International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 1, Jan 2022 pp: 1145-1150 www.ijaem.net ISSN: 2395-5252

A Study of Model Landfill Liner Material Used for Solid Waste Disposal for Low Hydraulic Conductivity

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Submission: 18-01-2022 Revised: 28-01-2022 Acceptance: 31-01-2022

Abstract - Solid waste disposal management in the small/large cities of India is a major problem. The ancient method for disposing of solid waste was landfill. disposing of solid waste as landfill is important as it protects ground water contamination. A model material having low hydraulic conductivity may be used as filler material for disposing off the solid waste. It may also work as a barrier for hazardous waste and used as buffer/backfill materials. To overcome this problem the model material should have the low hydraulic conductivity to avoid percolation of leachate in ground water reserve. In present research, sand was procured from the bank of BENI River from Pantnagar, district Udham Singh Nagar, (Uttarakhand). Sodium bentonite was mixed with sand at varying proportions to make the model material. Physical properties were determined of the sand and sodium bentonite. Determination of Optimum moisture content (OMC), Maximum Dry Density (MDD), shear strength and hydraulic conductivity properties were obtained in the laboratory. The test results obtained in laboratory are presented in the paper.

Keywords: Bentonite, Solid waste, Landfill, hydraulic conductivity, liner material.

I. INTRODUCTION

Solid waste is the unwanted or useless solid materials generated from human activities in residential, industrial or commercial areas. Solid waste originates from domestic, industrial, commercial, construction or institutional, organic material, glass, metal, plastic paper, toxic, non-toxin, flammable, radioactive, infectious etc.

Solid Waste Management overcome the adverse effect on the environment & human health. Municipality of every town/state effectively manage waste. This process include monitoring, collection, transport, processing, recycling and disposal. The quantum of waste generated varies mainly due to different lifestyles, which is directly proportional to socio economic status of the urban population.

One of the oldest methods of disposal of solid waste in a pit as landfill. This method is very effective and caused negligible impact on health and environment in past. As the humankind is moving towards the modern age world, solid waste is increasing rapidly.

Municipal solid waste (MSW) typically contains 51% organic waste, 17% recyclables, 11% hazardous and 21% inert waste. However, about 40% of all MSW is not collected at all. This MSW dumped in the open area in the city/town. This MSW found its own way to move nearby drains and water bodies. Due to mixing with drain/ waterbodies results choking as well as pollution of surface water. Unsegregated waste collection and transportation leads to dumping in the open, which generates leachate*(any contaminated liquid that is generated from water percolating through a solid waste disposal site).* Due to the biochemical reactions occurring within the waste body, landfills produce leachates, which pollutes the water and soil.

leachate and gaseous emissions besides causing nuisance in the surrounding environment. Leachate contaminates the groundwater as well as surface water in the vicinity and gaseous emissions contribute to global warming.

Isolation of landfill with liner of impermeable material is safe method of solid waste disposal. Method of disposing solid waste at landfill site with impermeable liner is called sanitary landfilling.

II. MATERIALS AND METHODS

A. Sand

Sand used was obtained from bank of BENI River from Pantnagar, district Udham Singh Nagar, (Uttarakhand). Sieve analysis was done on the river sand using IS sieves. The category of the sand found as SP. Various laboratory tests were conducted on the procured sand to determine the properties such as specific gravity, Atterberg’s limits, MDD, OMC, Angle of internal friction (ϕ), cohesion, grain size

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distribution etc,.The properties of sand is tabulated as given in Table 1.

Table 1: Physical properties of Sand

Parameter	Value
Specific gravity (G)	2.67
Bulk Density (γ), g/cc	1.98
Plasticity Index	Non-Plastic
M.D.D ($\gamma_{d\ max}$), g/cc	1.56
(OMC), %	4.62
Angle of internal friction (ϕ), degree	16.40
Cohesion (c), kg/cm²	Negligible
Grain size distribution Sand size fraction (%) Silt size fraction (%)	 96.94 1.72
Soil type as per IS: 1498-1970	SP

B. Bentonite

Sodium bentonite used in the present study for making the model material. The term Bentonite was first interduce for a clay found in about 1890 in upper cretaceous tuff near Fort Benton, Montana. The main constituent is the clay mineral montmorillonite and is an absorbent.

Bentonite micro structure contains two tetrahedral layers and one octahedral layer. In montmorillonite tetrahedral layers consisting of [SiO_4]-tetrahedrons enclose the [Al(O_5,OH)]-octahedron layer and [Mg(O_5,OH)]-octahedron layer.

The silicate layers have a slight negative charge. This charge is balanced by exchangeable ions in the intercrystallite region. Due to weak charge, the cations predominantly Ca2+, Mg2+ or Na+ ions, can be adsorbed in this region with their hydrate shell, Results the inter-crystalline swelling due to hydration produces.

Sodium Bentonite swells on absorbing the moisture/water. The property of swelling on contact with water makes sodium Bentonite useful as a sealant. sodium Bentonite provides a self-sealing, low permeability barrier. Physical properties of bentonite used are shown in Table 2.

Table 2: Physical properties of Bentonite

Parameter	Value
Specific gravity (G)	1.54
Liquid Limit (%)	121.26
Plastic limit (%)	70.68
Plasticity Index (%)	50.58
Angle of internal friction (ϕ), degree	0
Cohesion (c), kg/cm²	1.32
Soil type as per IS: 1498-1970	CH

C. Sample Preparation

Sodium bentonite used was dried in air and then kept in temperature and moisture-controlled environment. Sand used was oven dried and material retained on 2.36 mm sieve was rejected. Studies shows that the coarse material may not puncture other liner materials. Tests were conducted on samples without mixing in dry state. On mixing sand and sodium bentonite in the wet state showed irrelevant tests results, because of the non-uniformity of the model mix. sodium bentonite used for preparation of model mix, swelled immediately after adding water results prevented uniform mixing.

Sodium bentonite was mixed at varying proportions i.e., 4%, 8%, 12%, 16%, 20%, 24%, 28%, 32%, 36% and 40% were added with the sand to make the model mix. Mixing was done by properly mixing in the dry sample. After mixing dry samples desired amount of water was added as determined in the proctor test and prepared the model mix.

This method was adopted for uniformity of the mix. Samples for conducting proctor test were prepared at varying water content for all varying percentages of sodium bentonite. Samples were kept in polythene bags to swell properly for a period of 7 days.

Polythene bags were used to avoid any change in moisture content. Polythene bags helped sodium bentonite in the model mix to swell properly. Proctor tests were conducted on the samples after period of 7 days. Samples for Permeability test, CBR test and Direct Shear test were prepared at Maximum Dry Density and Optimum Moisture Content. Samples for Permeability test, CBR test and Direct Shear test were left for swelling in polythene bags for a period of 7 days.

D. **Experimental Program**

Geotechnical characteristics of sand and Bentonite samples with different proportion of sodium bentonite were determined in the laboratory by conducting grain size analysis, specific gravity test, and consistency limits test.

After determining the physical properties of different sand and Bentonite samples, engineering properties of sand and sodium bentonite model mix with different proportions of bentonite were determined. The sand was mixed with different percentages of bentonite (4%, 8%, 12%, 16%, 20%, 24%, 28%, 32%, 36% and 40%) by dry weight of total sample.

Various testes such as standard proctor test, specific gravity test, direct shear test, CBR test and

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the permeability test were conducted on model mix to determine geotechnical properties of sand and bentonite model mixes.

III. RESULTS AND DISCUSSION

A. Compaction Test

The proctor test were performed on the sand and Bentonite model mix with different proportions of Bentonite in accordance with IS: 2720 (Part-7)-1980. The results obtained from the proctor tests to determine Optimum Moisture Content (O.M.C) and Maximum Dry Density (M.D.D) of sand and Bentonite model mix samples are given in Table 3. The values presented in table 3 are an average value of the three tests conducted on the same mix. The variation of M.D.D with different percentage of Bentonite is shown in Fig 1 and variation of O.M.C with different percentage of bentonite is shown in Fig 2.

Table 3: OMC and MDD of Sand and Bentonite Mix

Material	OMC(%)	MDD (g/cm^3)
100% S + 0%B	4.62	1.56
96% S + 4% B	5.26	1.58
92% S + 8% B	6.12	1.59
88% S + 12% B	7.35	1.61
84% S + 16% B	8.8	1.62
80% S + 20% B	9.82	1.63
76% S+ 24% B	10.56	1.65
72% S + 28% B	11.76	1.68
68% S + 32% B	12.22	1.67
64% S + 36% B	13.05	1.67
60% S + 40% B	13.86	1.66

In the present study of model mix, initially upon mixing the sodium bentonite in sand, the plasticity index of the model mix slightly increases up to 8% of sodium bentonite. On further increasing the percentage of sodium bentonite in the model mix, clayey properties increases. These samples has shown an initial decrease in dry density before attaining Maximum Dry Density at Optimum Moisture Content.

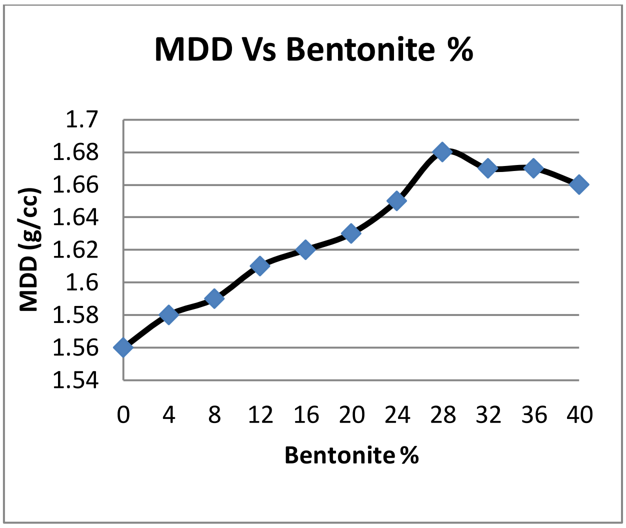

Fig 1: The variation of M.D.D with different Percentage of Bentonite

The curve represented in Fig.1 showed that with variation of sodium bentonite in sand, values of M.D.D increases from 1.56 g/cc at 0% Bentonite mix to 1.66 g/cc at 40%. MDD is maximum at 28% sodium bentonite added in the model mix.

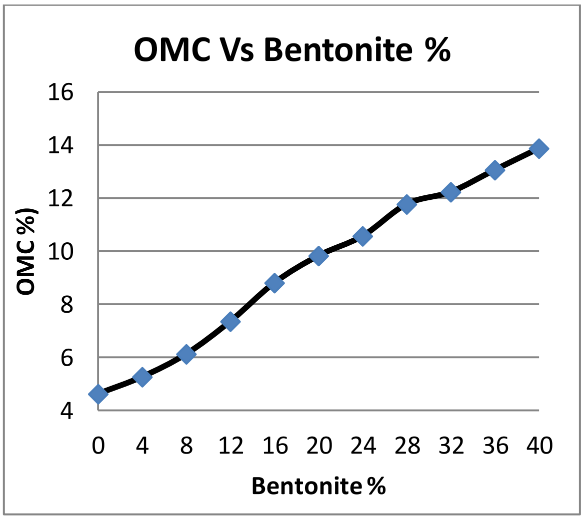

Fig 2: Variation of O.M.C with different Percentage of Bentonite

The curve represented in Fig. 2 showed that with variation of sodium bentonite in sand, values of O.M.C increases from 4.62% at 0% Bentonite mix to 13.86% at 40% Bentonite mix. Value of O.M.C. at 28% sodium bentonite added in the model mix is 11.76%.

Dry density increases with incresed percentage of Bentonite, because the voids with in the sand are occupied by the fine Bentonite particles,

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which in result, increases the mass of soil solids for same volume. O.M.C. increases of the model mix due to this densification and need water to absorbed by the sodium bentonite with increase percentage of Bentointe.

B. Direct Shear Test

Shear strength parameters such as angle of internal friction and cohesion were determined in laboratory by conducting direct shear test in accordance with IS: 2720 (Part 13) – 1986. Results obtained from direct shear tests are given as relation between normal stress and shear stress and value of cohesion and internal friction obtained from these plots is given in Table 4.

Value of cohesion is determined by plotting the normal stress vs shear stress curve and represented in Table 4. Angle of internal friction is also determined by calculating the slope angle of the normal stress vs shear stress curve.

Table 4: Direct Shear Test Result

bentonite %	Cohesion (kg/cm^2)	Angle of internal friction (Φ)
0	0.02	18.16°
4	0.04	17.98°
8	0.07	17.36°
12	0.11	16.88°
16	0.15	16.12°
20	0.21	15.16°
24	0.24	14.50°
28	0.28	13.65°
32	0.31	12.90°
36	0.33	12.25°
40	0.35	11.90°

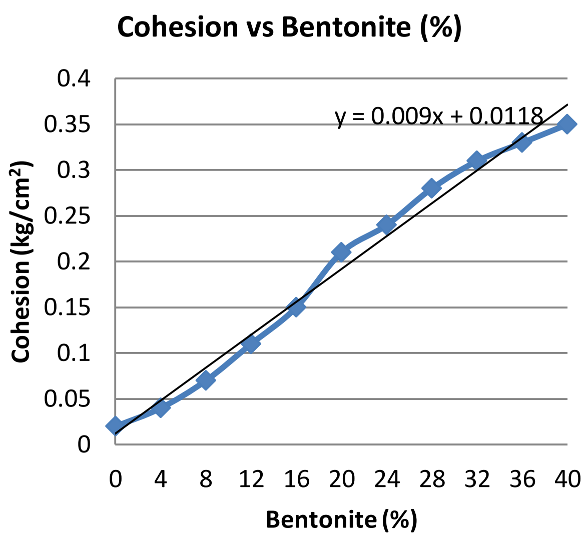

Fig 3: Variation of cohesion with different Percentage of Bentonite

From the laboratory results of cohesion and angle of internal friction it can be concluded that the value of cohesion increases with increase of Bentonite percentage. As cohesion is function of clay content therefore cohesion increases upon adding the Sodium bentonite.

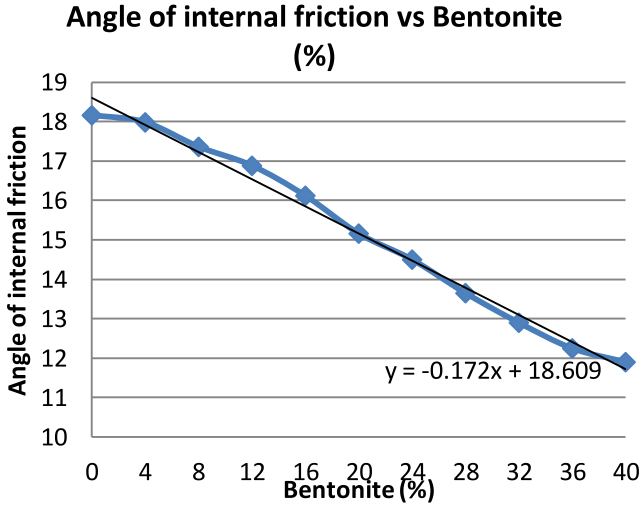

Fig 4: Variation of angle of internal friction with different Percentage of Bentonite

Angle of internal friction reduces with increase in percentage of bentonite. As angle of internal friction is function of contact points between sand particles therefore angle of internal friction decreases due to slipping of sand particles upon adding the Sodium bentonite.

C. Permeability Test

Samples prepared for permeability test by compacting model material directly in permability mould at maximum dry density and optimum moisture content obtained from proctor test. After proper compacting the samples, they were left fully immersed in water for complete saturation. When discharge of water comes out from outlet on surface of mould at lower end, saturation completed. Permeability test was performed on saturated samples in accordance with IS: 2720 (Part 17)-1986 under falling head condition. The results obtained from the permeability tests are shown in Table 5.

Table 5: Co-efficient of Permeability

Material	Permeability, (cm/s)
100% S + 0%B	8.05×10^{-5}
96% S + 4% B	5.68×10^{-5}
92% S + 8% B	1.25×10^{-5}
88% S + 12% B	9.46×10^{-6}
84% S + 16% B	4.75×10^{-6}
80% S + 20% B	1.08×10^{-6}
76% S+ 24% B	7.82×10^{-7}
72% S + 28% B	2.36×10^{-7}
68% S + 32% B	7.55×10^{-8}
64% S + 36% B	1.32×10^{-8}
60% S + 40% B	5.65×10^{-9}

Co-efficient of permeability values as shown in Table 5 decreases from 8.05×10^{-5} m/s at 0% Bentonite mix to 5.65×10^{-9} m/s at 40% bentonite in model mix.

Swelling of sodium bentonite starts after coming in contact with water. It occupies voids in model mix reduced porosity, results the decrease of permeability.

IV. CONCLUSIONS

Following conclusions may be drawn on the basis of present study

1) The condition for using the material as a landfill liner the co-efficient of permeability must be equal to or less than 1×10^{-7} cm/s. on conducting permeability test the values of co-efficient of permeability attains the desirable value from 24% Bentonite content in the model material. The model material having bentonite percentage between 24-28 may be used as a landfill liner.

2) Maximum Dry Density MDD increases with increasing proportion of Bentonite in the model mix. Model mix has maximum dry density at 28% Bentonite content. Hence we may conclude that at 28% bentonite mixing in the model mix provide stability of model mix as liner material.

3) Optimum moisture content (OMC) followed a increasing trend with increasing proportion of Bentonite in the model mix. Optimum moisture content (OMC) is 11.76% at 28% Bentonite content.

4) Angle of internal friction decreases with increasing percentage of Bentonite in the model mix. Angle of internal friction was 13.65º at 28% Bentonite content in model mix.

5) The value of Cohesion increased with increasing proportion of Bentonite in the model mix. The value of Cohesion was 0.28 kg/cm^2 at 28% Bentonite content in model.

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