Indian Journal of Science and Technology, Vol 10(7), DOI: 10.17485/ijst/2017/v10i7/111451, February 2017
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Basic Properties of Gebeng Bauxite in Accordance to IMSBC Code

Muzamir Hasan*, **Siti Hajar Aziz and Wan Nursyafiqah Wan Jusoh**

Centre for Earth Resources Research & Management, Faculty of Civil Engineering & Earth Resource, Universiti Malaysia Pahang, Lebuhraya Tun Razak, Gambang - 26300, Kuantan, Pahang, Malaysia; muzamir@ump.edu.my, sitihajaraziz930712@gmail.com, wrsyafiqah@gmail.com

Abstract

Background/Objectives: Due to a case where Bulk Jupiter, which was carrying 46,400 tons of bauxite from Kuantan sank about 150 nautical miles off the coast of Vung Tau, Vietnam, with 18 fatalities and only one survivor, where liquefaction has been identified as the main cause of the capsize of the bulk cargo; has embarked the idea for this study. **Methods/Statistical Analysis:** Laboratory test had been done to three different locations from bauxite mines and one from stockpile in Gebeng, Kuantan to identify its basic properties; particle size distribution, moisture content, specific gravity and its morphological properties. Results are then compared with International Maritime Solid Bulk Cargoes (IMSBC) Code; an international standard for cargo transportation for exporting purpose to ensure those raw materials are passing the standard so that the tendency for the material to liquefy is low. **Findings:** From laboratory test conducted, the average value of moisture content from air-dry and oven-dry method are 20.45 % and 23.33 %, respectively. Average particles size of Kuantan Bauxite smaller than 2.5 mm is 35% means bauxite samples collected consists of fine particles more than lumps and images obtained from SEM test proved that there is abundance of fine particles attached to the bauxite ore. **Application/Improvements:** Referring to the IMSBC Code, it can be stated that bauxite sample collected from Gebeng mines does not qualify to be classified under Group C as its basic properties are not within the limits imposed by IMSBC Code. This is due to the presence of high fine particles which tend to absorb water more than granular particles that may lead to liquefaction to occur. Liquefaction in bulk cargoes is very dangerous since the probability for the cargoes to capsize is very high. In order to ensure the bauxite is passing the standard, 'beneficiation' process should be conducted to eliminate fine particles.

Keywords: Basic Properties, Bauxite, Gebeng, IMSBC Code

1. Introduction

Besides smelter and manufacturing its own aluminium, Malaysia also exported the bauxite to China which is Malaysia's largest export destination. Bauxite reserve has been found in Kuantan district and bauxite mining activity has started due to strong demand from China, Malaysia increases the production of bauxite. There are some standard and regulation that need to be follow; in this case IMSBC Code to determine the safety of bulk cargoes carrying bauxite and to minimize the risk of the cargoes to capsize. Figure 1 shows the classification of Bauxite in Group C where it is neither liable to liquefy (Group A) nor to possess chemical hazards (Group B)[1]. If bauxite samples are complied with the specifications as stated in IMSBC Code, the samples are allowed be shipped and exported. Thus, this study is carried out to determine does the Kuantan bauxite samples are in accordance with the IMSBC Code or not, by comparing the parameters stated in the code.

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[1].

* Author for correspondence

This situation was highlighted when a 10-year-old Bahamas flag bulk carrier Bulk Jupiter, which was carrying 46,400 tonnes of bauxite from Kuantan sank about 150 nautical miles off the coast of Vung Tau, Vietnam, with 18 fatalities and only one survivor. The International Maritime Organization (IMO) warned ship Masters of the possible dangers of liquefaction associated with carriage of bauxite, following consideration of findings from the investigation conducted related to the tragedy[2,3]. Introduction of an export restriction can be used as a measure to control export flows and to fight illegal trade activities. By that, export restrictions on metals can help to preserve exhaustive natural resources[4].

According to[5], cargoes that are at risk of liquefaction are those containing at least some fine particles and some moisture, although they need not be visibly wet in appearance. During loading, the cargoes are normally in their solid state, where the particles are in direct contact with each other and, by that, there is physical strength of resistance to shear strains. However, during ocean transport, cargoes are exposed to agitation in the form of engine vibrations, ship's motions and wave impact, resulting in compaction of the cargo. This leads to a reduction of the spaces between the particles. If compaction is such that there is more water inside the cargo than there are spaces between the particles, the water pressure inside the cargo can rise sharply and press the particles apart. This suddenly reduces the friction between particles, and thus the shear strength of the cargo. This situation is shown in Figure 2.

The effect of this process is a transition from a solid state to a viscous fluid state in which all or part of the cargo can flatten out to form a fluid surface[5]. In this condition, cargo may flow to one side of the ship with a roll one way but not completely return with a roll the other way, progressively leading to a dangerous list and potentially the sudden capsizing of the vessel.

Percentages of moisture content of the sample do have a relationship with particle size distribution where the presence of fines particles will influence its water-holding properties[6]. Liquefaction occurs when the shear strength of the soil decreases and becomes zero. This condition usually occurred in ground due to increase in the pore water pressure in the sandy soils and the loose saturated layers at the time of seismic movement which happens because of the tendency of the soil to lose volume, leads to decrease of the comprehensive tension of the soil[7].

Besides identifying the standard quality of Kuantan bauxite, its morphological characteristic also studied 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. Materials and Methods

To determine basic properties of bauxite sample, there are total of 4 main samples; 3 samples from Gebeng mine (GBIS1, GBIS2 and GBIS3) and1sample from Stock Pile (GBSP1) were taken, tested, and analyzed shown in Figure 3. The samples were disturbed samples and stored in sealed plastic container and transported back to laboratory. Hydrometer Test, Wet Sieving Analysis and Dry Sieving Analysis (according to Geospec Standard) are conducted to determine particle size distribution of bauxite samples. Meanwhile, Small Pyknometer Test is conducted to determine specific gravity of bauxite samples and Moisture Content Test is carried out to identify moisture content presented in the samples.

Meanwhile, for morphological study, sample is sent for Scanning Electron Microscope (SEM) Test to have clear vision about the condition of bauxite particles under high magnification.

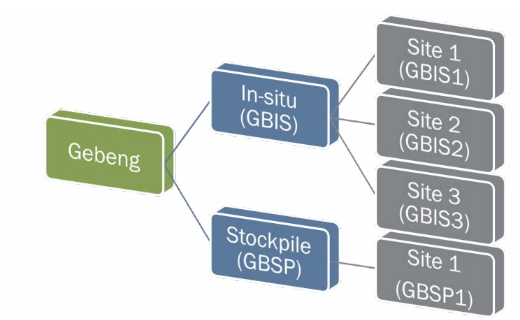

Figure 3. Bauxite samples.

3. Results and Discussion

Data collected from the test is analysed and it can be divided into three results which are the result for particle size distribution, result for specific gravity determination and result for moisture content determination.

3.1 Particle Size Distribution

Table 1 shows particle size distribution for all 4 samples where GBIS1, GBIS2 and GBIS3 showed percentages of particles smaller than 2.5 mm is 41%, 34% and 41%, accordingly. As for GBSP1, it has been recorded that the particles smaller than 2.5 mm is 25 %. Results show that percentages of particle size distribution for the samples are more than 30% and less than 70% of its total mass, except for GBSP1. Figure 4 shows representative result for GBSP1 from particle size distribution test.

Table 1. Particle size analysis

	Particle Size (%)	
Sample	**≤ 2.5 mm**	**> 2.5 mm**
GBIS1	41	59
GBIS2	34	66
GBIS3	41	59
GBSP1	25	75

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. Since samples possessed high value of fine particles; this situation will increase the risk of liquefaction to occur during transportation of bauxite in bulk cargoes.

3.2 Moisture Content

Moisture content of the sample is determined by both oven-dry shown in Table 2 and air-dry method shown in Table 3 where the difference between the data obtained from the tests was compared. Results from air-dry methods showed less moisture content in the samples compared with the results from oven-dry method. The results from this two moisture content determination is different from[8] where it is found out that the moisture content of bauxite is affected by the drying method and the drying method used. Besides the drying technique was used, the results of high moisture content percent are influence by the presence of large number of fine particles surround the bauxite ore. This fine particle will create large surface area for water absorption and storage resulting high moisture content. Results show that for all the samples tested by using both methods, the moisture content is more than 10 %; which is the limit set by IMSBC Code. This is due to high fine particles (which are soluble); it contributed to higher water absorption compared to granular particles.

Table 2. Average moisture content (Air-dry Method)

Sample	Moisture Content Container 1 (%)	Moisture Content Container 2 (%)	Average Moisture Content (%)
GBIS1	17.77	18.68	18.23
GBIS2	25.26	23.13	24.20
GBIS3	23.34	23.76	23.55
GBSP1	16.60	15.06	15.83

Table 3. Average moisture content (Oven-dry Method)

Sample	Moisture Content Container 1 (%)	Moisture Content Container 2 (%)	Average Moisture Content (%)
GBIS1	20.58	20.53	20.55
GBIS2	26.20	26.62	26.41
GBIS3	25.38	25.30	25.34
GBSP1	20.91	21.90	21.00

3.3 Specific Gravity

From Small Pycknometer Test, the results collected were tabulated in Table 4 where the specific gravity for GBSB1and GBSB2 is the same. Meanwhile, there is slight difference in specific gravity value for GBSB3 as well as GBSP1 sample. Based on studied carried out by[9], specific gravity for bauxite is between 2.5–3.0, thus the bauxite samples collected from Gebeng mine are still between the range of the study.

Table 4. Results of specific gravity

Sample	Specific Gravity of Container 1	Specific Gravity of Container 2	Average Specific Gravity
GBIS1	2.77	2.74	2.75
GBIS2	2.75	2.76	2.75
GBIS3	2.88	2.85	2.87
GBSP1	2.88	2.89	2.88

3.4 Morphological Properties of Bauxite

Morphological properties of bauxite were determined by SEM test. Figure 5 and Figure 6 shows clearly that there were many fine particles attached to the bauxite ore. As the sample was collected from the mine and did not undergo any washing process, there is a possibility of the image shown is combination of soil and also the bauxite ore. Under 10,000x magnification, fine particles attached to the bauxite sample are clearly can be seen. This figure explained the main cause of high percentage of moisture content as well as the huge number of bulk density of the bauxite sample.

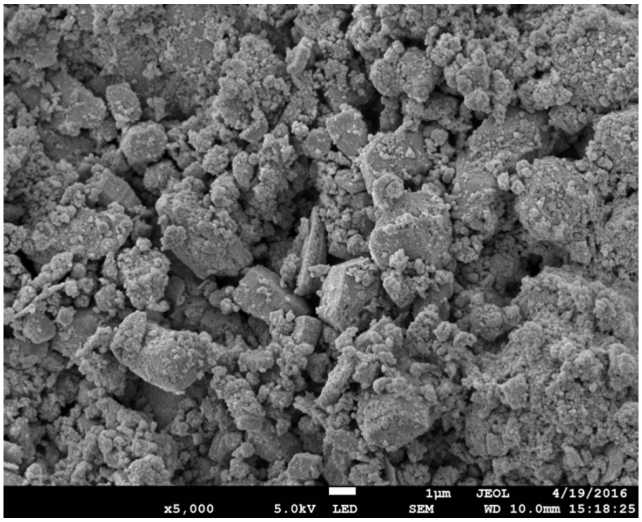

Figure 5. Magnification of GBSP1 sample under 5000x magnification.

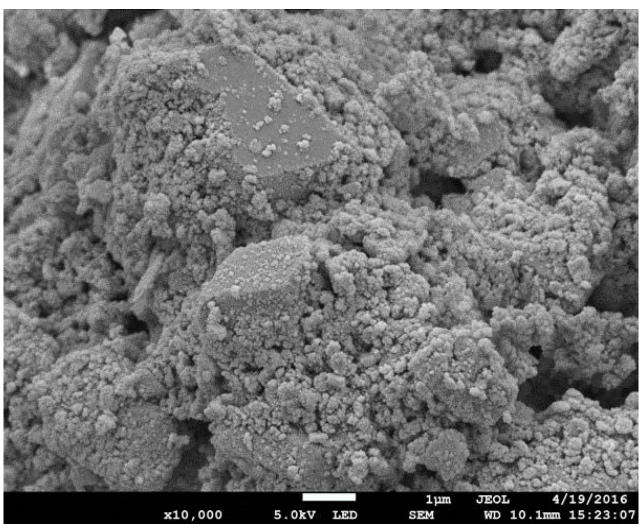

Figure 6. Magnification of GBSP1 sample under 10000x magnification.

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. These anti-liquefaction characteristics had been discussed by[10] where the granular or lump sizes of bauxite is stable array sand with better cementation resulting in ability to prevent liquefy of soil to occur. Besides that, as the bauxite samples collected from Gebeng mine are disturbed sample, the tendency for this sample to liquefy is higher than undisturbed soil because of sheer force of anti-liquefaction of undisturbed soil is 1.5 to 2 times greater than disturbed soil[7].

4. Conclusion

Results from the basic properties study is summarized where the average particle size distribution for lump particles; particles smaller than 2.5 mm to 500 mm for the samples are more than 30%; except for 1 sample from stockpile and the percentages of moisture content of the samples is higher than 10%.

The results obtained were compared with IMSBC Code where each of these basic properties is exceeding the specified value stated in the code. All this basic properties are influence factor for liquefaction to occur during bauxite cargoes transportation, hence it is important to meticulously identify the properties before it is being exported. As the results is doubling the required value, it can be conclude that the bauxite collected from Gebeng mine are not suitable to be transported.

Study on morphological properties of Gebeng bauxite shows the abundance of fine particle attached to the bauxite ore, resulting in higher percentage of moisture content, low percentage of lump particles distribution as well as high value of bulk density. This is because, the presence of fine particles absorbed more water, increasing moisture content of the samples in which the presence of this fine particles have been proven by bulk density value as well as percentage of particle size distribution.

Gebeng bauxite cannot be classified under Group C of IMSBC Code and it is not suitable to be exported as none of the basic properties are fulfilling the requirement stated in the code. If there is a will of transporting the bauxite, it will be high risk cargoes transportation due to string current from the waves at the ocean. This is due to the presence of high fine particles which tend to absorb water more than granular particles that may lead to liquefaction to occur. Liquefaction in bulk cargoes is very dangerous since the probability for the cargoes to capsize is very high. In order to ensure the bauxite is passing the standard, 'beneficiation' process should be conducted to eliminate fine particles.

5. Acknowledgement

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.

6. References

1. IMSBC Code. International Maritime Solid Bulk Cargoes Code and Supplement. International Maritime Organization. 2013.
2. IMO warns on bauxite liquefaction dangers. Available from: http://www.imo.org/en/MediaCentre/PressBriefings/Pages/38-bauxite-CCC.aspx
3. IMO: Bauxite Liquefaction Sank Bulk Jupiter. 2016. Available from: http://worldmaritimenews.com/archives/172059/imo-bauxite-liquefaction-sank-bulk-jupiter/
4. Vyboldina E, Cherepovitsyn A, Fedoseev S, Tsvetkov P. Analysis of export restrictions and their impact on metals world markets. Indian Journal of Science and Technology. 2016; 9(5):1-8. doi:10.17485/ijst/2016/v9i5/87633
5. Gard AS. Liquefaction of solid bulk cargoes: A selection of articles previously published by Gard AS. Gard News. 2015; 197:4-7.
6. Buchanan SJ, Kopittke PM, Menzies NW, So HB. Influence of texture in bauxite residues on void ratio, water holding characteristics and penetration resistance. Geoderma. 2010; 158:421-6. doi:10.1016/j.geoderma.2010.06.016
7. Shirzadyan J, Talkhablou M. Using GIS software for identification and zoning of the areas prone to liquefaction in the bed soil of the dams. Indian Journal of Science and Technology. 2015; 8(S9):62-6. doi:10.17485/ijst/2015/v8iS9/68555
8. Pantazidou M. Protection of the subsurface against contamination: Expected legislation. Proceedings of International Workshop in Geo-environment and Geotechnics, Milos Conference Center; Milos, island, Greece. 2005.
9. Gandhi RL, Jay N, Che Y. Cross-country bauxite slurry transportation. Essential Reading in Light Metals, Alumina and Bauxite. 2013; 1(10):70-4. doi:10.1002/9781118647868.ch10
10. Wu A, Sun Y. Granular dynamic theory and its applications. New York: Springer Berlin Heidelberg; 2008.