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Geotechnical Properties of Bauxite: A Case Study in Bukit Goh, Kuantan, Malaysia

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Abstract. The research focuses on the basic and morphological characteristics to ensure bauxite ore reached the International Maritime Solid Bulk Cargoes Code (IMSBC Code) standard before being exported to other countries. The testing procedure, referred to as Geo-spec 3: Model Specification for Soil Testing, was performed to discover the basic parameters of the soil, including pore size distribution, water content, particle density, and morphology qualities. At Bukit Goh, Kuantan, about four (4) samples were chosen, whereas two (2) samples were from the stockpile and two (2) samples were from the Bukit Goh mine. The results illustrated that the mean water content of the soil is 20.64% which is above 10% of the recommended value. The value of Bulk Density is not in the range of 1190 kg/m^3 to 1389 kg/m^3, which is 2836.25 kg/m^3 and the particle size distribution for fine material is greater than 30%, and coarse material is less than 70%. The SEM examination revealed a high concentration of tiny particles in bauxite samples. Bukit Goh bauxite cannot be classified as group C under the IMSBC Code. As a result, the bauxite does not meet the criteria and cannot be shipped.

Keywords: bauxite, geotechnical properties, IMSBC code

1. Introduction

Many manufacturing products based on aluminium are receiving good responses, resulting in high demand in the aluminium industry. This high demand leads to bauxite mining increase due to the major ore of bauxite in aluminium. Aluminium is a lightweight metal, and it is essential in the transportation industries, for example, aircraft, automobiles, ships and trains. [1] concluded that the specific gravity of aluminium is 2.7, and this is approximately one third that of iron and copper. Aluminium has excellent corrosion resistance because when exposed to air, a thin oxidized film develops on the surface, preventing it from corrosion.

The high demand from China for mineral bauxite Malaysia led to a tremendous increase extract and export of these raw materials. Alumina or bauxite is generated as a natural outcome of miles of rock sedimentation and compression over a prolonged period of time, maybe millennia, and mixed with dewatering components due to high temperatures. Bauxite is typically found in soil, in contrast to gas and oil, and even some mineral ores and metal, which necessitates excavation which is really profound [2]. Due to high demand from other countries, many bauxite mines have been opened, and various activities about mining are carried out, especially in Kuantan, Pahang.

Bauxite is not a cargo that one would expect to be prone to liquefaction. It is a cargo that typically comprises lumps with a low moisture content [3]. If the volume of the gaps seen between granules decreases as a result of vessel movement, the freight is compressed, liquefaction may occur. Besides that, The rise in water pressure reduces the surface tension between container molecules, leading to a decrease in cargo shear strength which is one of the factors for liquefaction. Ground improvement is required to change the qualities of the soil. Several approaches have been used to enhance the soft soil, including lime treatment, pre-consolidation acceleration utilizing pre-fabricated vertical drains, and the most popular option, stone column. Bottom ash is being used as a substitute for fine aggregate as it has almost similar properties as sand [4].

Certain characteristics of bauxite deposits influence the performance of the Bayer Process. The relative proportions of alumina-bearing minerals and the existence of deleterious minerals that also react with caustic soda are the most critical [5]. In caustic soda solution, the two primary aluminium oxides in bauxite react significantly; gibbsite is more permeable than boehmite. Therefore, deposits in which the only ore mineral is gibbsite have a powerful energy requirement at the refining stage and are inherently more valuable. Diasporic bauxites, which require more energy than either gibbsite or boehmite bauxites in their treatment, are less valuable [6].

The ground sintered red mud particles range from 0.7 to 100 m, with a mean value of 28.5 m. The Bayer red mud size distribution is less than that of red mud of Sintering. The Bayer red mud particles size ranges from 0.85 to 51.00 m, with a mean value of 14.9 m [7].

2. Methodology

There are five (5) major stages to complete this study which is in; the first stage is the preliminary process that is identifying the problems statement, and then built up the objectives of this study and also the scope of the study. The second stage of this study is finding the literature. A literature review was done to ensure there are some guidelines and references in order to achieve the objective. Data collection has been conducted after the literature review process has been done. This study was conducted at Bukit Goh, Kuantan, where four (4) samples were taken and tested. In the final stage, data were interpreted, and a concise discussion, recommendation and conclusion were produced.

The basic qualities of bauxite were investigated in order to determine whether Bukit Goh bauxites met the IMSBS Code required standard. To assess the quality of the alumina, several standards and rules must be followed by using the IMSBC Code. As a result, this study is being conducted to establish whether or not the alumina or bauxite manufacturing is classified as AC Group C in the IMSBC Standard for exporting.

3. Results and Discussion

All samples undergo six (6) analyses and testing, by which two (2) samples from a stockpile (SP-BS-1 and SP-BS-2) and two (2) samples from Bukit Goh mine (BGM-BS-1 and BGM-BS-2). Wet Sieving Analysis, hydrometer test, Small Pycnometer test, Dry Sieving Analysis and SEM test are the laboratory tests involved. The size distribution (PSD) of the alumina/bauxite samples is determined using a hydrometer test, analysis of dry sieving, and analysis of wet sieving. The Pycnometer Test and Water Content Determination can be used to determine the specific gravity (SG) and water content of the bauxite. All testing is done in accordance with Geo-spec 3: Model Specification for Soil Testing.

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3.1. Bukit Goh Bauxite Properties

The results of this study will be verified to the IMSBC Code. Table 1 summarises the features of bauxite.

Table 1. Properties of Bukit Goh Bauxite.

Properties	BGM-BS-1	BGM-BS-2	SP-BS-1	SP-BS-2	IMSBC Code
PSD (%)	< 70%	< 70%	< 70%	< 70%	70% to 90% lumps 2.5 mm to 500 mm
Bulk Density (kg/m^3)	2887	2807	2823	2828	1190 to 1389
Moisture Content (%)	23.14	21.90	21.76	23.18	0 - 10

3.2. Particle Size Distribution (PSD)

A few tests have been performed to establish particle size, and a size of 6.3 mm to pan sieve is used to segregate the particles based on size. Table 2 indicates the passing ratio of small particle identification for samples via the method of wet sieving. In Table 3, the passing percentage of 2.5 mm for sample BGM-BS-1 is 36 percent, BGM-BS-2 is 44 percent, SP-BS-1 is 31 percent, and SP-BS-2 is 40 percent. The particle size of Bukit Goh bauxite, according to the research, is within the region defined in the IMSBC Code. The results showed that Bukit Goh bauxite has more than 30% fine particles and less than 70% coarse particles on average. Because of the larger percentage of fine particles in the sample, the moisture content increased.

Table 2. Percentage Passing of Bukit Goh Bauxite Samples.

Sieve Size (mm)	BGM-BS-1	BGM-BS-2	SP-BS-1	SP-BS-2
6.30	73.96	88.18	60.76	73.08
5.00	59.49	72.61	53.78	58.61
3.35	44.10	55.61	39.38	43.49
1.18	22.67	25.35	16.26	20.70
0.60	17.84	20.59	12.13	14.98
0.30	13.88	16.96	8.87	10.89
0.15	7.84	10.73	5.21	6.73
0.063	0.04	0.64	0.17	0.03
Pan	0.00	0.00	0.00	0.00

Table 3. PSD of Bukit Goh Bauxite.

Sample	PSD (%)
BGM-BS-1	36
BGM-BS-2	44
SP-BS-1	31
SP-BS-2	40

3.3. Bauxite Specific Gravity Determination

The Pycnometer test results were obtained and summarized in Table 4, where the SG for SP-BS-1 and SP-BS-2 is the same. Meanwhile, the SG of BGM-BS-1 and BGM-BS-2 differs slightly.

According to [1,] the SG of alumina/bauxite in India is higher than that of Bukit Goh bauxite. The density of the mineral that makes up each soil particle has a considerable influence on the specific gravity of the soil. In order to compare the results in IMSBC Code, the specific gravity value was transformed to the bulk density value. 1kg/m^3 bulk density equals 0.001 specific gravity, and the findings of the samples are shown in Table 5.

According to IMSBC Code, the allowable bulk density for cargo transportation is between 1190 kg/m^3 to 1389 kg/m^3. It is clearly seen that the Bulk Density of Bukit Goh bauxites is doubling the expected value in IMSBC Code due to higher specific gravity.

Table 4. Specific Gravity of Bukit Goh Bauxite.

Sample	Specific Gravity		
	C1	C2	Average
BGM-BS-1	2.965	2.808	2.887
BGM-BS-2	2.871	2.742	2.807
SP-BS-1	2.892	2.753	2.823
SP-BS-2	2.897	2.758	2.828

Table 5. Bulk Density of Bukit Goh Bauxite.

Sample	Bulk Density (kg/m^3)
BGM-BS-1	2887
BGM-BS-2	2807
SP-BS-1	2823
SP-BS-2	2828

3.4. Bauxite Moisture Content Determination

The water content of a surface is measured using the method of air-dry and the method of oven-dry. The oven-dry technique is classified into two (2) types: oven-dry hot and oven-dry cool. The proportion of water content for oven-dry is higher than for air-dry, according to the data shown in the table below. The IMSBC Code allows for the overall water content of 0 -10% to assure that the alumina is safe for export. The findings illustrated that the water content of Bukit Goh bauxite exceeds the proportion recommended by the IMSBC Code. Bukit Goh bauxite requires a great proportion of fine particles than granular materials, owing to the increased moisture content.

High moisture content can cause liquefaction of mineral ores, causing the cargo to lose stability throughout the voyage. Liquidation can occur at any point throughout the trip in cargoes with excessive moisture content. Some containers liquefied and caused devastating cargo shifting almost immediately after leaving the loading port, while others liquefied after a few weeks of apparently undisturbed sailing. Table 6 is in effect until Table 8 displays the three (3) different methods for determining the moisture content of Bukit Goh Bauxite samples: air-dry, oven-hot dry, and oven-dry cool.

Table 6. Moisture content results obtained from the Air-dry Method.

Sample	Moisture Content (%)		
	C1	C2	Average
BGM-BS-1	24.71	24.39	24.55
BGM-BS-2	19.03	19.39	19.21
SP-BS-1	19.74	19.31	19.53
SP-BS-2	18.93	19.62	19.28

Table 7. Moisture content results obtained from the Oven-hot dry method

Sample	Moisture Content (%)		
	C1	C2	Average
BGM-BS-1	23.49	22.43	22.96
BGM-BS-2	22.59	25.25	23.93
SP-BS-1	23.92	23.10	23.51
SP-BS-2	26.07	25.83	25.95

Table 8. Moisture content results obtained from the Oven-dry Cool Method.

Sample	Moisture Content (%)		
	C1	C2	Average
BGM-BS-1	22.37	21.46	21.91
BGM-BS-2	21.29	23.84	22.57
SP-BS-1	22.57	21.89	22.23
SP-BS-2	24.42	24.18	24.30

3.5. Bukit Goh Bauxite Morphological Properties

The microstructure features of Bukit Goh bauxite were investigated using SEM tests, as shown in Figures 1 and 2. A closer look at the granules indicates a material layer covering most of their surfaces. With a better image of lump particles and a powdery like-structure of small particles, the changing particle sizes may be noticed. At 5000x magnification, a clear image of particles can be observed, and at 10000x magnification, small particles adhered to the alumina sample can be seen clearly.

Because of the great number of tiny particles clung to the specimen, the large proportion of water content and a large volume fraction of the alumina sample were attributed to this. Since these anti-liquefaction shear forces in the soil profile are 2.0 to 2.5 times larger than in disturbed soil, alumina samples retrieved from the Bukit Goh mine had a greater propensity to liquefy than undisturbed soil.

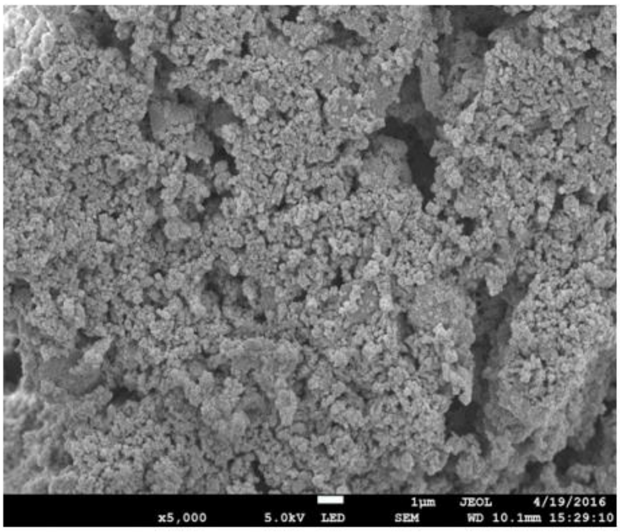

Figure 1. Magnification of Bukit Goh Bauxite Sample under 5000x Magnification

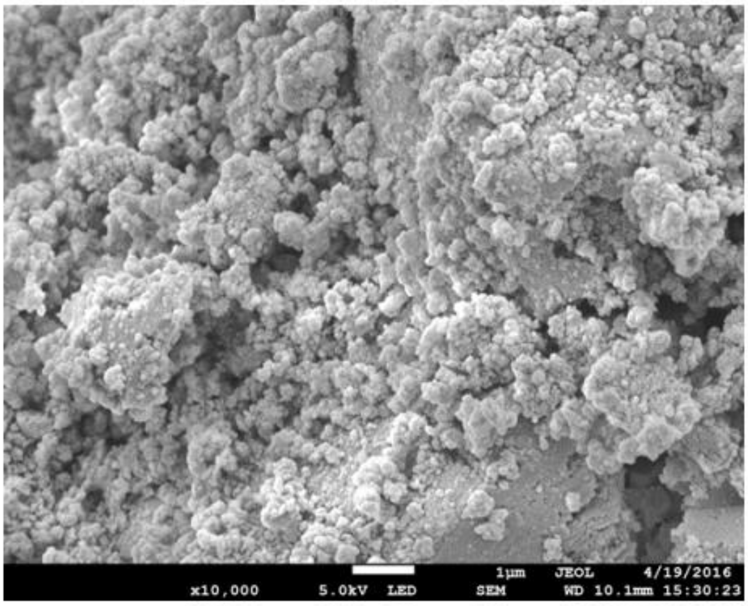

Figure 2. Magnification of Bukit Goh Bauxite Sample under 10000x Magnification

4. Conclusions

The mean particle size for samples ranging from 2.0 mm to 500 mm, according to the findings of the fundamental properties analysis, is 37.75 percent. The mean bulk density of the specimens is 2836.25 kg/m^3, and the average moisture content is 20.64 percent. The generated findings were compared to the IMSBC Code, and each of the basic attributes exceeded the code's specified value. All of the basic qualities can cause liquefaction during the transportation of bauxite shipments. As a result, it is critical to determine the attributes before exporting them. Compared to the IMSBC Code, the results show that the bauxite cannot be classified as Group C since the basic properties found do not meet the requirements of the standard IMSBC Code, making it unsuitable for export. Because of the ocean's waves, transporting bauxite will be extremely dangerous.

As shown in a research of the morphological characteristics of Bukit Goh alumina, the proportion of small particles is higher than the IMSBC Code's upper allowed. The small particle connected to the aluminium oxide clearly results in a higher proportion of water content, a lower percentage of grained particle, and a significant value of bulk density. Because of the existence of small particles, they will hold more energy than granular particles.

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References

[1] Deelwal K Dharavath K Kulshreshtha M 2014 *Evaluation of Characteristic Properties of Red Mud for Possible use as a Geotechnical Material in Civil Engineering International Journal of Advances in Engineering & Technology*

[2] Das B M 2007 *Principles of Geotechnical Engineering Cengage Learning* 200 First Stamford Place Suite 400 Stanford CT 06902 United States of America.

[3] Rajah S S 1986 *Bauxite in the Kuantan area, Peninsular Malaysia GEOSEA V*. Proceedings **1** pp 315-325.

[4] Musta B Wan Fuad W Mohamad M T 2000 *Geochemical Characterization of Concretion from Weathering Profile of Basaltic Rock in Kuantan, Pahang* University Kebangsaan Malaysia: Master Thesis.

[5] Sabriye P Aysel K F Emrah O Unal O 2013 *Effect of Red Mud Addition on Mechanical and Physical Properties of Roof Tile International Journal of Chemical Environmental & Biological Sciences (IJCEBS)* Volume **1** Issue 5 (2013) ISSN 2320-4079 EISSN 2320–4087.

[6] Gow N N Lozej G P 1993 *Bauxite* 687 Powell Court, Burlington, Ontario L7R 3E8.

[7] Wang P Liu D Y 2012 *Physical and Chemical Properties of Sintering Red Mud and Bayer Red Mud and the Implications for Beneficial Utilization Department of Military Architecture and Civil Engineering* Logistical Engineering University PLA Chongqing 401331 China.