Modification of Geosynthetic Clay Liners

Ms.Laxmi N. Kale[1], Mr.Sagar N. Phule[2], Mr. Viabhav S. Riswadkar[3], Mr.Sandip D. Jagtap[4]
[1, 2, 3, 4] Dept of Civil Engineering
[1, 2, 3, 4] S.M.S.M.P.I.T.R,AKLUJ

Abstract- *Modern landfills are highly engineering containment systems,they are designed to minimize the impact of solid waste such as (refuse, trash, and garbage) on the environment and the human health. In the modern landfills, the waste is contained by a liner system. The primary purpose of liner system is to an isolate the landfill contents from the environment and so that, to protect the soil as well as ground water from the pollution originating in the landfill.*

The one of the greatest threat to ground water posed by modern landfills is leachate. The Leachate is consists of the water as well as water soluble compounds in the refuse which are accumulate as water moves through the landfill. This water may be from rainfall or also from the waste itself. Leachate may be migrating from the landfill as well as contaminate soil and ground water, thus presenting a risk to human and environmental health.

Keywords- Leachate, Modern landfills, Liners, Geomembrane, Geosynthetic Clay Liners.

I. INTRODUCTION

Landfills are lined with systems that consist of alternating layers of low and highly permeable materials that perform barrier functions and drainage or filtration functions, respectively. There are two basic types of liner systems are single and double liner systems. Single liner systems include a hydraulic barrier layer overlain by a high permeability layer called the leachate collection system. Double liner systems include two hydraulic barrier layers that are separated by a drainage layer, known as the leak detection system, and overlain by the leachate collection system.

Most municipal solid waste landfills, are composed of seven systems-

1. Bottom and lateral side liners system
2. Leachate collection and removal system
3. Gas collection and control system
4. Final cover system
5. Storm water management system
6. Groundwater monitoring system
7. Gas monitoring system

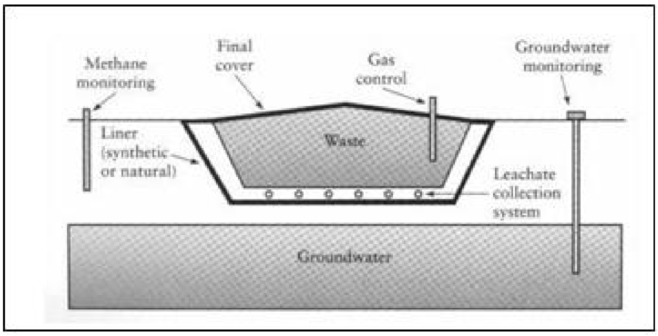
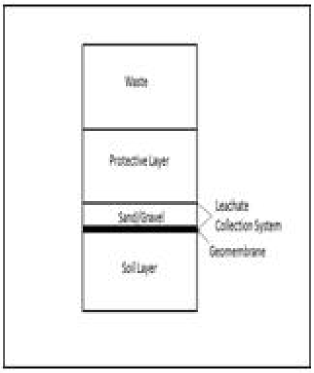


Fig.1.1 Schematic Diagram of a MSW Landfill

System of Liners:

i. **Single-Liner Systems-**Single liners consist of a clay liner, a geosynthetic clay liner, or a geomembrane as shown in fig. The single liners system is sometimes used in landfills designed to hold construction and demolition debris (C and DD). Construction and demolition debris which are results from building and demolition activities and includes concrete, asphalt, shingles, wood, bricks, and glass.

ii. **Composite-Liner Systems:**A composite liner system consists of a geomembranewhichj combined with a clay liner as shown in the fig.(1.3)Composite-liner systems are more effective at limiting leachate migration into the subsoil either than a clay liner or a single geomembrane layer. Composite liners which are required in municipal solid waste (MSW) landfills. Municipal solid waste landfills contain waste collected from various areas such as residential, commercial, and industrial sources. These landfills may also accept C and DD debris, but not hazardous waste.



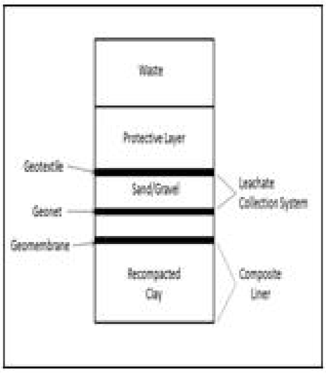


Fig.1.2 Single Liner System Fig.1.3Composite Liner System

iii. **Double-Liner Systems:** A double liner consists of either two single liners, two composite liners, or a single and a composite liner as shown in the fig-1.4. The function of upper (primary) liner usually to collect the leachate, while the lower (secondary) liner acts as a leak- detection system and backup to the primary liner. Double-liner systems are widely used in some municipal solid waste landfills and in all hazardous waste landfills. Hazardous landfill are constructed for the disposal of wastes that once were ignitable, corrosive, reactive, toxic, or are designated as hazardous by the U.S. Environmental Protection Agency (U.S. EPA).

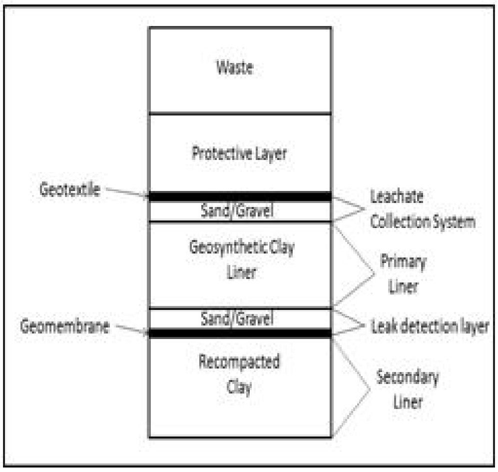


Fig.1.4 Double Liner System

II. STUDIESAND FINDINGS

The modified geosynthetic clay liner aims at reducing the problems faced by the present landfills. Improving the characteristics and performance of geosynthetic clay liners will help in preventing the penetration of leachate through the liner system and avoiding the puncture of the system. The model can be improved by using different materials and also by changing internal structure of the model. The characteristics and performance can be improved further using different methods of binding the materials. By using different materials and methods to bind them together its cost can be reduced.

Geosynthetic clay liners cost was reduced by using black cotton soil and sand mixture as internal material but the results obtained can be further improved by using different soil mixtures in Geosynthetic clay liners. The geosynthetic clay liner model proposed is complicated as compared to available models in market, so different simpler models can be proposed to obtain the same results and improvements. The objectives of the project were completed by improving the properties of the liners, but geosynthetic clay liners have some other disadvantages which are further to be studied and reduced.

III. METHODOLOGY

A. Tests performed onmaterials-

a) Liquid Limit Test
b) Plastic Limit Test
c) Plasticity Index
d) Free Swell Index
e) Falling Head Permeability Test
f) Self Healing capacity Test

B. Preparation of Geosynthetic Clay Linermodel-

a) <u>Model 1</u>

Materials used in the model are Geotextile, Geomembraneand Black cotton soil.

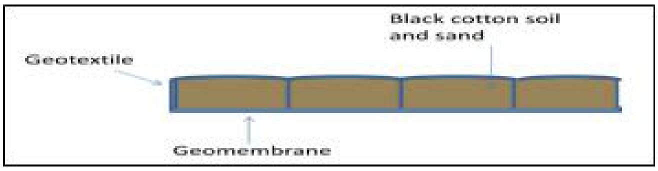


Fig3.(a)Model 1

Procedure for making model 1-

Step1-A 40 cm x 40 cm geomembrane layer is used as base layer for the model

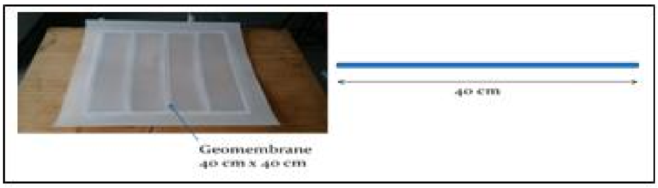


Fig3.1.(a) Using Geomembrane Layer

Step 2-The geomembrane layer was attached with strips of geotextile of 1 cm height. They were stitched together.

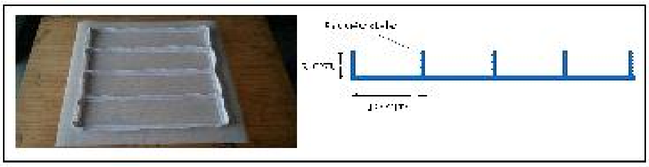


Fig.3.2.(a) Attaching Geotextile

Step 3-The formed rectangular boxes were filled with Black cotton soil up to 1 cm height.

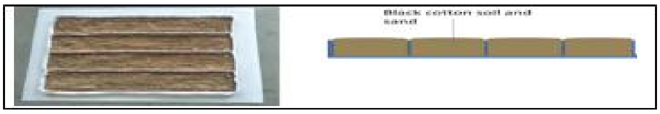


Fig.3.3.(a) Filling of Black Cotton Soil

Step 4-A layer of geomembrane was placed on the top and stitched to the geotextile strip

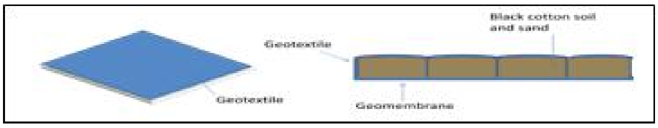


Fig.3.4.(a) Stitching Geomembrane

b) Model2

Materials used in the model are Geotextile, Geomembrane, black cotton soil, Sand and Cable ties**.**

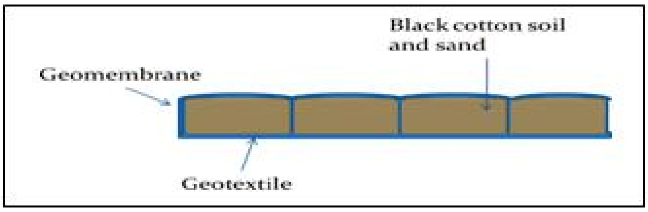


Fig.3.(b) Model 2

Procedure for making model 2-

Step-1 A 40 cm x 40 cm geotextile layer is used as base layer for the model.

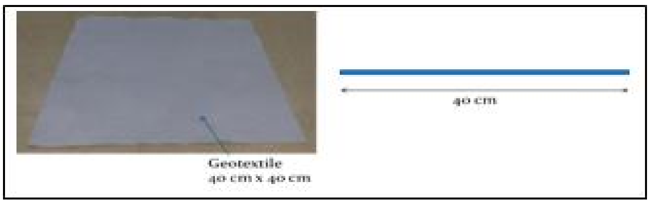


Fig.3.1(b) Geotextile Layer

Step 2-The geotextile layer was attached with strips of geomembrane of 1 cm height. They were stitched together**.**

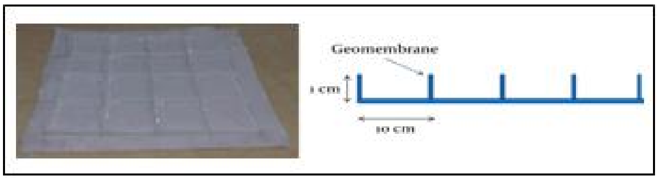


Fig.3.2(b) Attaching Geomembrane

Step 3-The formed rectangular boxes were filled with black cotton soil and sand mixture (80:20) up to 1 cm height.

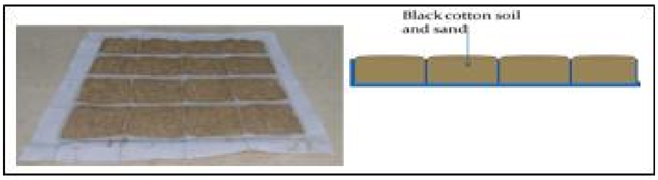


Fig.3.3(b) Filling Black Cotton Soil

Step 4 - A layer of geotextile was placed on the top and stitched to the geomembrane strips

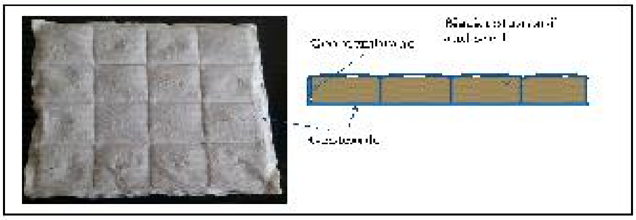


Fig.3.4(b) Stitching Geotextile Layer

c) Model3

Materials used in the model are Geotextile, Geomembrane, black cotton soil, Sand and Cable ties.

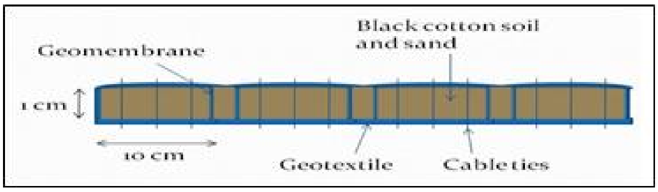


Fig.3.(c) Model 3

Procedure for making model 2-

Step -1 A 15 cm x 15 cm geotextile layer is used as base layer for the model**.**

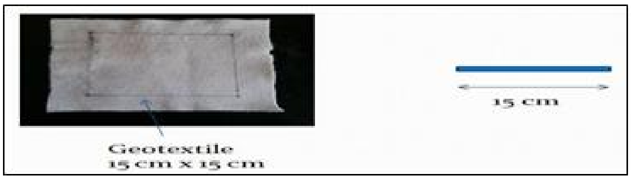


Fig.3.1(c) Geotextile Layer

Step 2-The geotextile layer was attached with strips of geomembrane of 1 cm height. They were stitched together.

Fig.3.2(c) Attaching Geomembrane

Step 3-The formed rectangular boxes were filled with black cotton soil and sand mixture (80:20) up to 1 cm height.

Fig.3.3(c) Filling Soil Mixture and Stitching Geotextile on Top

Step 4 - 16 boxes were stitched together and the gaps between the boxes were filled with the same black cotton soil and sand mixture (80:20).

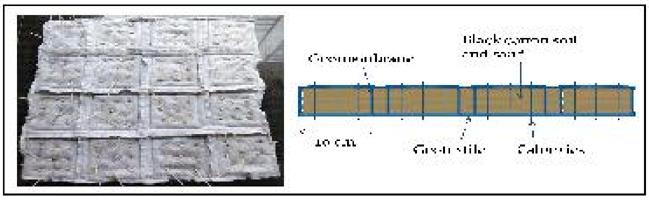


Fig.3.4(c) Stitching all boxes together

C. Use of Black cotton soil as Geosynthetic Clay Linermaterial-

Black cotton soils accounts about 20% of land area in India and are predominantly located in the Deccan trap covering the states. Black cotton soil is a highly clayey soil. The black colour in Black cotton soil is due to the presence of titanium oxide in small concentration. The Black cotton soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in colour. Expansive soils are the soils which expand when the moisture content of the soils is increased. The clay mineral montmorillonite is mainly responsible for expansive characteristics of the soil. The expansive soils are also called swelling soils or black cotton soils.

The physical properties of Black cotton soil vary from place to place 40 % to 60 % of the Black cotton soil has a size less than 0.001 mm. At the liquid limit, the volume change is of the order of 200 % to 300% and results in swelling pressure as high as 8 kg/cm2 **to 10 kg/cm2.**

D. Using Sand in Geosynthetic ClayLiners-

Geosynthetic clay liners available in market have high cost and it requires a very high budget to use it in a landfill. Sand is available at a very low price which can be used with bentonite clay or black cotton soil in a mixture. By reducing the cost of geosynthetic clay liners it can be also used in rural areaslandfill.

E. Using Mixture of Sand with Bentonite Clay and Black Cotton Soil–

- Bentonite clay/Black cotton soil and sand were used in different proportion of 60:40, 70:30, 80:20 and 90:10respectively.
- Test were conducted on these mixtures of bentonite clay and sand- Liquid limit, plastic limit, plasticity index and Falling head permeabilitytest.
- The results of the test were compared and the best result in balance between economy and performance weretaken.

Uses of Geosynthetic ClayLiners

1. Used as waste and contaminated soilcaps.
2. Used as landfill baseliners.
3. Used for gas and vapour seals.
4. As Surface impoundmentliners
5. As dams, canals, and water courses liners
6. For ground water protection.
7. Used as vertical barriers.
8. Used for water proofing.

Types of Liners

1. Compacted Clay Liners
2. Geosynthetic Clay Liners

IV. RESULT AND DISCUSSION

Following results obtained-

1. **Soil Properties**

Sr. No.	Type of Soil	Liquid Limit (%)	Plastic Limit (%)	PlasticityIndex (%)	Flow Index	Toughness Index
1	Bentonite Clay	44.40	19.79	24.61	8.484	2.90
2	Black Cotton Soil	54.66	29.2	25.46	19.785	1.287
Mixture of Bentonite Clay and Sand						
3	60:40	28.91	13.09	15.82	6.44	2.523
4	70:30	32.41	15.50	16.91	9.11	1.856
5	80:20	35.19	17.42	17.77	13.29	1.337
6	90:10	41.10	19.21	21.89	22.01	0.949
Mixture of Black Cotton Soil and Sand						
7	60:40	42.81	22.53	20.28	4.328	4.689
8	70:30	45.32	23.88	21.44	5.179	4.018
9	80:20	48.10	25.89	22.21	6.241	3.355
10	90:10	52.09	29.10	22.99	8.548	2.686

2. **Free Swell Index of BentoniteClay**

$$\text{Free Swell Index,(\%)} = \frac{18 - 13}{13} 100$$

$$= 38.46\%$$

The Free Swell Index of Bentonite clay obtained by comparing the increase in volume of soil in water and kerosene in 24 hours is 38.46%.

Free Swell Index of Black CottonSoil

$$\text{Free Swell Index,(\%)} = \frac{35 - 20}{20} 100$$

$$= 75\%$$

The Free Swell Index of Black Cotton Soil obtained by comparing the increase in volume of soil in water and kerosene in 24 hours is 75%.

3. **PermeabilityTest**

Test Details-

Burette Diameter, d = 0.8 cm	Burette area, a = 0.5026 cm^2
Specimen Diameter, D= 10 cm	Specimen Area, A= 78.53 cm^2
Length of Specimen, L= 9.5 cm	

Permeability Test on Bentonite Clay

Time (Days)	Time (hrs)	Time (sec)	h_0 (cm)	h_t (cm)	$\Delta h=h_0-h_t$ (cm)	Permeability (cm/sec)
1	24	86400	144	132.5	11.5	5.856×10^{-8}
2	48	172800	144	134.1	9.9	2.505×10^{-8}
3	72	259200	144	135.9	8.1	1.355×10^{-8}
4	96	345600	144	137.5	6.5	8.125×10^{-9}
5	120	432000	144	138.8	5.2	5.176×10^{-9}
6	144	518400	144	140.2	3.8	3.136×10^{-9}
7	168	604800	144	141	3.0	2.107×10^{-9}

Permeability Test on Black CottonSoil

Time (Days)	Time (hrs)	Time (sec)	h_0 (cm)	h_t (cm)	$\Delta h=h_0-h_t$ (cm)	Permeability (cm/sec)
1	24	86400	144	123.1	20.9	1.103x10^[illegible]
2	48	172800	144	125.6	18.4	4.808x10^[illegible]
3	72	259200	144	127.8	16.2	2.863x10^[illegible]
4	96	345600	144	130	14	1.799x10^[illegible]
5	120	432000	144	131.3	12.7	1.299x10^[illegible]
6	144	518400	144	132.8	11.2	9.495x10^[illegible]
7	168	604800	144	134	10	7.234x10^[illegible]

Permeability Test on Bentonite and Sand(80:20)

Time (Days)	Time (hrs)	Time (sec)	h_0 (cm)	h_1 (cm)	$\Delta h=h_0-h_1$ (cm)	Permeability (cm/sec)
1	24	86400	144	127.7	16.3	8.450×10^{-8}
2	48	172800	144	130	14	3.598×10^{-8}
3	72	259200	144	132.8	11.2	1.899×10^{-8}
4	96	345600	144	134.1	9.9	1.252×10^{-8}
5	120	432000	144	135.6	8.4	8.460×10^{-9}
6	144	518400	144	136.9	7.1	5.929×10^{-9}
7	168	604800	144	139	5	3.552×10^{-9}

Permeability Test on Black Cotton soil and Sand(80:20)

Time (Days)	Time (hrs)	Time (sec)	h_0 (cm)	h_1 (cm)	$\Delta h=h_0-h_1$(cm)	Permeability (cm/sec)
1	24	86400	144	117.9	26.1	1.407×10^{-7}
2	48	172800	144	119.5	24.5	6.656×10^{-8}
3	72	259200	144	121	23	4.080×10^{-8}
4	96	345600	144	122.7	21.3	2.816×10^{-8}
5	120	432000	144	125	19	1.990×10^{-8}
6	144	518400	144	126.6	17.4	1.509×10^{-8}
7	168	604800	144	129	15	1.105×10^{-8}

4. Self-Healing CapacityTest

Test Details-

Burette Diameter, d = 0.8 cm	Burette area, a =0.5026 cm^2
Specimen Diameter, D= 10 cm	Specimen Area, A=78.53 cm^2
Length of Specimen, L=1.3 cm	

Self-Healing CapacityTest on BentoniteClay

Time (Days)	Time (hrs)	Time (sec)	h_0(cm)	h_1 (cm)	$\Delta h=h_0-h_1$ (cm)	Permeability (cm/sec)
1	24	86400	144	99	45	3.607 x 10[illegible]
2	48	172800	144	105	39	1.520 x 10[illegible]
3	72	259200	144	110	34	8.644 x 10[illegible]
4	96	345600	144	113	31	5.83510[illegible]

Self-Healing CapacityTest on Black Cotton Soil

Time (Days)	Time (hrs)	Time (sec)	h_0 (cm)	h_1 (cm)	$\Delta h=h_0-h_1$ (cm)	Permeability (cm/sec)
1	24	86400	144	75	69	6.279 x 10[illegible]
2	48	172800	144	81	63	2.768x 10[illegible]
3	72	259200	144	86	58	1.654 x 10[illegible]
4	96	345600	144	89	55	1.15810[illegible]

COMPARISION OF GEOSYNTHETIC CLAY LINER PROPERTIES

Description	Standard Values	Obtained Results
Price	400-600 Rs. per sq. meter	350 Rs. per sq. meter
Permeability	1 x 10[illegible] cm/sec	1.105x10[illegible] cm/sec (soil)
Thickness	6-8 mm	10 m and above

V. CONCLUSION

1. The internal structure of GCL is modified by providing geotextile layer as top and bottom layer and geomembrane strips to form square boxes. Due to which the shear strength of GCL isincreased.
2. GCL is provided with thickness of 10 mm and due to two layers of geotextile the possibility of GCL getting punctured isreduced.
3. The modification in GCL increases its durability and lifespan.
4. Potential shear strength at the interfaces between materials is increased by using two layers of geotextile instead of geomembrane. The bond between Black Cotton Soil and geotextile is stronger as compared to between soil andgeomembrane.
5. By using Black Cotton Soil and Sand mixture (80:20) the cost of GCL decreases and also permeability of 1.105×10^{-8} cm/sec isachieved.
6. The Cost of GCL achieved is Rs 350 per sq. meter which is less than the cost of available GCL in themarket.

REFERENCES

[1] K. L. Hughes, A. D. Christy, and J. E. Heimlich; “Landfill Types and Liner Systems”.
[2] A. Bouazza; “Geosynthetic clay liners” (September2001).
[3] USA Environmental Protection Agency; “Geosynthetic clay liners used in muncipal solid waste landfills”(2001).
[4] N. Davies and E. Mander; “Geosynthetic Clay Liners (GCLS) –The Cost Effective Alternative for Waste Management”(2007).

[5] D. Cazaux, G. Didier; "Field evaluation of hydraulic performances of geosynthetic clay liners by small and large-scale tests" (July1999).
[6] K. Sari, J. Chai; "Self healing capacity of geosynthetic clay liners and influencing factors" (July2013).
[7] C. B. Lake, R. K. Rowe; "Swelling characteristics of needlepunched, thermally treated geosynthetic clay liners"(1999).
[8] M. V. Shah, H. J. Pandya, A. D. Shukla; "Influence of chemical additives on shrinkage and swelling characteristics of bentonite clay"(2017).
[9] J. Dutta and A. K. Mishra; "Consolidation behavior of compacted bentonite in the presence of Heavy metal"(2017).
[10] J. Lee and C. D. Shackelford; "Impact of Bentonite quality on hydraulic conductivity of Geosynthetic clay liners"(2005).
[11] D. C. Kolstad, C. H. Benson and T. B. Edil; "Hydraulic conductivity and swell of nonprehydrated GCLs permeated with Multispecies inorganic solution"(2004).
[12] M. H. Gleason, D. E. Daniel and G. R. Eykholt; "Calcium and Sodium Bentonite for Hydraulic containment applications"(1997).
[13] T. S. Umesha, S. V. Dinesh and P. V. Sivapullaiah; "Effects of acids on geotechnical properties of black cotton soil"(2012).
[14] S. M. Korwar, S. G. Patil; "Effects of Chemicals on Geotechnical Properties of Black Cotton Soil"(2015)