



GEO-CHARACTERISATION OF DREDGED MARINE SOILS FOR POTENTIAL REUSE ASSESSMENT IN CIVIL ENGINEERING APPLICATIONS

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ABSTRACT

This document contains the formatting information for the papers presented at the International conference on "Engineering Technology International Conference (ETIC 2015)". The conference would be held at (Bali, Indonesia) during August 10-11, 2015. Dredging is a necessary procedure to remove large quantities of sediments from the seabed. It is therefore imperative to examine the possibility of reusing the material. Accordingly, it is important to determine the material's inherent geo-characteristics as the first step in ascertaining its physical reusability. The paper describes the key geotechnical characteristics of 4 dredged marine soil samples retrieved from Malaysian waters. Overall, it was found that the dredged marine soils do not differ significantly from ordinary fine-grained soils, and could be reused as a sound geometrical with certain pre-treatment to improve the engineering properties accordingly.

Keywords: dredged marine soils, landfill, reclamation reuse and sustainable development.

1. INTRODUCTION

Dredging is important to remove materials from the bottom of rivers, harbor, and other water bodies. Dredging activities are needed to maintain or enlarge river and port channel, flood control, waterfront construction and access to harbor [1]. Sediments are the materials that settle at the bottom of a water body. It derives principally from natural processes (i.e. erosion of soil and weathering of rock) and anthropogenic activities (i.e. agricultural practices and construction activities). The term dredged marine soil refers to the sediment that has been dredged from a water body [2]. Dredged marine soils (DMS) are predominantly clean and usable products. It can be used for beach nourishment, wetland restoration, and construction material and wildlife habitat development.

DMS consist mainly of clays, silts, and sands. It is mingled with rocks, debris, large obstacles, and organic matter [3]. Organic matter usually derives from humus, decomposed plant and animal residues and other organic matter such as algae, worms, and amphipods that settle at the bottom of water's body. According to Torres *et al* [4], the beneficial uses, disposal or treatment options of DMS based on the soils' characteristics. In DMS management, information on its properties (e.g. physical, chemical, and biological properties) is essential to the selection of a suitable DMS management option [5].

There are three options in DMS management: sea disposal, land disposal, and beneficial use [6]. Disposal at sea is the most common practice in Malaysia. Land disposal are not applicable due to high cost and requires large area. However, both of these optional give adverse effect to human and environment when expose to contaminated DMS. Instead of treating DMS as a waste, it as been realized that DMS can be used beneficially for a variety of applications such as beach nourishment, habitat

restoration and construction material [7]. This paper reviews some of the civil engineering application for DMS where the geo-characteristic of the material are discussed in conjunction with the applications.

1.1. DMS samples: sources and properties

The DMS were collected as disturbed samples from Lumut (Perak), Marina Melaka (Melaka), Tok Bali (Kelantan), and Pasir Gudang (Johor) (Figure-1). The sample was dredged by trailing suction hopper dredger (TSHD) at a depth of 8-12 m from sea level (Figure 1a) for Lumut site. The marine soils from Marina Melaka were dredged out by backhoe dredger (BHD) at a depth of 3.5 - 6.5 m from sea level (Figure 1b). Backhoe dredger was also used at Tok Bali and the depth was 3.5 - 5.0 m from sea level (Figure 1c). Sample from Pasir Gudang site was taken from 0 - 10 cm of the sediment surface (Figure 1d). Figure-2 shows typical dredged marine soil sample. The DMS samples were put in sealed plastic bags to prevent moisture loss. The sample for biological properties test was placed in polystyrene box with ice to preserve the microorganism. Once the samples arrived at geotechnical laboratory, all the samples in the plastic bags were transferred to covered tank for storage. All the physical properties tests were carried out primarily based on the procedures given in British Standard [8]. The soil's geotechnical and chemical properties are summarized in Table-1 and 2. It is apparent that the DMS samples were all of the fine-grained which potentially contaminated from chemical sources.



Figure-1. Sampling sites of DMS.

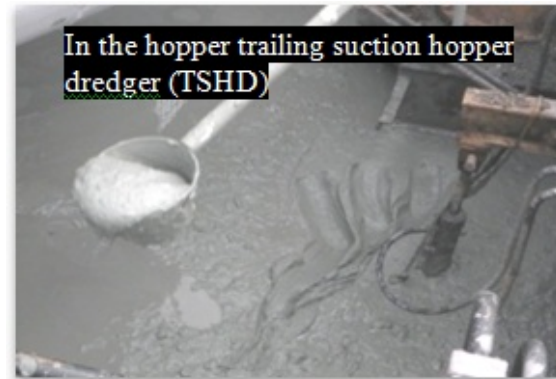


Figure-2. Dredged marine soil sample being retrieved from seabed.

Table-1. Physical properties of dredged marine soils.

| Experiment | Results | | | |
|---------------------------------------|----------------------|----------------------|---------------------|---------------------|
| | Lumut | Melaka | Tok Bali | P.Gudang |
| Particle Size Distribution (%) | | | | |
| Gravel (>2 mm) | 3 | 3 | 5 | 2 |
| Sand (2-0.075 mm) | 15 | 9 | 20 | 18 |
| Silt (0.075-0.002 mm) | 4 | 20 | 15 | 54 |
| Clay (<0.002 mm) | 78 | 68 | 60 | 26 |
| Moisture Content (%) | 166.16 | 145.77 | 92.23 | 122.29 |
| Atterberg Limits | | | | |
| Liquid Limit (%) | 95.80 | 58.50 | 36.80 | 46.10 |
| Plastic Limit (%) | 34.50 | 38.39 | 25.83 | 35.60 |
| Plasticity Index (%) | 61.30 | 20.11 | 10.97 | 10.50 |
| Soil Classification | CH | MH | ML | ML |
| | High Plasticity Clay | High Plasticity Silt | Low Plasticity Silt | Low Plasticity Silt |
| Specific gravity | 2.60 | 2.63 | 2.38 | 2.41 |

1.2. Reuse in civil engineering areas

1.2.1. Beach nourishment

Dredged marine soils have the potential to be used for beach nourishment. Beach nourishment, also known as beach replenishment, beach feeding or beach recharge, involves the process of rehabilitating a degenerated or deteriorated shore area. The key physical characteristic of the material to be used are particle size and density. The material should also be uncontaminated and slightly coarser than the natural beach material [9]. According to USEPA and USACE [10], sand remains the most favorable suitable material for beach nourishment.

This could be attributed to the coarse, interlocking fabric of the material which gives higher shear resistance as well as better drainage capacity to construct the new land mass. All the DMS in the present study were found to contain >50 % of fine particles, with presence of certain heavy metals (Table-1 and 2). Thus,

they are not suitable to be used for beach nourishment, unless being pre-treated to remove the contamination and enhance the engineering properties. Figure-3 shows beach nourishment at Alicante, Spain using dredged marine soils.



Figure-3. Beach nourishment at Alicante, Spain, before replenishment (left) and after (right) [11].

**Table-2.** Chemical properties of dredged marine soils.

| Experiment | Results | | | |
|---|---------|--------|----------|----------|
| | Lumut | Melaka | Tok Bali | P.Gudang |
| Loss on ignition (%) | 6.33 | 9.39 | 4.28 | 8.38 |
| pH value | 8.30 | 8.32 | 8.51 | 8.35 |
| Chemical composition (% dry wt.) | | | | |
| Aluminium oxide (Al_2O_3) | 17.10 | 20.73 | 21.10 | 21.15 |
| Calcium oxide (CaO) | 3.25 | 2.58 | 4.19 | 1.01 |
| Iron oxide (Fe_2O_3) | 4.60 | 6.50 | 7.50 | 2.5 |
| Potassium oxide (K_2O) | 2.24 | 2.81 | 2.75 | 0.71 |
| Magnesium oxide (MgO) | 2.44 | 2.30 | 2.20 | 0.71 |
| Silicon dioxide (SiO_2) | 63.40 | 55.67 | 55.67 | 50.9 |
| Sulfur trioxide (SO_3) | 1.66 | 1.53 | 1.84 | 5.74 |
| Electrical conductivity (dS/m) | 7.72 | 6.74 | 8.10 | 11.29 |
| Mineralogy (%) | | | | |
| Quartz (SiO_2) | / | / | / | / |
| Halite (NaCl) | / | / | / | / |
| Montmorillonite ($\text{Na}_{0.3}(\text{AlMg})_2\text{Si}_4\text{O}_{10}\text{OH}_2 \cdot 6\text{H}_2\text{O}$) | / | / | / | / |
| Kaolinite ($\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4$) | / | / | / | / |
| Calcite (CaCO_3) | / | / | / | / |
| Illite ($\text{K,H}_3\text{O}(\text{Al}_2\text{Si}_3\text{AlO}_{10}(\text{OH})_2$) | / | / | / | / |
| Pyrrhotite (Fe_7S_8) | | | / | / |
| Chalcopyrite (CuFeS_2) | | | / | / |
| Pyrite ($\text{FeS}_{1.96}$) | | | / | / |
| Chlorite ($\text{Mg}_2\text{Al}_3(\text{Si}_3\text{Al})\text{O}_{10}(\text{O})_8$) | | | / | |
| Dolomite ($\text{CaMg}_{0.77}\text{Fe}_{0.23}(\text{CO}_3)_2$) | | | / | |
| Heavy metal (mg/kg dry) | | | | |
| Arsenic (As) | 11.30 | 18.00 | 16.50 | 18.00 |
| Chromium (Cr) | 59.70 | 66.70 | 39.50 | 54.50 |
| Copper (Cu) | 5.00 | 21.70 | 6.50 | 10.50 |
| Lead (Pb) | 33.00 | 40.30 | 35.50 | 28.00 |
| Nickel (Ni) | 18.30 | 22.00 | 12.50 | 9.50 |
| Zinc (Zn) | 53.70 | 84.30 | 38.00 | 107.00 |

/ detected

1.2.2. Land reclamation

Land reclamation is a process to create a new land near the sea or riverbeds by filling the area with fill material [12]. Dredged marine soils can be used for land reclamation. Based on the suitability of fill material for land reclamation needs to be sufficiently addressed, as highlighted in Environmental Impact Assessment (EIA) [13]. The key properties to be examined for reuse in land reclamation or creation include organic content, variability of sediment texture, reduced permeability and pH level [5]. All the DMS in the present study contained >50 % of fine particles, rendering them unsuitable for land creation in their natural forms. Nonetheless the fine-grained DMS are not entirely useless, for treatment like admixing and solidification can be expedient in transforming the poor quality material to usable forms, with improved strength, stiffness and other required engineering properties [14].

Figure-4 shows land reclamation at Dubai that using dredged marine soils as fill material.

**Figure-4.** Land reclamation at Dubai [11].



1.2.3. Landfill cover

According to Harrington and Smith [5], the properties of material to be used for landfill cover should be a mixture of both coarse and fine-grained, of low moisture and clay contents with low permeability, minimum organic content (no more than 1.5% of material's dry weight) and pH range between 5.5-8. Landfills, if left unattended in the closure stage, could turn into a source of considerable environmental degradation, mainly from the flow of contaminated leachate into nearby water bodies. Landfill cover material is therefore needed to complete the final closure process.

Historically, compacted clay is widely used for the final capping of landfills due to its low permeability, which helps in the reduction of surface water infiltration and contaminant transport, as well as surface runoff maximization. It follows that fine-grained DMS, especially can meet these engineering criteria at a lower cost. With suitable top soil laid out, the cap can also serve as a vegetation plot for the growth of herbaceous or woody upland vegetation, providing habitat for migratory and resident wildlife. Nonetheless, the salt content and pH must be appropriate to support growth of the desired vegetation, especially for post-closure landfills designated for agricultural land use. It should be cautioned through that very fine-grained material is generally unacceptable for use as landfill cover of dust [15], particularly the poor drainage characteristics which can lead to leachate seeps on side-slopes. Other recommendations include treatments prior to usage of the DMS, such as pre-draining excess moisture to avoid poor workability, pre-mixing the fine grained DMS with other soils or materials to alter and improve the structural, hence drainage characteristics [16]. Figure-6 shows landfill was covered with DMS located in Belgium.



Figure-5. Landfill cover and construction of a centre for sediments located in Belgium [17].

1.2.4. BRICKS AND CERAMIC MAKING

Romero *et al* [18] summarized the benefits of brick- and ceramic-making from DMS as savings in resources, including raw materials and energy; improved final product quality, greening of the otherwise high-carbon-emission production process and the reduction of overall production cost with usage of the geowaste. The fact that DMS, particularly the fine-grained ones, consist

of a mix of clay, silt and sand in similar proportions as soils used as raw materials for brick production. Thus, make the material a potential usable substitute. For instance, soils used for brick-making are generally accepted to contain 10-50 % of clay fraction with some presence of silt and sand [19].

A higher sand content is sometimes favorable to enhance the bricks' texture uniformity, strength and workability [20]. It has also been reported that DMS can be recycled into other construction materials, such as constituent material in road pavement, light-weight aggregates ceramic tiles [18,21]. However, as reported by Baruzzo *et al* [21] in their work with DMS admixed with other industrial waste to form ceramic tiles, some setbacks may be encountered with the sintering process. The adverse effects observed of using DMS in the mixture were poor thermal expansion and shrinkage characteristics during firing, resulting in formation of large and irregular defects in the product. Interestingly, the overall mechanical properties were found to be good with low post-sintering release of hazardous elements. These suggest the advantages of using DMS in high-temperature production processes, including sintering and verification, where the contaminants are exterminated or entrapped in the hardened mass. Figure-7 shows an example of fired bricks produced from river sediments.



Figure-6. Brick made of dredged materials [22].

2. CONCLUSION

The paper exemplifies some civil engineering applications in which DMS can be put to use instead of being disposed off. The properties of four DMS samples from Malaysian waters were also presented and discussed. DMS have been shown to have great potential for reuse, including the fine-grained materials consisting mainly of clay and silt particles. Admittedly, heightened geo-environmental awareness makes long-term safety of the reused material a concern, treatment and conditioning methods are available to make gain more insights to the materials' engineering properties for field filed applications as mentioned above.

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