IOP Conf. Series: Materials Science and Engineering **318** (2018) 012025 doi:10.1088/1757-899X/318/1/012025

Basic and Morphological Properties of Bukit Goh Bauxite

Muzamir Hasan[1,2*], Ahmad Amirul Faez Ahmad Nor Azmi[1,2], Weng Long Tam[2], Biao Yu Phang[2] and M. Azizul Moqsud[3]

[1]Centre for Earth Resources Research & Management, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Malaysia

[2]Faculty of Civil Engineering & Earth Resources Research & Management, Universiti Malaysia Pahang, 26300 Gambang, Kuantan, Malaysia

[3]Department of Civil and Environmental Engineering, Yamaguchi University, Ube Shi, Tokiwadai 1, Japan.

E-mail : muzamir@unimap.edu.my

Abstract. Investigation conducted by International Maritime Organization (IMO) concluded that the loss of the Bulk Jupiter that carrying bauxite from Kuantan has uncovered evidence to suggest liquefaction led to loss of stability. This research analysed Bukit Goh bauxite and comparison was made with International Maritime Solid Bulk Cargoes (IMSBC Code) standard. To analyse these characteristics of the bauxite, four samples were selected at Bukit Goh, Kuantan ; two of the samples from the Bukit Goh mine and two samples from the stock piles were tested to identify the bauxite basic and morphological properties by referring to GEOSPEC 3 : Model Specification for Soil Testing ; particle size distribution, moisture content and specific gravity and its morphological properties. Laboratory tests involved including Hydrometer test, Small Pycnometer test, Dry Sieve test and Field Emission Scanning Electron Microscop (FESEM) test. The results show that the average moisture content of raw Bukit Goh bauxite is 20.64% which exceeded the recomended value of maximum 10%. Average fine material for raw bauxite is 37.75% which should not be greater than 30% per IMSBC standard. By that, the bauxite from Bukit Goh mine do not achieved the minimum requirements and standards of the IMSBC standard and need to undergo beneficiation process for better quality and safety.

1. Introduction

Bauxite is the principal ore of alumina (Al_2O_3), which is used to produce aluminium. The main compund of bauxite are hydrated aluminium oxides, hydrated aluminosilicates, iron oxides, hydrated iron oxides, titanium oxide and silica [1]. There are approximately 165 million tonnes of bauxite are mined every year around the world. The bauxite is transported to refineries by conveyor ship, or rail [2]. Bauxite is formed by the effects of sedimentation and compression miles of rock that takes a long period perhaps millions of years and mix with elements of dehydration by hot temperatures. Bauxite usually found in the soil compared to oil and gas as well as some iron ore and tin, which requires certain very deep excavation. In Kuantan, bauxite reserve has been found and discovered and due to high demanding from China the bauxite mining has started. Hence, Malaysia has increased the production of bauxite. Investigation conducted by International Maritime Organization (IMO) concluded that the loss of the Bulk Jupiter that carrying bauxite has uncovered evidence to suggest liquefaction led to loss of stability [3][4]. Liquefaction is a phenomenon where the soil experience a process by which water-saturated sediment temporarily loses strength and acts as a fluid [5]. Hence, in other to lower the risks of the liquefaction phenomenon, there are some standard and regulation that need to be follow; which is the International Maritime Solid Bulk Cargoes (IMSBC) code in order to determine the safety of bulk cargoes carrying bauxite and lower the risk of the cargoes from the liquefaction phenomenon to occur. Fig. 1 shows the classification of Bauxite in Group C which it is neither liable to liquefy (Group A) nor to possess chemical hazards (Group B) [6]. If bauxite samples are complied with the specifications as stated in IMSBC Code, the samples are allowed be shipped and exported.

BAUXITE

DESCRIPTION
A brownish, yellow claylike and earthy mineral. Moisture content: 0% to 10%. Insoluble in water.

CHARACTERISTICS

ANGLE OF REPOSE	BULK DENSITY (kg/m^3)	STOWAGE FACTOR (m^3/t)
Not applicable	1190 to 1389	0.72 to 0.84
SIZE	**CLASS**	**GROUP**
70% to 90% lumps: 2.5 mm to 500 mm 10% to 30% powder	Not applicable	C

Figure 1. Bauxite's Group C Classification.

There are a very close relationship between the moisture content and particle size distribution as the presence of finest particle will affect the water holding properties. Despite on identifying the standard quality of Kuantan bauxite, its basic and morphological properties of Kuantan bauxite also identified to determine the particles present and its effect. If the particles are found to be harmful, prevention and safety measure should be applied and discussed**.**

2. Methodology

2.1. Preparation of samples

The basic properties of bauxite have been studied to identify Bukit Goh bauxites fulfill the requirement standard in IMSBS Code. There are some standard and regulations that need to be follow by using IMSBC Code to determine the standard quality of bauxite. Thus, this study is carried out to determine does the bauxite production is categorized as Group C in the IMSBC Standard or not for exporting. All samples are undergoing six laboratory testing and analysis; 2 samples from Bukit Goh mine (M2L2B1 and M2L2B2) and 2 samples from stock pile (PTSTL1B1 and PTSTL2B1). The laboratory tests involved are 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 is done to determine the size distribution of bauxite samples (Table 2). The specific gravity and moisture content of bauxite can be determine Small Pycnometer Test and Moisture Content Determination. All the testing are based on Geospec 3: Model Specification For Soil Testing. The analysis data from the result will be compared with IMSBC Code.

Table 1. Laboratory test and standards.

Laboratory Tests	Standards
Moisture Content Test	Geospec 3: Part 2; 5 Clause 3.2
Specific Gravity Test	Geospec 3: Part 2; 7 Clause 3.4
Particle Size Distribution	Geospec 3: Part 2; 8 Clause 3.5
X-Ray Fluorescence (XRF)	Quantexpress (Full Analysis) by XRF S8 Tiger

3. Experimental results and analysis

3.1. Properties of main materials

A summary of the properties of bauxite were shown in Table 2.

Table 2. Summary of properties of bauxite.

Basic Properties	**Particle Size Distribution**	**Bulk Density**	**Moiture content**
M2L2B1	<70%	2887	23.14
M2L2B2	<70%	2807	21.90
OPSTL1B1	<70%	2823	21.76
OPSTL2B1	<70%	2828	23.18
IMSBC Code	70% to 90% lumps ; 2.5mm to 500mm	1190kg/m^3 to 1389kg/m^3	0-10

Based on the table above, it shows that the result from the particle size distribution, bulk density and, moisture content is compared and after comparing the bauxite in Bukit Goh do not fulfilled the requirement needed in the standard IMSB Code. This is because based on the analysis and result from the laboratory test all the particle size distribution is below 70% while the moisture content from all the bauxite samples is high which 20% above are. Hence, the results compared with the IMSBC Code are exceeding the specified value states in the code.

3.2. Particle size distribution

There are few test had been done to determine particles size distribution, 6.3 mm to pan sieve size is used to separate the particle according to the size. In Table 4 shows the percentage of passing for fine particle determination for the samples by using Wet Sieving Method. In Table 5 shows the percentage passing 2.5 mm for sample M2L2B1 is 36%, M2L2B2 is 44%, PTSTL1B1 is 31% and PTSTL2B1 is 40%. Based on the result analysis prove that the particle size distribution Bukit Goh bauxite's not in range the requirement size in IMSBC Code. The result proved that Bukit Goh bauxite's in average consist more than 30% fine particle and less than 70% coarse particle. This situation will resulting the moisture content of the sample increase due to higher percentage of fine particle.

Table 3. Percentage passing.

Sieve size (mm)	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 4. Particle size distribution.

Samples	Particle size distributio n (%)
M2L2B1	36
M2L2B2	44
PTSTL1B1	31
PTSTL2B1	40

3.3. Specific gravity

The result from Small Pycnometer Test was collected and tabulated in Table 6 where the specific gravity for PTSTL1B1 and PTSTL2B1 are just the same. Meanwhile, there is slightly difference in specific gravity for M2L2B1 and M2L2B2. This is because the sample M2L2B1 and M2L2B2 are from different locations of the same mining area while samples PTSTL1B1 and PTSTL2B1 are from the stockpiles in Bukit Goh area. Based on studied carried out by [7], specific gravity of bauxite in India is higher compared to Bukit Goh bauxite. The soil'specific gravity largely depends on the density of the mineral making up the individual soil particle.

Table 5. Results of specific gravity.

Samples	Specific gravity of container 1	Specific gravity of 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

3.4. Moisture content

Moisture content of the sample is determined by air-dry method and oven-dry method. The oven-dry method can be further divided into two which is oven-dry hot method and oven-dry cool method. The results are shown in Table 7, Table 8 and Table 9. From the table below show percentage moisture content for oven-dry is higher compared to air-dry. According to IMSBC Code, allowable average moisture content is 0%-10% to make sure the bauxite is save to be exported. The result shows moisture content of Bukit Goh bauxite is higher compared to recommended percentage in the IMSBC Code. Due to higher moisture content, it clearly show that Bukit Goh bauxite have large amount of fine particle compared to coarse particle.

High level of moisture content lead the liquefaction of mineral ores to be occurs resulting the cargo loss of stability during the voyage. In cargoes loaded with too high a moisture content, liquefaction may occur without warning at any time during the voyage. Some cargoes have liquefied and caused catastrophic shifting of cargo almost immediately upon departure from the load port whilst others have liquefied after several weeks of apparently uneventful sailing.

Table 6. Average moisture content (air-dry method).

Samples	Moisture content container 1 (%)	Moisture content container 2 (%)	Average moisture content (%)
M2L2B1	24.71	24.39	24.55
M2L2B2	19.03	19.39	19.21
PTSTL1B1	19.74	19.31	19.53
PTSTL2B1	18.93	19.62	19.28

Table 7. Average moisture content (oven-dry hot method).

Samples	Moisture content container 1 (%)	Moisture content container 2 (%)	Average moisture content (%)
M2L2B1	23.49	22.43	22.96
M2L2B2	22.59	25.25	23.93
PTSTL1B1	23.92	23.10	23.51
PTSTL2B1	26.07	25.83	25.95

Table 8. Average moisture content (oven-dry cool method).

Samples	Moisture content container 1 (%)	Moisture content container 2 (%)	Average moisture content (%)
M2L2B1	22.37	21.46	21.91
M2L2B2	21.29	23.84	22.57
PTSTL1B1	22.57	21.89	22.23
PTSTL2B1	24.42	24.18	24.30

IOP Conf. Series: Materials Science and Engineering **318** (2018) 012025 doi:10.1088/1757-899X/318/1/012025

3.5. Morphological properties of bauxite

The morphological properties of Bukit Goh bauxite had been studied by using SEM Test as in Figure 2 and Figure 3 where magnification for each figure 5000x and 10 000x respectively. 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 clear image of lump particles and powdery like-structure of fine. Clear image of particles started to be seen at 5000x magnification and under 10 000x magnification, fine particles attached to the bauxite sample are clearly can be seen.

This proved the main cause of high percentage of moisture content as well as the big number of bulk density of the bauxite sample because of many fine particle attached at the sample. Bauxite samples collected from Bukit Goh mine are disturbed sample, hence the tendency for this sample to liquefy is higher than undisturbed soil because of shear force of anti-liquefaction of undisturbed soil is 1.5 to 2 times greater than disturbed soil.

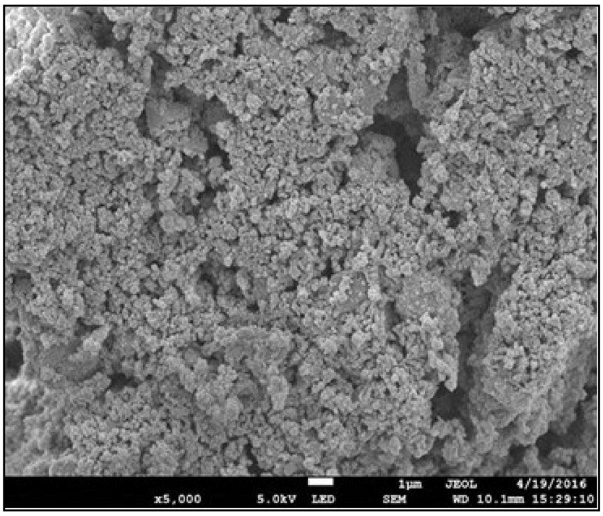

Figure 2. 5000x magnification of bauxite sample.

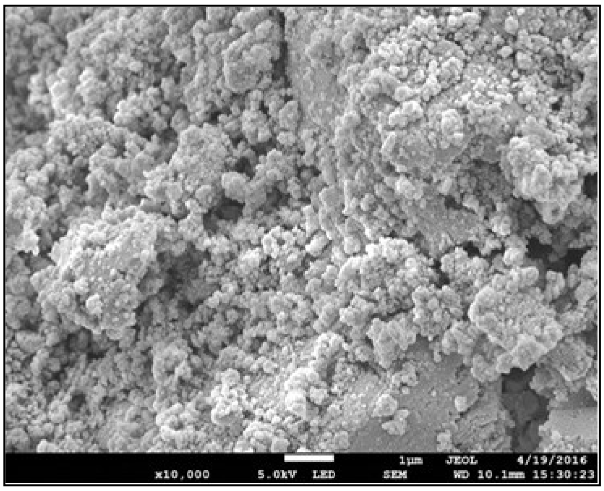

Figure 3. 10000x magnification of bauxite sample.

IOP Conf. Series: Materials Science and Engineering **318** (2018) 012025 doi:10.1088/1757-899X/318/1/012025

4. Conclusion

Results from the basic properties study is conclude that the average particle size distribution for percentage passing 2.5 mm to 500 mm for the samples is 37.75%. The average Bulk Density for the samples is 2836.25 kg/m^3 and the average percentage of moisture content of the samples is 20.64%. The results obtained was compared with IMSBC Code where each of this basic properties are exceeding the specified value stated in the code. All this basic properties are lead for liquefaction to occur during bauxite cargoes transportation, hence it is important to identify the properties before it is being exported. As results comparing to IMSBC Code, Bukit Goh bauxite's are cannot be categorized as Group C because the basic properties obtained are not fulfilling the requirement in the standard IMSBC Code and thus therefore it is not suitable to be exported. It will be high risk to transporting bauxite due to the waves of the ocean.

Study on morphological properties of Bukit Goh bauxite shows percent of fine particles is higher than the maximum limit set by the IMSBC Code. Clearly seen that the fine particle attached to the bauxite ore resulting in 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 particle, it will absorb more water compared to granular particles.

Acknowledgements

The authors would like to acknowledge the Universiti Malaysia Pahang (UMP) for financing this research through the Research University Grant Scheme, Project Number RDU1603122. The cooperation given by all parties involved in this research is greatly acknowledged.

References

[1] Shakhashiri, BZ 2012 Chemical of The Week: Aluminium. *University of Wisconsin: SciFun.org*

[2] Donoghue, AM 2014 Bauxite Mining and Alumina Refining: Process Description and Occupational Health Risk. *Journal of Occupational and Environmental Medicine*, **56** 5

[3] International Maritime Organization 2015 September 18 IMO warns on bauxite luquefaction dangers. Retrieved from http://www.imo.org/en/MediaCentre/PressBriefings/Pages/38-bauxite-CCC.aspx

[4] World Maritime News 2015 September 21 IMO : Bauxite liquefaction sank Bulk Jupiter. Retrieved from http://worldmaritimenews.com/archives/172059/imo-bauxite-liquefaction-sank-bulk-jupiter/

[5] Seed, HB 1996 Liquefaction of Saturated Sands During Cyclic Loadin. *Journal of the Soil Mechanics and Foundations Division*, 105-134

[6] IMSBC Code 2013 *International Maritime Solid Bulk Cargoes Code and Supplement. International Maritime Organization*

[7] Deewal, K., Dharavath, K., Kulshreshta, 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*