

RESEARCH ARTICLE

Basic and Morphological Properties of Bukit Goh Bauxite

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ABSTRACT - The research focuses on the basic and morphological characteristics to ensure bauxite ore reaches the International Maritime Solid Bulk Cargoes Code (IMSBC Code) standard before being exported to other countries. To analyze this characteristic of the bauxite, some laboratory tests referred to Geospec 3: Model Specification for Soil Testing had been done to identify the bauxite's basic properties: particle size distribution, moisture content and specific gravity and its morphological properties. Laboratory tests involved are hydrometer, small pycnometer, dry sieve, and scanning electron microscopy tests. About four samples were selected at Bukit Goh, Kuantan; two were from the Bukit Goh mine, and another two were from the stockpile. All studies on the characteristics of bauxite were analyzed and recorded to compare with the IMSBC Code. The analysis of the result shows that the average moisture content of the soil is 20.64%, which is above 10% from the recommended value; the value of bulk density is not in the range of 1190 kg/m³ to 1389 kg/m³, which is 2836.25 kg/m³ and the particle size distribution for fine material is greater than 30% and coarse material is less than 70%. From the SEM test, image analysis proved that there were many fine particles in bauxite samples. By the IMSBC Code, Bukit Goh bauxite cannot be categorized as group C. Hence, bauxite collected from Bukit Goh mines has yet to achieve the standard; thus, it is not suitable for export.

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1. INTRODUCTION

Many manufactured products based on aluminium received a good response, resulting in high demand in the aluminium industry [1-2]. This high demand increases bauxite mining because bauxite is the major ore in aluminium. Aluminium is a lightweight metal, so it is important in transportation, such as aircraft, automobiles, ships, and trains [3-4]. The specific gravity of aluminium is 2.7, approximately one-third that of iron and copper. Aluminium has excellent resistance against corrosion because when exposed to air, thin oxidized film forms on the surface, protecting it from corrosion [5-6]. The high demand from China for mineral bauxite in Malaysia led to a tremendous increase in the extraction and export of this raw material. Bauxite is formed by sedimentation and compression of miles of rock that takes a long period, perhaps millions of years, and mixes with dehydration elements by hot temperatures [7]. Bauxite is usually found in the soil compared to oil, gas, iron ore, and tin, requiring deep excavation [8]. Due to high demand from other countries, many bauxite mines have been opened, and various activities have been carried out, especially in Kuantan and Pahang.

Bauxite is not typically considered a liquefaction-prone cargo. It is a cargo that typically comprises lumps with a low moisture content [9]. Liquefaction may occur if the volume of the gaps between the particles decreases while the cargo is compressed due to ship motion. Furthermore, an increase in water pressure reduces friction between cargo particles, decreasing the cargo's shear strength, which is one of the factors contributing to liquefaction [10-11]. Certain features of bauxite deposits control the efficacy of the Bayer Process. The most important are the relative amounts of alumina-bearing minerals and the presence of deleterious minerals, which also react with caustic soda [12-13]. Bauxite's two main aluminium oxides react differently in caustic soda solution; gibbsite is more soluble than boehmite. Therefore, deposits in which the only ore mineral is gibbsite have a power energy requirement at the refining stage and are inherently more valuable [14-15]. Diasporic bauxites, which require more energy than either gibbsitic or boehmitic bauxites in their treatment, are less valuable. The ground sintering red mud particles are mostly 0.7–100 µm with a mean value of 28.5 µm. Compared with Sintering red mud, the Bayer one has a relatively small particle diameter. The particle diameter of Bayer red mud is between 0.8 µm and 50 µm with an average value of 14.8 µm [16].

2. METHODOLOGY

2.1 Preparation of Samples

The basic properties of bauxite have been studied to identify Bukit Goh bauxite and fulfil the requirement standard in the International Maritime Solid Bulk Cargoes Code (IMSBC). Some standards and regulations need to be followed by using the IMSBC Code to determine the standard quality of bauxite. Thus, this study is carried out to determine whether

bauxite production is categorized as Group C (refers to solid bulk cargoes that are neither liable to liquefy) in the IMSBC Standard or not for export. All samples undergo six laboratory tests and analyses: 2 from Bukit Goh mine (M2L2B1 and M2L2B2) and 2 from the stockpile (PTSTL1B1 AND PTSTL2B1). The laboratory tests involved are a hydrometer test, wet sieving analysis, dry sieving analysis, small pycnometer test to determine specific gravity and moisture content and SEM test. Hydrometer test, Wet Sieving Analysis and Dry Sieving Analysis are done to determine the size distribution of bauxite samples. A Small Pycnometer Test and Moisture Content Determination can determine bauxite's specific gravity and moisture content. All the testing is based on Geospec 3: MODEL SPECIFICATION for SOIL TESTING. The analysis data from the result will be compared with the IMSBC Code.

3. EXPERIMENTAL RESULTS

3.1 Moisture Content

Tables 1 to 3 show that the moisture content percentages for oven-dry are higher than for air-dry. According to the IMSBC Code, the allowable average moisture content is 0%-10% to ensure the bauxite is safe to export. The result shows that Bukit Goh bauxite's moisture content is higher than the recommended percentage in the IMSBC Code. Due to higher moisture content, Bukit Goh bauxite has many fine particles compared to coarse particles. High levels of moisture content lead to the liquefaction of mineral ores, resulting in the cargo's loss of stability during the voyage. Liquefaction may occur without warning during the voyage in cargoes loaded with a moisture content that is too high. Some cargoes have liquefied and caused catastrophic cargo shifting almost immediately upon departure from the load port, while others have liquefied after several weeks of apparently uneventful sailing.

Table 1. Average moisture content (Air-dry method)

Samples	% Moisture Content (Container 1)	% Moisture Content (Container 2)	Average % Moisture Content	IMSBC Code
M2L2B1	24.71	24.39	24.55	0 - 10
M2L2B2	19.03	19.39	19.21	
PTSTL1B1	19.74	19.31	19.53	
PTSTL2B1	18.93	19.62	19.28	

Table 2. Average moisture content (Oven-dry hot method)

Samples	% Moisture Content (Container 1)	% Moisture Content (Container 2)	Average % Moisture Content	IMSBC Code
M2L2B1	23.49	22.43	22.96	0 - 10
M2L2B2	22.59	25.25	23.93	
PTSTL1B1	23.92	23.10	23.51	
PTSTL2B1	26.07	25.83	25.95	

Table 3. Average moisture content (Oven-dry cool method)

Samples	% Moisture Content (Container 1)	% Moisture Content (Container 2)	Average % Moisture Content	IMSBC Code
M2L2B1	22.37	21.46	21.91	0 - 10
M2L2B2	21.29	23.84	22.57	
PTSTL1B1	22.57	21.89	22.23	
PTSTL2B1	24.42	24.18	24.30	

3.2 Specific Gravity

The result from the small pycnometer test was collected and tabulated in Table 4, where the specific gravity for PTSTL1B1 and PTSTL2B1 are identical. Meanwhile, there is a slight difference in specific gravity for M2L2B1 and M2L2B2. Based on studies conducted by Hasan et al. [11], the specific gravity of bauxite in Kuantan is higher than in Bukit Goh bauxite. The soil's specific gravity largely depends on the density of the mineral that makes up the individual soil particle. The specific gravity value was converted to bulk density value to compare the result in the IMSBC Code. 1kg/m³ of bulk density equals 0.001 specific gravity, and the results of the samples are in Table 5 below. According to the IMSBC Code, the allowable bulk density for cargo transportation is between 1190 kg/m³ to 1389 kg/m³. The Bulk Density of Bukit Goh bauxites doubles the expected value in the IMSBC Code due to higher specific gravity.

Table 4. Results of specific gravity

Samples	Specific Gravity (Container 1)	Specific Gravity (Container 2)	Average Specific Gravity
M2L2B1	2.965	2.808	2.887
M2L2B2	2.871	2.742	2.807
PTSTL1B1	2.892	2.753	2.823
PTSTL2B1	2.897	2.758	2.828

Table 5. Results of bulk density

Samples	Bulk Density (kg/m ³)	IMSBC Code
M2L2B1	2887	1190 to 1389
M2L2B2	2807	
PTSTL1B1	2823	
PTSTL2B1	2828	

3.3 Particle Size Distribution

A few tests have been done to determine particle size distribution; 6.3 mm to pan sieve size separates the particle according to the size. Table 6 shows the percentage of passing for fine particle determination for the samples using the wet sieving method. Table 7 shows the percentage passing 2.5 mm for sample M2L2B1 is 36%, M2L2B2 is 44%, PTSTL1B1 is 31%, and PTSTL2B1 is 40%. The result analysis proves that Bukit Goh bauxite's particle size distribution is not in the range of the requirement size in the IMSBC Code. The result proved that Bukit Goh bauxite, on average, consists of more than 30% fine particles and less than 70% coarse particles. This situation will increase the sample's moisture content due to a higher percentage of fine particles.

Table 6. Percentage passing (%)

Sieve Size (mm)	Percentage passing %			
	M2L2B1	M2L2B2	PTSTL1B1	PTSTL2B1
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
0.0063	0.04	0.64	0.17	0.03
Pan	0.00	0.00	0.00	0.00

Table 7. Particle size distribution (%)

Samples	Particle Size Distribution (%)	IMSBC Code
M2L2B1	36	70% to 90% lumps 2.5 mm to 500 mm
M2L2B2	44	
PTSTL1B1	31	
PTSTL2B1	40	

3.4 Morphological Properties of Bauxite

The morphological properties of Bukit Goh bauxite were studied using SEM Test as in Figure 1 and Figure 2, where magnification for each figure was 5000x and 10 000x, respectively. A closer inspection of the particles shows a layer of material coating most of the particle surfaces. The different sizes of particles can be observed with a clear image of lump particles and powdery-like structures of fine. A clear image of particles started to be seen at 5000x magnification, and under 10 000x magnification, fine particles attached to the bauxite sample can be seen. This proved the main cause of the

high percentage of moisture content and the large bulk density of the bauxite sample because of the many fine particles attached. Bauxite samples collected from the Bukit Goh mine are disturbed samples; hence, the tendency for this sample to liquefy is higher than undisturbed soil because the shear force of anti-liquefaction of undisturbed soil is 1.5 to 2 times greater than disturbed soil.

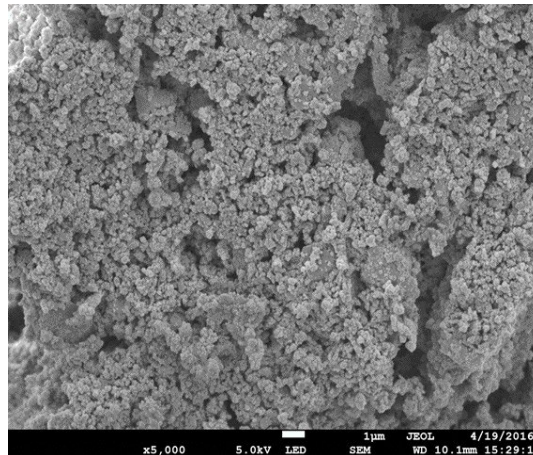


Figure 1. Magnification of bauxite sample under 5000x magnification

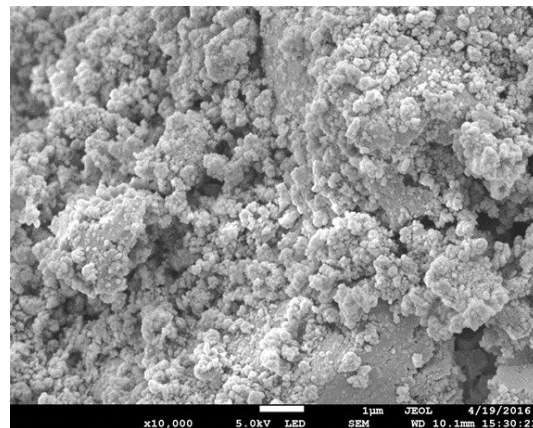


Figure 2. Magnification of bauxite sample under 10000x magnification

4. CONCLUSION

The basic properties study results conclude that the average particle size distribution for percentage passing 2.5 mm to 500 μm for the samples is 37.75%. The average bulk density for the samples is 2836.25 kg/m³, and the average percentage of moisture content is 20.64%. The results were compared with the IMSBC Code, where each basic property exceeds the specified value stated in the code. All these basic properties lead to liquefaction occurring during bauxite cargo transportation. Hence, it is important to identify the properties before they are exported. As a result, compared to the IMSBC Code, Bukit Goh bauxite cannot be categorized as Group C because the basic properties obtained do not fulfil the requirement in the standard IMSBC Code. Therefore, it is not suitable for export. It will be a high risk to transport bauxite due to ocean waves. A study on the morphological properties of Bukit Goh bauxite shows that the percentage of fine particles is higher than the maximum limit set by the IMSBC Code and shows that the fine particles attached to the bauxite ore resulting in a higher percentage of moisture content, low percentages of coarse particle as well as high value of bulk density. Due to the presence of high fine particles, it will absorb more water compared to granular particles.

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AUTHOR CONTRIBUTIONS

Muhammad Syamsul Imran Zaini: Original draft preparation, Conceptualization, Methodology, Software

Muzamir Hasan: Supervision

Ain Syaheera Zulkafli: Conceptualization

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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