International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 01 | Jan 2020 www.irjet.net p-ISSN: 2395-0072

A Review Paper on Enhancement of Sub Grade Strength of Black Cotton Soil using Paper Mill Sludge Ash

Karkar Ravi[1], Khushbu Gandhi[2]

[1]Student of ME Structure at Sarvajanik College of Engg & Technology
[2]Assistant Professor at Sarvajanik College of Engg & Technology, Gujrat, India

---

Abstract - *The South Gujarat is majorly having black cotton soil. This soil is considered as problematic soil as it is having a very high swelling potential and low bearing capacity. Structures/Pavements constructed directly on untreated soil face problems of settlements, development of cracks in pavements etc. Even now a day's bacterial culture is also successfully used to enhance the properties of such soil. In this project work there is an attempt to stabilize the soil using paper mill sludge ash which is a waste material and available in very large quantity.*

***Key Words*: : Black Cotton Soil, Paper Sludge Ash, Soil stabilization, South Gujarat, Highway Engineering, Soil Bearing Capacity**

1. INTRODUCTION

Major problem of black cotton soil is its expansive nature and have tendency to change volume, which may cause many causalities if structure comes in contact or constructed on black cotton soil. Soil stabilization techniques, physical, chemical, mechanical, or combined method of changing the behaviour of natural soil. Black cotton soil is most tedious soil for construction purpose which is situated in Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Tamil Nadu, Valleys of Krishna and Godavari regions of India. Increasing construction activities during recent era, demands more land with good strength characteristics for suitable outcome. In construction works, it is not possible to locate a construction land with all appropriate design requirements. However, the sites with unfavourable soil are to be modified by the various ground modification methods to manipulate its engineering properties to meet the design necessities.

In recent years, conventional method for stabilization of soil, use of waste materials as Fly ash, Bagasse Ash, Rise husk ash, etc. are in demand and showed significant improvement in the engineering characteristics of soil. Stabilization of expansive soil with different chemical additives like lime, gypsum, fly ash, bitumen, calcium chloride, Sodium silicate, etc. These components stabilize the soil and modify its properties to improve its strength include increasing the weight bearing capabilities in order to attain the stability of soil. This study was to perform a feasibility study concerning the use of Paper Mill Sludge ash to enhance the strength of the problematic pavement sub grade soil by Chemical stabilization. Black cotton soil is expansive soil, which has high swelling, high compressibility properties and low bearing capacity. The laboratory tests were conducted to know the study the influence of paper mill sludge ash on Swelling, Strength properties and Micro structural Analysis with effect of its cementitious properties.

2. MATERIALS

2.1 Black Cotton Soil

Black cotton soil is very beneficial for agriculture purpose. But on the other side in Civil Engineering aspects Black cotton soil is very troublesome, problematic and hazardous due to its high swelling and shrinkage characteristics, the black cotton soil has been a challenge to the engineers and constructions. As a sample we choose Palanpore area of Surat as a study which had a rich black soil.

2.1.1 Formation of Black Cotton Soil

From thousands of years, due to the Deccan Plateau volcanic activity from long ago. The soil is formed by the weathering of lava and cooling of lava after a volcanic eruption. The structure of soil and composition of soil is formed by lava the breakdown of igneous rocks during the volcanic action. Weathering action cause the chemical decomposition and physical disintegration of lava rocks and turn it into the black cotton soil. Montmorinolite is the key mineral in black cotton soil. Which cause its black color and the swelling and Shrinkage behavior of black cotton soil.

2.1.2 Characteristics of black cotton soil

2.1.2.1 Physical Characteristics

Physical characteristics of black cotton soil is mentioned in table below:

Table 1: Physical Characteristics

Sr. No.	Properties	Values. (in range of)
1.	Liquid Limit (%)	35-110
2.	Plastic Limit (%)	20-50
3.	Optimum Moisture Content (%)	20-30
4.	Free Swell Index (%)	40-180
5.	Specific Gravity	2.60-2.75
6.	Swelling Pressure	50-800

	(KN/m^2)	
7.	C.B.R. (soaked)	1.2-4.0
8.	Fines (<75µ)	70-100
9.	2 µ Fraction (%)	20-60
10.	Soil Classification (IS 1498:1970)	CH or MH clay/silt of high plasticity
11.	Proctor Density (Kg/m^3)	1350-1600

2.1.2.2 Chemical Characteristics

Table 2: Chemical Characteristics

Characteristic	Value
PH Value	Greater than 7 (Alkaline)
Organic Content	0.4 to 2.4 %
CaCo3	1-15 %
SiO2	50-55 %
SiO2 / Al2O3	3-5 %
Montmorillonite Minerals	30 – 50 %

2.1.2.3 General Characteristics

- The swelling and shrinkage behaviour of a soil depend upon clay minerals present in soil.
- Montmorillonite is the key mineral of Black cotton soil
- Organic matter in the form of humes makes soil more plastic and compressible.
- It swells more when wet and shrinks more when it's dry.
- It has great influence with water.

2.2 Paper Mill Sludge Ash

2.2.1 Paper Sludge

This material is a by-product of the deinking and repulping of the paper. The main recycling and treatment of paper sludge is land diffusion but the extent of landfill spread is limited. In terms of function, the paper sludge consists of cellulose fibers, fillers such as calcium carbonate combined with water. The moisture content is usually as high as 40%. The material is viscous, and difficult to dry, and may have different viscosity and roughness. Additionally, we took paper sludge from Rama paper mills, Hazira, Surat which is renowed paper mill and contains rich amount of paper sludge.

2.2.2 Paper Mill Sludge Ash

After the sludge is burned at 800 ⍰C, volatile ash can contain reactive silicon and aluminium (in the form of methane) as well as lime (CaO), which chemically contributes to the components of Portland cement. After feeding Cement-kiln, it brings calcium, silicone and aluminium - the manufacture ingredients of mixed cements.

Figure 1: Paper Sludge

Figure 2: Paper Sludge Ash

3. EXPERIMENTS AND RESULTS ON UNTREATED SOIL

Following Tests which are performing in the laboratory are given below:

1. Free swell index
2. Liquid Limit
3. Plastic Limit
4. Standard Compaction
5. California Bearing Ratio (CBR)

3.1 Free swell index

This test is useful to consider swelling properties of soil by taking reference from table below also known as free swell index of soils. "IS: 2720(Part 40)-1985- Methods of test for soils: Determination of free swell index of soil." is taken as reference.

Table 3: Free Swell Index

Free Swell Index	Degree of Expansiveness
<20	Low
20-35	Moderate
35-50	High
>50	Very High

Figure 3: Free Swell Index Apparatus

3.2 Liquid limit test

This test is essential to determine the liquid limit of soil using Casagrande apparatus. Moreover, we took "IS: 2720(Part 5)-1985- Methods of test for soils: Determination of liquid and plastic limit." as a reference.

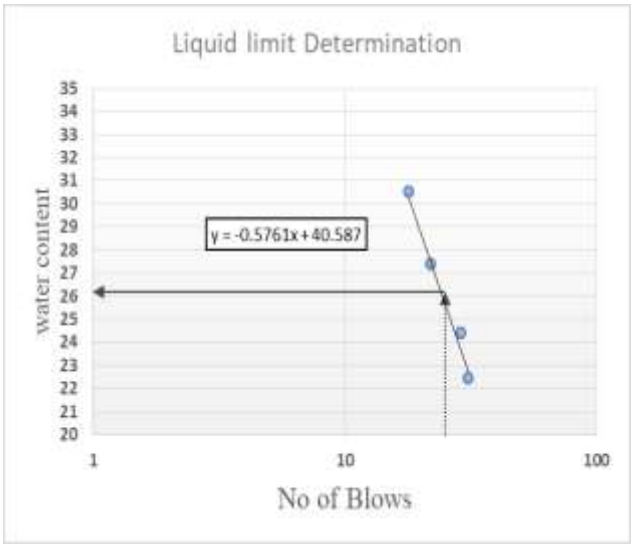

Fig 4: Liquid Limit of Soil specimen (From Graph) =26.1845

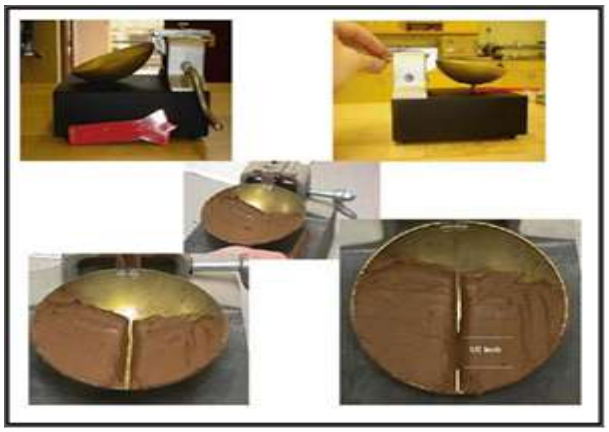

Fig 5: Casagrande Apparatus

Source: www.civilblog.org

3.3 Plastic limit test:

This is crucial to know plastic properties of black cotton soil by different water contents. Book "IS: 2720(Part 5)-1985- Methods of test for soils: Determination of liquid and plastic limit "is taken as standard

Figure 6: Rolled Cylinder for Plastic Limit test

Source: www.civilblog.org

3.4 Proctor Compaction Test

This test is crucial to check subgrade strength, compaction properties and water retaining traits of soil. Also, the main aim is to check moisture content and dry density relationship using heavy compaction or modified compaction method as per IS-2720-Part-8. Here we had found properties of untreated and treated soil mixed with paper mill sludge ash at some proportions by mass of the soil sample.

Figure 7: Soil sampling

3.5 California Bearing Test

This test is keen to determine CBR value of soil either in undisturbed or remoulded condition CBR value shows Subgrade strength of the soil sub base which is useful to know whether to add any material or not for stabilization.

Here, book "IS: 2720(Part 16)-1973- Methods of test for soils: Laboratory determination of CBR." is used as a reference. Here, this test is performed on both treated and untreated soils' value is calculated by formula

California bearing ratio = (P_T/P_S) x100

Where

P_T = Corrected unit (or total) test load corresponding to the chosen penetration curve, and

P_S = Unit (or total) standard load for the same depth of penetration as for P_S taken from standard code.

3.6 Results on Untreated Soil

Table 4: Results on untreated soil

Sr. No.	Properties	Values
1	Atterberg Limits (a) Liquid Limit (W_L) (%) (b) Plastic Limit (W_P) (%)	 26.184 21.59
2	Differential Free Swell Index (%)	42.85
3	Compaction Characteristics (a) M.D.D. (gm/cc) (b) O.M.C. (%)	 1.82 17.7
4	California Bearing Ratio Value (%) (a) 2.5 mm Penetration (b) 5.0 mm Penetration	 6.62 7.33

4. RESULTS ON TREATED SOILS

Table 5: Proctor compaction test results on treated soil

SR. No.	% Ash Added	Properties		Values
1	5%	Proctor Compaction Test	OMC	1.57
			MDD	1.77
2	7.5%		OMC	1.64
			MDD	1.81
3	10%		OMC	1.71
			MDD	1.79
4	12.5%		OMC	1.88
			MDD	1.75

Table 6: CBR test results on treated soil

SR. No.	**% Ash Added**	**Properties**	**Values**
1	5%	California Bearing Ratio Test	5.17
2	7.5%		6.46
3	10%		7.75
4	12.5%		7.7

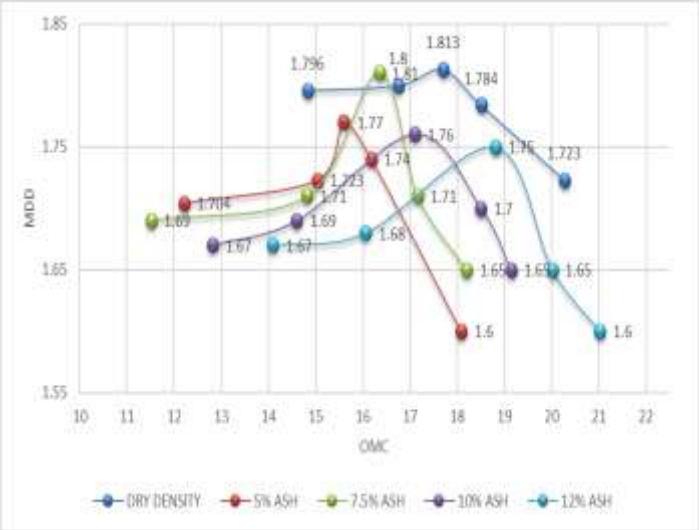

Figure 7: Proctor compaction test results on treated soil

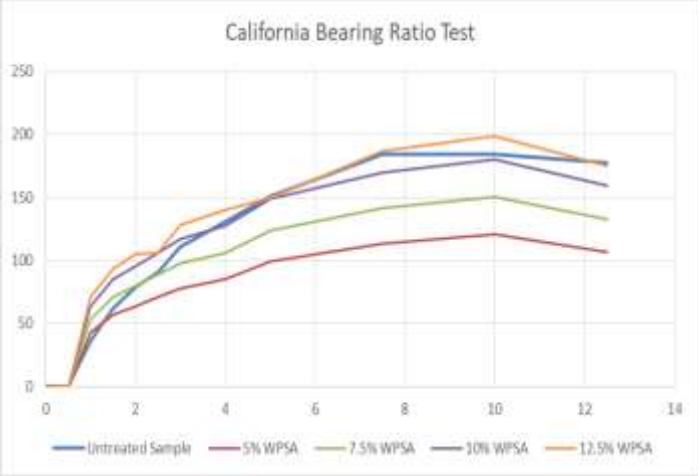

Figure 8: CBR test results on treated soil

5. CONCLUSIONS AND APPLICATIONS

The Concluding remarks from the analysis of untreated soil are as follows:

- The silt and clay concentration are higher for the soil of Palanpore, Surat.
- The Liquid Limit of the Untreated Soil is 26.1845 % which is quite unstable for construction without treatment.
- The Free Swell Index of Untreated Soil is 42.85% So, this soil was having High expansive property.
- The Untreated Soil Sample has OMC is 17.7 % and MDD is 1.82 gm/cc
- MDD is optimum at 7.5% and OMC is optimum at 12% which proves to maintain both properties one need to

add 10% of paper sludge ash in soil as per weight for excellent strength results.

- The CBR value of Untreated soil at 2.5 mm penetration is 6.62 % and CBR value for 5 mm penetration is 7.33%.
- The CBR value of Treated soil sample is increasing with adding more % of paper sludge ash up to certain limits.

Applications

- In Black cotton soil region, subgrade strength is very less. However, by adding the paper mill sludge ash into strata, subgrade strength can be increased by considerable amount up to certain limit.
- In foundation containing low bearing capacity, by adding paper mill sludge ash we can increase soil bearing capacity.
- As it is produced from the waste material application, operation and maintenance of paper mill sludge ash is very economic.
- Due to the paper mill sludge ash contains cementitious properties, product can be used in cement as binder material.

References

1. S. Iwahara, "Process for making paper sludge ash, the cement composition containing ash sludge paper Prepared by the process and the cement solid material formed by the solidification of the cement composition".

2. T. Hosaka, "Manufacturing method for hydrothermally solidified material of paper sludge incineration ash". Japan Patent JP2005313032A, 2004.

3. Miao Shiding, Huang Jigiu, Zhang Peiping, Shen Zhopu, Zhang Peng and Liang engnan, "Method for preparing porous clay bricks through black cotton soil". China Patent CN106495727A, 2016.

4. Jules E Havalin, Havertown and Frank Kahn, "Soil Stabilization". USA Patent US3131074A, 1961.

5. J. E. Havelin, "COMPOSITION AND ROAD STABILIZATION METHOD". USA Patent US7758280B2, 2004.

6. Norzlan Khalid, Mazidah Mukri, Faizah Kamarudin, "Soil Stabilization Using SOFT Blends of Waste Paper Mud Ash (WPSA").

7. Deng-Fong Lin, Kae-Long Lin, Huan-Lin luo, "A comparison between mud ash and flying ash in the Improvement in soft soils".

8. A. byiringiro, "Effect of paper ashes on the properties of swelling soils".

9. Vishvendra Singh, Ashok Verma, Ravi Prakash Chaurasiva, "Black Cotton Soil Stabilization Study with Kota Stone Sludge Replacement Sludge".

10. H. J. P. J. Z. Miao Shilding, "Method of adjusting expanding property of black cotton soil". China Patent CN107512722A, 2017.

11. C. Y. Li Wei, "Huang Xiaoming Black Cotton Curing Agent, Curing Agent Preparation Method and Black Cotton Base Removal Method".

12. "Method for manufacturing plastic molded article mixed with incineration ash of papermaking sludge". Japan Patent JP2003253138A, 2002.

13. "Paper sludge treatment method". Japan Patent JP2005233537A, 2004.