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Design of Eco-Friendly Geo-Composite Liner for Fly ash Ponds

Suresh Kommu, SS. Asadi

Abstract: This paper aims to design of geocomposite liner for fly ash ponds. Our country has many thermal plants, which generates huge amount of flyash as a waste and their disposal require some of the crucial treatment and engineered flyash pond. The problems from coal based thermal plants is disposal of such flyash. In the present research, Clayey soils, Sodium bentonite and black cotton soils used as a liner for fly ash pond, instead of HDPE sheet to reduce the heavy metal contaminants leachate. Recent GCL, HDPE or Geocomposite liners as bottom lining layers are a suggestive solution for preventing toxic materials from seepage into the surrounding areas. The obtained results of this research indicate that the more percentage of concentration of heavy metals like Arsenic, lead, cadmium and chromium are retained in sodium bentonite layer than the black cotton soil. Hence it is, recommended that among the different liners, sodium bentonite is the most appropriate geocomposite liner, as it's self-healing and swelling properties provides more retention capacity of toxic heavy metals. The present invention relates to a geocomposite liner system for fly ash pond to reduce the leaching of toxic metals in ground water. The geocomposite liner system comprises of at least one fibrous layer having a layer of sodium bentonite material; a non-fibrous layer mechanically and non-adhesively affixed between fibrous layers. A suitable thickness of bentonite clay is encapsulated between the fibrous and non-fibrous layers, it can retain the Arsenic, Cadmium, Chromium and Lead metals in it. This Geo composite liner is most suitable, economical and easy to install over CCLs and GCLs.

Key words: Geocomposite liner, fly ash pond, Sodium bentonite, toxic metals, leachate, self-healing, swelling, fibrous, non-fibrous. CCL,GCL.

I. INTRODUCTION

Rapid industrialization and urbanization have led to more power generation requirement in the country. India's major power generates from thermal power plants, which is nearly 73% of total installed power capacity. Out of which 90% is coal-based generation, thereby, the generation fly ash is increasing day-by-day. India positions fourth on the planet in the creation of coal slag as side-effect squanders after USSR, USA, and China (Bhoi et. al, 2015). By the year 2020, thermal power generation in India will be about 1,37,000 Mw, with the coal consumption of about 350 Mt, which will produce ash of about 140 Mt. The fly ash contains toxic heavy metals viz., As, Be, Cd, Cr, Cu, Pb, Hg, Mo, Ni, and V. These metals infiltrate into the rock mass/soil/geomaterials in the earth's upper crustal layer due to rain water/river/surface runoff water.

Thus, contaminate the groundwater and make an overwhelming danger to the human life and the environment. In the both the ways, human communities get affected, due to toxic heavy metals which are present in the fly ash. These heavy metals affect different parts of the human body. The existing CCLs, GCLs are solutions to reduce the effect of leaching, however, still the toxic metals infiltrates into the ground and contaminate groundwater and environment. Therefore, it becomes necessary to investigate the proper and suitable Geocomposite layer design with low cost for fly ash pond. In this regard, the work of earlier researchers is worth mentioning. From the earlier researches, it can be observed that at present, HDPE sheets are being used as a liner in the fly ash ponds and municipal waste dumping yards/grounds. It is noteworthy to state that such liners are quite difficult to manage and requires high cost.

With this in view, the aim of the present research work has been defined, which can lessen the centralization of major and follow components in the leachate produced from fly ash and to bind the leachate to the source i.e. not enabling it to relocate it from the purpose of disposal. Further, the author has attempted to design the suitable geo-composite liner for fly ash pond so that low cost geo-composite layer can be developed. A detailed investigation was carried out to study the suitable thickness of the composite layer, which can retain more percentage of toxic heavy metals. In the study, to adopt the suitable thickness of the liner, experimental methodology was developed to carry out the investigation by passing fly ash leachate through a sample of different clayey soil and of various thickness, i.e., 1.0cm, 2.0cm and 3.0cm, using Flexible wall permeameter equipment. The details of experimental methodology and procedures followed are mentioned in brief in the methodology section.

II. LITERATURE REVIEW

Gandhi (2005), states that, the generated fly ash from thermal power plant is a waste and the maintenance of ash ponds is not always a concern of electricity. Author has observed severe defects in the ash pond, which causes environmental harm by the ash slurry contained nearby to the water region..

Mishra et al. (2014) have studied in their research, employing leachate assembly liner placed in the pond system and composite of ash so that the leachate can be prevented from reaching to water table.

Pal and Ghosh (2013) have determined hydraulic conductivity of Fly, when it mixed with clay mixtures.

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Fly ash can contain various toxic metals produced by thermal power plants and can cause environmental problems such as leaching and dust, where leaching contaminates ground water.

Singh et al. (2015) have assessed coal ash–bentonite mixture for landfill liner.

Authors opined that wastes (fly ash) can be limited by a variety of waste reduction, sorting and recycling, resource recovery through waste disposal, waste conversion, and environmentally sustainable land disposal techniques.

Deka and Sekharan (2017) The authors states that it is vital to evaluate the pollutant retention properties, when applying the substances that is used as liners on the garbage dumping site. In this study, authors have investigated fly ash utility for use as dumping surface liner to understand the characteristics of its interaction with pollutants.

Rahel and Bhatnagar (2017) have presented review on adsorption of heavy metals and phenol from aqueous solution onto fly ash as low-cost adsorbent. Authors states that flyash, are the by-products of thermal plants that causes various types of pollution, damaging ecological cycles and are environmental hazards. Whereas, problems by toxic chemicals is major problem on the worldwide scale.

Objective: To design the geocomposite liner for flyash ponds.

Types of HDPE geomembranes

1. White Reflective HDPE Geomembrane: White reflective HDPE geomembrane liner improves wrinkle and damage detection due to its colour, reflects light and reduces frequent dehydration. White HDPE geomembranes are utilised in low budget projects where quality and performance are required.
2. High Temperature HDPE Geomembranes: These are specially formulated HDPE geomembranes that can withstand high temperatures up to 212^{o}F. Thus the formulation in this type of HDPE provides improved chemical stabilisation and enhanced mechanical performance in variations and elevated temperatures.
3. Conductive Geomembranes: These HDPE geomembranes are available in various configurations with white, smooth, conductive high and low temperature variant, textured materials which provide better chemical resistance properties and durability and offers great UV protections or intense weather stress resistances.

Hydraulic Conductivity:

GCL system provides barriers with low hydraulic conductivity (i.e., low permeability). Permeability of GCL products depends on various factors, such as amount and type of bentonite, geosythetic material, additives and the product organization. Shan and Lai reported that testing of GCLs swell-percentage showed to have better self-healing features. Further he also declared that the bonding methods for the GCL composites (needle-punching adhesive bonding or stitch-bonding), had a major impact on the self-repairing property of the GCLs. [7]

III. METHODOLOGY:

To find the Permeability k, clayey soil sample were considered, which are in cylindrical shape, tests conducted using FWP (Flex panel-HM-4150 Humboldt, USA), the apparatus consists of (i) a permeability cell; (ii) master control flex panel with three burettes (cell pressure, base burette, and top burette) with respective controlling valves;(iii) de- aired leachate tank; (iv) pore pressure measuring devices; (v) compressor of air; and (vi) pump of vaccum.

Determination of permeability employing FWP—the experimental procedure

In the present research, the following experimental procedure was adopted as follows:

To determine the Hydraulic conductivity of the clayey soils and fly ash (1) assembling the sample in the cell,(2) sample saturation , and (3) measuring k of the soil sample

Then, initial cell pressure of 100 kPa was applied on the soil sample from the air compressor and then pipe lines were flushed to remove the air bubbles. Further, the sample was allowed to achieve almost complete saturation by applying the back (base) pressure technique (ASTM D5084-03 2004). By measuring B-value saturation was ensured. The B-value is the ratio of change in pore pressure to change in cell pressure, Δu and $\Delta\sigma 3$ [ASTMD5084-032004].Theoretically, a B-value, indicates an almost fully saturated sample. However, in the fluid flow experiments, if the measured B values range which is equalto1,from 0.94 to 1, it is concluded that sample has attained complete saturation (fig.2 and fig.3). Here, it was ensured that all the identical samples attain the B-value of nearly 0.97 to 0.98 [BS 1377-6 1990]. Then, discharge(Q) was measured at an interval of 90 min. until a steady-state flow condition was achieved. It was observed that the time to achieve the steady state flow is approximately 3,16,29 days were taken to saturate respectively for 1cm,2cm,and 3cm thickness of samples in case of black cotton soils. In case of sodium bentonite 16,90,150 days were taken to saturate respectively for 1cm,2cm,and 3cm thickness of samples. The leachate was passed through the sample and collected in the burette, and then collected in a flask to measure the retention of heavy metal percentage. The following figure1. Shows Schematic diagram for Hydraulic conductivity of soil using leachate samples.

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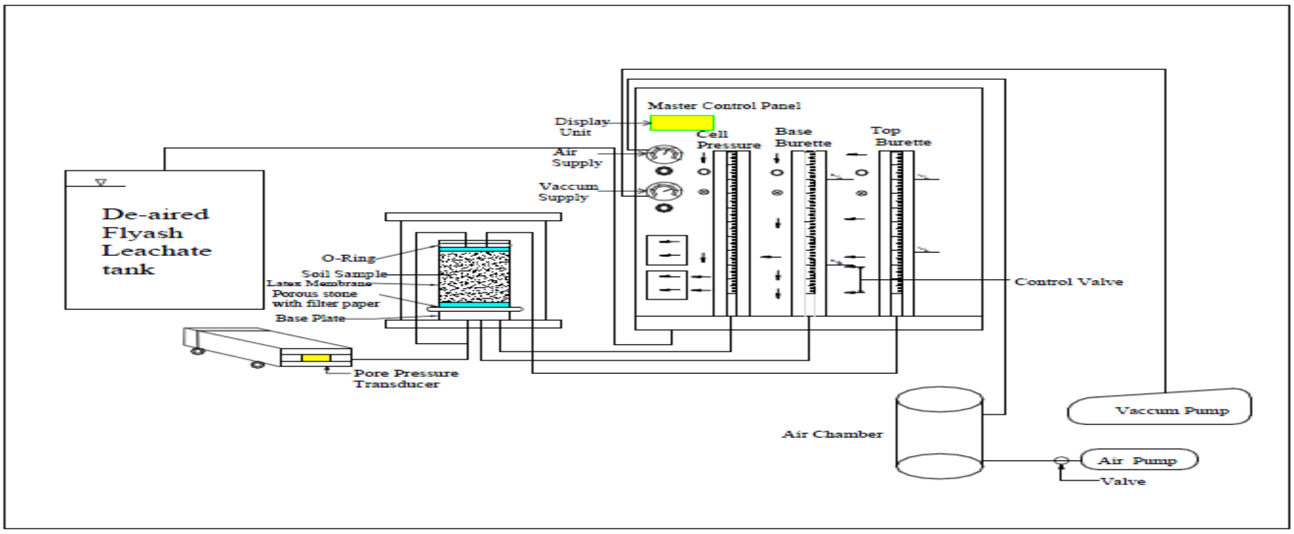

Fig.1. Schematic diagram for Hydraulic conductivity of soil using leachate samples.

The steady flow was also observed from the graph by drawing between time and discharge and the graph was observed as linear at certain stage for the black cotton soil. And by maintaining the hydraulic gradient, hydraulic conductivity(k) was determined.

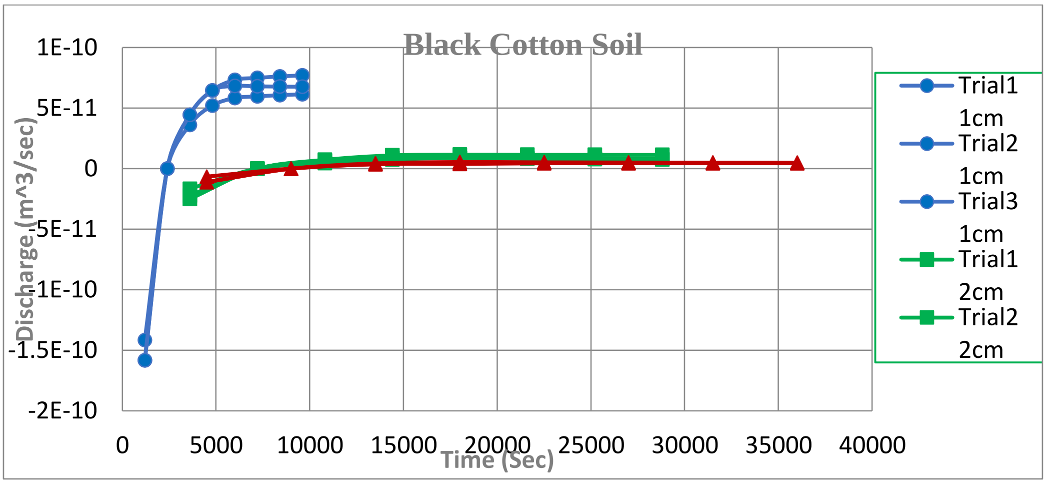

Fig.2. Hydraulic conductivity for Black cotton soil

In case of sodium bentonite soil, the following graph was observed for the steady flow for different thickness of samples and found hydraulic conductivity(k) of soil

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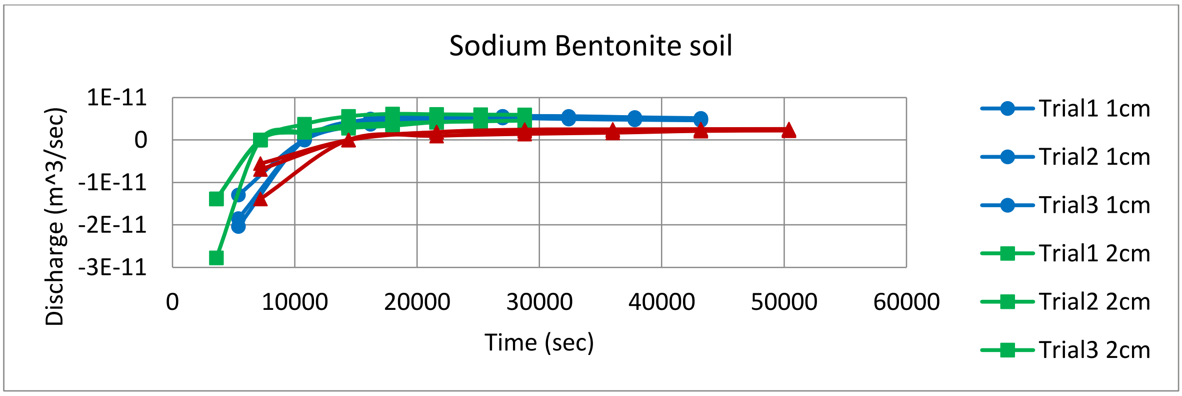


Fig.3. Hydraulic conductivity for Sodium Bentonite soil

After collecting the leachate from burette and then collected in a flask. The samples were tested the concentration of heavy metals like Lead, Chromium, Cadmium and Arsenic using Atomic Absorption Spectroscopy(AAS), The concentration of heavy metals found to be very negligible. Hence the following liner can suggest for the fly ash pond by considering the parameters like Original area of ash pond, Total pond area, Quantity of ash produced by plant per day, Water ash ratio, Quantity of water being pumped in to the pond , Maximum rain fall per hour , Estimated discharge in the pond area, Heavy metal concentration for As, Cd, Cr & Pb , Existing soil at site is considered. The geo-composite liner system comprises of at least one fibrous layer having a layer of sodium bentonite material; a non-fibrous layer mechanically and non-adhesively affixed between fibrous layers. The liner consists of the existing soil should compact up to 60mm thick, then use of non-fibrous geo-synthetic layer which is 2mm, and then 30mm of sodium bentonite soil is covered by fibrous geosynthetic layer which is 2mm thickness. *A suitable thickness of bentonite clay is encapsulated between the fibrous and non-fibrous layers, it can retain the Arsenic, Cadmium, Chromium and Lead metals in it.* This Geo composite liner is most suitable, economical and easy to install over CCLs and GCLs.

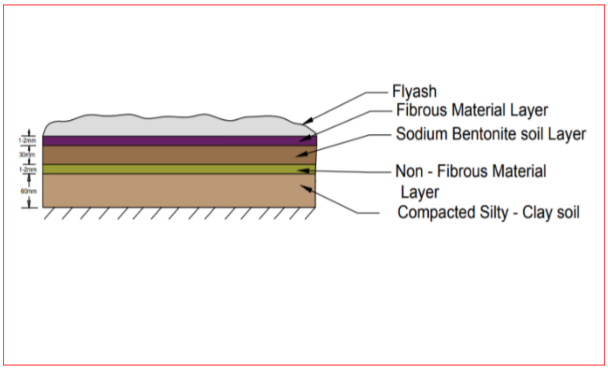


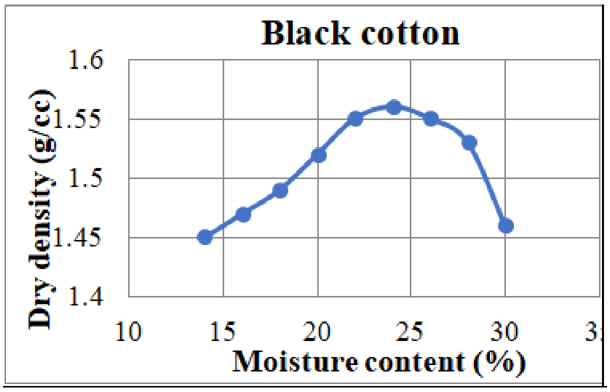
Fig.4. Suitable Geo-composite liner for fly ash pond with Sodium Bentonite soil.

IV. RESULTS

The following are the results for the black cotton soil and sodium bentonite soil.

Table 1.Standard proctor test for black cotton soil

Dry Density(gm/cc)	w%
1.45	14
1.47	16
1.49	18
1.52	20
1.55	22
1.56	24
1.55	26
1.53	28
1.46	30

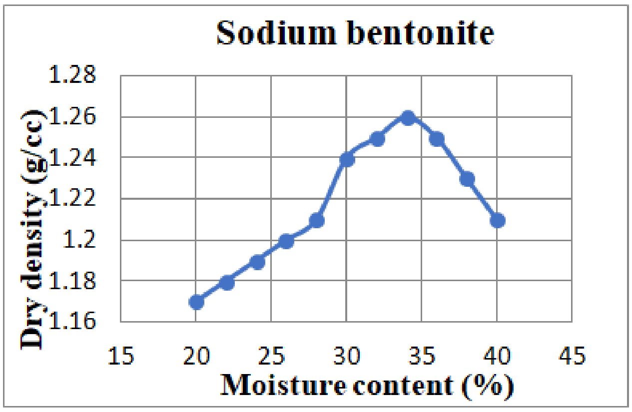


MDD= 1.56gm/cc, OMC=24%

A graph is drawn between moisture content and dry density, it is found OMC and MDD values for black cotton soil.

Table 2.Standard Proctor Test for Sodium Bentonite soil

Dry Density(gm/cc)	w%
1.17	20
1.18	22
1.19	24
1.2	26
1.21	28
1.24	30
1.25	32
1.26	34
1.25	36
1.23	38
1.21	40



MDD= 1.26gm/cc, OMC= 34%

A graph is drawn between moisture content and dry density, it is found OMC and MDD values for sodium bentonite soil.

Heavy Metals concentration in different leachate samples (AAS): The following are the heavy metal concentration after passing through the Black cotton soil and Sodium Bentonite clayey soils. The samples are prepared 1cm, 2cm, 3cm thickness respectively. And it is found that Sodium Bentonite 3cm thickness sample has retain the more concentration toxic metals in it, than the Black cotton soil 3cm thickness.

Hence it is suggested that the more than 3cm thickness of Sodium Bentonite liner is suitable, when it is encapsulated between fibrous and non-fibrous geosynthetic layers.

Type of Leachate Sample	Units	As	Cd	Cr	Pb
Prepared Leachate from fly ash	PPM	0.01	0.005	0.01	0.04
Leachate passed through 3cm thickness of BC soil	PPM	0.02	0.001	0.01	0.02
Leachate passed through 3cm thickness of sodium bentonite soil	PPM	0.01	0.001	0.01	0.01

Free Swell Index Values For Clayey Soils: The following are the Free swell index values, Sodium Bentonite soil has more swelling nature than the other soils. Sodium Bentonite soil has more swelling nature and it can retain more toxic concentration in it.

S.No.	Type of soil	Free swell Index(%)
1.	Black cotton soil	66.6
2.	Sodium Bentonite soil	414

V. CONCLUSIONS

1) The heavy metal retention capacity in 3.0cm as sodium bentonite liner are below, which are very negligible values. The above table shows sodium bentonite soil has more retention capacity of heavy metal concentration
2) Sodium Bentonite soil has more OMC and Less MDD, when compared with black cotton soil.

Type of soil	OMC(%)	MDD(g/cc)
Black cotton soil	24	1.56
Sodium Bentonite soil	34	1.26

3) Free Swell index (FSI) is more for Sodium bentonite soil, hence, it can retain the more concentration of heavy metals in it than the black cotton soil.

Type of soil	FSI(%)
Black cotton soil	66.66
Sodium Bentonite soil	414

4) Due to the presence of sodium bentonite, it is self-repairing a good hydraulic barrier.

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