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Research paper

The Performance of Earth Retention Pond Water Retain Capability Using Geotechnical Properties Evaluation

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Abstract

Development of a new modern housing areas has demand a retention pond for recreation activity and landscaping purposes. This study deals with the evaluation of water retain ability of a new retention pond from the soil condition perspective. Geotechnical laboratory testing was performed via particle size distribution, Atterberg limits and permeability to assess the retention pond soil condition. All the experiment was performed according to British Standard 1377 (1990). It was found that soil tested has been dominated by fine particles which ranged at 30.84 – 60.88 % compared to the coarse particles (sand and gravel). Atterberg limits results has found that all soil tested has a liquid limit (LL), plastic limit (PL) and plasticity index (PI) that was varied at 29 – 74 %, 16.9 – 33.6 % and 17 – 40.4 % respectively representing its promising water retain capability. Moreover, permeability result founds that all values of permeability coefficient, k was ranged at 3.11 x 10^{-4} – 5.65 x 10^{-7} cm/s thus conclude that all soil tested has low to very low degree of permeability. Finally, retention pond of a new development area has been evaluated directly according to its soil condition thus provide some valuable information to the responsible parties regarding the future planning and decision making of the sustainable catchment areas.

Keywords: *Geotechnical Laboratory Testing; Permeability; Retention Pond; Soil Condition.*

1. Introduction

Development of infrastructure in modern housing area consist of comprehensive system of transportation, water, sewerage, communication and electrical. Those task was crucial for civil engineers due to the application of science and technology together with wisdom and experience to design, construct, maintain and manage the infrastructure in line with the current human civilization development. Generally, infrastructure process involving planning, site visit, data collection, laboratory works, data analysis and design (code of practice, software modelling, etc.), construction and maintenance.

Retention pond is one of the main component constructed in a new developed housing areas. The function of retention pond is to retain and store runoff water permanently before the water being discharge to the nearby stream. Moreover, retention pond will service to prevent flooding, minimizing erosion of downstream and provide some water value benefit. Retention pond may constructed by concrete or original earth materials.

New earth retention pond may experience uncertainties regarding its water retain capability. Pond liner need to be installed if the earth material composed of highly permeable soil. However, the installation of this impermeable geomembrane will be expensive relative to size of the retention pond. Consequently, assessment of retention pond water retain ability need to be properly introduce before any further decision making regarding the necessity of the pond linear application.

Hence, the aim of this study is to demonstrate that the applicable of geotechnical properties to evaluate the performance of earth retention pond water retain capability.

2. Material and Method

This section was divided into three section namely geology of study area, soil sampling and laboratory testing. All of the related geotechnical laboratory testing was referred to the British Standard [1].

2.1. Geology of the study area

General geology of Peninsular Malaysia has well-being documented by Mineral and Geoscience Department Malaysia as shown in Figure 1. According to Figure 1, the study area was located at acid intrusive rock (granite). Granite is an igneous rock that injects, or intrudes, as magma into Earth’s crust and then cools. It consists of four main mineral compounds. Two of these are types of feldspar, a group of silica compounds that constitute the most abundant mineral group on Earth. Firstly, plagioclase feldspar which is a compound of sodium and silica. Secondly is potassic feldspar which is a compound of potassium and silica. Granite also contains quartz, the second most abundant rock-forming mineral after feldspar. The fourth main mineral compound is mica, which in granite is a silica compound with a crystalline appearance resembling sheets of paper. Other mineral may present in granite were muscovite and biotite. Muscovite is mica with a high concentration of potassium. Biotite is mica with iron and magnesium. The reaction of feldspar minerals in granite with rainwater produces kaolinite, white clay known as "China clay" used in the production of porcelain, paper and glass. Kaolinite is most abundant over weathered granite in hot and moist tropical climates. Biotite and muscovite micas also weather by hydrolysis into kaolinite and release iron, potassium and magnesium into the surrounding soil as nutrients. In geotechnical engineering, soil may classified based on its particle sizes. Originally, soils was derived from weathering of rocks. Generally, weathering of granite may produce various soil particles from gravel, sand, silt and clay. In most cases, composition of soils which derived from the granitic areas was mainly from silty or sandy followed by clayey soils due to the granitic composition of minerals (mainly quartz and feldspar). Commonly, weathering of quartz mineral from granite will produced sand particle with size ranging at 0.06 – 2 mm. Weathering of feldspar and quartz also may produce silt particle with size ranging at 0.002 – 0.06 mm. Weathering of feldspar may produce clay particle with size ranging at 0 – 0.002 mm. During field observation, surface soil consist of sandy, silty to clayey particles derived from weathered granitic bedrock. No obvious fresh outcrop of granite can be observed at study area. However, relict granitic texture may obviously found at study area. Detail range of particle sizes was shown in Figure 2.

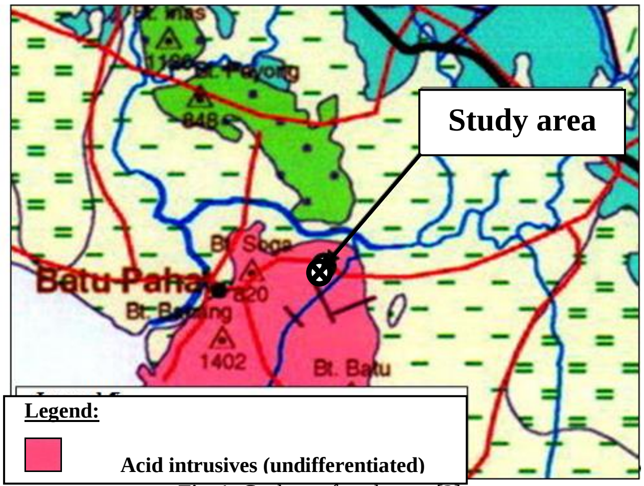

Fig. 1: Geology of study area [2]

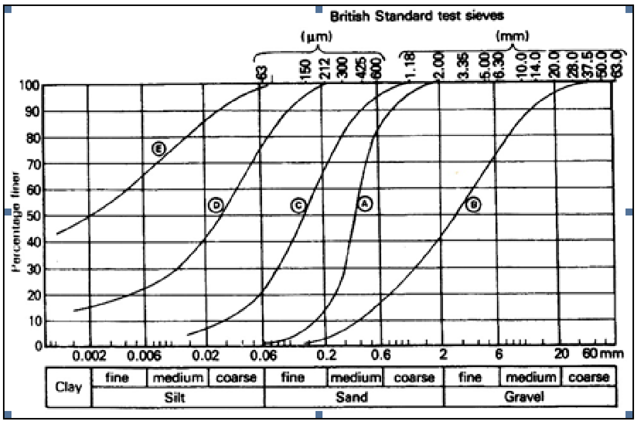

Fig. 2: Particle size distribution based on British standards [3]

2.2. Soil sampling

Eight (8) number of soil samples (Sample 1, 2, A, B, C, D, E and F) were taken at base of the retention pond using core cutter method. Samples were sealed with plastic bag and send to the laboratory for further action (Figure 3). Soil samples sampling location and its sampling progress was shown in Figure 4 and 5 respectively.


Fig. 3: Soil sample at lab

Fig. 4: Location of soil sampling

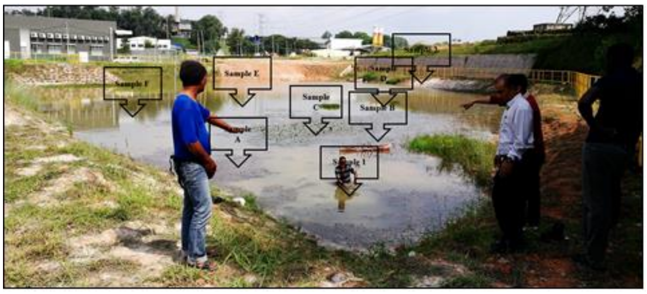
Fig. 5: Soil sampling in progress

2.3. Laboratory testing

Soil samples was tested for and permeability (Falling head test), particle size distribution (wet and dry sieve test) and Atterberg limits (liquid limit, plastic limit and plasticity index).

2.3.1 Permeability test

The falling head permeability test is a common laboratory testing method used to determine the permeability of fine grained soils with intermediate and low permeability such as silts and clays. This testing method can be applied to an undisturbed sample. Undisturbed sample of fin grained soils can easily obtained using core cutter.

All data related to size and dimensions of core cutter were recorded before the permeability test (Falling head) was performed. Then, the specimen was placed in a water tank for a few hours in order to ensure the sample was fully saturated. After that, connect all water tube and starts the measurement. Falling head permeability test was given in Figure 6. Coefficient of permeability, k was determine using the application of formula (1).

$$K = a/A \times l/t \times 2.3 \log_{10} h_1/h_2 \quad (1)$$

where a = area of burette, A = area of specimen, l = length of specimen, t = time, h_1 = head 1 and h_2 = head 2

Fig. 6: Permeability falling head test in progress

2.3.2 Particle size distribution test

Two methods of sieving are specified. Wet sieving is the definitive method applicable to essentially cohesionless soils. Dry sieving is suitable only for soils containing insignificant quantities of silt and clay. Quantifying soil particles using sieve test was useful to classify soil tested thus may revealed and conclude its characteristics for various types of engineering projects.

Particle size distribution of soil specimen was performed via wet and dry sieve due to soil composition which composed of significant amount of cohesive soil. Firstly, oven dried soil (100 g) was washed using 63 µm to separate fine and coarse particles. Then, retained particle at 63 µm sieve pan was proceed to dry or mechanical sieve (after being oven dried) while hydrometer test was performed for the particle that passed the 63 µm sieve pan. Sieve test was given in Figure 7.

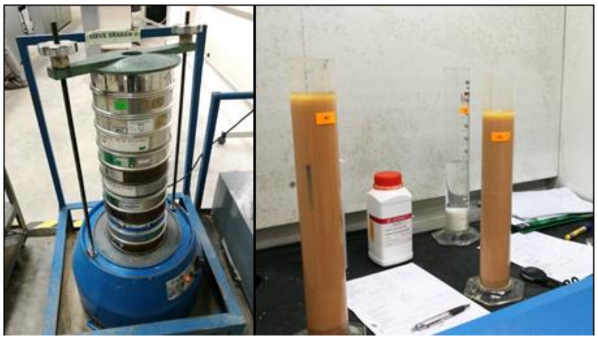

Fig. 7: Dry (left) and wet (right) sieve in progress

2.3.3 Atterberg limits

The Atterberg limits are a basic measure of the critical water contents of a fine-grained soil: its shrinkage limit, plastic limit, and liquid limit. Atterberg limits performed in this project consists of liquid and plastic limit. The liquid limit is the empirically established moisture content at which a soil passes from the liquid state to the plastic state. It provides a means of classifying a soil, especially when the plastic limit is also known. The plastic limit is the empirically established moisture content at which a soil becomes too dry to be plastic. It is used together with the liquid limit to determine the plasticity index which when plotted against the liquid limit on the plasticity chart provides a means of classifying cohesive soils. It is recognized that the results are subject to the judgement of the operator, and that some variability in results will occur.

This study performed liquid limit, plastic limit and plasticity index using cone penetrometer, finger mould and rolled and plasticity index (PI) formula. Liquid limit and plastic limit test was shown in Figure 8.

Soil specimen for liquid limit (300 g) was performed by passing the soil specimen at 425 µm test sieve (dry condition). Then, dried soil specimen was mixed with significant amount of distilled water and tested under cone penetrometer apparatus for liquid limit data measurement. Finally, moisture content of the specimen was recorded.

Soil specimen for plastic limit (20 g) was performed by passing the soil specimen at 425 µm test sieve (dry condition). Then, dried soil specimen was mixed with distilled water and roll it between hand palm until the specimen feeling heat and dry with a visible of slightly cracks. Finally, moisture content of the specimen was recorded.

Fig. 8: Liquid limit (left) and plastic limit (right) test

3. Results and Discussion

This section was divided into three subsection namely permeability, particle size distribution and Atterberg limits. All results was analysed based on British Standard [1] as given in Table 1. All specimen of the geotechnical properties obtained from the analysis then was plotted in SURFER software to determine the distribution of geotechnical properties in the retention pond studied.

Table 1: Summary results of geotechnical properties

Testing	Particle size distribution, d (%)				Specific gravity, Gs	Atterberg limit, (%)			Permeability coefficient, k (cm/s)
Sample	Clay	Silt	Sand	Gravel		Liquid limit	Plastic limit	Plasticity index	
1	22.99	36.16	37.25	3.60	2.301	74.0	33.6	40.4	1.690E-06
	59.15		40.85			Clay of very high plasticity (CV)			
2	12.78	13.59	73.00	0.63	2.534	35.0	18.0	17.0	2.847E-05
	26.37		73.63			Clay of low plasticity (CL)			
A	35.28	10.26	52.63	1.83	2.387	74.0	25.5	48.5	2.90E-07
	45.54		54.46			Clay of very high plasticity (CV)			
B	12.57	2.50	81.47	3.46	2.478	41.5	17.5	24.0	1.624E-06
	15.07		84.93			Clay of intermediate plasticity (CI)			
C	23.07	7.76	66.65	2.52	2.411	86.0	28.7	57.3	1.513E-06
	30.83		69.17			Clay of very high plasticity (CV)			
D	51.19	9.69	38.82	0.30	2.256	77.0	27.8	49.2	1.304E-06

	60.88		39.12			Clay of very high plasticity (CV)			
E	23.14	6.15	69.98	0.73	2.532	29.8	Nil	Nil	3.110E-04
	29.29		70.71			Non plasticity characteristic			
F	32.70	6.48	58.81	2.01	2.477	46.5	16.9	29.6	5.650E-07
	39.18		60.82			Clay of intermediate plasticity (CI)			

3.1. Permeability (Falling head)

Permeability was defined as the ability of a porous mass to allow passage of water through the medium. Water permeability of soil is the characteristic of the soil to transmit water. Permeability test (Falling head) was used to measure the rate of the flow of water through soil as known as coefficient of permeability, k (also referred as hydraulic conductivity of soil). Generally, water holding capacity are highest from clay to gravel (clay>silt>sand>gravel). Several factor that influence the permeability rate of soils are particle size, impurities in the water, void ratio and porosity, the degree of saturation and adsorbed water to entrapped air and organic material. According to all permeability results (Sample 1, 2, A, B, C, D, E and F), it was found that k values was range at 3.11 x 10^{-4} – 5.65 x 10^{-7} cm/s. As a result, all soil tested has a degree of permeability at low to very low category. According to Kulhawy and Mayne [4] and [5] Terzaghi and Peck [5], degree of permeability of low and very low (sand, dirty sand, silty sand, silt, silty clay) was ranged at 10^{-3} to 10^{-5} and 10^{-5} to 10^{-7} respectively. All k values obtain from permeability test was in line with the results from sieve test (soil has been dominated by sandy, clayey and silty particles) and previous literature values thus validate the k values obtained. Distribution of k values representing capability of soil permeability of the retention pond was presented in Figure 9. Soil material of the retention pond shows low permeability from middle to west zone towards north and south direction. Earth retention pond was crucial to be dominated by impermeable soil so that it will minimized losses of water through seepage and infiltration thus increase its efficiency to retain water.

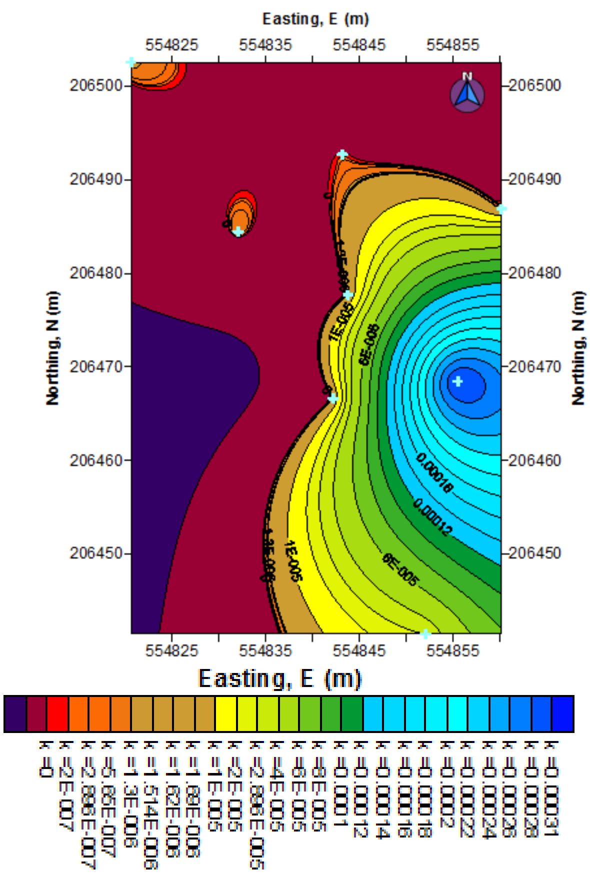

Fig. 9: Coefficient of permeability, k distribution

3.2. Particle size distribution (wet and dry sieve)

Particle size distribution of all soil samples has revealed that the soil samples was dominated by sand (37.25 – 81.47 %) followed by clay (12.57 – 51.19 %), silt (2.50 – 36.16 %) and gravel (0.63 – 3.46 %) particles respectively. Generally, soil tested (Sample 1, A, B, C, D, E and F) can be categorized as Clay SAND and silty SAND (Sample 2) according to its particle sizes quantification. Domination of sand particles in all soil samples has been expected earlier due to its geological condition (granitic rock) as discussed in section 2.1. According to British standard, particle size of sand can detailed up to three sizes representing fine (0.06 – 0.2 mm), medium (0.2 – 0.6 mm) and coarse (0.6 – 2 mm). Five (5) soil samples has been dominated by coarse sand (1 = 21.52 %, A = 22.86 %, B = 46.44 %, C = 41.89 % and F = 32.54 %) which ranged at 21.52 – 46.44 %. Two (2) soil samples was dominated by fine sand (2 and D) at 15.65 – 42.40 % and one of remaining soil sample was dominated by medium sand (E) at 29.45 %. However, most of soil samples consist of high quantity of fine particles (clay and silt: 1 = 59 %, A = 45.54 %, C = 30.84 %, D = 60.88 % and F = 32.70 %) which ranged at 30.84 – 60.88 % compared to the coarse sand. Meanwhile, the composition of gravel at all soil samples was found to be very low (0.63 – 3.46 %). Generally, combination quantity of coarse sand and gravel particles for all soil samples are still less compared to the combination quantity of fine particles thus may influence the rate of soil permeability from low to very low. Soils with smaller particles (silt and clay) have a larger surface area than those with larger sand particles, and a large surface area allows a soil to hold more water. In other words, a soil with a high percentage of silt and clay particles (fine soils) has a higher water-holding capability. Distribution of all soil particles was presented in Figure 20 – 23. Generally, clay particle was highly concentrated at middle of the pond towards west side in south and north direction. Silt particle was largely concentrated at northeast side of the retention pond. Sand particle has largely concentrated at middle to the west and east direction of the retention pond while gravel particle has found to be largely concentrated at centre to the north of the retention pond.

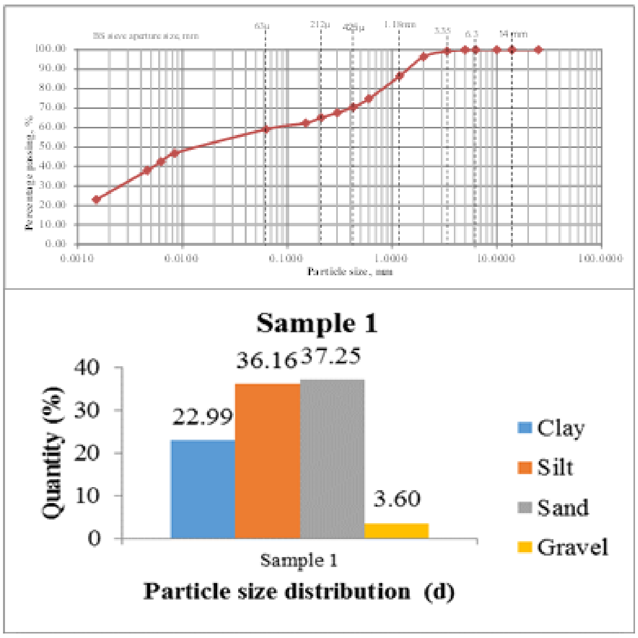

Fig. 10: Particle size distribution for sample 1

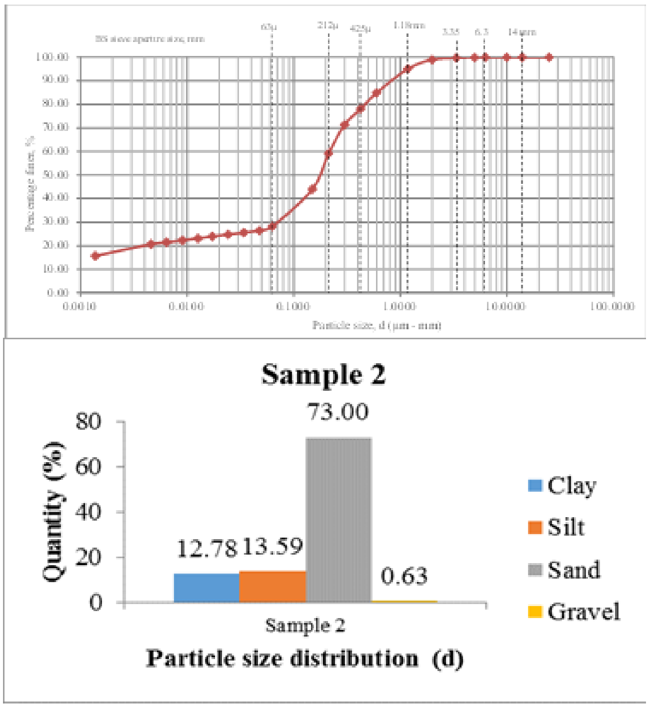

Fig. 11: Particle size distribution for sample 2

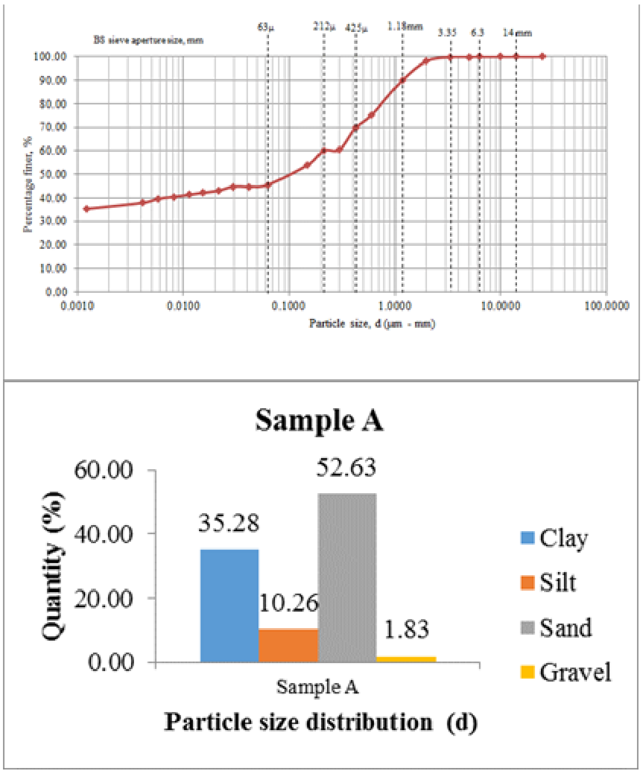

Fig. 12: Particle size distribution for sample A

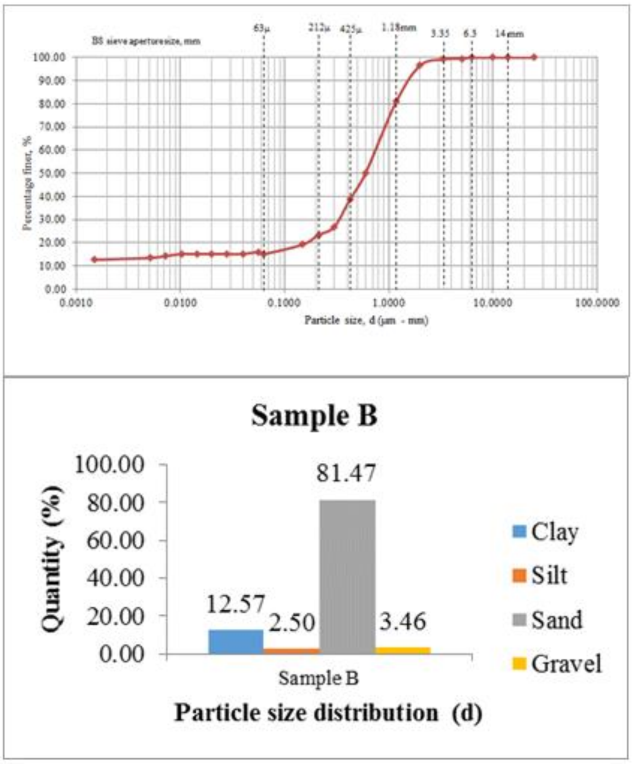

Fig. 13: Particle size distribution for sample B

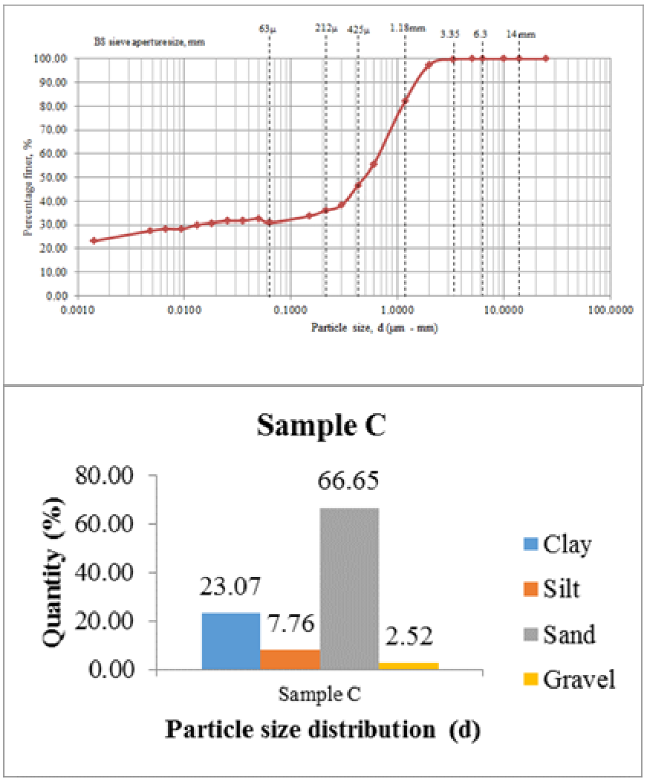

Fig. 14: Particle size distribution for sample C

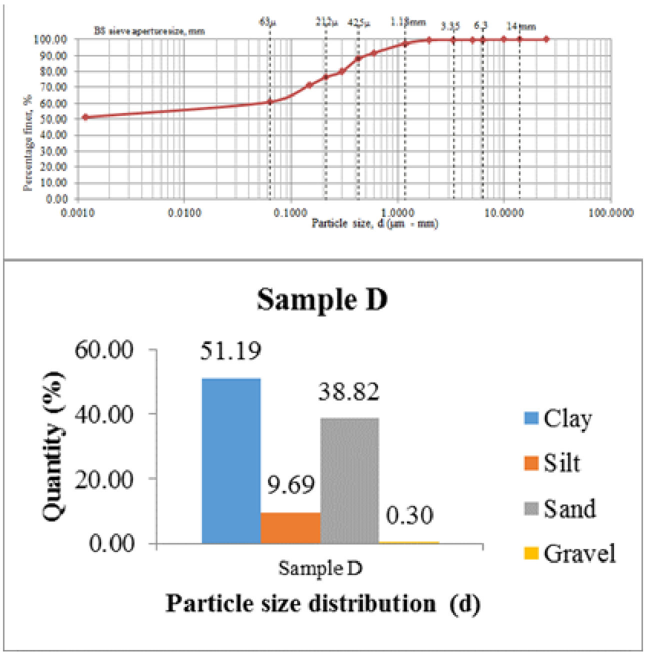

Fig. 15: Particle size distribution for sample D

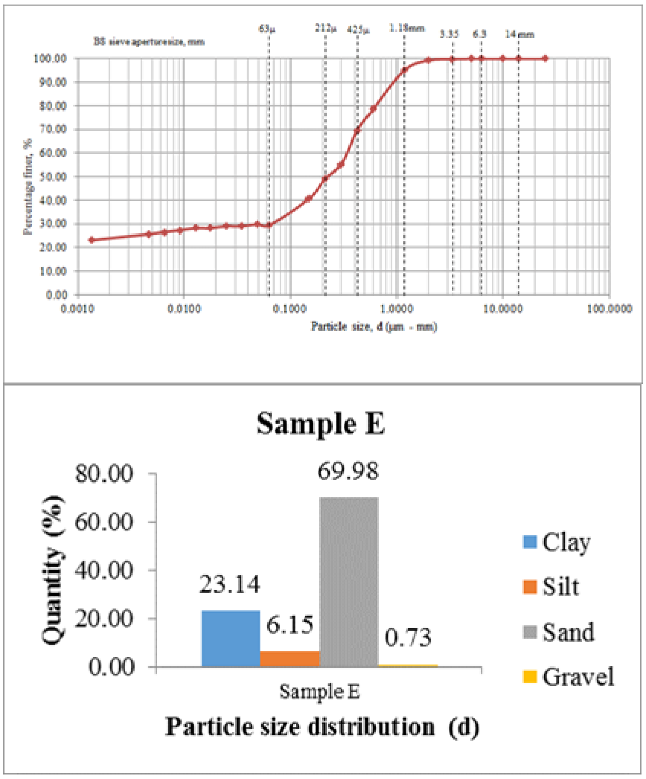

Fig. 16: Particle size distribution for sample E

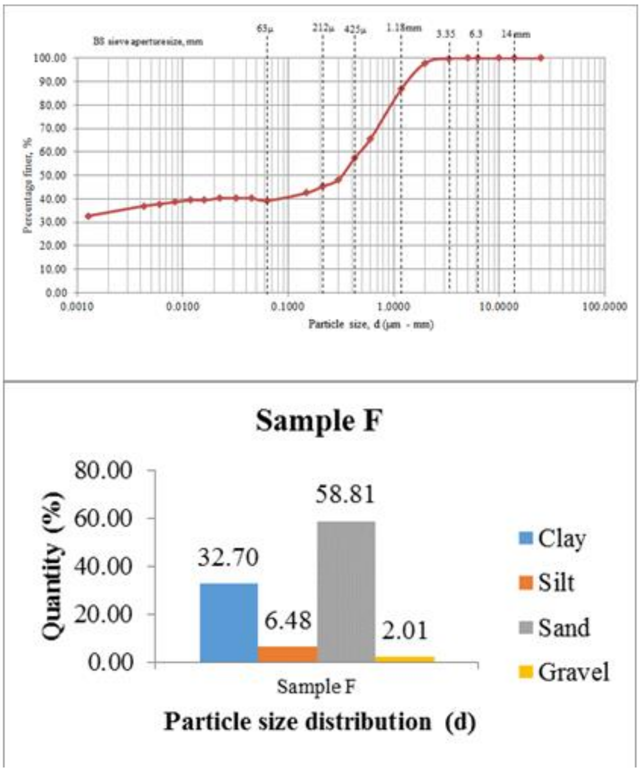

Fig. 17: Particle size distribution for sample F

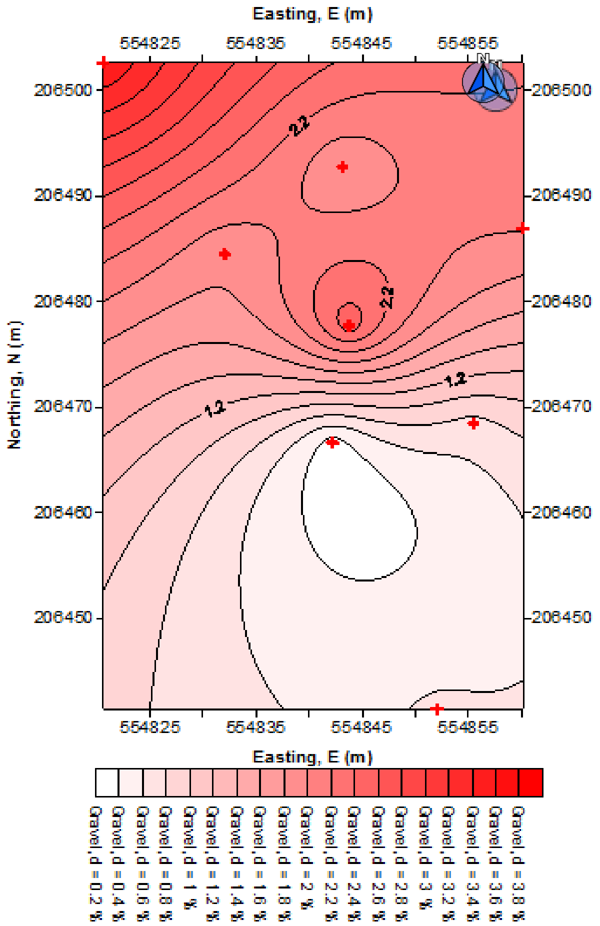

Fig. 18: Sand distribution

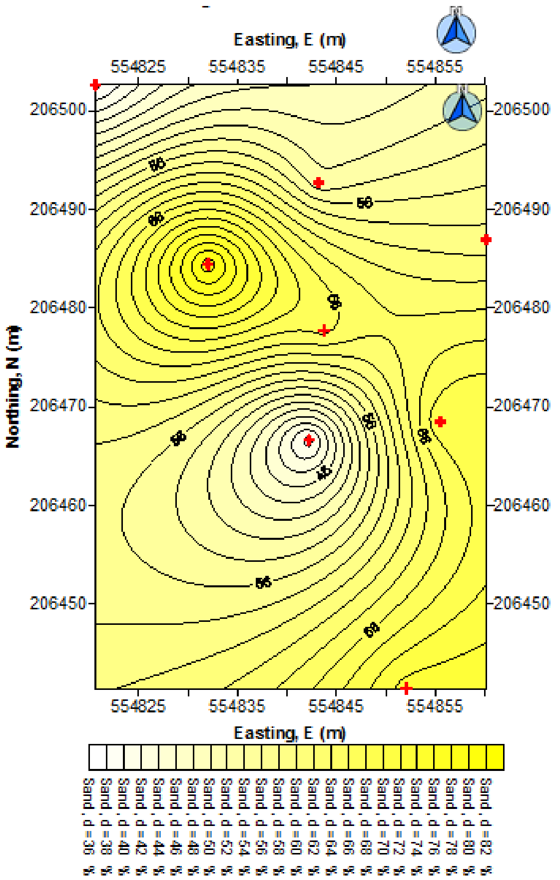

Fig. 19: Sand distribution

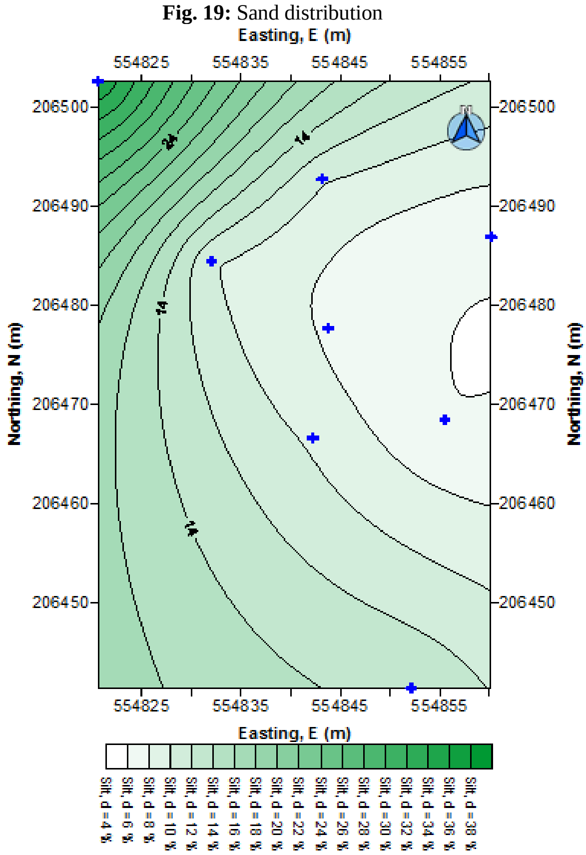

Fig. 20: Silt distribution

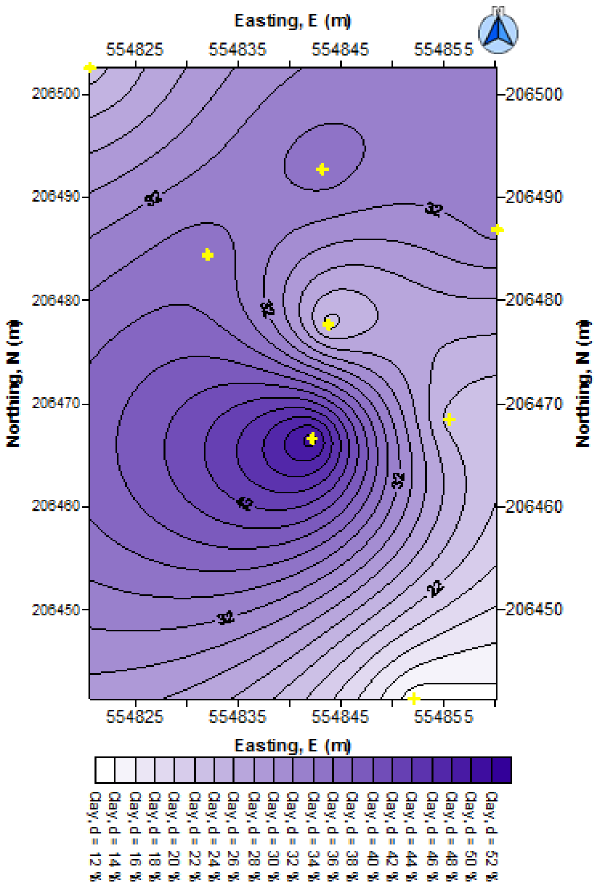

Fig. 21: Clay distribution

3.2. Atterberg limits

Laboratory works for Atterberg limits performed were liquid limit and plastic limit. Based on those data, plasticity index (pi) was able to be calculated for classification of fine grained soil. According to Table 1, liquid limit (LL), plastic limit (PL) and plasticity index (PI) was varied at 29 – 74 %, 16.9 – 33.6 % and 17 – 40.4 % respectively. Generally, soil will have a good ability to retained/preserved water provided its high liquid limit properties. Fine soil samples has a characteristics of clay of low (sample 2), intermediate (sample B and F) and very high (sample 1, A, C and D) plasticity. Sample E has non plasticity index due to the high composition of coarse (sand and gravel) grained particles. The variation of plasticity characteristics was highly influenced by composition of grained particles (fine or coarse) present at the respective samples. Generally, low quantity of sand with high quantity of clay/silt may cause the soil to have high plasticity. Distribution of liquid limit, plastic limit and plasticity index were presented at Figure 22 – 24. High concentration of liquid limit and plasticity index was located at the middle of the retention pond. Plastic limit properties was highly concentrated at northwest of the retention pond.

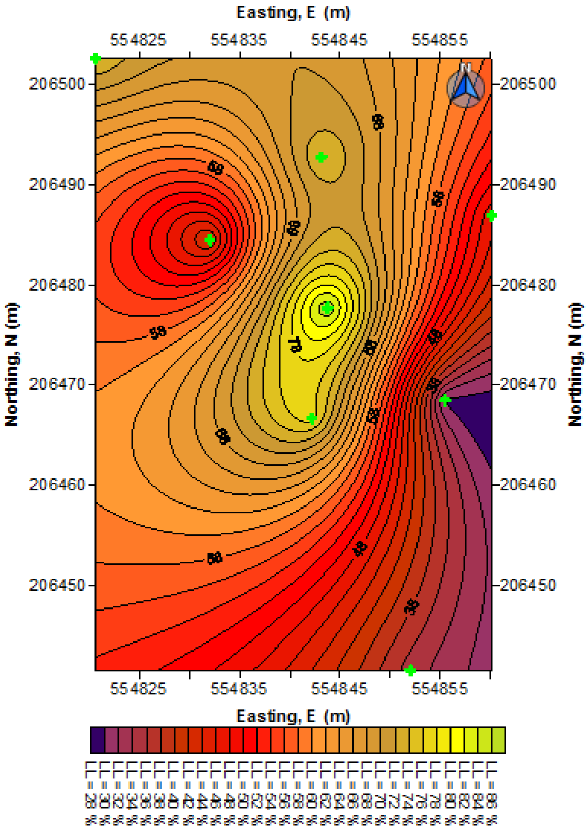

Fig. 22: Liquid limit distribution

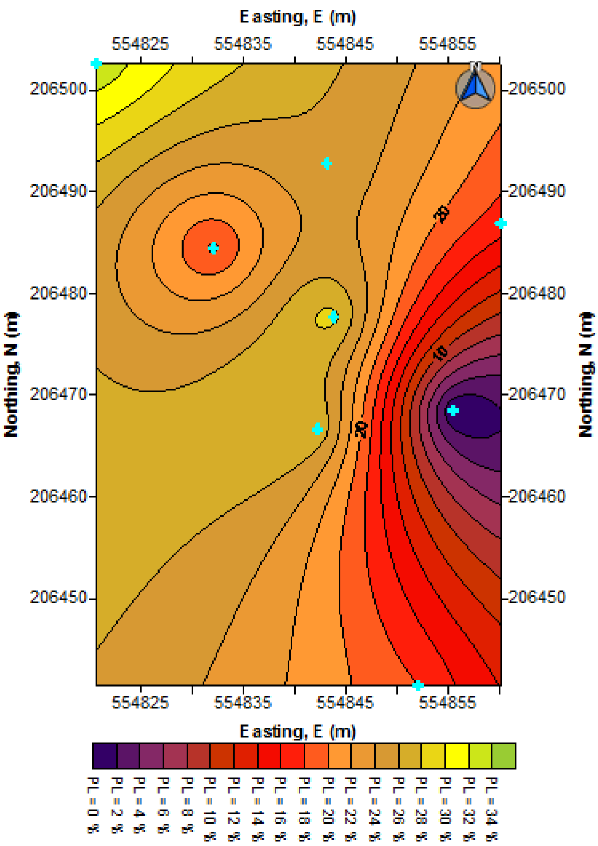

Fig. 23: Plastic limit distribution

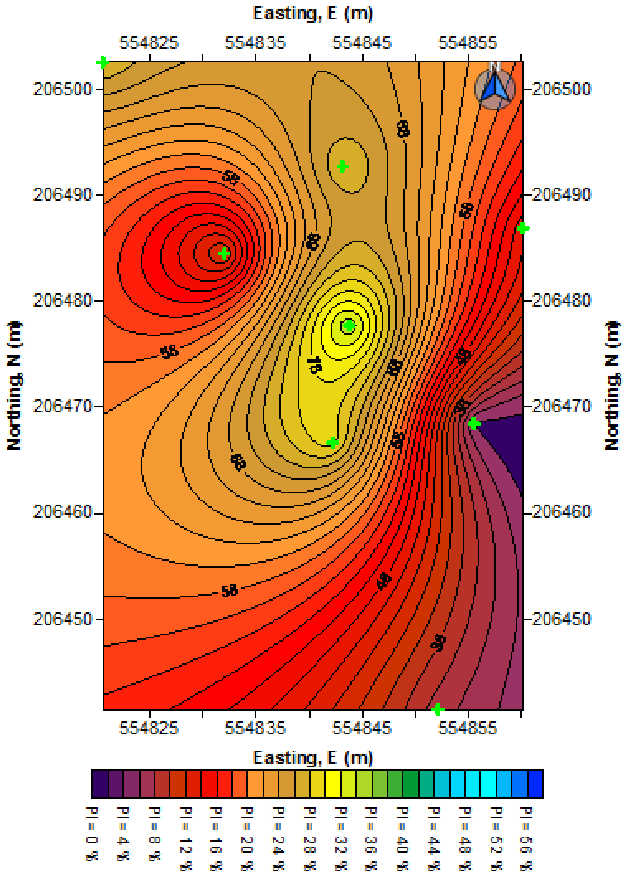

Fig. 24: Plasticity index distribution

4. Conclusion

Earth retention pond water retain capability was successfully being performed using geotechnical properties evaluation. It can be conclude that soil materials present at the earth retention pond has good capability to retain water in a long run according to geotechnical properties (high number of fine grained soils and low to very low coefficient of permeability) evaluated. This study have demonstrated that the applicable of geotechnical properties in earth retention pond water retain capability assessment which contribute to the sustainable decision making regarding the seepage control such as the significant of pond liner intallation.

Acknowledgement

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