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1-D COMPRESSIBILITY PARAMETERS OF LIGHTLY SOLIDIFIED DREDGED MARINE SOIL (DMS) USING CEMENT, GGBS AND COARSE SAND

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ABSTRACT: A consistent dredging is essential for the development along the coast and the maintenance of shipping routes. The dredging operation dislodges sediments from the seabed, and the retrieved materials, termed dredged marine soils, are considered a geowaste for dumping. Therefore reusing the material will benefit the civil sectors, and one option is solidifying with other materials, which are, cement, ground granulated blast furnace slag (GGBS) and sand. The present investigation is on a dredged marine soil (DMS) from Kuala Perlis state in Malaysia where in a laboratory study was undertaken to contemplate the compressibility characteristics of DMS with cement, GGBS and sand admixtures. Cement is the major constituent of concrete which is produced by natural raw materials like limestone rock, clay and chalk etc. These are produced by blasting quarries. Industrial wastes like Ground Granulated Blast Furnace Slag (GGBS) show chemical properties similar to cement. An attempt was made to understand the influence of cement plus GGBS as binder and sand as a granular material by studying the improved settlement rate of consolidation. The results showed that the optimum binder content was from 3C7G_20 specimen and when sand was added to it, it present that settlement decreased with increasing sand content. Binder combinations involving ratio of cement to GGBS of 3 to 7 with addition of sand were effective in improving the settlement and consolidation rate when compared to the performance of cement alone as binder.

Keywords: Solidification, Reclamation, Dredging, Cement, GGBS, Sand and Settlement

1. INTRODUCTION

Dredging can be described as underwater excavation of soils. It is necessary to maintain existing waterways, ports and water channels [1]. The need of increase in waterway depths might be due to the increased demand for transporting people, equipment, materials and commodities by water. Besides that, dredging process is also used in flood control measures to maintain or improve the river or channels flow capacities [2]. However, the benefits of the dredging project can be enhanced through the use or re-use of the dredged material for a beneficial purpose [3] and [4]. Thus, this geowaste could be regenerated as a new resource to substitute soil for civil works such as for embankment and land reclamation. The geowaste usually clay, silt or sand,

Clay is referred to as a cohesive soil which includes clayey silt, sandy clay, silty clay and organic clay. This type of soil has low strength and high compressibility. Compressibility of soils is an important engineering consideration. This is due to the fact that soils subjected to increased effective stress would decrease in volume hence resulting in surface settlement [5]. Thus, the addition of cement or other binder and granular materials could improve the weak soil with reduced settlement, e.g. [6] & [7] in oedometer tests. Therefore, this shows that solidification of this geowaste could be a beneficial reuse for application in land reclamation.

2. MATERIALS AND METHODS

The samples were collected from Kuala Perlis, Malaysia and the coordinate of the location is 6° 24' 0" North, 100° 8' 0" East. The soils were dredged from the sea by using clamshell dredger as shown in Fig 1. The soils were dredged at 6 – 7 m depth from the sea level. The dredged soil was temporarily stored in a barge. The soils were scooped out from the barge and placed into the sampling buckets and then transported from Kuala Perlis to laboratory. The soil samples were stored at UTHM laboratory. The soils were stored indoors to avoid sunlight and heat.

Fig. 1 Clamshell Dredger

2.1 Test Specimens Preparation

All the amounts were calculated using dry weight of DMS. For the purpose of documentation, the mass of DMS and moisture content was maintained as 500 g and 147 % respectively. During laboratory test moisture content might vary in about ±3 %, thus the binders and sand content will be calculated according to that particular moisture content. Percentage of DMS was maintained at 100 % for each test. All the samples were cured for 7 days. The test specimens details are as follows:-

Table 1 Test Specimens Details

Mix Proportion (C : G : CS)	Content (g)			Specimen
	Cement	GGBS	Sand	
30 :70 : 10	12.25	28.58	20.41	20_3C7G, 10_CS
30 :70 : 50	12.25	28.58	102.05	20_3C7G, 50_CS
30 :70 : 75	12.25	28.58	153.08	20_3C7G, 75_CS
30 : 70: 0	12.25	28.58	-	20_3C7G
0 :0 :0	-	-	-	CONTROL

3. SOIL CLASSIFICATION

Physical and chemical characterisations are important for describing the properties of DMS. Basic characteristics of the soil were obtained using the classification test referring to British Standard BS1377. Table 2 shows the physical and chemical characteristics of DMS sample. Based on the results obtained the value of moisture content is 147 %.

Table 2 Soil Classification Result

Parameters	Values			
	DMS	Sand	Cement	GGBS
Moisture Content	147.0 %	-	-	-
Specific Gravity	2.66	2.65	1.26	2.85
Liquid Limit	70.0 %	-	-	-
Plastic Limit	33.3 %	-	-	-
Plasticity Index	36.7 %	-	-	-
Loss on Ignition	10.6 %	-	-	-
pH	7.28	-	9.17	11
Soil Classification	CH	-	-	-

Figure 2 shows the particle size distribution curve. Data was obtained from wet sieving and hydrometer analysis. DMS consists of 67 % clay, 30 % silt and 3 % of sand. According to Unified Soil Classification System (USCS), DMS falls in high plasticity clay (CH) category.

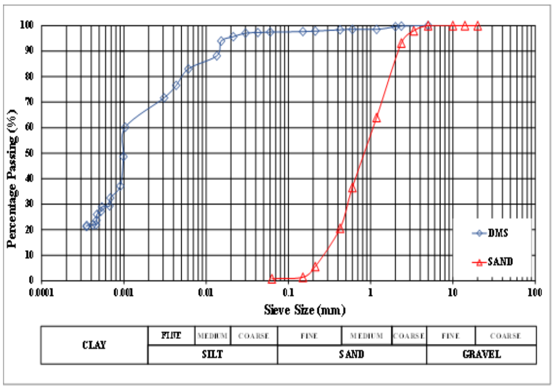

Fig. 2 Particle size distribution chart

4. RESULTS AND DISCUSSIONS

4.1 Compression Curves

Figures 3 and 4 show the compression curves of DMS with Binder + Sand addition, DMS with optimum binder and control. In the first phase of test, the chosen optimum binder ratio was 3C7G_20%. In the second phase of test which was to choose the sand addition, coarse and fine grain sand of 3 different percentages were put to test. In this final phase of test, 3 specimens were tested which were 20_3C7G, 10CS, 20_3C7G, 50CS and 20_3C7G, 75CS. All three specimens has same pattern of yielding. The specimen with 75CS has the lowest settlement followed by 50CS and 10CS respectively.

Maximum settlement of 4.5 m height embankments are allowed between 300 to 600 mm by National Cooperative Highway Research Program. North-South Highway Concessionaire Malaysia's design criteria say total settlement for the first 7 years shall not exceed 400 mm [8]. Thus, the lower limit of 300mm was taken as the permissible settlement limit. 300 mm is the on- site application for 4.5 m height embankment, while if it is simulated in a consolidation test the maximum settlement will be 1.2 mm for 20 mm height of sample or 6% of vertical strain value.

Specimen 20_3C7G, 10CS yielded after 6% but specimen and 20_3C7G, 50CS 20_3C7G, 75CS started yielding after 3 % and 5 % respectively. The applicable pressure on site will be 100 kPa: this was assessed based on the average highway embankment height of 4.5 m in the United States [9] and will be adopted in this study. Specimen 20_3C7G, 50CS and 20_3C7G, 75CS complies with the settlement criteria and the applicable pressure, thus can be practiced for soil solidification in the future.

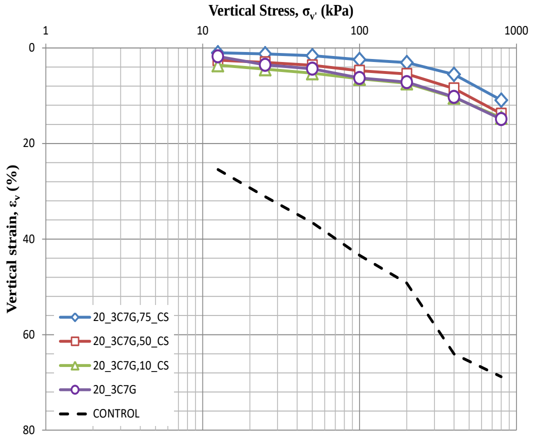

Fig. 3 Compression Curves

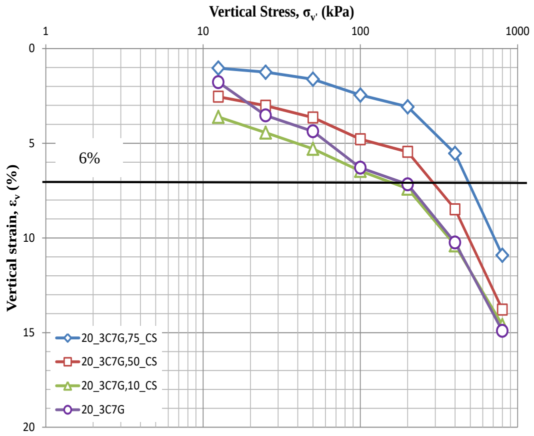

Fig. 4 Compression Curves (zoomed)

4.2 Coefficient of Volume Compressibility (mv), Consolidation (cv) and Permeability (k) of DMS + Binder + Sand

Figures 5-7 shows the relationship of parameters mv, cv and k respectively with consolidation pressure. Based on Figure 5, the variation in coefficient of volume compressibility (mv) decreases with increased loading pressure and admixture content. The specimen 3C7G_20-CS_75 is least compressible compared to other specimens initially but towards the end all the specimens fall into one line. All 3 solidified specimen shows a good improvement in the compressibility of soil. When a soil is less compressible, it indicates that soil is stiffer and structured.

As for Figure 6, it shows the relationship between pressure and coefficient of consolidation (c_v). All the treated specimens have more or less the same value of c_v where it shows that different percentage of sand do not give much affect to the consolidation process. The soil particles become more oriented with increase in effective consolidation and for more plastic soil forces mobilize and offer more resistance to compressive pressure. Robinson & Allam [10] found from their studies on the response of c_v to σ_v increase in clays that it is governed by the mechanical and physicochemical factors that govern the compressibility.

Referring to Figure 7, the permeability generally has not being helped by either the binders or the sand. Specimens with 10 and 50 % sand shows a higher permeability up to 100 kPa of consolidation pressure and begin to reduce its permeability and ended more or less same value with the natural soil. Since applied pressure on- site will be 100 kPa, thus specimens with 10 and 50 % sand can be considered as they have given a better permeability at atrsses lower than 100 kPa.

M_o is the ratio of a change in stress, divided by the resulting normal strain for a condition where there are no strains in perpendicular directions. The relationship between mv and M_o is, Mo is simply the inverse of m_v ($M_o = 1/m_v$).

In Figure 8, the M_o curve increased steadily during pre-yield and has a sharp increase at yielding point shows that the stiffness has increased compared to the natural soil. The high peak points occur at early stresses and the settlement between the stresses are lower. As the percentage of binders increased, the soil becomes stiffer and settlement improves, thus corresponds to the peaks in the figures.

All in all, the mv, cv and k values obtained from the experiments point towards the expediency of sand addition to the solidified DMS. While the cement effectively dehydrates the originally wet DMS, forms cementitious gel filling the voids and binds the clay particles / aggregates into a stronger and stiffer soil mass, the granular inclusions contributed to skeletal formation for the overall reduced compressibility. The final product could be described as a ‘sandy clay’ admixed with small cement dosage, with enhanced permeability for more rapid excess water dissipation when applied on site, e.g. reclamation works.

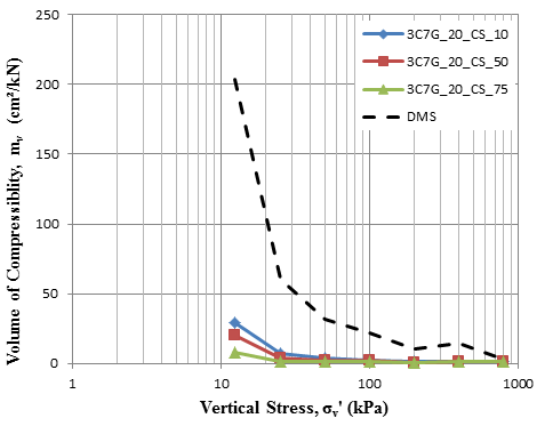

Fig. 5 Coefficient of volume compressibility in DMS + Binder + Sand

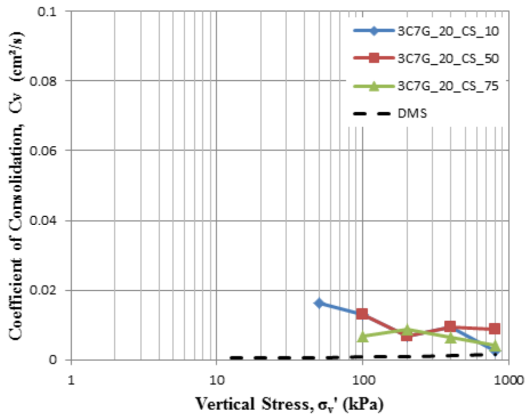

Fig. 6 Coefficient of consolidation in DMS + Binder + Sand

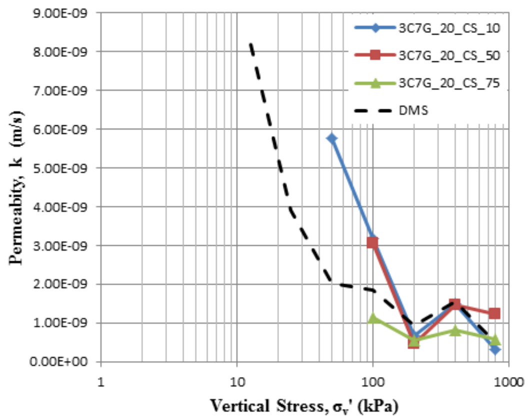

Fig. 7 Coefficient of Permeability in DMS + Binder + Sand

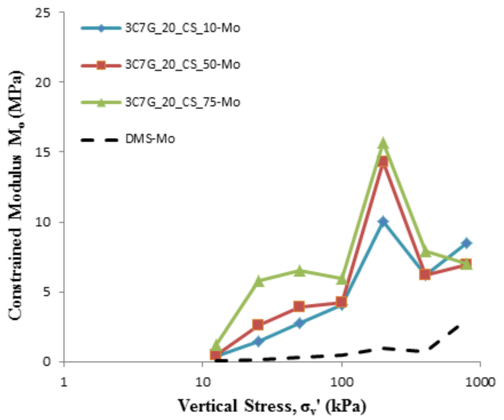

Fig. 8 M_o with σ_v' in DMS+binder+sand

5. CONCLUSIONS

The combination of cement – GGBS and sand admixture has helped in the improvement of soil settlement. The chosen specimen which complies the design criteria of embankment is 3C7G_20,75C and 3C7G_20_50C. A clear difference in the settlement between solidified and unsolidified soil with cement-GGBS and sand was seen. The difference was about 55 % at the effective stress of 800 kPa. The addition of binders provided additional bonding between the particles that increased the stiffness of the soil. cv and mv values of the binder-sand specimens were markedly improved in comparison with the natural clay. This clearly shows a significant settlement reduction of the solidified specimens in comparison with the original soil. The aim of DMS solidification is to enable the development of infrastructures on reclaimed land with DMS backfill. Generally, DMS has very high moisture contents consisting mainly of clay or silt, hence requiring solidification and acceleration of consolidation for construction with acceptable period. Thus solidification of DMS with cement-GGBS and sand has improved the settlement and can be used for constructing embankment.

6. ACKNOWLEDGEMENTS

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