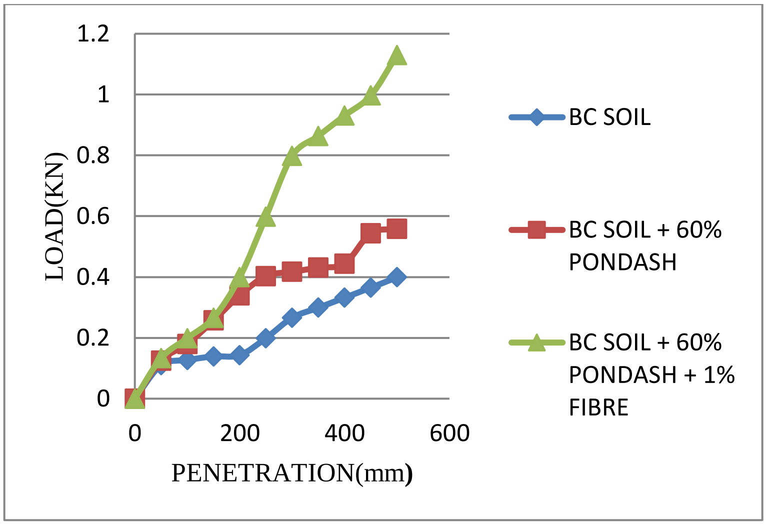

Figure 10: Load – Penetration graph of soaked normal soil and treated soil

The above results shows that CBR value has increased for treated soil(BC soil + 60% pondash + 1% fibre).

8.Design Of Pavement Subgrade

The CBR values for unsoaked and soaked black cotton soil are 5.5% and 2% respectively. The C B R values for unsoaked and soaked black cotton soil treated with optimum percentage of pondash (60%) are 7.61% and 3%. And the C B R values for unsoaked and soaked black cotton soil treated with optimum percentage of pondash and fibre (ie 60% pondash and 1% fibre) are 8.2% and 6% respectively

Thickness Design

In order to design a flexible pavement IRC: 37 – 2001 is used in which the evaluation of factors (design traffic, vehicle damage factor, design life, etc.) are considered for National highway.

Thickness design for untreated black cotton soil, treated with pondash and coir fibre is carried out. The data for pavement design are assumed for National highway which are given below and from that thickness design of flexible pavement is worked out. Data considered for design of pavement is given below.

1. Dual 4 lane divided carriageway
2. Initial traffic in each direction in the year of completion of construction = A =5200CV/day.
3. Design life = n = 15years.
4. The traffic growth rate = r =7.5%
5. Vehicle damage factor = f = 4.5
6. Distribution factor =D = 0.45

$$N = \frac{[365\times(1+r)^n - 1]}{r} \times A \times D \times F \quad (1)$$

N = 100 msa

Cumulative standard axels N= 100 is taken in to consideration according to IRC 37 - 2001

A. Composition of pavement for untreated soil from plate (IRC 37 p.g.No. 31)

The thickness of untreated soil, having CBR value 2% is worked out as per IRC :37

1. Bituminous surfacing = 50mm
2. DBM = 195mm
3. Base = 250mm
4. Sub-base = 460mm

Total pavement thickness = 955 mm

B. Composition of pavement for soil treated with 60% of pondash from plate (IRC 37 p.g. No. 30)

For untreated soil, treated with pondash, having CBR=3 % corresponding thickness design is worked out as per IRC: 37.

1. Bituminous surfacing = 50mm
2. DBM = 180mm
3. Base = 250mm
4. Sub-base = 380mm

Total pavement thickness = 860 mm

C. Composition of pavement for soil treated with 60% of pondash and 1% fibre from plate (IRC 37 p.g. No. 33)

For untreated soil, treated with tyre chips and CKD, having CBR=6 % corresponding thickness design is worked out as per IRC: 37.

1. Bituminous surfacing = 50mm
2. DBM = 140mm
3. Base = 250mm
4. Sub-base = 260mm

Total pavement thickness = 700 mm

D .Comparison of Thickness of Natural & Treated Layer:

Layer	**Untreated soil**	**Treated soil (60% pondash)**	**Treated soil (60% pondash +1% fibre)**
Bituminous Surface	50mm	50mm	50mm
DBM	195mm	180mm	170mm
Base	250mm	250mm	250mm
Sub-base	460mm	380mm	330mm
Total Thickness	955mm	860mm	700mm

From above pavement design due to increase in the CBR value of sub-grade total thickness of pavement is decreased by 255mm

CONCLUSION

- The basic engineering properties of the Black Cotton Soil and pondash was studied.
- The pond ash consists of grains mostly of fine sand to silt size with uniform gradation of particles. The specific gravity of particles is lower than that of the conventional earth materials.
- The optimum percentage of pondash in stabilization of expansive soil was found out to be 60%.
- The optimum coir fiber content was found to be 1%.
- It is observed that by addition of 1% of fibre, the UCS of soil increases to 39.2kN/m^2 from 23.95kN/m^2. There is a 15 % increase in UCS of the untreated soil by the combined effect of pondash and coir fibre.
- The maximum dry density of the expansive soil decreases and OMC increases with the addition of different percentage of pondash on expansive soil.
- The maximum dry density of the expansive soil increases while OMC decreases with the addition of fibre to pondash stabilized expansive soil.
- There is a considerable increase in CBR value of the untreated soil by the combined effect of pondash and coir fibre.
- Due to increase in the CBR value of sub-grade total thickness of pavement is decreased by 255mm.

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