Suitability of Locally Occurring Clay as Liner Material

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Abstract: The lowest permeability and highest shear strength are desirable factors when designing a liner system. Adding additives such as coal or mixing with fine clays such as kaolin was also invented to improve the desirable properties of the liner. The fundamental soil experiments and tri axial tests were carried to determine the properties of original and mixed clay types. After analyzing, the particle size distributions of clay types, the mixing compositions of additive materials were determined. The compacted mixed clay samples of Bricks and Tile clays from Intermediate zone with kaolin clay to the 70:30 composition gave lowest permeability as $4.591 * 10^{-08}$ cm/s. The friction angle is important when determining shear strength of liner.The internal friction angle that was improved by adding finely powdered roof tiles (from 12^0 10′ 8″ to 17^0 54′ 14″). The cohesion between clay particles that was increased by adding lime (from 51.56 Kpa to 54.23 Kpa). Local abandoned clay can be improved as a liner materials.

Key Words: Coal, Cohesion, Durability, Internal Friction angle, Permeability, Shear strength

1. Introduction

Experimenting the suitability of clay as liner material is vital. There are few requirements to be fulfilled by a clay material to be used as a liner material.

Typically, a liner material should fulfill the following criteria; *(Binnas 2008, 3-5)* the typical thickness for these layers ranges at least 15 cm; permeability at saturated state varies between 10^{-6} and 10^{-8} cm/s; properties of ion exchange and adsorption and capabilities to hold some preferentially pollutants; physical stability of the material while in contact with water; a swelling potential that ensure good contact with the host rock and permit the replenishment of existing cracks or that will develop in the future.

Above properties of common Sri Lankan clay, types can be determined by soil tests such as Atteberge Limit, Hydrometer and Particle size analysis and Proctor

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compaction tests and permeability test. The shear strength of the material can be determined by using Triaxial Test.

2. Materials & Methodology

Preliminary details of subjected clay types are being mentioned in below (Table 1). Those clay types were subjected to preliminary tests such as Atteberge, Proctor compaction, Hydrometer and Particle size analysis. From the preliminary experiments, clay types **A**, **B**, **C** were selected as suitable clay types and clay type **D** was failed due to lower plasticity index vs. Liquid Limit. The selected clay types were subjected to the falling head permeability test under different conditions (Table 3). To decreas the permeability factor of selected clay types coal (hydrophobic material) was added to the original clay types with the compositions 20:1 (clay 20 and coal 1) and 10:1. Results of the experiments are in figure 1. To reduce the permeability through the liner material brick and tile clay mixed with kaolin clay type after consider the particle size distributions of both clay types. The mixing compositions of Brick and Tile clay (Clay type **A** and C) with kaolin (Clay **B**) were 85:15 and 70:30 respectively.

The clay mixture **A** and B (70:30) were used for the permeability test with organic solutions (Glucose) and inorganic solution (Ammonium Nitrate) of the concentrate 0.5 mol/dm^3. (Table 3). A sample of clay body was subjected to the microscopic tests to analyze the particle arrangement of the clay body (Figure 2). The clay mixture **A** and B to the composition 70:30 was selected to demonstrate the Triaxial test. The mixing compositions of additives (Finely powdered roof tile, Lime and Partially burned saw dust) are pre-determined.

3. Results & Discussion

3.1 Plasticity Index (PI)

The highest plasticity index is in clay B (Kaolin) and lowest value in clay D. The clay **A** and C are marginal for suitability for liner material (Table 2).

3.2 Maximum Dry Density & Moisture content

Clay C achieved the highest dry density in lowest optimum moisture content. The voids between clay C particles are taken lowest value comparatively. The particle and sieve analysis tests the clay C perform a well-graded distribution. The clay **A** is taken the highest optimum moisture content to lowest maximum dry density. Voids between clay **A** particles are comparatively taken higher value (Table 2).

3.3 Permeability Factor

The 2nd lowest permeability factor is following to clay C and **B** mixtures to the composition 70:30 (Even thought the clay B perform the lowest permeability factor, it was not used as major components, because it is not economical viable). The mixing

Table 1: Primary details of clay types

Clay Sample Index	Location	Zone	Clay Type	Mineralogy (Chemical formula)	Location Coordinates	
					N	E
A	Puhulwella, Matara	Wet	Brick & Tile	(Ca,Mg) $Al_2O_3.2SiO_2.2H_2O$	006° 00' 01"	080° 36' 00"
B	Meetiyagoda, Galle.	Wet	Keolin	$Al_2O_3.2SiO_2.2H_2O$	006° 15' 05"	080° 04' 01"
C	Mahiyanganaya, Badulla	Intermediate	Brick & Tile	(Ca,Mg) $Al_2O_3.2SiO_2.2H_2O$	007° 27' 41"	081° 00' 29"
D	Mahawilachchiya, Anuradapura	Dry	Brick & Tile	(Ca,Mg,Fe) $Al_2O_3.2SiO_2.2H_2O$	008° 28' 16"	080° 12' 36"

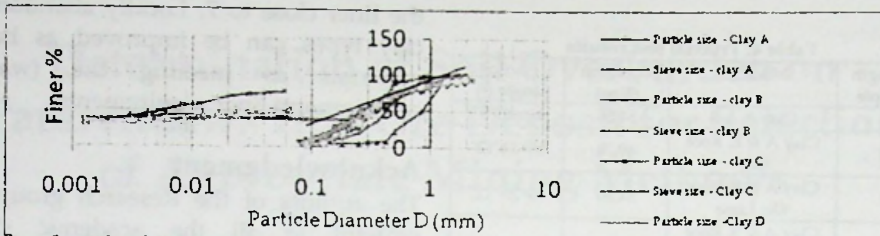


Figure 1: particle and sieve size distributions

compositions of both above clay materials were determined by analyzing particle size distribution curves of both clay materials (Table 3).

Coal was used as an additive material for the clay due to its hydrophobic property, with two different compositions (20:1 and 10:1 with clay). Even though the low permeability factor in the composition was 20:1, the permeability factor has been increased in the compositions 10:1. Averagely the particle size of coal is larger rather than clay particle.

Table 2: Preliminary test results

Clay Type		A	B	C	D
Atteberge Limit test	Liquid Limit (%)	48	71.14	29.36	45.49
	Plastic Limit (%)	28.06	27.49	11.11	41.37
	Plasticity Index (%)	19.92	43.64	18.25	4.12
Proctor compaction test	Max. D. Dens. (Kg/m³)	1372.48	1426.	2104	1499
	O. M.C (%)	30.31	25.59	12.39	24.23

Table 3: Permeability test results (N-Not done)

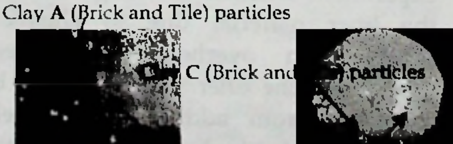
Clay Types		A	B	C
Remarks		-	-	-
Permeability Test (Permeability Factor) xx.xxx * 10⁻⁸	Normal	9.0095	8.1687	8.5288
	Dry	7.3301	-	N
	Wet	11.667	-	N
	Compacted	6.1361	4.2467	5.6598
	With coal (20:1)	5.89	-	5.541
	With coal (10:1)	9.49	-	6.613
	With clay A (85:15)	-	-	N
	With clay A (70:30)	-	-	N
	With clay B (85:30)	5.6598	-	5.4219
	With clay B (70:30)	4.7093	-	4.591
	With clay C (85:30)	N	-	-
	With clay C (70:30)	N	-	-
	With clay D (85:15)	-	-	-
	With clay D (70:30)	-	-	-
Chemical Activities (Permeability factor)	With NH_4Cl	4.71	-	N
	With $C_6H_{12}O_6$	4.73	-	N

Two another permeability experiments were deployed to behold the behavior of clay mixture with organic ($C_6H_{12}O_6.2H_2O$) and inorganic solution (NH_4NO_3) with the concentration of 0.5 mol/dm³. There were no significant derivations from the original permeability results.

3.4 Shear Strength of the clay Mixture

The Internal friction angle and cohesion between particles in clay mixture are important parameters in determination of the shear strength of the liner; (Triaxial test). The fine powder roof tile was added to the clay mixture to increase the Internal friction angle, Lime was used to increase the cohesion between clay particles and partially burned saw dusts to increase the durability of the liner material by taking the pH of the liner to close to 7. From the Triaxial test result, the internal friction angle and the cohesion between liner mixture has been increased in each corresponding step.

3.5 Microscopic test



(a) Clay A and B (70:30) (b) clay C and B (70:30)

Figure 2: Microscopic analysis of particle

Table 4: Triaxial test results

Strength sample	Mixtures	Cohesion (Kpa)	Friction angle (⁰)
1	Clay A & B	51.56	12° 10' 8"
2	Clay A & B, Roof tile	49.74	15° 54'12"
3	Clay A & B, Roof tile, Lime	54.89	18° 20' 12"
4	Clay A & B, Roof tile, Lime, Saw dust	54.23	17° 54' 14"

4. Conclusion

Original Clay type **B** (Kaolin) performed the highest clay properties comparatively others and also the clay content is highest in **B**. The clay sample **C** from Intermediate zone, is also performed desirable properties for liner material and clay **A** are also could be improved as suitable for liner by additives. The clay **D** (Dry zone) was refused form the experiment due to failed from preliminary experiments.

Coal can be utilized as additive to reduce the permeability of Liner material in control manner. The coal has the hydrophobic property and before adding coal particles to clay material, it should be finely grounded. The kaolin is one of most desirable additive to reduce the permeability of clay mixture. There are no short-term effects on permeability of the liner material either the organic or the inorganic solution on overhead. However, it is vital to experiment whether the long effect on the liner material due to chemical solution on overhead. The shear strength of the liner material could be improved from adding Lime, finely powder roof tile by demanding the internal friction angle and cohesion. The durability of the liner can be improved by adding partially burned sawdust to the liner material by taking the pH of the liner close to 7. Locally abandoned clay types can be improved as liner materials as meeting the (waste containment) liner requirements.

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