Optimization of Pond Ash for Black Cotton Soil in Design of Flexible Pavement as Per IRC 37 Guidelines

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Abstract - Black cotton soil is a problematic soil which covers 20% of the Indian land. Construction of infrastructural projects-in particular roads on such soil offers greater challenge to highway engineers due to its low bearing capacity in presence of water and low resistance to moisture change due to presence of montmorillonat a type of clay mineral. Thus it increases the thickness of the flexible pavement to overcome above problem. In this investigation an attempt is made to reduce the moisture movement capacity of the black cotton soil and clay content by addition of particles which are finer than clay and behaviour as silt type- that is pond ash. From direct shear test under the normal stress of 100 kPa with curing it is found that, black cotton soil stabilized with 30% pond ash (by weight of soil) show higher strength carrying capacity. Flexible pavement is designed after conducting CBR test under soaked conduction as per Indian Road congress-37 guidelines, from the design it is found that addition of optimum pond ash to black cotton soil- pavement thickness reduces by 27% on compared with black cotton soil alone.

Key Words: Flexible Pavement, Soaked, CBR

I. INTRODUCTION

Black cotton soil causes many problems to structures constructed on that ground in general and light weight structures like road in particular due to presence of problematic mineral called montmorillonat a type of clay mineral. About 20% of the soil found in India is expansive problematic black cotton soil. Thus black cotton soil is very poor and undependable subgrade materials. The only remedial measure before using such soil for pavement subgrade is to stabilize the soil before its usage to road work. Many stabilization methods were available starting from old lime stabilization to reinforced earth. However, we are making an attempt to use the waste material from the thermal power plant as ash. But as on dated accountable research work were carried out about utilization of fly ash as stabilizing material to soil, however in thermal power plant another biggest challenge is effective disposal/utilization of pond ash. The research related to pond as is not as high as fly ash. Therefore, it is necessary to invent large scale utilization of pond ash in soil, which can be possible through pavement subgrade construction. So many researchers done notable work on utilization of pond ash to stabilize the soil. According to Girish and Sushma (2015) says that addition of pond ash to black cotton soil maximum dry density increases up to optimum percentage of pond ash beyond that density decreases. They also conclude that at their optimal combination(soil with 20% pond ash (by weight of soil) there will be improvement of California bearing ration by 1.53% on compared to other combination of soil with pond ash. Hima Latheef and Dipin (2016) says that soil treated with pond ash decreases the maximum dry density and unconfined compressive strength increases up to 60% pond ash (by weight of soil) there after trend reverses. From the above literature it is found that still some more research is required to optimize the soil with pond ash combination for arriving a concrete air mark about the density and strength relationship.

II. MATERIALS AND METHODS

Soil sample used for the present investigation was collected from Raichur at a depth of 1.5 m below the natural ground level through open pit method of direct soil exploration technique and soil passing through 425 micron Indian standard sieve exception for sieve analysis. The basic properties of the soil is shown in Table 1.0

Pond ash is an by-product obtained from the thermal power plant in Raichur Thermal Power Plant Station and the research wing of RTPS strongly appreciated the methodology proposed by us for during research in pond ash area and they are issued a encouragement letter as indicated in Photo.3.0 and the basic properties as indicated in Table 1.0 Particle size distribution of soil and pond ash is shown in Fig.1.
Table 1.0 Basic Properties of Block Cotton Soil and Pond Ash

<table>
<thead>
<tr>
<th>SI No</th>
<th>Physical parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>BCS</td>
</tr>
<tr>
<td>1</td>
<td>Colour</td>
<td>Black</td>
</tr>
<tr>
<td>2</td>
<td>Natural water content</td>
<td>8.18%</td>
</tr>
<tr>
<td>3</td>
<td>Specific gravity</td>
<td>2.44</td>
</tr>
<tr>
<td>4</td>
<td>Atterberg Limits</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Compaction characteristics</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Particle size distribution</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>UCS in KN/m²</td>
<td>129.53</td>
</tr>
<tr>
<td>8</td>
<td>Angle of shearing resistance Ø°</td>
<td>21</td>
</tr>
<tr>
<td>9</td>
<td>Cohesion (kN/m²)</td>
<td>37.27</td>
</tr>
<tr>
<td>10</td>
<td>CBR (%), soaked sample</td>
<td>2.91</td>
</tr>
</tbody>
</table>

Note: NP= Non Plastic, PA=Pond Ash BCS=Black Cotton Soil

Table 2.0 Chemical properties of Pond ash

<table>
<thead>
<tr>
<th>SI No</th>
<th>Chemicals</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SiO₂+Al₂O₃+Fe₂O₃</td>
<td>91.04</td>
</tr>
<tr>
<td>2</td>
<td>SiO₂</td>
<td>67.24</td>
</tr>
<tr>
<td>3</td>
<td>MgO</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>SO₃</td>
<td>0.19</td>
</tr>
<tr>
<td>5</td>
<td>Loss on ignition</td>
<td>3.19</td>
</tr>
<tr>
<td>6</td>
<td>Insoluble residue</td>
<td>91.22</td>
</tr>
<tr>
<td>7</td>
<td>CaO</td>
<td>3.53</td>
</tr>
</tbody>
</table>

III. METHODOLOGY

All the tests were conducted as per IS: 2720 Guidelines except for compaction test, which is conducted by using mini compaction test apparatus (Sridharan and Sivapulliah, 2005). Direct shear test is conducted under a constant normal stress of 100 kPa and the black cotton soil is mixed with 10 to 100 % pond ash (by weight of soil) and The CBR tests were conducted according to IS 2720 part-16, 1997. The soil-additives mixture were compacted to optimum moisture content and soaked in water for 4-days under a surcharge weight of 5 kg before testing.

IV. RESULTS AND DISCUSSIONS

From Fig 2.0 it is observed that addition of varying percentage of pond ash to black cotton soil reduces the specific gravity of the matrix. This is because of replacement of higher specific gravity of soil by lower specific gravity of pond ash reduces the matrix specific gravity.
Fig 2.0 Variation of specific gravity for BC soil treated with varying percentage of pond ash

From Fig 3.0 it is observed that black cotton soil stabilized with pond ash in general maximum dry density reduces and optimum moisture content increases exceptional for 10% combination. This may be due to the replacement of higher density soil particles by lower density light weight ash particles.

Fig 3.0 Variation of maximum dry density for BC soil treated with varying percentage of pond ash

Fig 4.0 Variation of optimum moisture content for BC soil treated with varying percentage of pond ash
To assess the shear strength at a constant normal stress rate of 100 kN/m² with a constant rate of 1.25 mm/min strain is applied for BC soil alone, BC soil treated with different percentage of pond ash. From Fig.5.0 it is observed that, as the percentage of pond ash in soil increases both for immediate as well as with curing the strength increases. However, it is found that soil stabilized with 30% pond ash (by weight of soil) is found to be optimum. This may be due to formation of cluster up to optimum combination and disintegration of cluster beyond the optimum combination due to more silt particle rather than clay particles.

![Graph showing shear stress vs pond ash percentage]

After direct shear test, CBR test were performed on obtained optimum proportions of soil and pond ash matrix (BC Soil+ 30% pond ash). CBR test were most important because as per the IRC-37 the pavement thickness is depends upon CBR value of soil. The CBR values obtained from the matrix of BC Soil, BC Soil and optimum pond ash as shown in below figure 6.0

![Graph showing CBR vs pond ash percentage]

**Design of flexible pavement as per IRC 37-2001 for black cotton soil stabilized with pond ash**

Design is to done based on IRC: 37-2001, the crust thickness is calculated for CBR value of treated and untreated black cotton soil. The obtained CBR value for untreated black cotton soil is 2.91% and for treated block cotton soil with an optimum of 30% pond ash is 6.65%.

In order to design a flexible pavement IRC: 37-2001 is used in which the evaluated of factors (design traffic, vehicle damage factor, design life, etc) are considered for state highway of 2 lane.

The data for pavement design are assumed for state highway which are given below and from that thickness design of flexible pavement is carried out as per the IRC 37-2001 guidelines. Data considered for design of pavement is given below.
1. Number of lanes= 2 lane, two way traffic
2. Initial traffic in each direction in the year of completion of construction A=1200 CVPD (assumed)
3. Design life n=15 years
4. The traffic growth rate \( r = 7.5\% \)
5. Vehicle damage factor (VDF) = 3.5
6. Distribution factor D = 0.75

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

\[
N = \frac{365 \times (1 + 0.075)^{15} - 1}{0.075} \times 1200 \times 0.75 \times 3.5
\]

\[N = 3.36\text{ msa}\]

Cumulative standard axles \( N = 3.36\text{ msa} \) is taken into considering according to IRC 37-2001

A. Composition of pavement for untreated soil, having CBR = 2.91% and the corresponding thickness is worked out as per from the plate (IRC 37 pg. No 22) and the corresponding IRC chart is as shown in below fig.
1. SDBC = 25 mm
2. DBM = 60 mm
3. Base = 250 mm
4. Sub-base = 335 mm

Total pavement thickness = 690 mm

B. Composition of pavement for soil treated with optimum of 30% pond ash from plate 2 (IRC 37 pg. No 26) and the corresponding chart from IRC 37-2001 is as shown in below fig

Photo 2.0 Crust thickness chart for the CBR value of 3% and traffic range 1-10 msa (Curtsey by IRC 37-2001)
For untreated soil, treated with 30% pond ash, having CBR= 6.65 % corresponding design is worked out as per IRC: 37

1. SDBC= 25 mm
2. DBM= 50 mm
3. Granular Base= 250 mm
4. Granular sub base= 180 mm

Total pavement thickness = 505 mm

![Crust thickness chart](Photo 3.0)

Photo 3.0 Crust thickness chart for the CBR value of 7% and traffic range 1-10 msa (Curtesy by IRC 37-2001)

C. Comparison of thickness of natural and treated soil

Table 3.0 Out-lay about pavement thickness between soil stabilized with pond ash on compared with unsterilized soil

<table>
<thead>
<tr>
<th>Pavement Layer</th>
<th>Untreated BCS</th>
<th>BCS+30%PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDBC</td>
<td>25 mm</td>
<td>25 mm</td>
</tr>
<tr>
<td>DBM</td>
<td>60 mm</td>
<td>50 mm</td>
</tr>
<tr>
<td>Base</td>
<td>250 mm</td>
<td>250 mm</td>
</tr>
<tr>
<td>Sub-base</td>
<td>335 mm</td>
<td>180 mm</td>
</tr>
</tbody>
</table>

From the above Table 3.0, it is observed that black cotton soil stabilized with optimum pond ash reduces the thickness of the pavement by 27% on compared with untreated black cotton soil

V. CONCLUSIONS

Based on the above experimental investigation following conclusions were drawn
1. Addition of pond ash to black cotton soil reduces the specific gravity and increases the maximum dry density.
2. Black cotton soil stabilized with 30% pond ash (by weight of soil) improves the strength carrying capacity to a maximum extend and its improvement continues with long term curing effect.
3. Black cotton soil stabilized with optimum pond ash improves the CBR value by 128% on compared with black cotton soil alone
4. Optimum utilization of Pond ash in black cotton soil reduces the flexible pavement thickness by 27%.
VI. ACKNOWLEDGMENTS
We are very much thankful to the RTPS Research wing CASHUTEC for encouraging us to do research work on the current trend of practice and also we are thanks to Govt.SKSJTI Principle, HOD and PG Highway Technology coordinator for permitting us to do research in the area of soil stabilization using pond ash.

VII. REFERENCES

ABBREVIATION USED
BCS - Black cotton soil
CBR - California Bearing Ratio
MSA - Million Standard Axles
MDD - Maximum Dry Density
OMC - Optimum Moisture Content
PA - Pond Ash