The modified Proctor & Fagerberg test

A boon or a bane? An independent surveyor's perspective

Capt Ruchin C Dayal
AFNI

The modified Proctor and Fagerberg (P&F) test for identifying the transportable moisture limit of certain cargoes, which has now been approved in the context of amendments to the present International Maritime Solid Bulk Cargoes (IMSBC) Code, presents a serious dilemma for seafarers.

This test results in significantly higher values for the Transportable Moisture Limit (TML) than those produced by existing methods in the IMSBC Code. While the test has been accepted by the IMO and has the backing of apparent sound research and adequate vetting, it has evoked a mixed reaction from the industry. Some prominent experts believe that the test risks undermining the safety of ships and seafarers.

To understand the extent of the difficulties posed by the new test, it is necessary to dig a little into the background of the iron ore trade, the development of the IMSBC code, and the test methods currently available.

The development of sintering technology has created a demand for iron ore fines, which were previously considered as a waste product. Iron ore fines are made up of powdery material below 10 mm in size, and belong to Group 'A' in the IMSBC Code, meaning that they may liquefy if shipped at a moisture content in excess of their TML. About 1000 million tonnes of iron ore fines are transported in ships each year, most of it from Brazil and Australia to China.

Development of the IMSBC Code

The *mandatory* IMSBC Code was adopted by the IMO in Dec 2008, replacing the previous *recommendatory* Code of Practice for Sold Bulk Cargo (BC Code). In 2011, Brazil proposed the formation of a working group to study the inadequacies of the test methods in the new code. This new research culminated in amendment 3/2015, which came into force on 1 January 2017. The most important feature of the amendment was the introduction of the new schedule for iron ore fines and the approval of the modified P&F test to determine the TML.

As part of the review of the IMSBC Code, the three existing tests detailed opposite were analysed in a controlled, systematic and transparent environment. All three were found to have limitations for testing iron ore fine cargoes:

- The flow table test was subjective, and restricted the particle size to 7mm
- The input vibrational energy in the penetration table test was found to have little connection with the actual experienced conditions inside a ship's hold
- The P&F test was considered the most consistent. However, it had a size restriction of 5mm. Furthermore, use of a 350g hammer to input energy was determined to be excessive when compared to actual hold conditions.

Having established that the P&F test was the most consistent and objective of the existing methods, extensive tests were conducted to make it more fit for purpose.

The modified P&F test

Without going too deeply into the technical details, the broad principles on which the research was conducted were as follows:

The experienced bulk density of iron ore fines increases when loaded into the ship's holds; initially as a result of the loading process, and then as a result of particle re-distribution within the material itself due to the vibration and motions experienced within the hold during the voyage.

Simply put, *Bulk Density = Mass/ Volume*. While mass remains constant, the volume reduces due to compaction during the loading and the subsequent voyage, resulting in an effective increase in bulk density. Today, in-hold cargo density volumes/bulk densities can be measured extremely accurately using a variety of modern techniques using sophisticated scanners, cameras and other equipment in the holds from load-port until discharge.

The tamping pressure applied during the testing process must result in densities representative of the actual experienced bulk density inside the ship's holds. A modified P&F hammer weighing 150gms with a drop height of 15cm was deemed best suited for this purpose. In short, the compacting force used in the standard P&F has been reduced to match hold densities ascertained by modern techniques. To put the matter in extremely nontechnical terms, a sponge can hold more water if squeezed with less force. In the same way, the TML will be higher if the tamping pressure used in determining it is lower.

In the modified P&F test, TML is considered to be the moisture content at 80% of saturation (in contrast, the original P&F test sets it at 70% of saturation). This leaves a 10-15% margin of safety.

The research and development which went into making of these amendments spanned over half a decade, with every technical aspect being vetted and reviewed by Japanese experts, Imperial College London, P&I Clubs and non-governmental organisations like BIMCO and INTERCARGO. They were discussed at length by states and stakeholders at every session of the IMO Subcommittees on Dangerous Goods, Solid Cargo & Containers (DSCC) and Carriage of Cargoes and Containers (CCC) between 2010 and 2015.

However, our marine laboratory has tested over 100 different samples of Indian iron ore fines, using all of the above methods for each individual sample. While the results for methods 1-3 described opposite were found to be consistent and produced almost identical TMLS, the modified P&F test always resulted in TML values that were higher by nearly 2-3%.

Existing testing methods (pre 2017)

Iron ore fines are tested for their moisture content and transportable moisture limit (TML). The Moisture Content (MC) must be less than the TML for the cargo to be compliant with the code for sea carriage.

Determination of the moisture content itself is fairly straightforward and governed by national and international standards. By contrast, determination of the Transportable Moisture Limit is guided by the methods set out in Appendix 2 of the IMSBC Code. It may be relevant to note this appendix is *recommendatory* only.

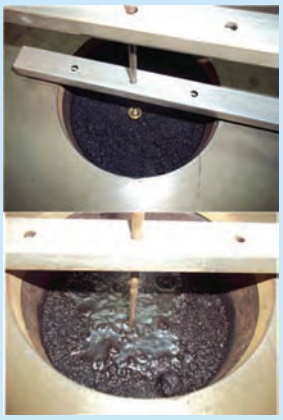
Until the advent of the modified P&F test, the IMSBC listed three methods to determine the TML of a cargo. In each case, the sample is first dried. A known amount of water is then added to a series of samples. These samples are then tested to determine the TML of that particular consignment.

1. The Flow Table Test (FTT)

This test was first adopted in the 1980s, and has become a standard test for the determination of the flow moisture point of concentrate fine materials. It is applicable for minerals with a minimum particle size of 1mm and may be used for particles with a maximum size of up to 7mm. The sample is compacted into a mould and placed on a horizontal plate, which is connected to a supporting table mounted in a concrete base. Once the mould is removed, the sample and its supporting table are rotated and dropped repeatedly. The plate is dropped from a height of 12.5mm at a rate of 25 drops per minute for two minutes. The test revolves around imparting physical energy into the sample in a similar way to what happens inside a ship's holds. The behaviour of the sample is observed, and the water content at which the sample exhibits plastic deformation, rather than crumbling, is deemed the flow moisture point (FMP). The TML is defined as being 90% of the Flow Moisture Point. Cargoes with moisture content above the Flow Moisture Point may be liable to liquefy.

While the flow table test is a relatively simple test requiring little interpretation of data, the critical aspect is the reliable identification of a flow state in the test sample. As the flow state is measured visually, the result is heavily dependent on the skill and judgement of the chemist performing the test.

The Flow Table Test



The Penetration Table Test

The P&F Test

2. The Penetration Table Test (PTT)

Adopted in the 1990s, this method was developed as an alternative to the flow table test which reduced dependence on the skills of an individual chemist, and accommodated a particle size up of up to 25mm.

The penetration table test is based on the principle that there is a direct relationship between loss of shear strength by cyclic vibration and liquefaction. The test is performed by placing a sample in a cylindrical container, tamped as per the FTT method, and then subjecting it to cyclic vibrations of 2G±10% on a vibrating table. A weight in the form of a penetration bit is placed on top of the sample. The point at which the weight sinks by more than 50mm, is considered as an indication of the loss of shear strength. The moisture content of the sample at this point is determined to be the FMP. The TML is then calculated as 90% of the FMP. While the construction of the penetration test table may appear to be complicated, the test itself is simple and relatively objective when compared to the FTT.

3. The Proctor and Fagerberg Test (P&F test)

The P&F test is a dynamic compaction laboratory test method. It reproduces the dry bulk densities experienced in the ship's holds by inducing compaction energy using a compaction tool incorporating a 350g hammer with a drop height of 20 cm. The dry bulk density is then co-related to the corresponding void ratio and the moisture content. The TML is considered to be the moisture content at 70% saturation.

The test uses extremely simple equipment and is easy to perform. However, the compaction curves must be plotted using standard calculation methods and the results are heavily dependent on the accurate determination of specific gravity. The results are objective and consistent.

This is deeply concerning. Since the introduction of the IMSBC Code, ships have continued to have problems with liquefaction, even when the cargo they carried was tested and had been certified safe before being loaded. Against this background, it is hard to see how diluting the standards for the TML will help enhance safety.

The key question is whether the new schedule and test procedures for iron ore fines will compromise the safety of ships and seafarers in any way. Already, there seems to be evidence that it will.

Take the case in the pictures (right), where the stockpile MC (above) was measured at 6.9%. Use of the modified P&F test gave a TML of 8.3%, and the cargo was therefore accepted for loading. We believe that it would have been rejected had the TML been set by the flow table test or the penetration table test.

Shippers carried out loading during six days of torrential rain, with total rainfall measured at 450mm. At the end of this period, MC in the holds reached 9% – with only 2-3000 MT loaded in each hold (lower pic). The owner's P&I Club intervened, and the cargo had to be discharged. This vessel was lucky to have a supportive P&I Club – but note that use of the modified P&F test had eroded the safety margin that would have prevented the cargo being loaded in the first place. Use of the modified P&F test means that the margin which worked to absorb the callous attitude of some shippers will itself be marginalised.

Solving the problem

I firmly believe that it is not the IMSBC itself, but rather the implementation of it which is the problem, both in India and most other places in the world. Those making new laws based on the updated IMSBC must take into account the local context, including capacity, capability and the surrounding environment.

The biggest challenge was, and will remain, ensuring the accountability and responsibility of shippers – not just in India, but around the world. How can we best educate shippers on their obligations under the code? How do we make them accountable for anything beyond the Charter Party (in other words, demurrage and expenses)? A clause in the charterparty requiring appointment of owner's surveyors, vetted by International Group of P&I Clubs, on the *primary shipper's time and costs*, without which the P&I cover is prejudiced, may help, but this may be expecting too much too soon.

Laboratory competence

Considering that the IMSBC Code has been in existence for nearly a decade, the competence of the laboratories that carry out cargo testing is not at the levels we should expect. The majority of labs are happy with the flow table test, and will use it irrespective of the particle size of the consignment. This opens up a major challenge for validation of the new test. Laboratories are expected to have sufficient data on various cargoes tested by alternate methods to validate the results obtained by the modified P&F test. With the new schedule for iron ore fines clearly defining the criteria for particle size, it becomes imperative that laboratories which are authorised to carry out the new test are equipped to carry out both the flow table test and the penetration table test. This would mean that they could test consignments with a nominal particle size of up to 25mm, and results obtained by the modified PFT can be properly validated.

Furthermore, the integrity of the laboratories will always be in question when their very existence is based on the business of quality-testing for iron content for the shippers. The solution is to have *marine* laboratories, defined as a separate category, with strict parameters for manning and other relevant standards. Testing carried out for safety reasons cannot be mixed up with any testing which may form the basis of a commercial contract.

Advice to Masters

While the revisions to the IMSBC Code became mandatory on 1 January 2017, it is the prerogative of individual states to establish compliance with the code. The use of the prevailing testing methods had great benefits for the maritime industry. The risks posed by the largely uncontrolled export environment were to some extent mitigated by the greater margins of safety built into these existing testing methods. It may be noted that awareness of this greater margin has only been evident after the advent of the modified P&F test.

The present environment demands that the introduction of the modified P&F test must be handled with extreme caution. Stringent measures must be introduced for validation of the results, and the competency standards for laboratories must be raised to take into account the limitations of the test procedure. Even more urgently, the IMSBC Code must be properly understood and implemented within the shipper and surveyor communities.

Masters, P&I representatives and others concerned with the safety of the cargo should ensure they know which method has been used to determine the TML, and its likely implications. My advice – **do not accept a TML set by the modified P&F test unless a transparent system of validation is in place.**

Contrary or complementing points of view are welcome; please contact me at: ruchin@edot-solutions.com