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Geotechnical Properties of Dredged Marine Sediments from Malaysian Waters

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Abstract

This paper describes an experimental evaluation of engineering characteristics of dredged marine soils (DMS) which excavated during the dredging works carried out from Malaysian waters. DMS mainly consists of clays, silts and sands mingled with debris, rocks and organic matter. The samples were retrieved from Kuala Muda (Kedah) and Kuala Perlis. In laboratory works, physical properties of DMS are depends to space, time and land in the watershed. Due to its poor engineering properties, the material was destined for disposal offshore. Dredged marine soils, commonly classified as geo-waste. The parameters examined include particle size distribution, morphology, water content, Atterberg limits, specific gravity and organic content. The DMS from Kuala Perlis Kuala Muda Kedah can be classified as high plasticity of silt (MH) and low plasticity of silt (ML) respectively. Reasonable agreement can be noticed at different locations have different physical properties. Thus, the geo-characterization of DMS is significant in decision making either to be reused or disposed to the designated open waters.

Key-word: - Dredged marine soils, Physical properties, Geo-properties

1. Introduction

Activity of dredging is to excavate or removing the sediments from the bottom of waterways and marine location (Azhar *et al.*, 2014). Dredging works had been carried out in order to deepen the sea vessels. It is necessary to keep the waterways unblocked and prevent the rivers from flooding as well as to restore the ecosystem in rivers (Winkels and Stein, 1997; Zhu *et al.*, 2007; Kim *et al.*, 2011 and Ganesalingam *et al.*, 2011). As mentioned by Manap (2008), the first concept of dredging was started since 1913 in mining industry at Kuala Lumpur. The type of dredger was Cutter Suction Dredger with capacity of 750 m/hour. Sediments which come from dredging activities are known as dredged marine soils (DMS).

Every year large volumes of dredged marine soils (DMS) are removed from Malaysian water (Shahri and Chan, 2015). Unfortunately, it is commonly practice in Malaysia which is dump back to the open waters or inland landfills. Wang *et al.* (2012) mentioned by disposed into the open ocean without any treatment are unfavourable because of the negative effects on the environment.

Based on Chan (2014), Malaysia’s practice for the dumping sites from the shoreline are about 10 nautical miles (18.52 km) but the practice in Italy, the dumping site is over 3 miles from the coastlines (Bortone and Palumbo (2007). However, Salim *et al.* (2013) cautioned that there is a high possibility for the DMS to return to the river mouth because of wave flow and rapid sedimentation. In addition, the disposal of DMS back in the water body can harm the marine ecosystems even the impact might be effect on the physical (for clean sediment).

According to Bortone and Palumbo (2007), the sediments that settle at the bottom of water body are loose particles of sand, clay, silt and other substances. In addition, IADC (2009) stated that rocks and gravels also considered types of dredged sediments. Dredged marine soils especially the fine-grained types have low shear strength, low permeability, high water contents and very compressibility which are susceptible to have large settlements. Hence, DMS are generally classified as waste materials (geo waste). This paper focused on the study of geo-properties of dredged material that was collected from two different locations.

2. Materials and Methods

2.1 Materials

Dredged marine soils (DMS) in this study were originally retrieved from dredging activities located at Kuala Perlis and Kuala Muda, Kedah (Figure 1) in December 2015. Both DMS samples were collected in different location to represent different localities which have different anthropogenic activities in each location.The DMS from Kuala Perlis was collected by using backhoe dredger (Figure 3) at depth between 4 m – 6 m from sea level while Kuala Muda, Kedah was collected by using trailing suction hopper dredger (Figure 2) at 8 – 10 m. The disturb samples were then taken into the storage tank from dredger manually. The storage tanks for the samples were kept in double-layer plastic sampling bags to prevent moisture loss during transportation back to the laboratory. The samples were stored indoors to avoid direct sunlight and heat because it can destroy the organic matter resulting in loss of mass. Figure 4 show typical picture of DMS.

3. Megalithic Culture Influences

Megalithic is known as the earliest Malay stone carving. Megalithic culture is a reflection of the rich belief systems and rituals which characterized early Malaysian societies (Nik Hassan Suhaimi, 2004). The prehistoric was belief was extended to the next era with and the fragments of the culture have been brought together which create culture continuity. According to Abdul Halim *(1987)*, the art of stone carving in Peninsular Malaysia started during the prehistoric era with the megalithic culture. As a one of earlier Malay culture, Megalithic culture used to be a monumental, spiritual and as an ancestral worship. The art of stone in Malay culture is also presenting the Malays in appreciation context of art, carving and sculpturing even though they had no knowledge of the aesthetic and artistic nature of work. The distribution of megalithic culture in Negeri Sembilan and some part of Malacca shown the art of stone carving is valuable towards historical context which the variety shapes of Megalith such as sword shaped, rudder, spoon, tortoise, snake, baby deer and else (Abdul Halim, 1987). The art of stone carving is an invaluable heritage with the lasting historical and cultural importance.

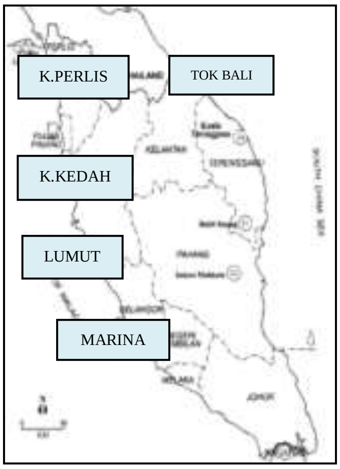

Figure 1 Location map of sampling sites

Figure 2. Trailing suction hopper dredger at dredging site (Kuala Muda, Kedah)

Figure 3. Backhoe dredger (Kuala Perlis, Perlis)

Figure 2. Typical dredged marine Soils (DMS)

Note that all the physical and chemical properties were performed in accordance with prescriptions by BS1377 (1990). Moisture content is used to determine the moisture content of a soil specimen as a percentage of its dry mass. In this study, the moisture content of dredged marine soil samples was taken from its natural condition, and the moisture content of the samples was oven-dried at 105°C for 24 hours to remove the entrapped moisture. For each mixture in this study, the measurement was carried out on 10 samples to ensure better accuracy in the data obtained.

The transitions of soil structure from solid to plastic and then to liquid states are marked by the parameters of Atterberg limits. The moisture content of soil influences the plasticity and liquidity of soils. According to the British Soil Classification System (BSCS), the soils criteria are based on the relationship between Liquid Limit (LL) and Plasticity Index (PI). The range of the particle size of soil can be determined by screening soil in an arranged manner of sieves with different size of aperture. There are two types of sieving method namely dry sieve and wet sieve methods. Dry sieve method is suitable for soil that contains fewer amounts of silt and clay. Generally, fine-grained soil such as dredged marine soil (DMS) considered the wet sieve method to obtain its particle size distribution.

Hydrometer is one of the laboratory techniques to determine the size range, average or mean size of the particles in a solid (powder) or liquid sample. This device is used to analyses the particle by using a floating technique. The sizes of aperture used in wet sieving was 2.36 mm, 1.18 mm, 1.0 mm, 0.6 mm and 0.063 mm. Briefly, the experiment commenced with mixing the sample with a solution of sodium carbonate and sodium hexamethaphosphate. The solution was used to separate discrete particles of the samples. By combining the particle size distribution of wet sieve and hydrometer, a continuous soil distribution curve is able to be plotted.

Specific gravity test is strongly dependent upon the amount and organic constituents (O'Loughlin and Lehane, 2003). Normally, distilled water used as the liquid in the density bottle, but if the soil samples contains of soluble salts, kerosene or white spirit should be used. The pH test is the common practice to measure the pore fluid of all the geo-materials. The sample used must pass through 2 mm aperture size as mentioned in BS 1377:1990 Part 3 Clause 9. In the present study, the soil's pH was determined with the water slurry method. The pH meter was calibrated according to the instructions provided by the manufacturer and using buffer solutions of pH 4, 7 and 10. 10 g of soils was placed in 25 ml of distilled water. Then, it was stirred for 2-3 minutes to disperse the soil particles completely. The water slurry was next left to stand for 2 hours (BS 1377: Part 3: 1990: 9). The pH meter was then lowered into the soil-water mixture to obtain the readings of pH.

3. Results and Discussion

Geo-properties are an important to predict and describe the engineering properties of DMS. The main physical characteristics of DMS are reported in Table 1. Note that it was collected in a slurry state from the dredge site and was greyish in colour with an unpleasant smell (due to microbial activities). Figure 5 showed the comparison of particle size distribution from previous studies on DMS in Peninsular Malaysia. The particles size distribution was determine by using wet sieve and hydrometer analysis experiment test. The PSD indicated that silt portion is the higher particles than sand portion for KP. Meanwhile, the curve for KM show that sand more dominant than clay with 47 % of sand, 32 % silt and 27 % clay. As comparison between others samples from previous studies at different sites, Melaka and Pasir Gudang have higher of silt than sand. The economic activities near the dredge site and sampling area could contribute significantly to the particle size composition of the dredged sample. Besides the sampling location is an important factor to consider when analysing the particle size distribution of a dredged sample.

Shown in Figure 6 is the water content, Wc and Liquid Limit, LL of dredged marine soils from different sites at Peninsular Malaysia. Based on the results obtained the value of initial water content, Wc for Kuala Muda, Kedah (KM) was 97.50 % and Kuala Perlis (KP) sample was 218 %. Grubb *et al.* (2011) stated that usually high water content between 100 - 200 %. Based on water content from Salim *et al*. (2012), it was much lower than the Wc in this study. This indicated that the space of time did influence the water content due to the settlement of sediments. Furthermore, dredged marine soils have the ability to retain water due to the arrangement of the soil particles.

Liquid limit for samples Kuala Muda and Kuala Perlis are 31.50 % and 55.81 % while plastic limit are 47.70 % and 66.50 %. Therefore, PI for KM and KP is 16.20 % and 10.69 % respectively. Both samples are 2 – 3 times of liquid limit and considered as soft soils. It same goes to Melaka, Tok Bali and Pasir Gudang, which have between 2LL – 3.5LL. Therefore, by referring to the Unified Soil Classification System (USCS) in Figure 7, the soil was classified as a low plasticity of silt (ML) and high plasticity of silt (MH).

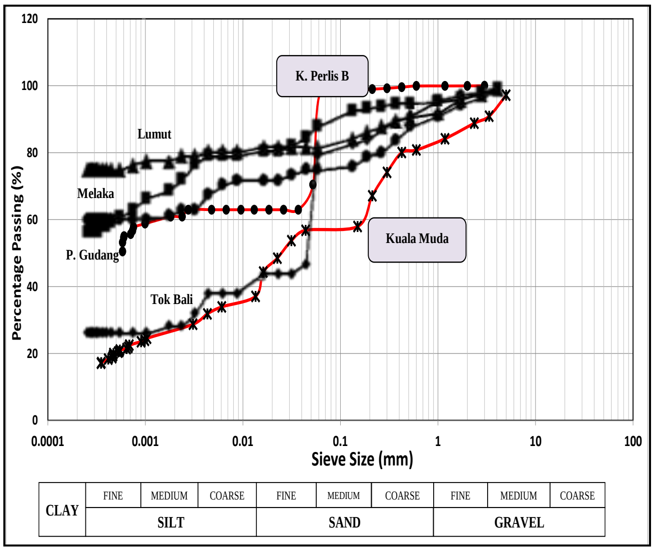

Figure 5. Comparison of particle size distribution between DMS from previous researcher

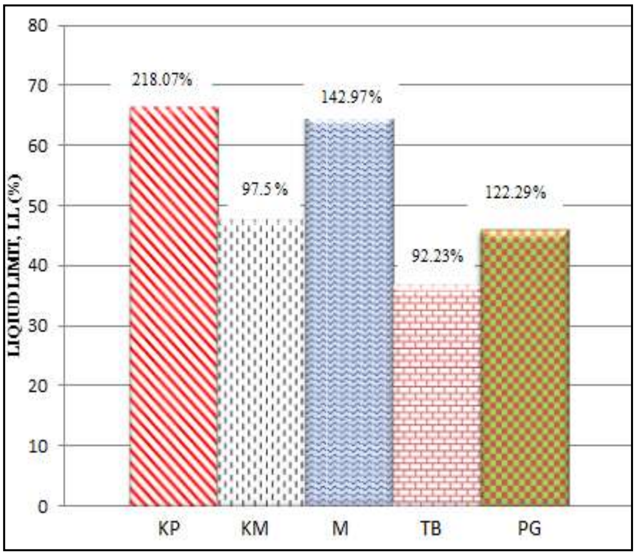

Figure 6. Wc vs LL of DMS

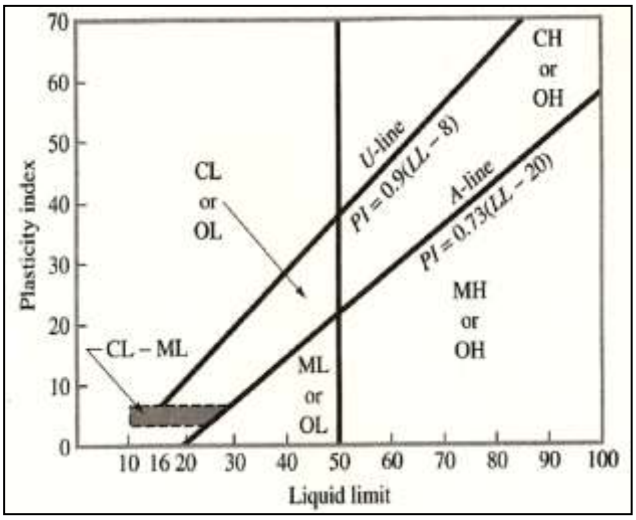

Figure 7. Unified soil classification system (USCS) of DM

Table 1. Comparisons DMS physical and chemical properties from others researcher on Malaysian waters

Sites	Properties						
	Wc (%)	LL (%)	PL (%)	PI	Gs	pH	USCS
*K. Muda, Kedah (KM)	97.50	31.50	47.70	16.20	2.57	8	ML
`*K. Perlis (KP)	218	55.81	66.50	10.69	2.68	8	MH
Kuala Perlis (Salim *et.al.*, 2013)	66.13	39.13	71.05	31.77	2.15	6.7	MH
K. Muda, Kedah (Rahman *et.al.*, 2013)	65.90	42.00	72.00	30.00	2.60	-	MH
Marina Melaka (M) (Azhar, 2015)	142.97	50.46	65.00	14.54	2.56	8.3	CH
Tok Bali, (TB) Kelantan (Azhar, 2015)	92.23	25.83	36.90	11.07	2.41	8.5	ML
Pasir Gudang, (PG) Johor (Shahri & Chan, 2015)	122.29	35.60	46.10	10.50	2.41	-	ML

The specific gravity for KM and KP samples were 2.57 and 2.68 respectively. The results were compared with the previous research (Table 1). The specific gravity of DMS could be influenced by the soil mineral and also depends on the particle size samples (Das, 2010). This can be explain that when excavated, removed or re-deposited at the same location, the soil properties will be drastically change. pH is a measure of hydrogen ion concentration of a solution. The solution that has high concentration of hydrogen ions, will have a low pH and vice versa. Therefore, the value pH for KM and KP is 8 which are ≥ 7, and it means that it is alkaline. Same goes to M and TB have alkalinity value of pH. The result of pH value on Kuala Perlis by Salim *et al*. (2012), where the pH value is 6.7 less than 7 have slightly acidic. Again, the location of sampling sites could contribute into the changes of chemical reaction on DMS because of the contamination.

4. Conclusions

This study was conducted to examine the geotechnical properties of DMS from Kuala Muda, Kedah and Kuala Perlis, Perlis. DMS samples from both dredging sites are the first subjected to Atterberg limits, moisture content, hydrometer analysis, particle density and also the pH value. The results of geo-properties of dredged marine soils for both samples are compared with previous research as illustrated in Table 1. The studied properties clearly shown that DMS at Peninsular Malaysia have high water content between 2LL – 3LL. Further study need to be conducted to reuse the DMS without dispose into the open waters.

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