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Reuse of Dredge Material as a Liner in Landfills

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Abstract. Waste disposal is an important issue for human societies. Landfill sites are widely used for the disposal, treatment, and management of waste materials. Leakage of leachate from landfills results in the pollution of the local environment, contamination of soil, and groundwater. The risks of leachate generation and leakage can be mitigated by proper design of engineered landfill sites that use impermeable clay liners. Parvathy Puthanar, the highly polluted canal in Trivandrum, Kerala, India is under cleaning. Its dredge material disposed on the roadsides is a major issue to the authorities and public. Attempts are under way to reuse the dredge material. In this study, the characteristics of the dredge material and its suitability as a clay liner was studied. The dredge material is classified as poorly graded sand with a permeability of 1.18×10^{-2} cm/s, making it unsuitable as a liner. So, the optimum percentage of bentonite required to be added to obtain a clay liner was found out by conducting laboratory studies. The optimum bentonite percentage of 30-40% was obtained based on percentage fines, permeability, plasticity index, and UCC value. A water content of 2% above OMC based on placement water content, can be used for the preparation of clay liner. A Geosynthetic Clay Liner (GCL) was also developed with this modified dredge material by adding 40% of bentonite. The GCL section proposed consists of modified dredge material bonded by 2 mm geosynthetic at the ends. The developed Compacted Clay Liner (CCL) gave a permeability value of 6.7×10^{-7} cm/s while the GCL gave 6.34×10^{-9} cm/s, thus the GCL developed is more efficient in preventing the permeation of leachate.

Keywords: Dredge material, Clay liner, Bentonite, Compacted clay liner, Geosynthetic clay liner.

1 Introduction

The risk to human health and the environment due to the disposal of municipal and hazardous wastes has become an important concern all over the world. Engineers, scientists, and waste managers are actively involved in the safe disposal of solid waste, design of new disposal facilities, and the operation of existing disposal sites. One of the most common waste disposal methods is landfilling. The term engineered landfill is used to denote a landfill designed and operated to minimise environmental impact. The main components of an engineered landfill are the liner system, leachate collection facility, and gas control facility. The key challenge of the waste disposal facility is the control of leachates generated so that it does not contaminate the underground soil or the groundwater. Leachate contamination can be mitigated by proper design of the liner system. Liner system comprises of a combination of leachate drainage, collection layer, and barrier layers (Datta, 1997).

When low permeable natural clay materials are available at the site these can be excavated and recompacted to construct Compacted Clay Liner (CCL); the basic requirement being lower hydraulic conductivity. If the soils found in the vicinity of the waste disposal are not sufficiently clayey to be used as a liner material, a common practice is to blend natural soils available on or near the site with bentonite to reduce the hydraulic conductivity. Geosynthetic Clay Liner (GCL) comprises of a thin layer of bentonite bonded to a layer or layers of geosynthetics. The incorporation of natural clay with bentonite and geosynthetic material reduces the hydraulic conductivity to a significant amount.

The essential requirement of a liner is that its hydraulic conductivity should be less than 10^{-7} cm/s. The percentage of fines and plasticity index should be in the range of 20-30% and 7-10% respectively (Boyton and Daniel, 1985). Bagchi (1989) suggests that for a liner material, the liquid limit and clay content should be between 25-30% and 18-25% respectively and the percentage fines should be between 40 and 50%.

Ojuri and Oluwatuyi (2017) studied the use of Igbokoda sand-bentonite mixtures as a landfill liner. Igbokoda sand was mixed with varying percentages of bentonite and a series of tests- hydraulic conductivity, compaction test, California Bearing Ratio (CBR) and direct shear test were performed and the best percentage of bentonite was selected for the design of landfill liner. Widomski et al. (2018) studied the possible application of seven clay substrates sampled from rural areas to be used as waste landfill liners thus meeting the main principles of sustainability, utilizing locally available materials and limiting the environmental threats posed by landfill leachate. The substrates were tested for their saturated hydraulic conductivity after compaction, shrinkage and swelling characteristics. The results showed that the tested clay substrates were found applicable to the construction of compacted clay liner and the durability of such liners are strongly related to the compaction parameters applied during liner construction.

Suguna and Rao (2009) designed a landfill for Farukhnagar block in Gurganon district of Delhi. The standard proctor compaction test, permeability test, unconfined compression test and direct shear test were carried out on virgin soil, virgin soil plus different percentages of bentonite and virgin soil plus different percentages of gagghar clay. The percentage of bentonite, gagghar clay and thickness of clay liner required were determined; the layout of the landfill and the leachate collection layer were also designed. HELP model analysis was also carried out to find the maximum head over the leachate collection layer. Giridhar et al. (2015) carried out experimental studies on the use of clay bentonite mixes as liner material, by accessing the hydraulic conductivity, shear strength, compressibility and shrinkage volume. George et al. (2016) designed a clay liner using kuttanad clay, bentonite and crushed tile waste and its geotechnical characteristics like consistency limits, shear strength, permeability and percentage swell were studied to evaluate the capacity of the liner for use in waste landfill. Prakash and Poulose (2016) studied the amendment of local laterite soil with

Kuttanad clay as a landfill liner. The tests conducted were hydraulic conductivity, compaction, unconfined compression strength and consistency limits.

In this study, the reuse of dredge material from Parvathy Puthanar as a compacted clay liner was evaluated. A GCL section was also created and the permeability of developed CCL and GCL were compared.

2 Materials and methods

The dredge material used in the study was collected from the canal Parvathi Puthanar, Thiruvananthapuram, Kerala when dredging was carried out by the government agencies in 2016. From the particle size analysis, the dredge material is classified as poorly graded sand. The permeability of the dredge material lies in the range of medium sand. Calcium bentonite is used along with dredge material to achieve a suitable blended material as CCL. The properties of dredge material and calcium bentonite used in the study are presented in Table 1 and Table 2 respectively. Non-woven geosynthetic obtained from Maccaferri, Ernakulam was used for the preparation of GCL.

In the study, the dredge material was mixed with 5,10,20,30,40,50 and 60% of bentonite content. The proctor tests were conducted on each mix to obtain OMC (Optimum Moisture Content) and maximum dry density. The unconfined compressive strength of each mix was determined by preparing samples at OMC and maximum dry density. Atterberg limit test was also conducted on each sample. After the selection of required bentonite percentage, permeability test, free swell test and shrinkage test were conducted to access its suitability. A GCL sample was prepared and its permeability was also tested.

Table 1. Properties of dredge material

Properties	Value
Water content of collected sample (%)	30
Specific gravity	2.54
Coarse sand (%)	2
Medium sand (%)	58
Fine sand (%)	34
Silt and clay (%)	6
C_u	3.33
C_c	1.13
Coefficient of permeability (cm/s)	1.179×10^{-2}
Classification	SP

Table 2. Properties of calcium bentonite used

Properties	Value
Specific gravity	2.61
Liquid limit (%)	295

Plastic limit (%)	54
Plasticity Index (%)	241
Clay (%)	82
Silt (%)	18
Activity	2.94
Coefficient of permeability (cm/s)	3.1×10^{-8}
Classification	CH

3 Results and discussion

Compaction tests were carried with different bentonite percentages such as 5, 10, 20, 30, 40, 50 and 60. The maximum dry density and OMC obtained from compaction curves for the seven samples are presented in Fig. 1 and Table 3.

The maximum dry density decreased with the addition of bentonite. Nearly 7 percentage decrease of dry density was observed with the addition of bentonite from 5% to 40%. By adding more than 40% of bentonite a drastic decrease in the dry density was observed. The increase of OMC from 5% bentonite to 30% of bentonite content is minimal. For 40% bentonite sample the OMC increased to 21%. By increasing bentonite above 40% the OMC increased drastically. Selection of mix with higher OMC will result in a lower permeability but shear strength can decrease considerably. Thus, the addition of bentonite content is limited to 40% based on the decrease of dry density and the increase of OMC.

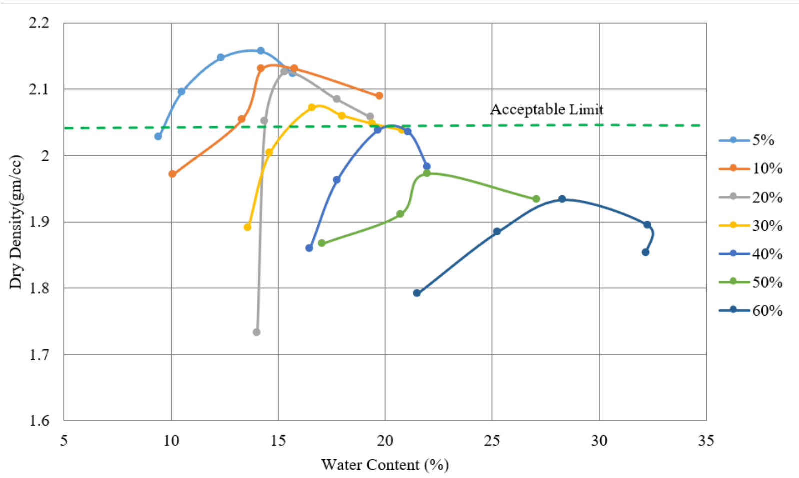

Fig.1. Compaction test results with varying bentonite content

Table 3. Compaction test results for different bentonite content

Bentonite (%)	Maximum dry density(gm/cc)	OMC (%)
5	2.16	14

10	2.13	14.5
20	2.11	15.5
30	2.07	16.54
40	2.03	20.72
50	1.96	21.94
60	1.93	28.45

Table 4 and Fig.2 shows the unconfined compressive test results for dredge material blended with different percentages of bentonite. The UCC values of blended mix indicate that when the bentonite content reached 30 to 50% the material attained soft consistency at OMC and when the bentonite content reached 60%, the mix attained very soft consistency at OMC. The bentonite content of 30-40% gave the maximum value of UCC and hence this range of bentonite can be adopted for liner material.

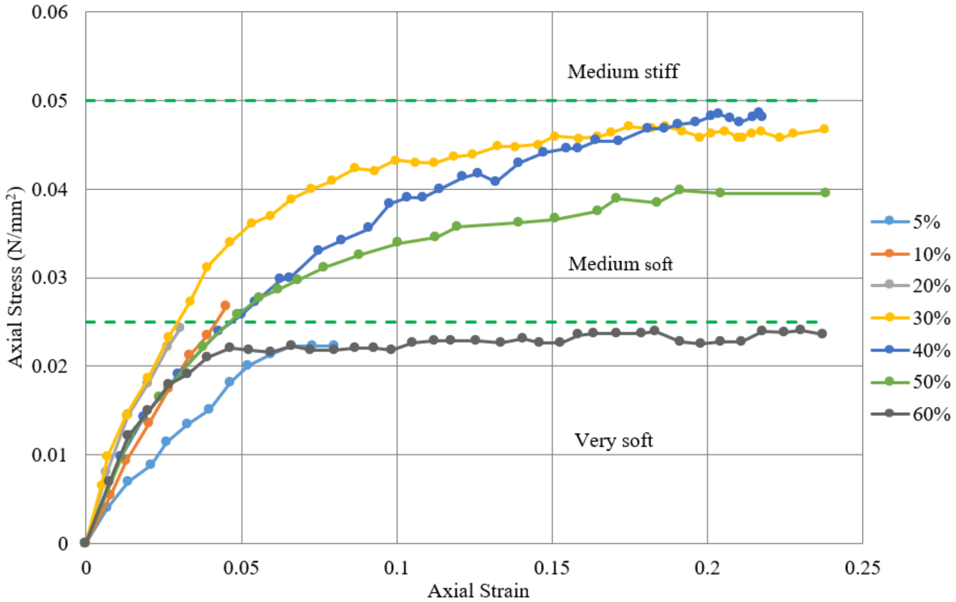

Fig.2. UCC test results for various percentages of bentonite addition

Table 4. UCC values and the nature of the failure of samples

Bentonite (%)	UCC (kN/m^2)	Strain (%)	Consistency/nature of failure
5	23	5	crumbled
10	25	5	crumbled
20	26	5	crumbled
~~30~~	~~48~~	~~20~~	~~soft~~
40	49	20	soft
50	40	20	soft
60	20	20	very soft

The selection of bentonite content required in the dredge material to modify it as a liner with permeability less than 10^{-7} cm/s is done based on the suggestions from Boyton and Daniel (1985) and Bagchi (1989). The percentage of fines content increased with the addition of bentonite in dredge material. Addition of 20% and above bentonite content provided required fines content (≥20-30%) as suggested by Boyton and Daniel (1985). The percentage of gravel is less than 30 % for all bentonite mixes. The Plasticity Index (PI) increased with bentonite content and 30-40% bentonite content gave PI as suggested by Bagchi (1989). The observations of fines content, gravel content, and plasticity index are shown in Table 5.

Table 5. Selection based on minimum specifications to reach k≤10^{-7} cm/s

Properties	Samples with different Bentonite percentage						Recommendations
	5-10	20	30	40	50	60	
Fines% (<75μm)	11-16	26	36	46	56	60	≥20-30 (Boyton and Daniel 1985)
Gravel% (>4.75mm)	0	0	0	0	0	0	<30 % (Boyton and Daniel 1985)
Plasticity Index (%)	0	10	21	28	85	120	Between 10% and 30% (Bagchi1989)

By considering these recommendations selection of bentonite mix to reach permeability value less than 10^{-7} cm/s was chosen. As per the values shown in Table 5, the bentonite percentages of 30-40% were selected as the suitable bentonite content required to reduce the permeability of dredge material less than 10^{-7} cm/s.

Based on the above selection criteria, bentonite samples with 30% and 40% were tested for permeability using a consolidometer fitted with burette as a standpipe for water column (IS:2720-Part 17, 1986). The sample diameter was 6 cm and height 2 cm. The samples were prepared with maximum dry density and moulding water content 2% above OMC. Samples were saturated for 24 hrs at a pressure of 0.25 kg/cm^2. The coefficient of permeability of samples with 30% and 40% bentonite content were 7.122×10^{-7} cm/s and 6.881×10^{-7}cm/s respectively. Hence, a bentonite percentage between 30-40% can be recommended for mixing with the dredge material in the preparation of liner.

The differential free swell test (IS: 2720-Part 40, 1977) was conducted on samples of 30% and 40% bentonite mixes. From differential free swell values, it was noted that samples with higher bentonite proportion have a high degree of expansiveness. The differential free swell for 30 and 40% bentonite content was 70% and 90% respectively. These values indicated that degree of expansiveness is very high as per IS: 2720-Part 40, 1977. A higher degree of expansiveness can result in swelling when leachate comes in contact with liner and thus the voids further reduce.

The shrinkage limit of samples with 30% and 40% bentonite was 35.72% and 38.21% respectively. The shrinkage ratio of the samples with the above percentages were 11.23 and 12.00. Soils with less than 5% degree of shrinkage are considered as good, whereas those with greater than 10% degree of shrinkage are considered as poor. Soils with high shrinkage will show desiccation cracking upon drying and special control measures (such as spraying of water) will be required in the field after compaction of liner material.

The GCL was prepared by bonding a 2 mm thick geosynthetic with dredge material containing 40 % bentonite using adhesives. The permeability of the prepared GCL was tested using consolidation cell fitted with stand pipe. The coefficient of permeability of GCL was found to be 6.34×10^{-9} cm/s. The schematic view of the GCL prepared is shown in Fig. 3 and the GCL prepared is presented in Fig.4.

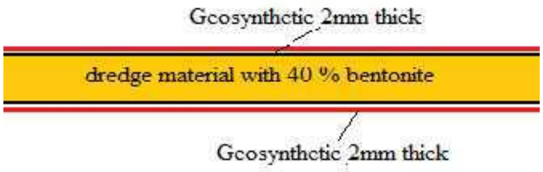

Fig.3. Schematic view of GCL prepared

Fig.4. GCL prepared using dredge material and 40 % bentonite

4 Conclusions

In this study, the suitability of dredge material from Parvathy Puthanar as a landfill liner was assessed. Due to higher hydraulic conductivity (1.18×10^{-2} cm/s), pure dredge material cannot be used as a clay liner. To lower the permeability and thus facilitate the creation of a CCL, different bentonite mixes were tried. The bentonite percentages of 30-40% were selected as the suitable bentonite content which is required to reduce the permeability of dredge material to less than 10^{-7} cm/s. A simple GCL section was also prepared using the above mix bounded by a 2 mm thick geosynthetic. The permeability of CCL and GCL developed were 6.7×10^{-7} cm/s and 6.34×10^{-9} cm/s respectively.

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References

1. Bagchi, A.: Design Construction and Monitoring of Landfills, John Wiley and Sons, Inc., New York (1989).
2. Boynton, S. S., Daniel, D. E.: Hydraulic Conductivity Tests on Compacted Clay. Journal of Geotechnical Engineering, ASCE, 111(4), pp. 465–478 (1985).
3. Datta, M.: Waste disposal in Engineered Landfills, Narosa Publishing house, New Delhi, (1997).
4. George, B. M., Alex, A., Jose, J., Roy, L., and Thomas, S.: A Study on Amended Liner Using Kuttanad Clay and Crushed Tile Chips. International Journal of Innovative Science, Engineering & Technology, IJISET, 4(5), pp. 127-132 (2017).
5. Giridhar, V., Kumar, P. S. P., and Venkatasubbaiah, M. C.: Experimental Studies on Clay, Bentonite and Leachate Mixer as Liner Material. International Journal of Innovative Research in Advanced Engineering, IJIRAE, 1(2), pp. 23-31 (2015).
6. IS 2720-Part 17: Methods of test for soils – Laboratory determination of permeability, Bureau of Indian Standards, New Delhi (1986).
7. IS 2720-Part 40: Methods of test for soils- Determination of free swell index of soils, Bureau of Indian Standards, New Delhi (1977).
8. Ojuri, O., and Oluwatuyi, O.: Strength and hydraulic conductivity characteristics of sand-bentonite mixtures designed as a landfill liner. Jordan Journal of Civil Engineering. 11, pp. 614-622 (2017).
9. Prakash, A. and Poulose, E.: Kuttanad Clay Amended Laterite as a Landfill Liner for Waste Disposal Facilities. International Journal of Scientific Engineering and Research (IJSER), 4(3), pp. 75-78 (2014).
10. Suguna, J. and Venkatappa Rao, G.: Design of landfill for rural areas. In: Venkatappa Rao, G. and Sasidhar, R.S. (eds.): Solid Waste Management and Engineered Landfills, pp.206-223, Sages Publications, Hyderabad (2009).
11. Widomski, M. K., Stepniewski, W., and Musz-Pomorska, A.: Clays of Different Plasticity as Materials for Landfill Liners in Rural Systems of Sustainable Waste Management: Sustainability, 10(7), 2489 (2018).