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PROPERTIES AND LIQUEFACTION RISK ON BULK CARGO CARRYING BUKIT GOH, KUANTAN BAUXITE; IN ACCORDANCE WITH IMSBC CODE

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ABSTRACT: Bauxite is a raw material used in the production of alumina and, subsequently, aluminium. Like many metals, world demand for aluminium, and therefore bauxite, has grown substantially over the past 10 years in response to economic growth in emerging Asian economies. Bauxite is a relatively soft ore with a distinctive reddish brown colour. Bauxite ore from Malaysia exported to manufacturing country such as China to be processed into aluminium. Basic properties of bauxite are determined for exporting purpose in which several international specifications need to be followed while handling bauxite in order to ensure those raw materials are passing the standard to be imported. Laboratory test had been done to bauxite samples from Bukit Goh in Kuantan to determine its basic and morphological properties. It is found out that moisture content of raw Bukit Goh bauxite is higher compared to processed bauxite where it has the average of 24.33% over 7.16% only on the processed bauxite sample. For particle distribution, it shows that the processed bauxite has less fine particle compared to raw samples with the average of 16.60% compared to raw with 38.50%. Result from FESEM test proves that the lesser fine particle attached to the processed bauxite ore. Referring to the IMSBC Code, it can be stated that raw bauxite samples from Bukit Goh does not pass the standard. This is due to the presence of bulky fine particles which tend to absorb water more than granular particles that may lead to liquefaction to occur. Liquefaction during cargo transportation is high risk especially when there are strong current at the sea. In order to ensure the bauxite is passing the standard, beneficiation process must take place where it include washing, wet screening and mechanical or manual sorting.

Keywords: International Maritime Solid Bulk Cargoes (IMSBC) Code, Bauxite, Liquefaction

1. INTRODUCTION

Cargo liquefaction has been an arising issue since it is the major reason for numerous bulk carriers' capsizes. Many solutions have been adopted by researchers and seafarers to avoid these incidents which can be divided into experimental tests and numerical simulations [6] , [1]. The main cause of the problem is excess pore water pressure within the bulk cargo. The presence of unmanageable pore water pressure will weaken the microstructure of the soft soil particles, and it can make the unloading creep damage of soft soil extremely strong and even cause liquefaction [8]. The scenario is similar to liquefaction in solid bulk cargo. The ship’s motion and the engine vibration during passage may cause particle rearrangement and compaction [3]. The gaps between the particles become smaller in the process, with the corresponding pore pressure progressively increasing [2]. As a result, the water holding ability of particles and the friction coefficient between cargoes decreases. In particular, the water in the interstellar spaces comes together to form a liquid layer that allows the cargo above to move relative to the cargo below – as if the two layers were part of a liquid and hence the term ‘liquefaction’. Such a transition during ocean carriage can cause a sudden loss of stability of the carrying vessel. In the last ten years, more than ten ships capsized and sank due to a loss of hull stability attributed to the cargo liquefaction [4]. In addition, the problem of water pollution was widely reported by mainstream and social media. Bauxite is the major alumina (Al2O3) bearing ore used in the aluminum manufacturing industries. The bauxite containing less than 50% Al2O3 is called low-grade bauxite ore which is commonly used for the alumina-based abrasives and refractories productions. The alumina-silica and alumina-ferrite complexes are the foremost impurities present in the low-grade bauxite [9]. Aluminium is the most abundant metal in the crust of the earth and also can be recycled repeatedly while maintaining its quality, so it is an environmentally friendly choice for many products. It does not rust, is not magnetic and it conducts both heat and electricity with ease. It is light and more easily shaped than many other metals while still staying remarkably strong [7]. Adaptable and practical, aluminium is often brought to our daily life through the process of aluminium extrusion. Besides smelter and manufacturing its own aluminium, Malaysia also exported the bauxite to China which is Malaysia's largest export destination. Due to strong demand from this country, Malaysia had to double and tripled the production of bauxite in order to meet the demand [10]. Thus, this study is carried out to determine does the bauxite production is achieved the IMSBC Standard or not for exporting where its basic properties; specific gravity, moisture content and particle size distribution is measured.

Percentage of moisture content of the sample does have a relationship with particle size distribution where the presence of fines particles will influence its water-holding properties [2]. Fine particles will increase total void ratio therefore increasing the capacity of the particles to store water. High moisture content as well as high value of specific gravity is not acceptable for solid bulk cargoes because it will be too risky to transport them.

2. OBJECTIVES

In general, this research aims to identify the geotechnical properties of raw and processed Kuantan bauxite by doing a laboratory test on Bukit Goh bauxite samples. In order to achieve the research aim, the following objectives had been established:

I. To determine basic properties of Bukit Goh, Kuantan bauxite
II. To determine morphological characteristics of Bukit Goh, Kuantan bauxite
III. To determine the suitability and quality of Bukit Goh, Kuantan bauxite according to IMSBC code.

3. SCOPE OF STUDY

The samples of bauxite ore were taken from Bukit Goh, Kuantan, Pahang which is located approximately 25km from Kuantan. A full laboratory scale test is carried out through this research in order to determine the correlation between the basic properties of Kuantan bauxite. The required testing are moisture content test, specific gravity test, sieve analysis test, field emission scanning electron microscope (FESEM) and x-ray fluorescence (XRF).

4. METHODOLOGY

In this study, to determine basic properties of bauxite sample, there are about five laboratory test and analysis done to 4 samples; 2 samples from Bukit Goh mine (M2L1 and M2L2) and 2 sample from stock pile (PTST1 and PTST2) to list out the required data. Sieving Analysis is done to determine particle size distribution of bauxite samples. Meanwhile, specific gravity of bauxite samples and moisture content determination is carried out to identify the specific gravity and moisture content present in the samples.

Meanwhile, for morphological study, samples is sent for FESEM test to have clear vision about the condition of bauxite particles under certain magnification while XRF test is conducted to identify the composition of elements and oxides of Bukit Goh bauxite

Table 1 Type of Test and Standard of Sample Tested

Soil Sample	Laboratory Tests	Standard
Bauxite (Bukit Goh)	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)	QUANT-EXPRESS (Full Analysis) by XRF S8 Tiger
	Field Emission Scanning Electron Microscopic (FESEM)	By JSM 7800-F

5. RESULTS AND DISCUSSIONS

Raw data of basic properties of the samples collected from laboratory test were analysed by referring to the formula and method stated in Geospec 3: Model Specification for Soil Testing. There are some standard and regulations that need to be follow by using IMSBC Code. Table 2 below shows the percentage of fine particles between raw and processed Bukit Goh Bauxite for four samples.

This test was conducted to evaluate the size characteristic of the Bukit Goh bauxite to determine whether it is safe to be exported undisturbed or otherwise. The deposits size that is permitted by IMSBC Code for fine particles content is between 10% to 30%. For bigger lumps; 2.5mm to 500mm, the suitable size for safe transportation is from between 70% to 90%

Table 2 Percentage of fine particles between raw and processed Bukit Goh Bauxite

Sample	Raw (%)	Processed (%)
M2L1	34	19
M2L2	40	24
PTST1	40	22
PTST2	40	18
Average fine particle	38.50	16.60

Referring to IMSBC Code, allowable size for cargo transportation is between 2.5 mm to 500 mm with total percentage of 70% to 90% lumps and only 10% to 30% powder. 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 raw Bukit Goh bauxite's in average consist more than 30% fine particle and less than 70% coarse particle. Due to this situation, the moisture content of the raw bauxite will increase. Meanwhile, bauxite of the same sample that has been beneficiated has fine particle less than 30% which prove that beneficiation method can reduce the number of fine particles in bauxite.

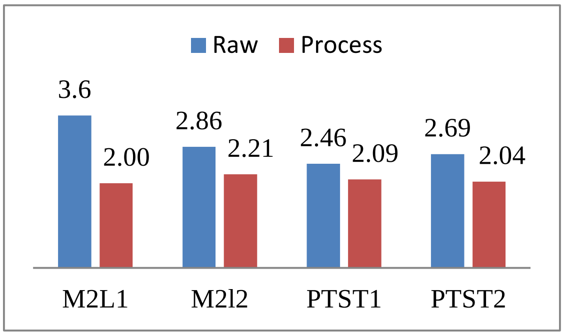
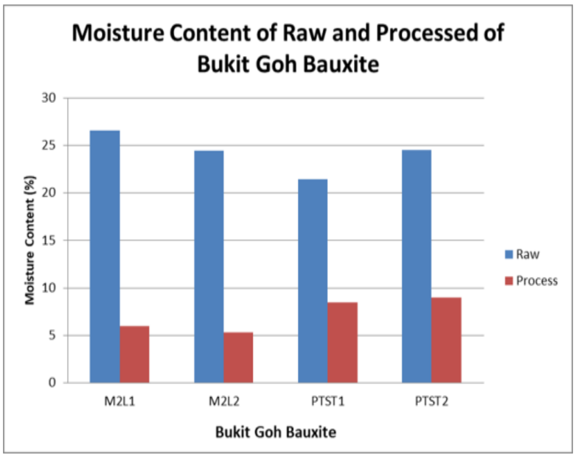


Fig.1 Tabulation of average specific gravity

The result from Small Pycnometer Test was collected and tabulated in Figure 1 for PTST1 and PTST2 are almost the same. Meanwhile, there is slightly difference in specific gravity for M2L1 and M2L2. The specific gravity of processed bauxite samples is slightly lower than the raw sample. Specific gravity for bauxite is between 2.0 – 3.0, thus the bauxite samples collected from Bukit Goh mine are still between the range of the study.

From the comparison in the histogram in Figure 2, it shows that the moisture content of raw Bukit Goh bauxite is higher compared to processed bauxite where it has the average of 24.33% over 7.16% only on the processed bauxite sample.



`Fig.2 Tabulation of average moisture content

Table 3 Raw and processed Bukit Goh Bauxite elements

Parameters	Unit	Raw	Processed
Iron (FE)	%	31.38	26.49
Aluminium (AL)	%	7.48	7.25
Titanium (Ti)	%	3.96	3.33
Silicon (Si)	%	0.50	0.44
Phosphorus (P)	%	0.40	0.41
Calcium (Ca)	%	0.09	0.11
Sulphur (S)	%	0.09	0.07
Chromium (Cr)	%	0.08	0.09
Manganese (Mn)	%	0.06	0.05
Zirconium (Zr)	%	0.05	0.05
Strontium (Sr)	%	0.02	0.02
Niobium (Nb)	%	0.02	0.02
Zinc (Zn)	%	0.01	0.02
Gallium (Ga)	ppm	69	79
Yttrium (Y)	ppm	35	48

Table 4 Raw and processed Bukit Goh Bauxite oxides

Parameters	Unit	Raw	Processed
Iron (III) Oxide	%	44.86	37.88
Aluminium Oxide	%	14.13	13.69
Titanium Dioxide	%	6.60	5.55
Silicon Dioxide	%	1.07	0.94
Phosphorus Pentoxide	%	0.91	0.93
Sulphur Trioxide	%	0.22	0.18
Calcium Oxide	%	0.13	0.15
Chromium (III) Oxide	%	0.12	0.13
Manganese Oxide	%	0.08	0.06
Zirconium Dioxide	%	0.07	0.06
Niobium Pentoxide	%	0.03	0.02
Strontium Oxide	%	0.02	0.02
Zinc Oxide	%	0.01	0.02

Due to higher moisture content, it clearly demonstrates that raw Bukit Goh bauxite have large amount of fine particle compared to coarse particle. Meanwhile, the moisture content for processed bauxite is within the allowable range in the IMSBC Code; 0%-10% which makes the bauxite safe to be exported [5].

From Table 3, it shows that the quantity of Silicon (Si) is reduced from 0.50% to 0.44% and from Table 4, the amount of Silicon Dioxide (SiO2) or also known as silica is minimized from 1.07% to 0.94% after beneficiation process. Unfortunately, the value of aluminium element also decreases slightly from 7.48% to 7.25% although it has not much effects on the bauxite products. As mentioned before, the core target of washing bauxite is to decrease the amount of silica and improve the amount of aluminium. In addition, along with silica, the insoluble iron and titanium oxides in red mud will also be removed that will abolish lower grade fines and enhance the quality of bauxite

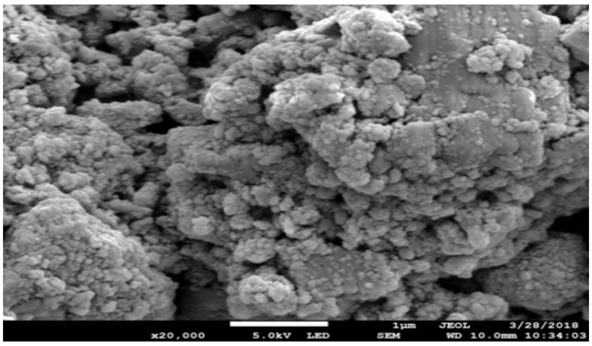


Fig.3 Raw Bauxite Morphology under 20000x magnification

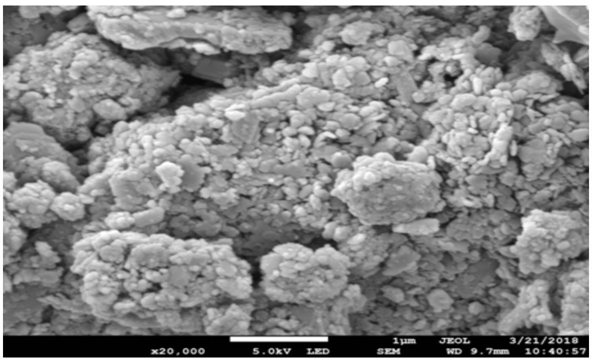


Fig.4 Process Bauxite Morphology under 20000x magnification

Clear image of particles started to be seen under 20000 x magnifications, fine particles attached to the bauxite sample are clearly can be seen for raw samples. This figure explained the main cause of high percentage of moisture content. Large amount of fine particles at the bauxite ore may result liquefaction to take place due to fine particles that have low anti-liquefaction characteristics compared with lump particles and granular particles. Clearly seen that the lesser fine particle attached to the processed bauxite ore. This proved the washing of bauxite can reduce the amount of fine particle in bauxite lump.

6. CONCLUSION

The potential liquefaction of bauxite cargoes has been the subject of a number industry bulletins in recent years. These concerns have been renewed following the recent sinking of the bulk carrier Bulk Jupiter reportedly carrying 46,400 MT of bauxite loaded at Kuantan in Malaysia [10]. Due to series of cargo liquefaction increased while shipping mineral ores, The Maritime Safety Committee of International Maritime Organization (IMO) has adopted the IMSBC Code to facilitate the safety of the cargo while transporting solid bulk. The main purpose of IMSBC Code is to provide a better guidance while handling solid bulk shipping in the cargo in terms of stowage and shipment. Thus, beneficiation process is a good method to reduce the fine particles in bauxite deposits that will minimize the dust pollution when transporting on land by lorries. This process also will decrease the water content of bauxite because there is a lesser fine particle content as well as improving the quality of bauxite that will be extracting into good quality aluminium. This study is focused on three basic properties which are particle size distribution, moisture content and specific gravity. Based on the results and discussion gained from the previous chapter, there are several conclusions that can be finalized as follow:

I. Results from the sieve analysis study concluded that the average fine particle sizes of raw bauxite are 38.50% which is higher than already processed bauxite sample with the average of 16.60%. Thus, by comparing to IMSBC Code, raw Bukit Goh bauxites are not fulfilling the maximum fine particle size passing of 30% requirement in the standard IMSBC Code and therefore it is not suitable to be exported.

II. From the outcome of beneficiation, the Bukit Goh bauxite has lower moisture content percentage with the value of 7.16% compared to raw bauxite with moisture content of 24.33% which exceed the 10% limitation. It is due to the lower content of fine particle in processed bauxite that absorbs less water.

III. The chemical properties of both raw and processed bauxite are tested by X-ray Fluorescence test. The Silicon (Si) element and silicon dioxide that made up most of the fine particle in bauxite was reduced from 3.81% to 1.53% and 4.61% to 2.32% respectively.

IV. Study on morphological properties of Bukit Goh bauxite displays that the fine particles of raw bauxite is higher than the beneficiated bauxite. Clearly seen that the lesser fine particle attached to the processed bauxite ore resulting in lower absorption of moisture. All these basic properties are lead to lower risks of liquefaction to occur during bauxite cargoes transportation.

V. To be classified as Group C, the moisture content of bauxite must be within the 0% to 10%. For particle size, 70% to 90% for coarse lumps, varying between 2.5 mm and 500 mm and 10% to 30% for powder.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Bao, X., Zhiyang, J., Hongzhi, C., Xiangsheng, C., and Xiongyao, X. (2019). Soil Liquefaction Mitigation in Geotechnical Engineering: An Overview of Recently Developed Methods. Soil Dynamics and Earthquake Engineering 120: 273–91

[2] Buchanan, S.J., Kopittke, P.M, Menzies, N.W and So, H.B. 2010. Influence of texture in bauxite residues on void ratio, water holding characteristics and penetration resistence. Geoderma. (158): 421-426

[3] Daoud, S., Imen, S., Samir, E., and Mounir, B. (2018). Numerical Analysis of Cargo Liquefaction Mechanism under the Swell Motion. Marine Structures 57:52–71

[4] Hasan, M., Faez, A. A, Moqsud, M. A., Tam, W. L. and Phang, B. Y (2017) Properties of Raw and Processed Bukit Goh Bauxite In Kuantan, Pahang In Accordance With IMSBC Code. In: Seventh International Conference on Geotechnique, Construction Materials and Environment, 21-24 November 2017, Mie, Japan. pp. 1-6

[5] IMO. 2011. International Maritime Solid Bulk Cargoes Code MSX. 393 (95)

[6] Ju, L., Dracos, V., Qing, W., Yongkui, W., and Yang, L. (2018). Numerical Investigation of Solid Bulk Cargo Liquefaction. Ocean Engineering 159:33–47

[7] Liu, Y., Ming, H. and Naidu, R. 2012. Surface electrochemical properties red mud (bauxite residue): Zeta potential. Journal of Colloid and Interface Science.394 (2013): 451-457

[8] Li, D., Farshad, A., Wei, H., Kejun, W., Xiaojia, D., Lin, L., and Haifei, J. (2019). Experiment Study of Lateral Unloading Stress Path and Excess Pore Water Pressure on Creep Behavior of Soft Soil. Advances in Civil Engineering 2019:1–9.

[9] Sukla, L. B., Pattanaik, A., and Pradhan, D. (2019) Advances in Beneficiation of Low-Grade Bauxite. In: Chesonis C. (eds) Light Metals 2019. The Minerals, Metals & Materials Series. Springer, Cham.

[10] The Bauxite Index. 2016. Bauxite mining. https://bauxiteindex.com/en/cbix/industry101/bauxite-101/bauxitemining#bauxite_101, (2016).