Research into the Behavior of Bauxite During Shipping: An Overview of the Global Bauxite Working Group (GBWG) Findings

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Abstract

In ocean transportation, solid bulk cargoes containing considerable amounts of fine particles and moisture may shift when the ship is exposed to adverse sea conditions. In 2015, the loss of 18 seamen and a vessel has been attributed to bauxite cargo shift. Following the incident, the bauxite industry formed a research group (the Global Bauxite Working Group – GBWG) to develop research on the bauxite behavior during maritime transportation. The research aimed to provide technical background for bauxite safe shipping, allowing the International Maritime Organization (IMO) to amend regulation related to bauxite maritime transportation in bulk. Between 2015 and 2017, the GBWG collected and analyzed samples representing over 90 % of all seaborne traded bauxite. The various experimental techniques applied include cyclic triaxial testing and physical modelling to investigate all possible bauxite instability modes due to moisture. Based on the GBWG findings, the IMO has established: i) a particle size criterion to distinguish between finer bauxites that may exhibit instabilities due to moisture and coarser bauxites that may not; ii) a suitable laboratory test to determine the maximum moisture content (Transportable Moisture Limit – TML) of finer bauxites to avoid any potential instability due to moisture during maritime transportation.

Keywords: Bauxite, shipping, solid bulk cargo, maritime transportation, TML, Global Bauxite Working Group

1. Introduction

Bauxite has been shipped safely for many decades. However, recent events have changed this record and required industry to investigate the behavior of bauxites during shipping. In 2015, the vessel Bulk Jupiter sunk off the coast of Vietnam, registering 18 casualties. The vessel was carrying 19 men and 46,400 tons of bauxite from Malaysia to China. Investigation led by the vessel flag state attributed the incident to liquefaction of the cargo [1], [2].

After ship motions, solid bulk cargoes containing considerable amounts of fine particles and moisture may shift during an ocean voyage due to liquefaction phenomena. In soil mechanics, liquefaction describes the behavior of a material that flows in a viscous liquid fashion when monotonic, cyclic, or shock loading is applied. Such behavior is caused by pore pressure increase within the material, resulting in the loss of effective stress and shear strength [3], [4]. After liquefaction, the unstable cargo may move freely on vessel hold following ship motions. Later, the pile cargo may become stable again and accumulate at one side of the vessel hold. Due to this instability factor, the ship may develop a list or even capsize [5].

As recently concluded by Rahman [6], [7], [8] and others and reviewed by Munro and Mohajerani [4], "*Some incidents attributed to liquefaction may also be more accurately described as cyclic instability, which is a form of unstable behavior (strain softening) caused by a succession of dynamic load cycles*".

After the Bulk Jupiter incident, concern was raised about safety of bauxite shipping and the bauxite industry formed the Global Bauxite Working Group (GBWG) with the aim of conducting a detailed investigation into the characteristics and behavior of bauxite during ocean transportation. The GBWG membership comprises a variety of stakeholders, with expertise in diverse disciplines, such as mine owners/operators, transporters (ship owner/operators), users (alumina refinery operators) and consultants with backgrounds in geotechnical and hydraulic engineering, maritime science, plant, port and ship operations [1].

The GBWG research output offers a contribution to the International Maritime Organization (IMO), which is the United Nations agency in charge of setting regulation and guidance for the safety of maritime transportation and prevention of pollution by ships. IMO's International Maritime Solid Bulk Cargoes (IMSBC) Code is a rulebook issued by the IMO on how to deal with solid bulk cargoes. The document is periodically reviewed and updated by IMO's Sub-Committee on Carriage of Cargoes and Containers (CCC) and by IMO's Maritime Safety Committee MSC). In the IMSBC Code, general description and characteristics of solid bulk cargoes are presented in individual schedules of cargoes. Also, the Code classifies cargoes in 3 Groups: Group A – cargoes which may liquefy; Group B – cargoes which possess chemical hazards; Group C – those which are neither liable to liquefy nor to possess chemical hazards [9].

The Group A cargoes can only be shipped when moisture of the cargo is below its Transportable Moisture Limit (TML), which is assessed by one of the test methods prescribed by the IMSBC Code. The TML is the maximum moisture content for safe shipping of the cargo and due to particular cargo's characteristics, improvements to existing test procedures may lead to more suitable test apparatus and more accurate test results. Following this line, TML test procedures specific for certain cargoes have been developed in the past years, such as the Iron Ore Fines Modified Proctor/Fagerberg test procedure [10] and the Coal Modified/Proctor Fagerberg test procedure [11].

As derived from IMSBC Code's bauxite schedule, until 2015 bauxite cargoes were listed as Group C only. Hence, no moisture related hazard was considered. The GBWG research assessed characteristics of bauxites shipped worldwide, providing a science-based background for IMO's review of IMSBC Code's provisions on bauxite shipping.

This work brings an overview of the research conducted by bauxite industry and provides a brief summary of the current bauxite shipping regulatory frame.

2. Materials and Methods

Between 2015 and 2017 the GBWG collected and analyzed samples representing over 90 % of all seaborne traded bauxite. Bauxites characterized and investigated by the GBWG include those from Australia, Brazil, India, Indonesia, Guinea, Guyana, Jamaica and Malaysia.

cargoes which may have hazards arising from cargo instability due to moisture. This would be analogous to a Group B classified cargoes, which may have chemical hazards, but is not limited to one type of chemical hazard such as fire or explosion.

4. Conclusions

The GBWG findings led to recommendation to the IMO of the following amendments on regulation of bauxite maritime transportation: i) Split the existing single schedule for bauxite cargoes into Group A (bauxite fines) and Group C (bauxite); ii) Adopt the GBWG-developed TML test method (Modified Proctor-Fagerberg test procedure for bauxite) to assess the TML of Group A bauxite; and iii) consider other mechanisms for excess moisture related cargo instability within Group A in addition to classification of cargoes as "liable to liquefy".

The compliance to the IMSBC code and the details contained in the schedules ensures that bauxite cargoes safe shipping. The research on bauxite behavior during maritime transportation has identified insights into instabilities due to moisture occurring in bauxite that offers potential safety benefits in cases where a bauxite cargo has been misdeclared. In this case, understanding the effect of a dense free slurry surface on vessel stability is paramount.

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