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AN EXPERIMENTAL INVESTIGATION ON THE GEOENGINEERING PROPERTIES OF POND ASH-BENTONITE MIXES

Suryaleen Rout
PhD Scholar, Department of Civil Engineering, National Institute of Technology Rourkela, Rourkela – 769008, Odisha.
suryaleen1512@gmail.com

Suresh Prasad Singh
Professor, Department of Civil Engineering, National Institute of Technology Rourkela, Rourkela – 769008, Odisha.
spsingh@nitrkl.ac.in

ABSTRACT: An engineered landfill necessitates an impervious barrier to control the intrusion of groundwater into the landfill facilities and migration of leachate to the surrounding ground. The liner material should have sufficient shear strength along with highly impermeable. This paper aims at investigating certain features of a novel material that may serve as a landfill liner material as a substitute to sand-bentonite mixture. In this investigation bentonite was blended with coarse pond ash ranging from 0 to 30% by weight of the total material in 5% intervals. The compaction characteristics, strength behaviour, and permeability characteristics of these mixes are evaluated. It is observed that with bentonite content varied from 20 to 30%, the average hydraulic conductivity reduces from 3×10^{-7} to 9×10^{-9} cms^{-1} for samples compacted to MDD at OMC corresponding to a compactive effort of 595 kJ/m^3. However, when the samples are compacted with 2674 kJ/m^3 energy; the hydraulic conductivity as mentioned above is achieved at a bentonite content of 15%. With the gradual addition of bentonite the cohesion of the mixture increases whereas the angle of internal friction decreases. Hence it is concluded that sand-bentonite mixes can effectively be replaced by pond ash-bentonite mixture in the landfill liners.
KEYWORDS**:** *Bentonite, pond ash, land fill, permeability and strength parameters.*

INTRODUCTION

Wastes are generated more and more with increasing industrialization and population growth. Based on the safety level, these wastes can be controlled by different options such as waste reduction, separation and recycling, resources recovery through waste processing, waste transformation, and environmentally sustainable disposal on land. The most frequently used disposal option for solid waste in the landfill because of its low cost and efficiency. The core component of a waste disposal facility is its liner system. The design of liner is made so.as to isolate the waste from the environment minimizing the passage of leachate into the groundwater. To ensure this the important characteristics for compacted landfill liners are selection of materials, hydraulic conductivity and strength. Usually, soil rich in clay minerals are used as compacted liner materials for their low hydraulic conductivity which is required to be less than 1.0×10-7 cm/s (Daniel, 1987; 1990; Benson and Trast, 1995). Instead of clay, mixture of expansive soil such as bentonite with fly ash and pond ash can is used as compacted barriers (Brian et al. 2000). The current work focus on finding an accurate mixture of pond ash and bentonite that can be used as compacted clay liner. Even though pond ash and bentonite have extremely opposite properties, when mixed together they show complimentary behavior. Pond ash is highly permeable but with the addition of bentonite the hydraulic conductivity can be reduced. Bentonite being an excellent sealant helps check the passage of leachate to the ground water (Mishra et al.; 2010). The bulk availability of pond ash helps to reduce the cost of raw materials required for liner as well as providing their safe disposal on a large scale. A number of researcher used the pond ash and its engineering properties (Kumar et al. 1999; Arrykul et al. 2005; Subbarao et al. 2007; Ghosh et al. 2007; Ghosh et al. 2010; Bera 2010; Pradeep et al. 2013; Arvind et al. 2014. This paper investigates the geo-engineering properties of pond ash–bentonite mixes and its suitability as a land fill liner material.

MATERIALS AND METHODOLOGY

Bentonite

Bentonite is primarily composed of the montmorillonite group of minerals. Commercial sodium based bentonite procured from local market is used in this experimental investigation.

Pond ash

Pond ash used in the present investigation was collected from ash pond of National Thermal Power Plant (NTPC) Talcher, Odisha. The samples were mixed thoroughly to bring homogeneity and dried at an oven temperature of 105-110^{0}C. These were stored in airtight containers for subsequent use. The physical properties of the bentonite and pond ash are presented Table1.

Methodology

In this present study, synthetic mixes are prepared by adding bentonite of 5 to 30% by weight at 5% intervals with the pond ash. In this manner, six different mixes were synthesized. The OMC and MDD of these mixes corresponding to compactive efforts of 595 kJ/m^3 and

2674 kJ/m^3 are determined as per IS: 2720 (Part 7) 1980 and IS: 2720 (Part 8) 1983 respectively. Prior to the compaction tests, these synthetic materials were mixed with initial water and were kept in an airtight container for 48 hours for proper distribution of water in the mix. To find out the shear strength parameters synthetic mixes were compacted in standard Proctor mold to their respective MDD at OMC using compactive efforts of 595kJ/m^3, and 2674 kJ/m^3. Undisturbed specimens of size 60mm×60mm×25mm were recovered from the mold and were sheared at a rate of 0.2 mm/min. The shear parameters (i.e. c and Φ values) were found out from the plots between normal stress and shear stress. These tests were performed as per IS: 2720 (Part 13) 1986. Unconfined compressive strength tests on specimens compacted to their corresponding MDD at OMC was performed according to IS: 2720 (Part 10) 1991. The cylindrical test specimens were of size 50mm in diameter and 100mm in height, and these were sheared at an axial strain rate of 1.25 mm/min. Hydraulic conductivity of different pond ash-bentonite mixes, compacted to their respective MDD at OMC are evaluated as per IS: 2720(Part 17) 1987.

Table 1 Physical property of pond ash and bentonite

Physical Parameters	Pond ash	Bentonite
Sand size (%)	88	0
Silt size (%)	22	0
Clay size (%)	0	100
Uniformity coefficient, C_u	1.09	-
Coefficient of curvature, C_c	2.8	-
Specific gravity	2.23	2.7
Liquid limit	-	200
Plastic limit	-	68
Plasticity index	NP	132
Soil type	SP	CL

RESULT AND DISCUSSION

Compaction characteristics

Figure 1 shows that with the addition of bentonite, the OMC value decreases up to an optimum bentonite content after that it remains almost unchanged. Figure 2 shows the variation of MDD with bentonite content. It is found that with the addition of bentonite to pond ash, MDD value increases up to an optimum bentonite content after that it remains almost constant. This trend is observed for samples compacted either with 595kJ/m^3 or 2674 kJ/m^3 energy. The optimum content of bentonite for both the cases is found to be 20%. This may be due to the fact that when bentonite percentage is small, the finer particles of bentonite mostly go into the intra-void spaces present in the conglomerated ash particles. As the percentage of bentonite is further increased, these particles filled-up the inter-particular void spaces available in the pond ash sample. This increases the MDD value. Further increase of bentonite creates a space for itself forcing the ash particles to move apart, thus stabilizing the MDD value.

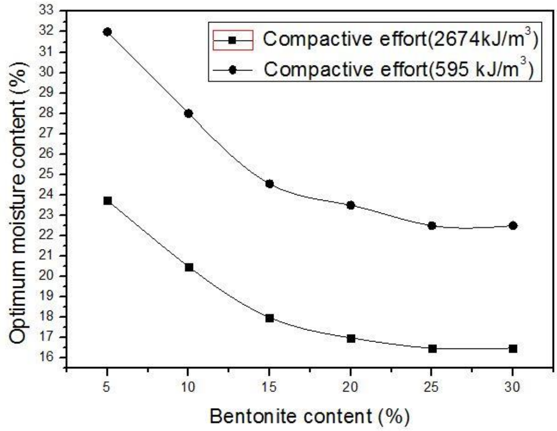

Fig. 1 Variations of optimum moisture content with bentonite content

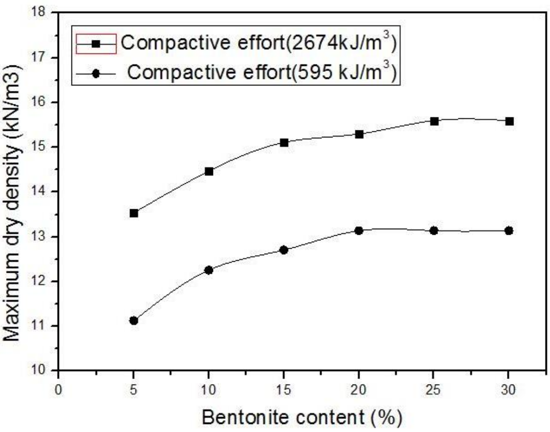

Fig. 2 Variations of maximum dry density with bentonite content

Hydraulic conductivity

Hydraulic conductivity values of bentonite-pond ash mixes compacted with 595 kJ/m^3 and 2674 kJ/m^3 energy were found to be in the range of 8.83×10^{-4} to 9.23×10^{-9} cm/s and 3.42×10^{-4} to 5.15×10^{-9}cm/sec respectively. The hydraulic conductivity values are given in Table 2. It is obvious that an increase of bentonite content in the compacted mixtures lowers the hydraulic conductivity values. This has been verified by many studies. Since bentonite alone has characteristics of impervious material and has extremely low hydraulic conductivity values in the order of 10^{-10} to10^{-12} cm/s, it is expected to have lower hydraulic conductivities as its percentage in the mixture increases. The experimental data shows that the reduction in hydraulic conductivity with bentonite content is not linear. Initially, the rate of reduction is mild followed by a sharp decrease in the hydraulic conductivity value. At low bentonite content, the finer bentonite particles get adjusted in the intra-particle void space of pond ash thus there is an appreciable reduction in capillary void space. However, as its content increases it reduces the capillary void thus a sharp reduction in the hydraulic conductivity value.

Unconfined compressive strength

Unconfined compressive strength test was performed for sample compacted with both 595 kJ/m^3 and 2674 kJ/m^3 energy. Compressive strength of pond ash-bentonite mixture compacted for both the energy were found be in the range of 52 to 197 kPa and 99 to 691 kPa respectively as shown in Figure 3. As per the general requirement of isolation material such as liner, the compressive strength should have a value more than 200 kPa. The above strength is accomplished for the samples containing 15% or above bentonite and compacted with 2674 kJ/m^3 energy.

Table 2 Hydraulic conductivity of compacted pond ash bentonite

BENTONITE CONTENT (%)	**HYDRAULIC CONDUCTIVITY *(cm/sec)***	
	Compactive effort (595 kJ/m^3)	Compactive effort (2674kJ/m^3)
5	8.83×10^{-4}	3.42×10^{-4}
10	1.05×10^{-4}	9.08×10^{-5}
15	1.18×10^{-5}	6.99×10^{-7}
20	3.47×10^{-7}	9.9×10^{-7}
25	8.32×10^{-8}	1.23×10^{-8}
30	9.23×10^{-9}	5.15×10^{-9}

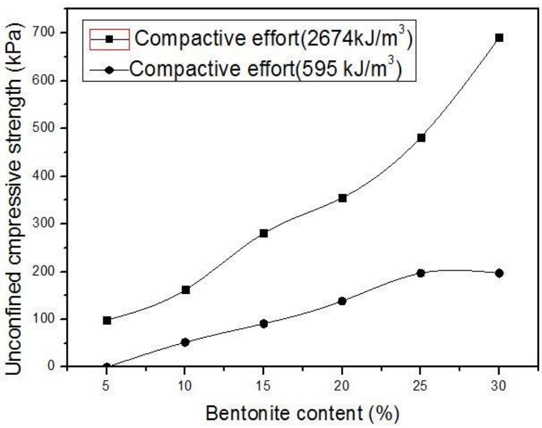

Fig. 3 Variations of unconfined compressive strength with bentonite content

Shear strength parameters

Shear strength parameters such as unit cohesion (c) and internal friction angle (ϕ) were found to be in the range of 16.27 to 63.81 kPa and 42.5° to 28.4° for mixtures compacted with 595 kJ/m^3 energy, 12.67 to 89.59 kPa and 44.6° to 30.9° for the mixtures compacted with 2674kJ/m^{3}energy when the bentonite content of the mixture is changed from 5 to 30%. Figure 4 and 5 presents the variation of unit cohesion and angle of internal friction with bentonite content. It is seen that as the bentonite content increases, the cohesion increases and internal friction angle decreases. This may be due to the fact that as pond ash particles are irregular in shape, there exist a good interlocking between the particles hence the angle of internal friction is high. When a smaller amount of bentonite is added to the mixture, the finer particle of bentonite tries to fill the intra-void spaces present in the conglomerated ash particles. But as the bentonite content increases, the excess bentonite coats the surfaces of the ash particle. As bentonite particles are lubricative in nature, the bentonite coated pond ash particles losses their contact and slips over each other and hence frictional angle decreases. However, due to the presence of strong inter-particular attractive forces between the bentonite particles the mixture gradually develops cohesion with an increase in bentonite content.

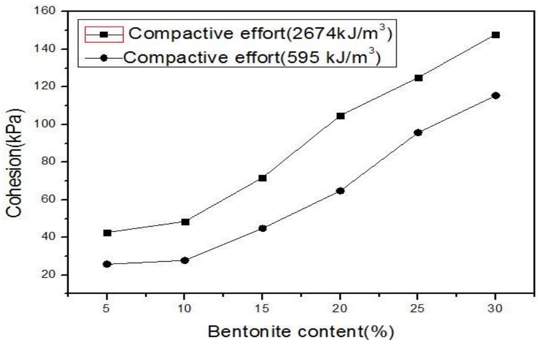

Fig. 4 Variations of cohesion with bentonite content

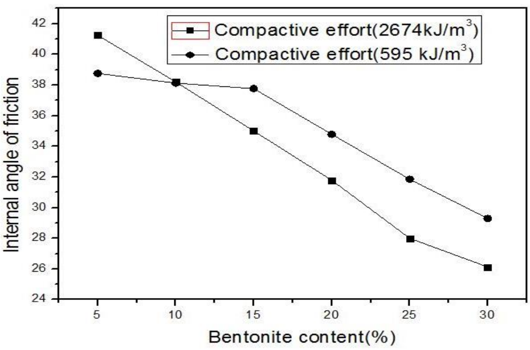

Fig. 5 Variations of internal angle of friction with bentonite content

CONCLUSION

The suitability of pond ash-bentonite mixes as landfill liner material was investigated in this work. The compaction, strength and hydraulic conductivity characteristics are evaluated. Based on the experimental investigation, the following conclusions are drawn:

- When the samples were compacted with compactive effort of 595 kJ/m^3 the maximum dry unit weight increases from 11.13 to 13.14 kN/m^3 and the corresponding optimum water content of the compacted mixtures decreases from 32 to 22.5% as the bentonite content varies from 5 to 30%. However with compactive effort of 2674 kJ/m^3, the maximum dry unit weight increases from 13.54 to 15.6 kN/m^3 and the corresponding optimum water content decreases from 23.75 to 16.5%
- Compressive strength of pond ash-bentonite mixture compacted for both the energy were found vary from 52 to 197 kPa and 99 to 691 kPa respectively.
- Shear strength parameters such as cohesion (c) and internal friction angle (ϕ) were found to be in the range of 16.27 to 63.81 kPa and 42.54° to 28.4° for mixtures compacted with compactive effort of 595 kJ/m^3. These values are 12.672 to 89.59 kPa and 44.55° to 30.90° for the mixtures compacted with compactive effort of 2674 kJ/m^3.

From this study, it can be concluded that sand bentonite mixture can effectively be replaced by pond ash bentonite mixture when sand is not easily available and wastes are to be utilized.

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