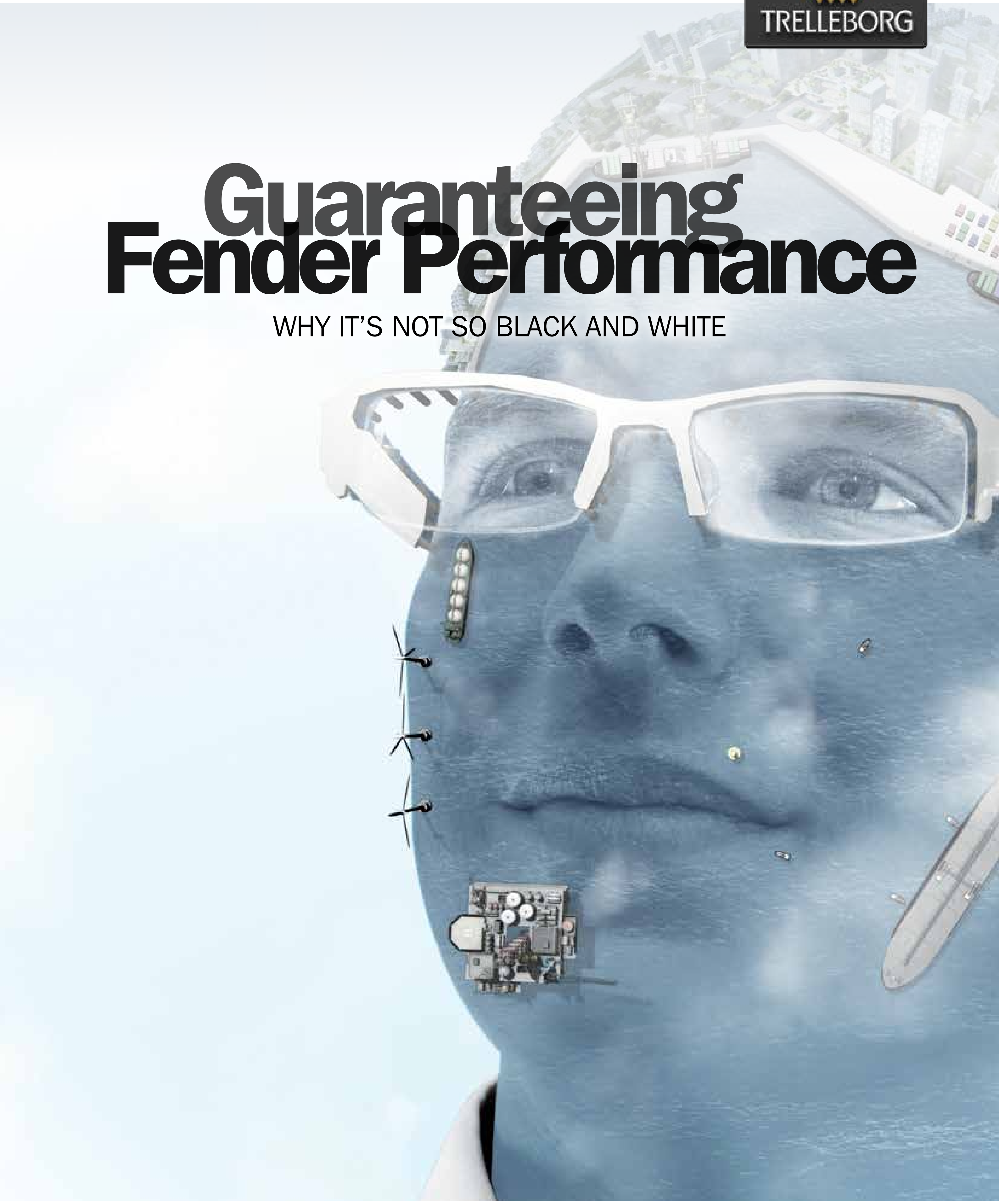
Guaranteeing Fender Performance

WHY IT'S NOT SO BLACK AND WHITE



Trelleborg Marine and Infrastructure

Fendering systems

Fendering systems are mission critical equipment for marine environments globally. Long gone are the days of wooden or rope fenders, and the use of rubber has become standard best practice. Although rubber fenders have a long lifecycle, ultimately it is still limited. Depending on the environment and quality of the fender itself, the expected average lifespan will be approximately 15 to 20 years.

Designing a fender system requires engineers to determine the berthing energy of a vessel or range of vessels that are likely to be docked against the system, then determining what capacity the fender needs to have to absorb that kinetic energy. Finally, engineers must find a way to avoid creating too much force and damaging either the wharf structure
or vessel.

It's accepted that high quality fenders can add value to port operations as sourcing quality materials and fully tested compounds allows ports to drive cost efficiencies, minimise maintenance requirements and reducing the risk of incidents. High quality fenders also have a longer service life and, due to reduced maintenance requirements, also lead to fewer "lost" days for ports, and their shipping operators.

In addition to these commercial concerns, fendering systems are a port's first line of defence when a vessel comes into dock and play a key role in protecting the safety of port personnel, vessel crew, cargo and infrastructure.

However, there has been a worrying trend becoming more pronounced across the industry in recent years, of putting up front costs higher on the agenda than whole life costs. Although this enables immediate cost savings for procurement managers it means that, over the course of the fender's lifecycle, costs will be higher.

Some unscrupulous fender suppliers are taking the opportunity to undercut reputable fender manufacturers by supplying lower cost, but lower quality fenders. They are able to elicit cost savings to pass on to their customers (in the immediate term) in two ways:

- By using a higher percentage of recycled rubber within the fenders, instead of virgin rubber
- Replacing carbon black fillers with non-reinforcing fillers

A simplified comparison chart representing the whole life cost differences between the two can be found below:

Spending requirements	Low quality fender	High quality fender
Purchase price of a CONE 1000 fender	$8,000	$10000
Installation	$4000	$4000
Replacement after five years	$9200	n/a
Re-installation	$6000	n/a
Maintenance	$9000	$4000
Maintenance installation	$12000	$4800
Total 10 year whole life cost	**$48200**	**$22800**

These manufacturers also 'copy' correction factors from reputable manufacturers without understanding these factors are derived based on both rubber compound used as well as fender geometry. They do not make any investment in PIANC Type approved fenders.

Setting the Standards

"Although PIANC is not in a position where it may "regulate the industry" or deliver any certification, PIANC is very careful to promote best practice. We also stress that in the long term, through life cycle approaches, it is recommended to use the most adapted, strong and resistant fender protection to quays."

Geoffrey Caude, PIANC President, 2011

There are a number of different standards used worldwide to design fender systems but the most commonly used is PIANC's "Guidelines for the design of fender systems, 2002", which was updated from its predecessor of 1984.

Although PIANC set out these guidelines, they do not regulate the industry, or indeed, enforce the guidelines in practical terms. This has led to some fender suppliers misusing PIANC "certification" by applying it to fenders that use higher percentages of filler and recycled rubber than is appropriate.

PIANC's guidelines specify that robust material testing is a necessity, and the fact that this is not routinely performed by all suppliers as part of their quality assurance process is a serious concern. Laboratory and full scale testing are fundamental to the design and production of mission critical equipment and the industry needs the reassurance that both sets of testing have been performed.

Some suppliers are able to cut costs though replacing natural rubber with reclaimed rubber, and using large amounts of non-reinforcing fillers, which is a poor substitute for the carbon black reinforcing filler used in high quality fenders.

These lower cost fenders, therefore, do not meet the required specifications, won't perform adequately whilst they're in use and, as such, won't have the product lifecycle they are claimed to have. Additionally, port owners, contractors and consultants have no simple method available to test the quality of the fender's material once it is purchased and installed.

Benchmarking Performance – the tests

A new analytical test has been developed to help buyers understand and substantiate what is in a fender and ensure that port owners, operators and contractors can ensure the highest quality of fenders going forward.

Both chemical and physical testing are required to verify the rubber quality of the fender and ensure that it remains stable and suitable for the use it was intended for, throughout its lifecycle, to ensure maximum protection of the port infrastructure and the vessels that come to berth there.

To demonstrate and quantify the difference in performance characteristics of a high quality and low quality fender, the following tests were carried out in an independent third party laboratory:

- Comparison of the physical properties of the rubber samples. The samples were cut from two commercial sized fenders: one a typical high quality fender, and one a typical low cost fender
- Comparison of the chemical properties of the fenders. The samples were taken from the fender surface of two commercial sized fenders: one a typical high quality fender, and one a typical low cost fender

The following tests were conducted:

Physical analysis:

Test	Equipment Used	Expected Standard
Density	Weighing balance	ISO 2781
Hardness	Shore A hardness tester	ASTM D2240
Tensile strength	Universal test machine	ASTM D412
Elongation at break	Universal test machinea	ASTM D412

Chemical analysis:

Test	Equipment Used	Expected Standard
Polymer (virgin plus recycled rubber) %	**TGA /FTIR**	ASTM D6370/D297
Carbon black %	**TGA /FTIR**	ASTM D6370/D297
Ash %	TGA	ASTM D297
Calcium Carbonate (white filler %)	Chemical method	ASTM D297

1. For further information on TGA and FTIR equipment, please see footnote.

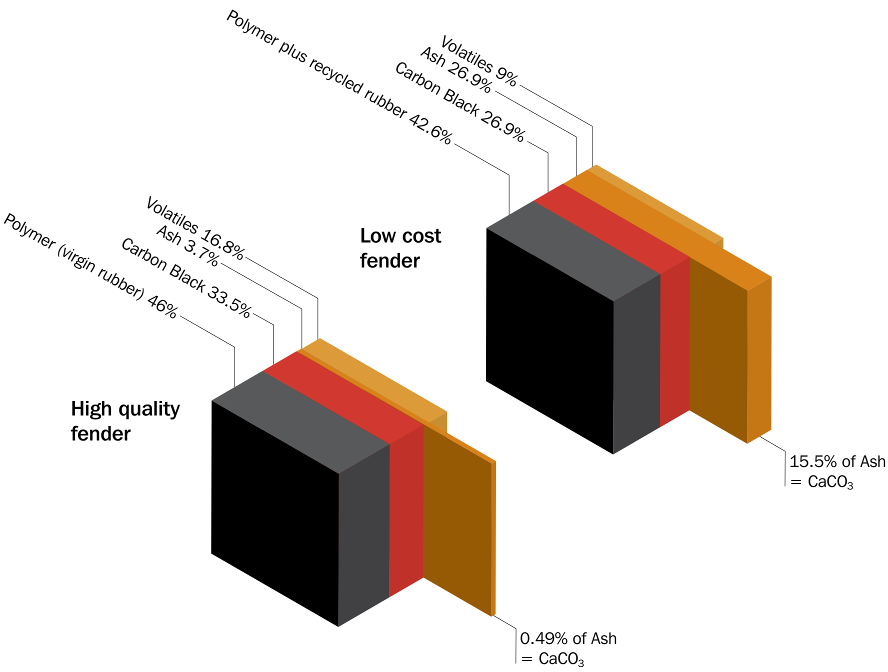
Benchmarking Performance – the results

Physical analysis:

Test	Standard	High quality fender	Low cost fender	Requirement
Density (g/cc)	ISO 2781	1.15	1.29	Not specified
Hardness (shore A)	ASTM D2240	67	71	Max. 78
Tensile Strength (Mpa)	ASTM D2240	15.4	9.3	15.2 - 13.6 (Note)
Elongation @ Break (%)	ASTM D2240	364	278	297 - 333 (Note)

2. For more detailed information on results, see footnote.

Chemical analysis:



NB: Carbon Black is the high quality, reinforcing filler. Ash contains $CaCO_3$, the non-reinforcing white filler.

Interpretation of Test Results

The cost of a fender is often reduced by using a higher percentage of recycled rubber, and low cost non-reinforcing white calcium carbonate ($CaCO_3$) fillers in the formulation. We found that fenders with recycled rubber and filler are heavier (and denser) than virgin rubber fenders. This significant weight difference enables a user to evaluate whether a fender uses low cost recycled materials, or is the genuine article, made with high performance rubber compound, with the benefits of long life and superior resilience.

Chemical and physical analyses revealed some further interesting insights into the materials used for manufacturing the fenders, and the properties these materials have:

- Values of tensile strength and elongation at break for the low cost fender were lower than the high quality fender and not in compliance with the user specification.
- Rubber to filler ratio (Polymer % : Carbon Black % + Ash %) for the high quality fender was 1.23. This simply means 1 kg of filler was blended with 1.23 kg of rubber. The rubber to filler ratio for low cost fender was only 0.88, which means 1 kg of filler was blended with just 0.88 kg of rubber.
- The low cost fender contained 28.45% less rubber than high quality fenders. The presence of more rubber in high quality fenders explains the reason behind better physical properties of these fenders, and also justifies the higher cost. For perspective, the cost of rubber is usually three times higher than fillers like carbon black.
- Most of the raw rubbers are weak when vulcanized and need reinforcing filler to increase mechanical properties of the final product. Ash analysis of the high quality fender indicated that it contains 100% carbon black filler which is high quality reinforcing filler.
- On the other hand, the ash analysis result of the low cost fender showed presence of only 55% carbon black and 45% $CaCO_3$. The price of $CaCO_3$ is approximately a fifth cheaper than carbon black. $CaCO_3$ is considered as white, non-reinforcing filler which is usually used to reduce the cost of the rubber compound but does not help in improving the properties.
- The density of low cost fender is 12% higher than the high quality fender. The reason behind the higher density of the lost cost fender could be attributed to the following two factors:
  - The presence of high density $CaCO_3$ in the formula at 15.54%, as determined by ash analysis. Note that density of $CaCO_3$ is 2.7 g/cc while that of Carbon black is 1.8g/cc.
  - The presence of a high percentage of recycled rubber in the formulation is the other contributing factor. The density of recycled rubber is 1.15 to 1.20 g/cc while that of virgin rubber is 0.92 g/cc.

Recycling of rubber is a hard line, energy intensive process in which rubber powder is cooked with aggressive chemicals. This process breaks long rubber molecules into shorter ones and thereby reduces the physical properties. Usually tensile strength of recycled rubber is one-third of virgin Natural rubber (NR). Chemical analysis showed that the low cost fender contained 60% NR. However, the low tensile strength, elongation at break and high density of the fender pointed towards the presence of high percentage of recycled rubber instead of virgin rubber.

Test now available

These newly developed physical and chemical tests provide a reliable, viable analytical method which can now be made available for buyers to be able to assess the composition of recently procured fenders prior to delivery, using a simple sampling procedure from the surface of the fender. This new technique will help to ensure that fenders supplied use the correct quality of rubber compound required to adhere to the specification.

The recommended tests to evaluate the quality of fenders, based on a sample of only 20-50grams are listed in the table below. These samples can be easily gathered by obtaining scrapings from the final product prior to installation, without affecting the fenders performance during application.

Test	Standard	Specification
Density	ISO 2781	Max 1.20 g/cc
Polymer %	ASTM D6370	Min. 45%
Carbon Black %	ASTM D6370	Min 20%
Ash %	ASTM D297	Max 5%

The need to test twice

Chemical testing is not enough the guarantee fender performance and full scale testing should also be performed in the factory to guarantee the lifecycle and performance of fenders meet the specification they are intended for.

As demonstrated, manufacturers with in house design and engineering capabilities are able to test their compounds in the laboratory and provide full scale testing on prototypes and finished products. It's therefore imperative that port owners and specifies understand the importance of not making procurement decisions purely based on up-front costs. The equipment will need to be replaced earlier, and in the long term, require heavier investment, not to mention the higher risks of failure during service life.

Decision makers should be aware of these key differences and the varying quality on offer when buying on the basis of short term cost savings. There is a need for the whole industry to come together to discuss changes to a culture that is causing unprecedented levels of downtime and putting ports at risk.

Footnotes

1. Analytical equipment like TGA/FTIR are not usually used in testing for the fender industry for quality control checks, but were applicable in this case to enable chemical analysis of the rubber compounds.

   TGA: Thermogravimetric Analysis measures the amount and rate of change in the weight of a material as a function of temperature or time in a controlled environment. Measurements are used primarily to determine the composition and predict thermal stability at temperatures up to 1000°C. The technique can characterize substances that exhibit weight loss or gain due to decomposition, oxidation or dehydration.

   FTIR: Fourier Transform Infrared Spectroscopy is most useful for identifying chemicals that are either organic or inorganic in nature. It can be utilized to quantify some components of an unknown mixture. It can be applied to the analysis of solids, liquids and gases. The term Fourier Transform Infrared Spectroscopy refers to a fairly recent development of the manner in which the data is collected and converted from an interference pattern to a spectrum. Today's FTIR instruments are computerized which makes them faster and more sensitive and accurate for composition analysis.

   NB: TGA/FTIR are unable to differentiate between virgin and recycled rubber generated from natural rubber.

2. It is assumed that tensile strength and elongation at break of samples prepared from cured product will be 5-15% lower than samples prepared in the laboratory by moulding of uncured rubber

3. Specification: Tensile Strength Min 16Mpa, Elongation at break 350% min. (Ref: Physical Testing of Rubber by Roger Brown, Chapter 3, page 47). The values reported were median of five reading. Tensile strength 16mpa min, E@B 350% min when tested in the compound. These values are lower when tested in the sample taken from final produce (fender).

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