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RESEARCH ARTICLE

The Permeability of Granite Weathering Soil in Tanjungpinang, Bintan Island, Indonesia

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Abstract

Bintan Island is a part of Riau Islands Province. On this island, the capital city is Tanjungpinang. The compliance of public facilities such as landfill waste is a priority in this city. Landfill design that suitable in this area is a sanitary landfill system. The soil layer uses to cover the waste in this landfill system. The closure did gradually avoid the disruption of waste processing. The type of soil for its landfill cover has to be able to control the leachate. It controlled by the permeability of the soil.

The methods used in this study are the analysis of the physical and mechanical properties of soil. Rock and soil samples are obtained systematically through trenching. Sampling-based on changes in physical properties of soil that reflect its mechanical properties. A probabilistic approach used to solve the problems and to get accurate results.

The geomorphology of the study area divided into four units. They are very flat terrain, flat terrain, slightly steep hills, and steep hills. The sample used for the study is undisturbed soil. Analysis of the physical and mechanical properties of soil shows the types of soil, such as SW, GM, MH-OH, and CH. However, MH is the most dominant type of soil. Each of the soil types represents a certain degree of weathering. The degree of weathering in the study area varies from the III degree to VI degrees. Rocks are weathering form clay mineral, which compiles the soil. Clay mineral in the soil layer is varied from quartz, illite, kaolinite, gibbsite, goethite, and hematite—the impact of the swelling of clay. The swelling of clay in the study area ranged from low to high. The properties and composition of the soil are affected by the permeability value.

Keywords: Permeability, granite, weathering, waste disposal site, Riau Islands

1. Introduction

The research area is in the Tanjungpinang City region, which is the capital of the Riau Islands Province, located on Bintan Island (Fig.1). The population of this city in 2010 reached 187,359 people with a population density of 804 people per square kilometer (https://tanjungpinangkota.bps.go.id). In 2018, the population of the city will increase to 209,280, with a density of 1,387 people per square kilometer (Susilowati et al., 2019).

As an area with a relatively high population density and continues to increase compared to the surrounding area, the problem of waste becomes crucial and requires professional management.Fulfillment of public facilities, the final processing site for domestic waste is a priority. Appropriate design in areas with relatively high population growth and limited land, in general, is the sanitary landfill system (Erawan, 2015).

This kind of landfill requires suitable soil to cover landfills (Fig. 2) periodically.Soil with good permeability and suitability are needed so that leachate inflow into the channels that have been available under the garbage pile. The availability of soil needed needs to mapped to ensure the sustainability of waste management.

1.1. Geological Setting

The Riau Islands region has many islands, one of which is Bintan Island. This area is located on the southeastern tip of the Malay Peninsula and is part of a tin route sourced from granite rocks, which includes Bangka Island and Belitung Island. Some rocks on this island have experienced weathering and erosion processes that are sufficiently intensive and extensive so that it appears as a monadnock when viewed from the aspect of Sundanese exposure (Molengraaf & Weber, 1921).

Bintan Island is composed of Pre-Tertiary to Quaternary rock formations (Fig.3). The porphyry bedrock formed on Perm-Carbon. This rock formation can also compare to the Pahang Volcanic Series Formation of the Malay Peninsula. The Berakit Formation is a low-grade metamorphic rock of the Perm-Carbon age that can be found at the northern tip of Bintan Island and is the oldest rock in the region (Kusnama et al., 1994). This bedrock is broken through by younger igneous rock.

Granite is widespread, occupies the northern, eastern, and southern coastal regions of Bintan Island and occupies a small portion of the western coast. This rock is Triassic, exposed widely on Bintan Island to form the Kawal Granite Pluton and intrusion into the older Berakit Formation (Kusnama et al., 1994). Andesite igneous rocks also found in the form of intrusions that breakthrough granite. Irregular distribution forms hilly areas of Bintan Island, such as Lengkuas Mount and Bintan Besar Hill. This rock formation thought to be of Miocene age.The Goungon Formation is a tuff sandstone that also dominates the Bintan Island region and thought to be of Plio-Pleistocene age. At the top of the Goungon Formation deposited alluvium. Besides, also found conglomerate composed of granite gravel, metamorphic rocks, and sandstone, as well as swamps and coral sediment, uplifted.

The geological structure in this area is in the form of folds, joints, and faults. Some of them appear as geomorphological lineaments. They can see on Bintan Island and Batam Island. Tectonically, the Riau Islands region included in the Karimata Lane, which lies east of the Tin Lane (Kusnama et al., 1994).

The landscape in granite rocks is bimodal because soils have not yet been formed completely and are side by side with arid rocks ranging from meter-sized lumps to mountain-scale domes (Hutabarat et al., 2016; Sudradjat et al., 2018).

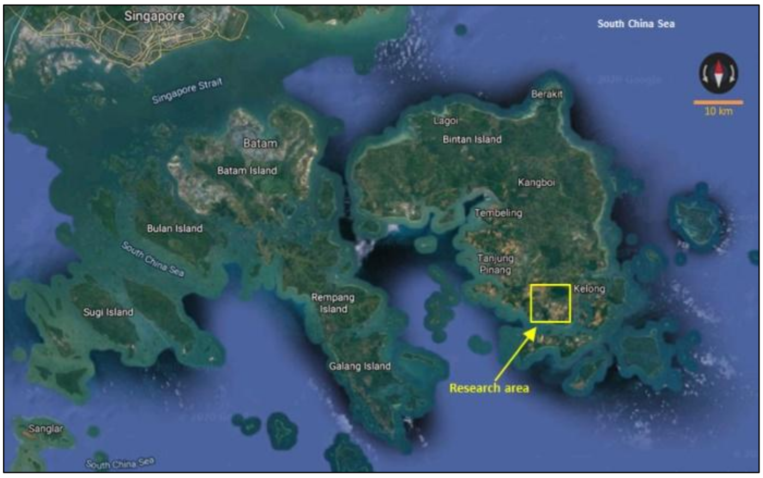

Fig1. The research area, eastern Tanjung Pinang City.

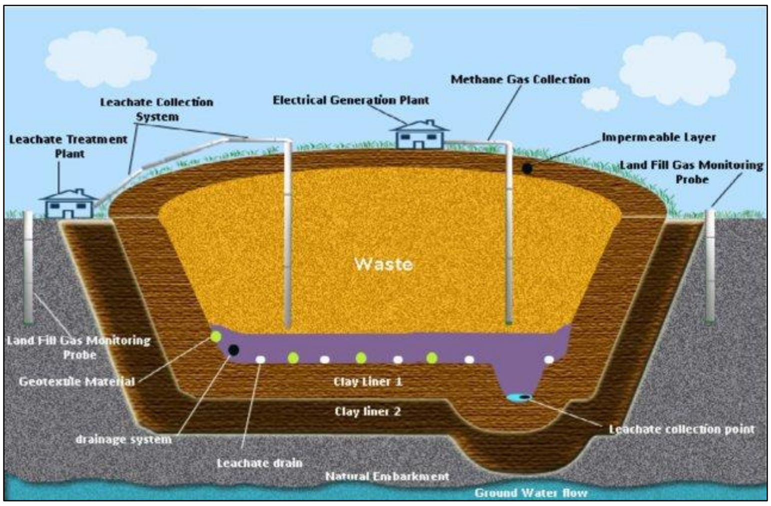

Fig 2. A modern sanitary landfill (Amadi et al., 2012)

1.2. Research roadmap

Research that has carried out in the Riau Islands region is diverse, covering material aspects, territorial potential, and waters. Erawan (2015) conducted a study on the valuation of geological aspects to assess the feasibility of selecting the location for the final processing site for domestic waste in the Singkep Islands, Riau Islands Province.

Irzon et al. (2016) researched rare earth elements in soils produced by granite weathering on Singkep Island. Hutabarat et al. (2016) discuss the core stone of granite, which is widely available in the eastern and northern Bintan Island. Lubis et al. (2017) state that temperature and wind velocity characteristics associated with Indian Ocean Dipole (IOD) in Batam waters have low sea surface temperatures. Rizki et al. (2017) also did a mapping of vegetation and mangrove distribution levels in Batam Island using SPOT-5 satellite imagery. This region also owns geological potential in terms of mineral content, hydrocarbons and beautiful landscape, in addition to local history and culture (Sukiyah et al., 2018). Sudradjat et al. (2018) discussed the characteristics of soils in the Riau Islands concerning overburden landfills, where Final Waste has conducted from 2015 to 2018. Heavy metals content and pollution in tin tailings from Singkep Island have also investigated by Irzon et al. (2018). Ahnaf et al. (2019) examined the granite's genetic makeup and its characteristics, but the study conducted in the Bayah area, Banten Province. The results showed a variety of granite both the formation process and the time of its formation.

However, research on granite weathering related to the nature of permeability in the Riau Islands has not yet found.Therefore, the results of this study are significant for the solution to the problem of overburden at domestic landfills.

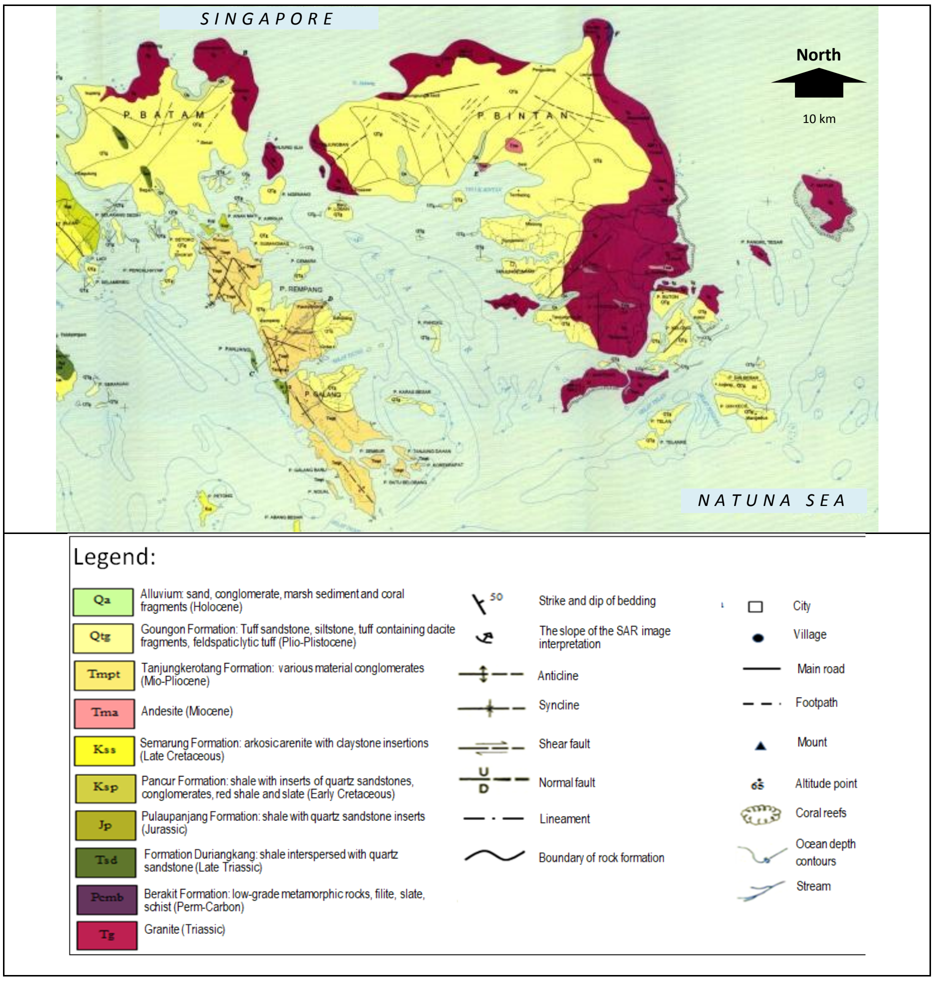

Fig.3 Regional geology of Bintan Island and surroundings, Riau Islands (Kusnama et al., 1994)

2. Material and Method

Materials needed in this research are Digital Earth Indonesia Map with a scale of 1: 50,000, Geological Map of Tanjungpinang Sheet of 1: 250,000 scale (Kusnama et al., 1994), satellite imagery of Bintan Island and surrounding areas, thematic maps related to conditions territory, soil samples, and other supporting data.

This research requires field survey equipment such as a compass, a geological hammer, measuring tape, tubes for soil samples, tubes for leachate samples, 4 mm, 0.063 mm, and 2 mm size sieves for grain size analysis, image processing software and GIS (Geographic Information Systems).

The research subject is the physical-mechanical properties of the weathering results of rocks. The research objects include rocks, both fresh and weathered, landscape, domestic waste leachate, and rivers. The object of research is identified through field surveys as well as through satellite imagery and maps.

Soil samples pick using the trenching method. This method is one of the cheapest methods. However, it can still get a three-dimensional subsurface image so that the boundaries between weathering, cracking, and weathering in weak rocks can be identified (Woodward, 2005). Undisturbed soil sampling also carried out.

The level of weathering rocks refers to the Classification of the engineering weathering profile (Mclean & Gribble, 1979) which divides into six classes, namely (I) fresh rock, (II) slightly weathered, (III) moderately weathered, (IV) highly weathered, (V) completely weathered, and (VI) residual soil.

The process of preparing rock-soil samples and testing done in a laboratory. Analysis of soil physical-mechanical properties based on USCS. Determination of soil type based on USCS classification as shown in the scheme in Fig. 4 (Briaud, 2013)

Variables of the physical and mechanical properties of the soil are often analyzed. They are water content, specific gravity, dry soil volume weight, saturation level, natural void ratio and natural porosity, liquid limit, Plastic Limit, grain size analysis, and permeability (Kalinski, 2011). Factors affecting permeability include pore ratio, pore distribution in grains, and degree of saturation (Elhakim, 2016; Gallage et al., 2013). Permeability allows water to pass through the space between the pores (Gupta et al., 2016). Calculation of permeability using Darcy's law:

$$\boldsymbol{v} = \boldsymbol{k}.\boldsymbol{i} \qquad (1)$$

where v = flow velocity, k = permeability coefficient (cm/s or in/s), i = hydraulic gradient (h/L), L = slope length.All research data, both obtained in the field and analyzed in laboratories and studios, are considered in determining the type of overburden suitable for the final processing site for domestic waste in the Riau Islands region.

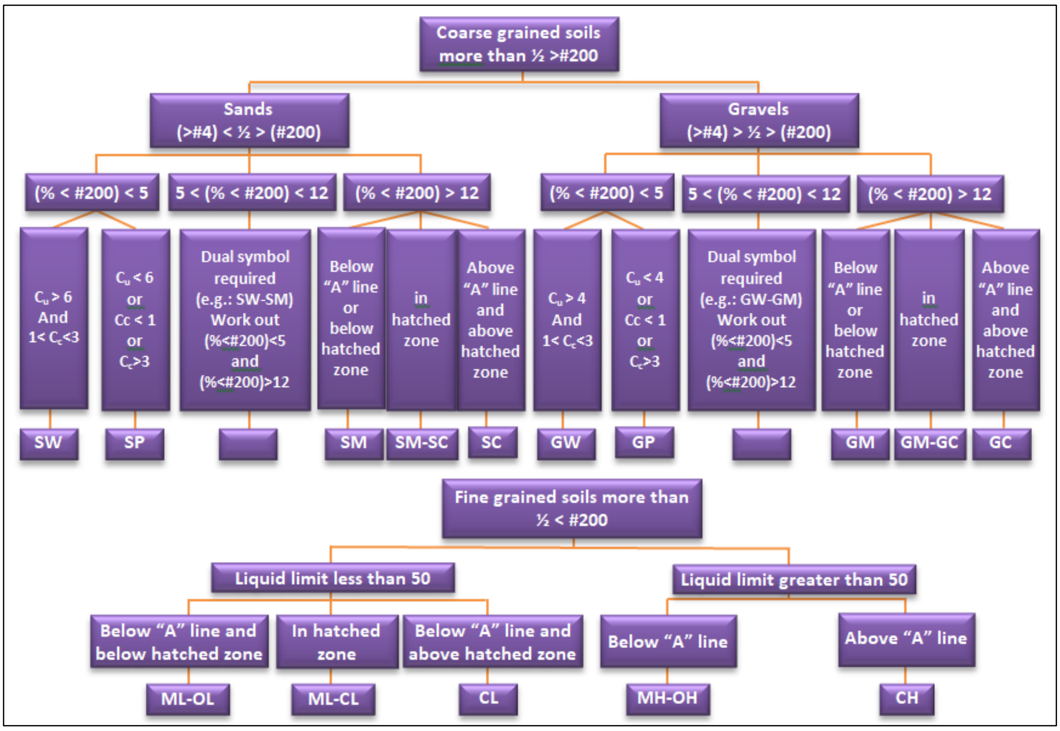

Fig.4. USCS modified from its classification flow chart (Briaud, 2013).

3. Result and Discussion

The results of observations at the waste final processing site of Ganet, it is known that the problem that is still an obstacle is leachate.The liquid from the decay is sometimes unable to penetrate the soil cover at the bottom. Leachate that has a strong odor sometimes runs out of control (Fig.5).

Leachate flow control facilities are not optimal. It indicates that the soil cover at the bottom of the pile of waste is not functioning correctly. Its permeability is incompatible with leachate characteristics. This liquid has different properties compared to water, where leachate has a higher viscosity than water. Therefore, it is necessary to engineer this soil ofgranite weathering to obtain the appropriate permeability value.

Fig 5. Black leachate in the Ganet waste processing site seeps out of control. Leachate is unable to penetrate the cover soil at the bottom of the waste landfill.

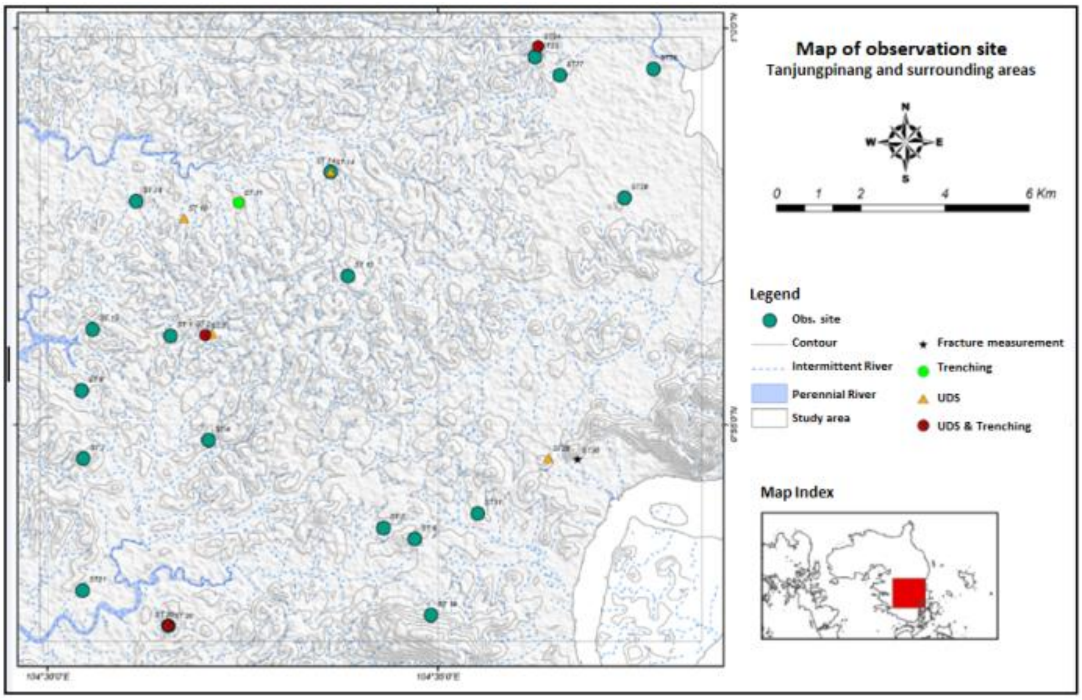

Fig.6 The observation location of the granite weathering profile in the Tanjungpinang and surrounding areas.

The dominant granite rocks make up the study area and both exposed as new rock and in weathered conditions with varying degrees. Observations made at 24 survey sites (Fig. 6).

In general, granite weathered outcrops found in the study area have a reddish-brown to light-brown color, silt to sand particle size, brittle, if wet slightly plastic, weathering levels IV to VI (topsoil). Outcrops of new granite rocks rarely found. Field observations include measuring thickness at each weathering level (Fig. 7).

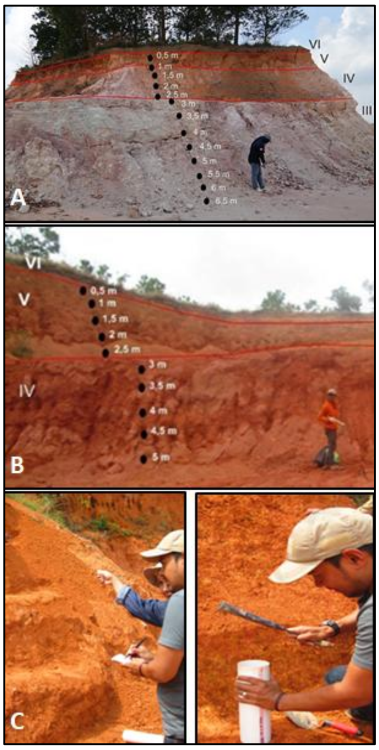

Fig.7 Field observation activities. (A, B, C) outcrop descriptions, thickness measurements in each weathering zone, undisturbed sampling.

3.1 The soil classification

Granite weathered soils in the Tanjungpinang and surrounding areas classified as SW, GM, CH, MH-OH, where MH is dominant. Variations in soil types in the study area represent the different depth and level of weathering.

SW soil types represent weathering level VI (ST24-A). GM soil types represent weathering levels of IV-V (ST 03-A; ST 24-B) wherein some locations, the level of chemical weathering, is relatively high, as seen from the CaO and Na_2O content. The soil type CH represents the weathering level V (ST 24-B). Meanwhile, MH-type soils have weathered III-IV (ST 20) weathering levels, where this type of soil shows high chemical weathering.

3.2 The soil physical-mechanical characteristic

The soil in the study area has a value of water content that varies in the low-moderate range—the lowest water content in ST 24-C with a value of 6.24%. Content weights obtained also vary, at ST 10-B has the highest value of weight content of 2.67% and the lowest weight value of land owned at ST 03-A with a value of 2.57%.

The distribution of soil grain size that is fine on average, but in some locations shows the size of coarse grains including ST 03-A at a depth of 3.50-4.80 m, ST 14-B at a depth of 4.70-5.00 m, ST 24-A at a depth of 0-0.3 m (Fig. 7B), and ST 24-C at a depth of 7.0-7.3 m.Coarse soil particles are almost all gravel size, only soil particles at ST 24 at a depth of 0-0.3 m are sand size. The sand-sized soil particles in ST 24-A reach 90.70%.

Soil particles are passing through sieve no. 200 is less than 5% with different sizes, which reflected in the grain size (Cu) uniformity coefficient that is more than 1 (Fig. 8A). Because the value of the curvature coefficient (Cc) is <1 and> 3, it has a pattern of particle distribution decreasing and increasing. Based on the USCS classification, the soil classified as SW (Sand-Well Sorted).Coarse gravel-sized soil spread on ST 03-B at a depth of 3.50-4.80 m, ST 14-B at a depth of 4.70-5.00 m and ST 24-C at a depth of 7.0-7.3 m.

Gravel-sized particles at these locations and depths have a percentage of 68.20%, 47.70%, and 50.90%, respectively. Particles that passed the no.200 sieve test are more than 12%. At the three locations, the naming of soil particles then added to the results of the plasticity test.

In the plasticity diagram for the three locations and depths, the material character position is below line A (Fig. 8a). It indicates the type of mud soil. Therefore, the naming of soil types in ST 03-B, ST 14-B, and ST 24-C is GM (Gravel Mud). Soil particles in ST 2 with a depth of 0.6-1.0 m and 4.95-5.25 m; ST 3 at a depth of 0-0.4 m; ST 10 at depths of 0.5-0.8 m and 3.5-3.75 m; ST 14 at a depth of 1.7-2.0 m; ST 20 at a depth of 5.6-6.0 m; ST 24 at a depth of 0.9-1.2 m; and ST 29 at 0.5-0.75 m depth are fine grain size. The naming of the soil type based on the Relationship between the plasticity index and the liquid limit (Fig. 8b).

Soils with a liquid limit of <50% are categorized into soil type M (Mud) while soil with a liquid limit> 50% included in the category of soil C (Clay) or soil M-O (Mud-Organic). Land at ST02-A (depth 0.6-1.0 m); ST 02-B (depth 4.95-5.25 m); ST 03-A; ST 10 A (0.5-0.8 m depth); ST 10-B (depth 3,5-3,75 m); ST 14-A (depth 1.7-2.0 m); ST 20 (depth 5.6-6.0 m); ST 24-B (depth of 0.9-1.2 m); and ST 29 (0.5-0.75 m depth) is a fine particle soil and has a liquid limit of> 50%. Land on ST 03-A; ST 14-A; and ST 24-B located above line A, so the ground at this station is called CH (Clay High Plasticity). While the soil at ST 02-A; ST 02-B; ST 10-A; ST 10-B; ST 20; and ST 29 is below line A so that the soil at that location is called MH-OH (Mud High Plasticity-Organic High Plasticity) based on the USCS classification. Fine particle size soils tend to be plastic. MH-OH type soil is the most dominant soil type at the study site.

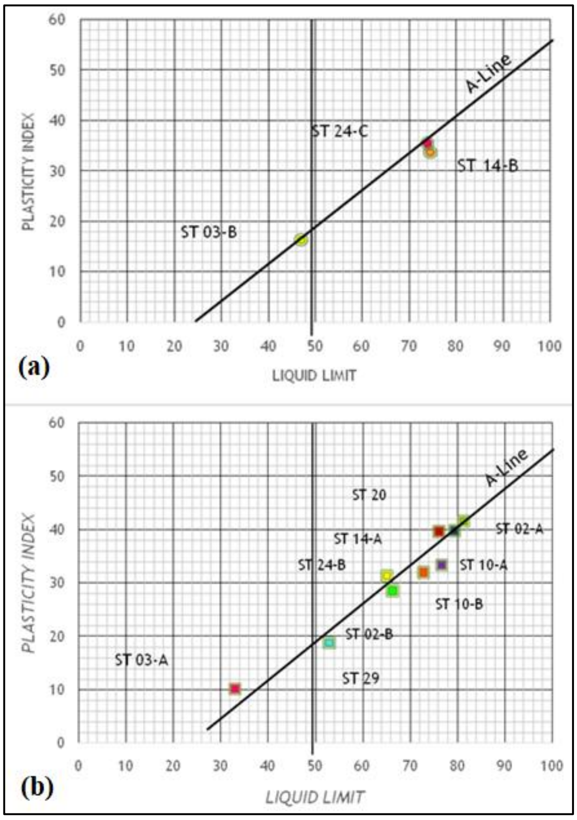

Fig.8 Relationship between plasticity index and liquid limit. Dominant fine-sized soil particles are below line A

3.3. Permeability

Permeability coefficient test on 13 soil samples is carried out in the laboratory (Table 1). The permeability coefficient values range from 6.083 x 10^{-7} to 3.790 x 10^{-3}. Soil layers at locations ST 14-A and ST 20 have a permeability of 6.083 x 10^{-7} cm/s and 6,597 x 10^{-7} cm/s, respectively. The soil permeability value is valid to use as final cover soil for a sanitary landfill system. Besides, the permeability range of the two layers of soil is relatively low so that it can withstand incoming water.

Permeability of other soil layers, namely soil in ST 02-A; ST 02-B; ST 03 A; ST 03-B; ST 10-A; ST 10-B; ST 14-B; ST 24-A; ST 24-B; ST 24-C; and ST 29 has a range of values of 1.517 x 10^{-3} cm/sec to 7.357 x 10^{-6} cm/sec which is quite high. High permeability indicates that this layer can hold and pass water quite effectively. So, this soil layer is sufficient to use as an intermediate soil cover.

Table1. The permeability coefficient of laboratory test

No.	Sample Code	Coefficient of Permeability (cm/sec)
1.	ST 02-A	7.357 x 10^{-6}
2.	ST 02-B	1.637 x 10^{-5}
3.	ST 03-A	4.305 x 10^{-6}
4.	ST 03-B	2.601 x 10^{-5}
5.	ST 10-A	1.517 x 10^{-3}
6.	ST 10-B	3.579 x 10^{-4}
7.	ST 14-A	6.083 x 10^{-7}
8.	ST 14-B	7.706 x 10^{-5}
9.	ST 20	6.597 x 10^{-7}
10.	ST 24-A	1.672 x 10^{-6}
11.	ST 24-B	1.213 x 10^{-6}
12.	ST 24-C	3.790 x 10^{-3}
13.	ST 29	1.380 x 10^{-6}

The grain size distribution of soil material is closely related to the value of the soil permeability coefficient. In general, uniform grain size distribution can form space between items so that the permeability value is high. If the grain size distribution is not uniform, the space between the grains that form closed pores (interlocking) results in a low permeability value.

Porosity is related to permeability. The greater porosity, the smaller the permeability coefficient value. In this study also found porosity values with permeability coefficients whose effects are not comparable. Based on laboratory test results, there are different porosity values when compared with the coefficient of permeability. The value of porosity is low along with the low coefficient of permeability produced, but there is a portion of the value of porosity is low while the coefficient of permeability is high. Therefore, in this study porosity and permebility do not affect each other less. This is due to the inhomogeneous soil conditions.

4. Conclusion

The treatment of leachate in the final landfills in Tanjungpinang and surrounding Riau Islands Province is not optimal. The relevant agencies have not fully supported the study of the overburden availability in the research area.

The variation of physical and mechanical characteristics of soils resulting from granite weathering requires engineering in order to obtain a formula that is suitable for sanitary landfill cover.

Characterization of permeability of granite rock weathering results can be used as a reference for engineering and become input for SNI to the land cover of domestic waste landfills. The permeability of granite weathered soil $<10^{-7}$has fulfilled the standard of Minister of Public Works Regulation Number 3, 2013. The regulation states that the permeability for the final cover is 1×10^{-7} cm/s.

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References

Ahnaf, J. S., Patonah, A., Permana, H., 2019. Petrogenesis of Volcanic Arc Granites from Bayah Complex, Banten, Indonesia. J. Geoscience, Engineering, Environment, and technology 4 (2), 104-112. DOI: 10.25299/jgeet.2019.4.2.3171.

Amadi, A. N., Olasehinde P. I., Okosun E. A., Okoye N. O., Okunlola I. A., Alkali, Y. B., Dan-Hassan M. A, 2012. A Comparative Study on the Impact of Avu and Ihie Dumpsites on Soil Quality in Southeastern Nigeria. American Journal of Chemistry 2(1), 17-23. DOI: 10.5923/j.chemistry. 20120201.05.

Briaud, Jean-Lous, 2013. Introduction to Geotechnical Engineering: Unsaturated and Saturated Soils. John Wiley & Sons, 998 p.

Elhakim, A.F. 2016. Estimation of Soil Permeability. Alexanfria Engineering Journal, Vol. 55. Pp. 2631 – 2638.

Erawan, F., 2015. Geological valuation for the location of the final processing of domestic waste in Singkep Islands, Riau Islands Province (abstract in English). (thesis).

Gallage, C., J. Kodikara, dan T. Uchimura. 2013. Laboratory Measurement of Hydraulic Conductivity Functions of Two Unsaturated Sandy Soils During.

Gupta, P., J. Alam, dan M. Muzammil. 2016. Influence of Thickness and Position of The Individual Layer on The Permeability of The Stratified Soil. Perspective in Science, Vol. 8. Pp. 757 – 759

Hasil sensus penduduk 2010 Kota Tanjung-pinang. URL [https://tanjungpinangkota. bps.go.id/publication/download.html] <accessed 10.12 16>.

Hutabarat, J., Syafri, I., Sulaksana, N., Sukiyah, E, Fauzielly, L., & Sudradjat, A. 2016. Fenomena Pelapukan Granit “Corestones” Di Daerah Bagian Timur dan Utara Pulau Bintan. Seminar Nasional III FTG Unpad.

Irzon, R., Syafri, I., Hutabarat, J., & Sendjaja, P., 2016. REE Comparison between Muncung granite samples and their weathering products, Lingga Regency, Riau Islands. Indonesian Journal on Geoscience 3 (3), 149-161. DOI:10.17014/ijog.3.3.149-161.

Irzon, R., Syafri, I., Hutabarat, J., Sendjaja, P., Permanadewi, S., 2018. Heavy Metals Content and Pollution in Tin Tailings from Singkep Island, Riau, Indonesia. Sains Malaysiana 47(11), 2609–2616. http://dx.doi.org/10.17576/jsm-2018-4711-03.

Kalinski, Michael E., (2011) Soil Mechanics Lab Manual 2nd Edition, John Wiley & Sons, Inc. 193p.

Kusnama, Sutisna, K., Amin, T.C., Koesoemadinata, S., Sukardi, Hermanto B. 1994. Peta Geologi Lembar Tanjungpinang, Sumatera skala 1: 250.000. Pusat Penelitian dan Pengembangan Geologi. Bandung.

Lubis, M.Z., Anurogo, W., Kausarian, H., Surya, G., Choanji, T., 2017. Sea Surface Temperature and Wind Velocity in Batam Waters Its Relation to Indian Ocean Dipole (IOD). J. Geoscience, Engineering, Environment, and technology 2 (4), 255-263. DOI: 10.24273/jgeet.2017.2.4.778.

Mclean, A.C., Gribble, CD., 1979. Geology for civil engineering. E & FN Spon, London.

Molengraaff, G. A. F. & Weber, M.,1921. On the relation between the Pleistocene Glacial Period and the Origin of the Sunda Sea (Java- and South China-Sea), and its Influence on the Distribution of Coral Reefs and the Land and Freshwater Fauna. Proceedings of the Section of Sciences 23, 395-439.

Rizki, F., Situmorang, A.D.L., Wau, N., Lubis, M. Z., Anurogo, W., 2017. Mapping of Vegetation And Mangrove Distribution Level In Batam Island Using SPOT-5 Satellite Imagery. J. Geoscience, Engineering, Environment, and technology 2 (4), 264-267. DOI: 10.24273/jgeet.2017.2.4.1002.

Sudradjat, A., Sukiyah, E., Haryanto, E.T., Purnomo, D., 2018. Karakteristik hasil pelapukan batuan di wilayah Kepulauan Riau dan Jawa Barat serta desain pemanfaatannya untuk tanah penutup TPA sampah domestik. Laporan Akhir ALG, Universitas Padjadjaran.

Sukiyah. E., Isnaniawardhani, V., Sudradjat, A., & Erawan, F., 2018. The geologic potentials of Riau Islands Province and its development design. Jurnal Perspektif Pembiayaan dan Pembangunan Daerah Vol. 5. No.3: 181-190.

Susilowati, S.K., Kapriaji, M. N., Puspitasari, T.R., Beti, Mardayani, & Rizqal, M., 2019. Tanjungpinang Municipality In Figures. BPS-Statistics of Tanjungpinang Municipality. https://tanjungpinangkota.bps.go.id <download July 5, 2020>.

Woodward, John, 2005. An Introduction to Geotechnical Processes. Spon Press. London & New York. 307 p.