Suitability of Waste Foundry Sand with Fly Ash and Lime as Landfill Liner

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Abstract - *Sanitary landfilling is the most prevalent method to eliminate municipal solid due to its low cost. But it becomes a threat to environment, when leachate from the landfill reaches the ground water table causing various health hazards. To prevent this infiltration landfill liners are provided. This laboratory investigation was carried out to study the suitability of waste foundry sand with fly ash (0%, 2%, 4%, 6% and 8% to the dry weight of foundry sand) and lime (10% to the dry weight of fly ash) as a liner material. Standard proctor test was conducted on different mix to determine the optimum moisture content (OMC) and maximum dry density (MDD). The samples were prepared at OMC and MDD for falling head permeability test, unconfined compression test and volumetric shrinkage test. From the various laboratory test results foundry sand with 6% of fly ash is selected as the optimum mix. Because it satisfy the various requirements of liner material. Such as Liquid Limit (LL) >20%, Permeability < 1x10^{7}cm/s, Volumetric Shrinkage Strain (VSS) <4% and Unconfined Compressive Strength (UCS)>200kN/m^{2}.*

Key Words: **Landfill liner, Hydraulic Conductivity, Foundry Sand, Fly Ash, Lime**

1.INTRODUCTION

Landfilling is a major waste disposal option due to its low cost. The infiltration of atmospheric precipitation and moisture content of waste can generate leachate, when this leachate reaches the ground water table cause various health problems. To prevent the infiltration of leachate from sanitary landfill to the ground water table, landfills are provided with a liner system. A landfill liner is a low permeable barrier with hydraulic conductivity less than 1x10^{-7} cm/sec. Traditionally these liners are constructed using locally available clayey soil. The non-availability of suitable clay opens a door for the research and utilization of other less permeable material.

Foundry sand is a mixture of fine uniform sand, bentonite, pulverized coal and water. It is used in the process of sand casting for preparing the mould cavity. This sand was reused several times within the foundry. These reuses eventually make the sand unsuitable for casting process. A portion of the sand is continuously removed and replaced with new sand. The removed foundry sand is generally landfilled or they can be recycled for non foundry application. The bentonite content in foundry sand reduces the hydraulic conductivity which helps the foundry sand to use as a liner material.

Fly ash is a coal combustion product that composed of fine particles of burned fuel. Fly ash is used in many of the soil stabilization because of its self hardening property. Fly ash improves the compressive and shearing strength of soils. Also it can control the shrinkage and swelling of soil, due to its self hardening property.

1.1 Scope

- Provides a solution for the disposal of waste foundry sand and fly ash
- Utilization of waste foundry sand and fly ash helps to construct landfill liners at low cost
- Solves the problem for constructing clay liners, due to its non-availability

2. LITERATURE RIVIEW

Numerous studies were conducted to access the suitability of waste foundry sand as a hydraulic barrier. The laboratory study conducted by Abichou[1] found that the hydraulic conductivity of foundry sand is less than X10^{-7}cm/s if its liquid limit is greater than 20 or its bentonite content is greater than or equal to 6%. Also the study shows that the permeability of foundry sand is unaffected when it is permeated with salt water or municipal solid waste leachate. VSS is an important parameter considered in the selection if a liner material, because higher strain can induce shrinkage cracks that increases the hydraulic conductivity. Moses [2] conducted study on the dedication induced volumetric shrinkage of compacted foundry sand treated with Cement Kiln Dust (CKD). The research suggested that the VSS should be less than or about 4% up on drying for soil liners. Also the study shows that by increasing the CKD percentage the VSS comes to an acceptable value. This is due to the pozzolanic action of CKD. In the study conducted by Osinubi [3] the foundry sand was treated with different percentage of baggage ash in order to access its suitability as a liner material. Initially with the addition of baggase ash the hydraulic conductivity decreases but beyond 4% baggase ash by weight of foundry sand the hydraulic conductivity increases. This increase in hydraulic conductivity value is possibly due to the presence of excess baggase ash that would have change the soil matrix. Even though the minimum required UCS of soil to be used as a soil liner is not specified. Osinubi [3] suggested that the soil should have a minimum UCS of 200kN/m2 in order to support the maximum bearing stress from landfill. Abichou [4] conducted field study on foundry sand as a hydraulic barrier. The field hydraulic conductivity followed the same trends with LL and bentonite content. If LL is greater than 20 or its bentonite content is greater than 6% by weight of foundry sand, the hydraulic conductivity of foundry sand is less than $1X10^{-7}$cm/s. Also the study shows that field hydraulic conductivity is not affected by the summer and winter weather. Jayaranjan [5] reviewed about the several reuse options of fly ash and bottom ash. Fly ash is used as light weight backfill material, base material on road construction, binder material, sand replacement material, absorbent material to remove toxin compounds, for hazardous waste management etc. Also the physical properties, structural and chemical compositions were discussed. Ghosh [6] study the shear strength characteristics of Class F fly ash modified with lime alone and in combination with gypsum. Stabilization of Class F fly ash with lime up to 10% is effective to improve the shear strength. Addition of gypsum along with lime enhance the gain in strength at early curing period. But at higher curing period the contribution of gypsum is less, because at higher curing period lime stabilized mix attains high shear strength.

3. METHODOLOGY

3.1 Materials

Foundry sand, Class F Fly Ash and Lime are used in this study. Waste foundry sand was collected from Neelanchira Metals and Engineering works, Poovanthuruthu. Class F fly ash was used as an additive. It was collected from Crystal CLC Bricks. Amount of fly ash was a varying parameter (0%, 2%, 4%, 6% and 8% to the dry weight of foundry sand). Based on fly ash content the different mixes are named as M_0, M_2, M_4, M_6 and M_8. Since the free lime in Class F fly ash is less, its self hardening property is affected. So additional lime is added to accelerate the hardening property of class F fly ash. Based on the study by Ghosh [6] 10% of Lime was added to the dry weight of fly ash to each mix to accelerate the hardening property of fly ash.

3.2 Laboratory investigation

Laboratory tests were conducted to find the properties of different mix. For evaluating the suitability of waste foundry sand with fly ash and lime as a landfill liner. Tests such as Atterberg's limits (as per IS 2720 part 5 and IS 2720 part 6), Specific gravity (as per IS 2720 part 3), Grain size analysis (as per IS 2720 part 4), Standard procrtor test (as per IS 2720 part 7), Falling head permeability test (as per IS 2720 part 17), Unconfined compressive strength test (as per IS 2720 part 10) were carried out. Unconfined compressive strength at 28 day curing was taken. For falling head permeability test and unconfined compressive strength test samples are prepared at MDD and OMC.

For measuring VSS of the specimen cylindrical specimen were prepared in mould of 40mm diameter and 77mm length at MDD and OMC. Specimen was kept for natural drying for 30 days. Natural drying in the lab duplicates the field condition. Diameter and height of specimen were taken with the help of a vernier caliper accurate to 0.02mm. This procedure for measuring VSS was referred from the study by Moses [2]. The properties of different mix are shown in Table-1.

Table -1: Properties of different mix

Property	Mix name				
	M_0	M_2	M_4	M_6	M_8
Fly ash content (%)	0	2	4	6	8
Liquid limit (%)	23.9	24.3	24.5	24.6	24.8
Plastic limt (%)	NP	NP	NP	NP	NP
Linear shrinkage (%)	0.93	0.91	0.88	0.85	0.81
Specific gravity	2.68	2.67	2.66	2.65	2.63
MDD(kg/cm^3)	1.77	1.75	1.73	1.70	1.68
OMC %	11.9	13.5	14.3	14.9	15.4
Permeability (cm/s)	6.2E-8	3.1E-8	0.8E-8	0.6E-8	0.9E-8
UCS (kN/m^2)	180	191	213	224	242
VSS (%)	3.8	3.6	3.2	2.8	2.1

4. RESULTS AND DISSCUSSION

4.1 Atterberg's limits

There is an increase in liquid limit with the addition of fly ash and lime. This increase can be due to the increased water absorption [3]. Due to the high percentage of sand, foundry sand does not show plasticity. Treatment of foundry sand with fly ash and lime does not improve the plasticity. On treatment with fly ash and lime decreases the linear shrinkage due to binding property of fly ash. So that the chance of shrinkage can be reduced.

4.2 Specific gravity

Specific gravity of fly ash, lime and different mixes were determined. Fly ash is having a specific gravity of 2.15 and lime is having a specific gravity of 4.83. Specific gravity of the mix decreases with addition of fly ash and lime. This is due to the lower specific gravity of fly ash in the mix.

4.3 Particle size distribution

Particle size distribution of fly ash, lime and different mix were found out. The particle size distribution curve of fly ash and lime are shown in Fig-1 and the particle size distributions for different mix are shown in Fig-2. Results show that for No.200 sieve fly ash shows a percentage finer 87.6% and lime shows a percentage finer of 89.7%. This indicates both fly ash and lime contain finer particles, which helps to fill the void spaces of liner material. The steep particle size distribution curve of different mix indicates they contain particles of almost the same size and such soils are known as uniform soil. With the addition of fly ash and lime the percentage of finer material in the mix increases.

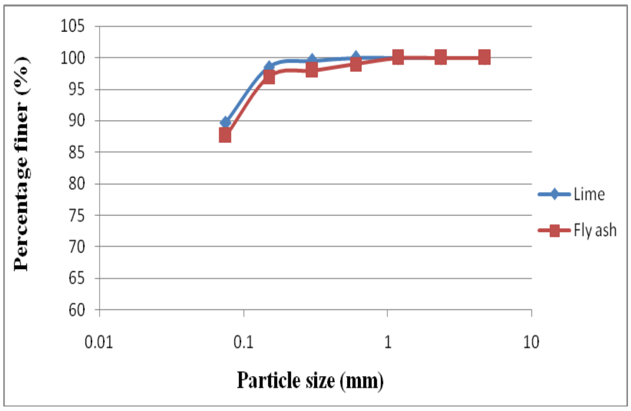

Fig-1: Particle size distribution of lime and fly ash

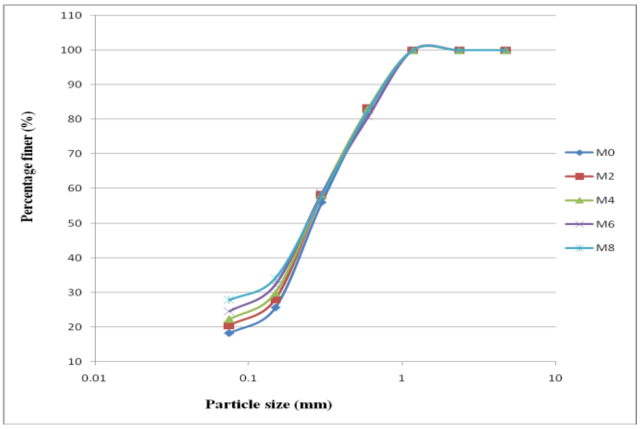

Fig-2: Particle size distribution of different mix

4.4 Compaction results

The MDD and OMC for different mix are find out using standard proctor test. The compaction curve for different mix is shown in Fig-3. With the addition of fly ash and lime MDD decreases and OMC increases. The decrease in MDD was due to the low specific gravity of fly ash. The increase in OMC can be due to the water required for the hydration of fly ash.

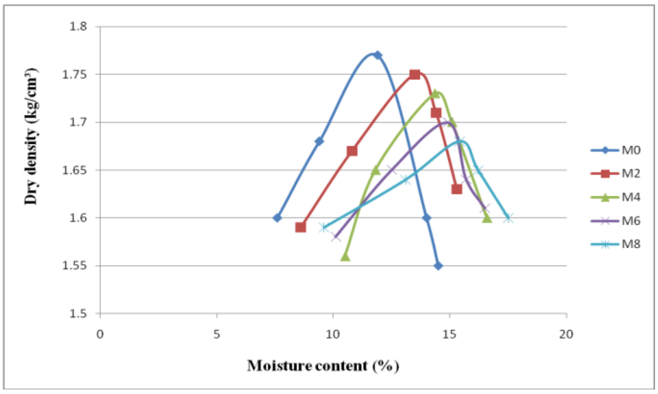

Fig-3: Compaction curve for different mix

4.5 Hydraulic conductivity

Hydraulic conductivity was measured with falling head permeability test with permeant liquid as tap water. On treatment with fly ash up to 6% the hydraulic conductivity decreases and reaches a minimum value of 0.6E-8cm/s but after that hydraulic conductivity increases. With the addition of fly ash and lime the amount of fines in the mix increases that help to fill the void spaces causing the decrease in hydraulic conductivity. However beyond 6% fly ash treatment, the hydraulic conductivity increases this can be due to presence of excess fly ash that would have change the soil matrix [3]. All the mix shows hydraulic conductivity less than permissible value.

FIG-4: Falling head permeability test

4.6 Unconfined compression strength

The UCS increases with fly ash content. The increase in UCS is due to the physical cementing mechanism of fly ash that helps to bind the particles together which helps to increase the compressive strength of sample. Fly ash content of 4% and above meets the unconfined compressive strength requirement.

4.7 Volumetric shrinkage strain

The entire specimen didn't shows any visible shrinkage cracks on drying. The VSS on all specimens is less than the permissible limit. With increase in fly ash content the VSS decreases. Due to the cementing property of fly ash, soil particles are binded together that reduces the soil to undergo volumetric change.

5. CONCLUSION

This laboratory study was carried out to study the suitability of waste foundry sand with fly ash and lime as a landfill liner. The results of various laboratory experimental studies show that waste foundry sand with fly ash and lime can be used as a landfill liner. From the results of Hydraulic Conductivity, LL, UCS and VSS M6 mix can be selected as an optimum mix for the liner material. Because,

- M6 mix has the lowest hydraulic conductivity of 0.6E-8cm/s which is less than the maximum permissible value of 1E-7cm/s for a landfill liner material.
- M6 mix has a liquid limit of 24.6% which is greater than the minimum permissible value of 20% for a landfill liner.
- M6 mix has an UCS of 224kN/m^2 which is greater than the minimum permissible value of 200kN/m^2 for a landfill liner.
- M6 mix has a VSS of 2.8% which is less than the maximum permissible value of 4% for a landfill liner.

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