Marine Safety Investigation Unit

Transport Malta


# MARINE SAFETY INVESTIGATION REPORT

**Safety investigation into the lifting sling failure and subsequent damage to the rescue boat on board the Maltese registered chemical / oil tanker**

# *SICHEM LILY*

**in Huelva, Spain**

**on 13 January 2013**

**201301/011**

**MARINE SAFETY INVESTIGATION REPORT NO. 02/2014**

**FINAL**

Investigations into marine casualties are conducted under the provisions of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011 and therefore in accordance with Regulation XI-I/6 of the International Convention for the Safety of Life at Sea (SOLAS), and Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council.

This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 13 January 2013. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

The findings of the safety investigation are not binding on any party and the conclusions reached and recommendations made shall in no case create a presumption of liability (criminal and/or civil) or blame. It should be therefore noted that the content of this safety investigation report does not constitute legal advice in any way and should not be construed as such.



MARINE SAFETY INVESTIGATION UNIT
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# CONTENTS

# LIST OF REFERENCES AND SOURCES OF INFORMATION

International Maritime Organization [IMO]. (1998). Resolution MSC.81(70). Revised recommendation on testing of life-saving appliances. London: IMO.

Managers and crew of MT *Sichem Lily*

University of Malta. Sling Analysis Lab Report

# GLOSSARY OF TERMS AND ABBREVIATIONS

| | |
|---|---|
| °C | Degrees Celsius |
| ATR-FTIT | Attenuated total reflectance Fourier transform infrared spectroscopy |
| BHP | Brake horse power |
| cm | Centimetres |
| DNV | Det Norske Veritas |
| HP | Horse power |
| IMO | International Maritime Organization |
| DNV | Det Norske Veritas |
| Kg | Kilogramme |
| kW | Kilowatts |
| m | metre |
| $m^3$ | Cubic metres |
| MSC | Maritime Safety Committee |
| m $min^{-1}$ | Metres per minute |
| MSIU | Marine Safety Investigation Unit |
| Rpm | Revolutions per minute |
| SOLAS | The International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended |
| T | Tonnes |
| UV | Ultra Violet |
| XRD | X-ray diffraction |

**SUMMARY**

On 13 January 2013, in the port of Huelva, Spain, *Sichem Lily* was undergoing a scheduled annual Cargo Ship Safety Equipment survey and inspection.

During the load-test of the rescue boat launching appliance, the three point lifting sling failed. The boat fell in the sea. There were no crew members on board. The boat was eventually recovered and secured on board.

No injuries and / or pollution were reported.

Following the accident, the laboratory analysis after destructive and non-destructive testing of the three point lifting sling concluded that the material used for stitching the lifting sling splice had failed during the launching of the boat. The tests further concluded that the stitching material had degraded along one side of the lifting sling for almost its entire length. The weakening and eventual failure of the stitches was attributed to age, wear and tear, and exposure to Ultra Violet (UV) and the harsh elements of the sea.

The Marine Safety Investigation Unit (MSIU) has issued recommendations to the vessel's managers and Norsafe AS as the manufacturers of the 'Matrix 450' Rescue Boat with the scope of improving the inspection, maintenance and eventual disposal of the lifting slings against a set criteria, with the aim of preventing future similar accidents.

# 1 FACTUAL INFORMATION

## 1.1 Vessel, Voyage and Marine Casualty Particulars

| | |
|---|---|
| Name | *Sichem Lily* |
| Flag | Malta |
| Classification Society | Det Norske Veritas |
| IMO Number | 9393395 |
| Type | Chemical / Oil Tanker |
| Registered Owner | Eitzen Chemical (Singapore) PTE Ltd. |
| Managers | Thome Ship Management Pte Ltd. |
| Construction | Steel |
| Length overall | 115.255 m |
| Registered Length | 107.4 m |
| Gross Tonnage | 5744 |
| Minimum Safe Manning | 16 |
| Authorised Cargo | Liquid cargo - Chemicals |
| Port of Departure | Safi, Morocco |
| Port of Arrival | Huelva, Spain |
| Type of Voyage | Short international |
| Cargo Information | Phosphoric acid |
| Manning | 18 |
| Date and Time | 13 January 2013 at 1630 |
| Type of Marine Casualty or Incident | Less Serious Marine Casualty |
| Location of Occurrence | Huelva |
| Place on Board | Ship – Boat deck |
| Injuries/Fatalities | None |
| Damage/Environmental Impact | None |
| Ship Operation | Normal operation – Alongside/moored |
| Voyage Segment | Alongside |
| External & Internal Environment | North Westerly winds at seven knots. Good visibility with an air temperature f 18 °C |
| Persons on Board | 18 |

## 1.2 Description of Vessel

*Sichem Lily* is a double hull chemical / oil tanker, owned by Eitzen Chemical (Singapore) PTE Ltd. The vessel was built by Sekwang Heavy Industries, Ulsan, Korea in 2008 and is classed by Det Norske Veritas (DNV).

*Sichem Lily* has a length overall of 115.25 m, a moulded breadth of 18.223 m and a moulded depth of 9.60 m. The vessel has a summer draught of 7.45 m and a summer deadweight of 8110 tonnes.

The vessel is fitted with five pairs of cargo tanks on port and starboard with a total volumetric capacity of 8731.9 $m^3$. She is mainly engaged in the carriage of chemicals in bulk.

Propulsive power is provided by a 6-cylinder MAN-B&W 6L35MC, two stroke, single acting, medium speed diesel engine, producing 4200 kW at 210 rpm. This drives a single pitch blade propeller, giving a service speed of 14.0 knots.

*Sichem Lily* is equipped with a range of safety equipment, including a free fall lifeboat and 'Matrix 450' rescue boat, which is fitted with an outboard engine.


**Figure 1: MT *Sichem Lily***

## 1.3 The Rescue Boat

The rescue boat 'Matrix 450' was designed and manufactured by Norsafe AS. The hull of the 4.5m rescue boat was moulded from fire retardant polyester resin and the buoyancy spaces were filled with polyurethane foam. It weighed about 450 kg including equipment and fuel, and was capable of carrying up to 15 persons (Figures 2 and 3). The rescue boat was propelled by an 18 HP outboard engine and was capable of reaching a speed of six knots with six persons on board.

The rescue boat formed part of the ship's life saving equipment and was therefore certified of being built in accordance with the requirements of the amended SOLAS Convention and the relevant MSC Resolution[1].

**Figure 2: Rescue boat 'Matrix 450' fitted with an outboard engine**

1 MSC. Resolution 81(70) part 1, section 6 and Resolution MSC. 81(70) part 2, section 1.1.

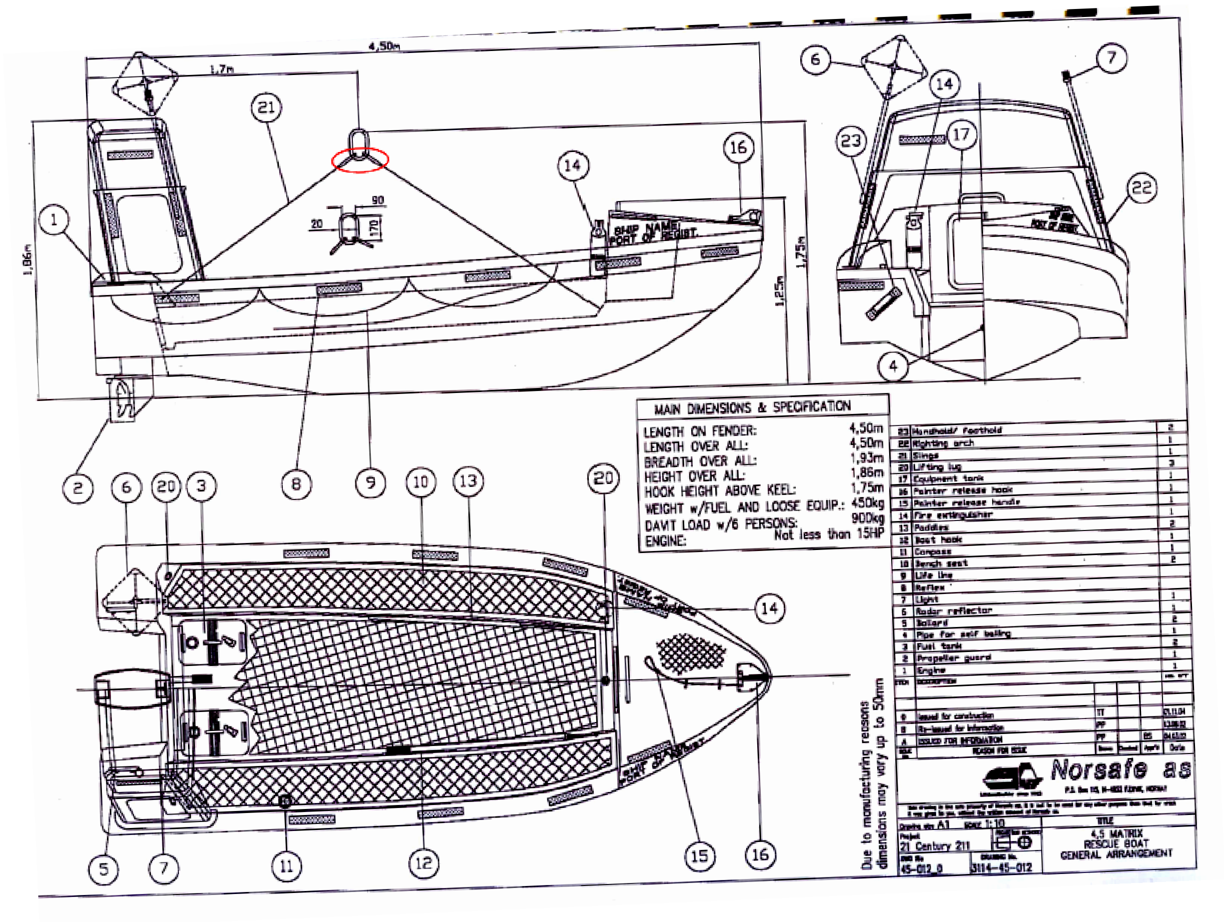


**Figure 3: Rescue boat General Arrangement Plan**

## 1.4 Launching Arrangement

The rescue boat is launched by the ship's davits / crane (Figure 4). The davits' fall is hooked to a ring, which in turn is connected to the three point lifting sling. During the launching operation, the rescue boat is swung out over the ship's side and then lowered. Being a rescue boat, the lowering speed is between 54 to 72 m $min^{-1}$. Each individual lifting sling was made up of synthetic webbing strap about 10 cm wide. The ends were overlapped and stitched together to form an eye or loop.

Each eye / loop was covered with a fibre sleeve to prevent chafing against the boat lugs and connecting ring. The lifting sling had to be released manually by lifting it off the hook when the boat was fully waterborne.

The three point lifting sling was tested on 13 June 2008 to a load of 3.75 tonnes. The sling's safe working load was certified at 1.50 tonnes.

The Life Saving Appliance Certificate is attached as **Annex A**.

**Figure 4: Davit/crane for launching rescue boat**

## 1.5 Rescue Boat Inspection and Maintenance Schedule

Company Form TSM 088 (**Annex B**), which was provided by the vessel, showed a very comprehensive weekly maintenance / inspection of the rescue boat and its ancillary safety equipment. The third mate was assigned the responsibility of the rescue boat maintenance. The rescue boat and ancillary equipment were last visually inspected on 05 January 2013, eight days before the accident. No abnormalities were recorded.

## 1.6 Narrative

On 13 January 2013, at 1500[2], *Sichem Lily* berthed in the port of Huelva, Spain to discharge 6126.6 tonnes of phosphoric acid.

*Sichem Lily* was scheduled for the annual Cargo Ship Safety Equipment survey and inspection in Huelva. At about 1530, two DNV surveyors, along with service engineers from Dextinsur S. L., a company appointed to do annual inspection of safety equipment, boarded *Sichem Lily*. A safety meeting was held by the master to plan out the sequence and method of inspections. The meeting was attended by the chief engineer, the chief mate, the DNV surveyors and Dextinsur S. L. engineers.

At 1615, the safety inspection commenced with a winch brake test of the rescue boat. This involved operating the davit / crane and applying the brakes while lowering the rescue boat over the ship's side. The rescue boat, without personnel on board, was initially lowered at different speeds. The brakes were then applied just before it reached the water level.

On the third attempt, as the boat was being launched and lowered at a faster speed, the lifting sling attached to the boat's forward lug (Figure 5) failed when the brakes were applied. This caused a sudden shift of load to the remaining lifting slings. The two aft lifting slings, unable to take the extra tension, also failed almost concurrently, and the rescue boat fell into the sea.

**Figure 5: Failed section of the forward lifting sling**

[2] Unless otherwise stated, all times are ship's time (UTC +1).

There were no reported injuries and pollution.  The port authorities were informed and at about 1910, the harbour service boat recovered the vessel's rescue boat from the water.

## 1.7 Environmental Conditions

The vessel was in port with calm sea conditions; wind about seven knots from the North West.  The air and sea temperatures were 18°C and 17°C respectively.

# 2 ANALYSIS

## 2.1 Aim

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

## 2.2 Rescue Boat Maintenance Schedule

Thome Ship Management Pte Ltd. had a structured safety equipment maintenance schedule for the rescue boat, as indicated in TSM Form 088 (**Annex B**). On 05 January 2013, *i.e.* a week before the accident, the launching appliances were inspected and found operationally ready for use. However, for almost four years since the delivery of the vessel in 2009, the lifting slings had been continuously used and exposed to the natural environment.

Although the lifting sling webbing visually appeared in fairly good condition, the stitches forming the loop showed signs of ageing. A number of individual stitches were already either worn or broken. In retrospect, the weekly inspections of the lifting sling by the third mate appeared to be subjective; there being no specific direction or requirement in the safety management system on the stitches or stitching material forming the loop.

The intrinsic safety of a piece of equipment may be related to its design and quality of material. However, its safety after it has been installed is mostly attributed to, *inter alia*, maintenance. Therefore, inadequate maintenance or inability to predict failures which may occur throughout its lifespan, is correlated to lack of reliability. In fact, reliability is considered to be a key indicator of maintenance efficiency.

Integrity management of equipment and (preventive) maintenance are related. Actually, while integrity management is a process which starts from the design to the discarding of the equipment after its lifespan would have expired, preventive maintenance is one important step within the integrity management process.

Therefore, lack of preventive maintenance (which may also encompass regular testing and thorough inspections) has the potential to stall the maintenance regime adopted on board, endanger the ship and persons on board, and necessitate the switch from preventive maintenance to breakdown maintenance, which is not necessarily an optimal situation on board a ship.

## 2.3 Examination and Testing of the Three Point Lifting Sling

The lifting slings, which were recovered from the accident site, were collected by the MSIU and subsequently tested at an engineering lab. The purpose of the tests was to provide the MSIU with a technical analysis for the failure of the lifting slings.

The lifting slings were subjected to visual and technical examinations, using destructive and non-destructive testing techniques. The stitches forming the loop were also tested for tensile load.

Full lifting sling analysis and the laboratory test report is attached as **Annex C**.

The visual examination show that the lifting slings were evenly aged. The green colour of webbing material exposed to the sun appeared bleached and lighter, whereas the inside sections of the loop surfaces had a bright greenish colour (Figure 6).

**Figure 6: Failed section exposed to sunlight**

There was no evidence of damage, abrasion, wear, cuts or snags. The stitching at the spliced section was clearly pulled out and appeared to be the result of thread failure.

A detailed microscopic investigation was then conducted to establish whether the damage to the stitching fibres had happened over an extended period of time or occurred as a result of the abrupt failure during launching of the boat. Micrographic imaging showed that the lifting sling webbing was sufficiently protected from the elements underneath intact regions of the stitching pattern, allowing the yarn of the former to maintain its original green colour. However, there were several areas on the lifting sling webbing under the white stitching thread which appeared discoloured; suggesting that breaking of the stitching thread had been occurring for some time.

In fact, the complete absence of green pigment under the stitches confirmed that the stitching thread had been absent for a considerable period of time. Moreover, the sling webbing under these stitches showed no signs of wear and tear, except for the presence of salt crystals and other fine grit. Following micrographic imaging, it was concluded that the stitching present prior to the sling failure and more specifically at the splice, had been already severely degraded, completely broken or significantly worn.

Although, neither the loading parameters nor the condition and layout could precisely replicate the conditions experienced by the sling during actual launching, the tensile test did demonstrate that the degree of thread damage affected the residual strength of the sling. Three tensile tests were conducted in such a way to measure the (shear) loading, which could be sustained by the stitches along the sling splice prior to these being pulled through the webbing. The sample with the stitching in the poorest condition showed a massive reduction in the load required to separate the two parts of the sling webbing.

Once the load reached 253 kg, the stitching thread pulled clean through the webbing material. These samples were tested along their principal axis. In practice, three point slings are used at an angle and therefore, their rated capacity would decrease, meaning that the load which would have been safely supported by this sling would have been even less than that measured in this test.

Although all synthetic fibres are susceptible to UV degradation, the degree of degradation, however, largely depends on the fibre type. The severe degradation of the stitching thread relative to the sling webbing suggested dissimilar materials used for the sling webbing and stitching. Therefore, further tests were carried out to analyse the material used in the sling webbing and the used thread for stitching the ends of the sling forming the loop/eye. This was essential to clarify whether the stitching was made of appropriate material, capable of withstanding the environmental conditions to which it was exposed.

Initially, a simple burn test confirmed that the sling webbing and thread material were made of different materials. They were then subjected to X-ray diffraction (XRD) and material analysis, and attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy to identify the exact nature of the two materials. The XRD patterns generated for the sling webbing and stitching correlated with synthetic polymer fibres respectively to polyester and nylon.

These results were also confirmed by ATR-FTIR spectrometer, an analytical tool used for screening and profiling polymer fibres. The polyester fibre pigmented dark green of the sling webbing was more resistant to UV, humidity, water and sea-air. This explained why the degradation of stitching made of white nylon thread was more severe under the same environmental conditions.

**THE FOLLOWING CONCLUSIONS, SAFETY ACTIONS AND RECOMMENDATIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.**

# 3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

## 3.1 Immediate Safety Factor

.1 The rescue boat fell following the failure of the thread stitched to form an eye / loop in the sling webbing.

## 3.2 Latent Conditions and other Safety Factors

.1 The thread was severely degraded and worn over time from the harsh environment of the sea and sun. This resulted in severe reduction of load strength and pull-out of stitches during the rescue boat test.

.2 There were neither periodic tests nor preventative maintenance measures in place with respect to the rescue boat slings.

# 4 RECOMMENDATIONS

In view of the conclusions reached,

**Thome Ship Management is recommended to:**

***02/2014_R1*** Amend its safety management system manual to include procedures on the inspection and eventual renewal of lifting slings with particular attention to stitches forming the loop.

**Norsafe AS is recommended to:**

***02/2014_R2*** Promulgate and issue awareness notice to its customers and introduce written instructions and guidelines on periodic inspection, maintenance, retirement/replacement of lifting sling and/or proof testing, where necessary.

# ANNEXES

## Annex A Life Saving Appliance Certificate

### LIFE-SAVING APPLIANCE CERTIFICATE

*This LSA is manufactured in accordance with Chapter III of the International Convention for the Safety Of Life At Sea (SOLAS), 1974 as amended and IMO Resolution MSC.48(66). EC-type examined by the See-Berufsgenossenschaft (See-BG)*
*The LSA is tested and inspected according to IMO Resolution MSC.81(70) part 2, section 5.3.1 and 5.3.3 for Life- and Rescueboats respectively 5.3.2 and 5.3.3 for Free Fall Boats, and to ISO 9001 assessed Quality Assurance System of Norsafe a.s.*

| | | | |
|---|---|---|---|
| Build no. | 21488 | Month/year of production | June,2008 |
| Boat type | Matrix 450 | | |
| Version | Rescueboat | | |
| Regulation | IMO Resolution MSC.48 (66), LSA Code Chapter V, Rescueboats | | |
| Approval no. | 403.033 | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Engine type | TOHATSU 18HP | Serial no.: | 066920XG | | | | |
| Propulsion | | Serial no.: | | Bollard pull: [kN] | | 1.2 kN | |
| Air cylinders | | Serial no. | | | | | |
| Lifting arrangement | 3-point lifting sling | Serial no. | 08027 | Test load | 3.75T | S.W.L. | 1.50T |
| | | Serial no. | | Test load | | S.W.L. | |

| | | | |
|---|---|---|---|
| Dimensions (LxBxH) | 4.50 X 1.96 X 1.85 m | No. of persons | 6 |
| Weight with equipment | 450 Kg | Total davit load | 900 Kg |
| Volume of buoyancy matr. | 1.228m3 | Buoyancy material : | Polyurethane Foam |
| Hull material | GRP with Fire Retardant Polyester Resin | | |

| | | | |
|---|---|---|---|
| Delivered to | Sekwang Heavy Industry 1170 | Date: | 13th June,2008 |

[redacted]

Boatbuilder signature

[redacted]

Norsafe QC inspector signature

*This is to certify that this LSA is built in accordance to the the International Convention for Safety Of Life At Sea (SOLAS) 1974 as amended. IMO Res. MSC. 81(70) Part 1, section 6 and that the manufacturer is subject to random inspection in accordance with IMO Res. MSC. 81(70) part 2, section 1.1.*

NORSAFE FIBREGLASS REINFORCED PLASTIC CO. LTD JIANGYIN 江阴 挪赛大玻璃钢有限公司

0736 08

Stamp: 江阴挪赛大玻璃钢有限公司 质检部 Quality Control Dept. JIANGYIN NORSAFE F.R.P. CO., LTD.

| | | | |
|---|---|---|---|
| Onboard test place : | | Date : | |

Classification society signature:

Stamp :

| | | |
|---|---|---|
| Address : [redacted] | Phone : Fax. no: Email: | [redacted] |

## Annex B Maintenance Schedule

THOME MANAGEMENT PTE LTD

**TSM Form No. 088**
**Safety Equipment**
**& Load Line Survey**
**Maintenance Schedule**

### Weekly Requirements

| Week No | | | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 2 Lifeboat | RESCUE BOAT | | Check Box | | | | | | | | | | | | |
| Releasing Gear and Hook | The condition of Releasing Hook | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | On-load release Gear to be properly/ completely reset | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Attachment for the Boat | Drain Valve | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Rudder and Tiller | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Handhold or Bouyant Lifeline outside of Hull | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Hand-hold on underside of Hull | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Watertight Locker or Compartments | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Painter and Painter securing device | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Arrangement for sitting and securing antenna | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skates and Fender fitted with Lifeboat | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Flashed manually controlled Lamp (Canopy Light) | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Illumination Light | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Launching Applicances | Boat to be moved from stowed position for confirming operation | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Condition of Boat Davit/Launching Appliances | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Life Boat Engine | Test run for total more than 3 minutes | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Checking condition of gear box and gear box train | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

| | | | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 1 Liferaft | Location ( FWD STBD SIDE ) | | | | | | | | | | | | | | |
| No. 2 Liferaft | Location ( AFT A DECK STBD ) | | | | | | | | | | | | | | |
| No. 3 Liferaft | Location ( AFT A DECK PORT ) | | | | | | | | | | | | | | |
| No. 4 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 5 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 6 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| Checking Officers Confirmation. | | Initials/Date | 3/0EM 03/04/12 | 3/0EM 12/04/12 | 3/0 EM 19/04/12 | 3/0EM 26/05/12 | 3/0EM 02/05/12 | 3/0EM 09/05/12 | 3/0EM 06/05/12 | 3/0EM 23/05/12 | 3/0EM 31/05/12 | 3/0EM 9/06/12 | 3/0EM 16/06/12 | 3/0EM 23/06/12 | 3/0 [illegible] 07/07/12 |

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Revision: 01 Jan 2011
Approved by DPA/DMR
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## Weekly Requirements

| **Week No** | | | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **No. 2 Lifeboat** RESCUE BOAT | | | Check Box | | | | | | | | | | | | |
| Releasing Gear and Hook | The condition of Releasing Hook | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | On-load release Gear to be properly/ completely reset | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Attachment for the Boat | Drain Valve | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Rudder and Tiller | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Handhold or Bouyant Lifeline outside of Hull | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Hand-hold on underside of Hull | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Watertight Locker or Compartments | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Painter and Painter securing device | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Arrangement for sitting and securing antenna | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skates and Fender fitted with Lifeboat | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Flashed manually controlled Lamp (Canopy Light) | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Illumination Light | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Launching Applicances | Boat to be moved from stowed position for confirming operation | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Condition of Boat Davit/Launching Appliances | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Life Boat Engine | Test run for total more than 3 minutes | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Checking condition of gear box and gear box train | ◷ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | | | | | | | | | | |
| No. 1 Liferaft | Location ( FWD ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 2 Liferaft | Location ( PORT SIDE A DECK ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 3 Liferaft | Location ( STBD SIDE A DECK ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 4 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 5 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 6 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| Checking Officers Confirmation. | | Initials/Date | 14 JUL 12 [illegible] | 21 JUL 12 [illegible] | 26 JUL 12 [illegible] | 02 AUG 2012 [illegible] | 11 AUG 2012 [illegible] | 16 AUG 2012 [illegible] | 3/O Aug 18 AUG 2012 | A.G 25 AUG 2012 | 3/O GA 31 AUG 12 | 3/O G.A 07 SEP 12 | 3/O G.A 13 SEP 12 | 3/O G.A 21 SEP 12 | 3/O GA 28 SEP 12 |

[redacted]

## Weekly Requirements

| Week No fl | | | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 2 Lifeboat RESCUE BOAT | | Check Box | | | | | | | | | | | | | |
| Releasing Gear and Hook | The condition of Releasing Hook | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | On-load release Gear to be properly/ completely reset | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Attachment for the Boat | Drain Valve | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Rudder and Tiller | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Handhold or Bouyant Lifeline outside of Hull | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Hand-hold on underside of Hull | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Watertight Locker or Compartments | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Painter and Painter securing device | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Arrangement for sitting and securing antenna | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Skates and Fender fitted with Lifeboat | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Flashed manually controlled Lamp (Canopy Light) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Illumination Light | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Launching Applicances | Boat to be moved from stowed position for confirming operation | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Condition of Boat Davit/Launching Appliances | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Life Boat Engine | Test run for total more than 3 minutes | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Checking condition of gear box and gear box train | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | | | | | | | | | | | | | | |
| No. 1 Liferaft | Location ( FWD ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 2 Liferaft | Location ( AFT A DECK STBD ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 3 Liferaft | Location ( AFT A DECK PORT ) | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| No. 4 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 5 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| No. 6 Liferaft | Location ( ) | | | | | | | | | | | | | | |
| Checking Officers Confirmation. | | Initials/Date | GA 3/0 05 OCT 12 | GA 3/0 13 OCT 12 | GA 3/0 20 OCT 12 | GA 3/0 27 OCT 12 | 3/0 03 NOV 12 | 3/0 10 NOV 12 | 3/0 17 NOV 12 | 3/0 24 NOV 12 | 3/0 01 DEC 12 | 3/0 09 DEC 12 | 3/0 15 DEC 12 | 3/0 22 DEC 12 | 29 DEC 12 |

[redacted]

**THOME**
*SHIP MANAGEMENT PTE LTD*

**TSM Form No. 088**
**Safety Equipment**
**& Load Line Survey**
**Maintenance Schedule**

## Weekly Requirements

| Week No → | | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | | **Check Box** | | | | | | | | | | | | | |
| All survival craft & rescue boats launching appliances are to be visually inspected to ensure that the equipment is operationally ready for immediate use. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Lifeboat & Rescue Boat engine/s are to be operated for a minimum of three (3) minutes with gears being engaged in both forward and reverse. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Test of General Emergency Alarm. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Test of all Other General Alarms and PA System. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Check & confirm all SCBA, EEBD, ELSA & lifeboat air bottles are not leaking & are fully charged with compressed air ready for use. | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| **No. 1 Lifeboat** | | **Check Box** | | | | | | | | | | | | | |
| Releasing Gear and Hook | The condition of Releasing Hook | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | On-load release Gear to be properly/ completely reset | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Attachment for the Boat | Drain Valve | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Rudder and Tiller | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Handhold or Bouyant Lifeline outside of Hull | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Hand-hold on underside of Hull | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Watertight Locker or Compartments | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Painter and Painter securing device | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Arrangement for sitting and securing antenna | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Skates and Fender fitted with Lifeboat | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Flashed manually controlled Lamp (Canopy Light) | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Illumination Light | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Launching Applicances | Boat to be moved from stowed position for confirming operation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Condition of Boat Davit/Launching Appliances | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Life Boat Engine | Test run for total more than 3 minutes | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| | Checking condition of gear box and gear box train | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | |
| Checking Officers Confirmation. | | Initials/Date | [illegible] | AA [illegible] | AA [illegible] | AA [illegible] | AA [illegible] | | | | | | | | |

CONTROLLED

Revision: 01 Jan 2012
Approved by DPA/DMR

# Annex C Sling Analysis Laboratory Report

L-UNIVERSITA TA' MALTA
Msida MSD 2080 – Malta
*DIPARTIMENT TAL- METALLURGIJA U MATERJALI*

UNIVERSITY OF MALTA
Msida MSD 2080 – Malta
*DEPARTMENT OF METALLURGY AND MATERIALS*

| | |
|---|---|
| Customer ID. | Dr. Kevin Ghirxi<br>Head of Marine Safety Investigation<br>Marine Safety Investigation Unit<br>Malta Transport Centre<br>Marsa MRS 1917<br>Malta |
| Customer reference: | **Lab test of 3 rescue boat slings**<br>(PO016229)<br>MT Sichem Lily IMO # 9393395 |
| DMME ref no. | 40005873 |
| Purchase Order No. | 016229 |
| Date of issue. | 24th April 2013 |
| Report compiled by: | Dr Ing. Glenn Cassar<br>*Lecturer*<br>Rm105, Engineering Building<br>Department of Metallurgy and Materials Engineering<br>Faculty of Engineering<br>University of Malta<br>Tel.: (356) 2340 2140<br>Fax: (356) 2134 3577<br>e-mail: glenn.cassar@um.edu.mt |

## Objective

The purpose of this report is to provide the Marine Safety Investigation Unit, Malta, with a technical analysis for the failure of a *NORSAFE AS three-point lifting sling*. This multi-legged sling was intended for launching a 4.5m 'Matrix 450' rescue boat; however, it failed during lowering. The rescue boat has a davit load of 900 kg, which would include the boat (together with equipment and fuel) and a total of six people on board [1].

## Methodology

The three-point lifting sling provided (without its eye ring connection/masterlink) was visually inspected and then examined using both destructive and non-destructive characterisation and testing techniques which included the following:

- Stereomicroscopy for detailed visual examination
- X-ray diffraction (XRD) for material analysis
- Attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy for material analysis
- Tensile testing for assessing the stitching pull-out strength

## Results and Discussion

Visual examination of the lifting sling showed that failure of all three legs occurred at the (load-bearing) stitching where the eye loop lap was stitched to the sling body, as shown in Figure 1. In this case, the sling manufacturer has created a continuous loop which is closed by joining the ends of the webbing together with a portion of the web sling length. Separation of the stitch pattern at the splice appeared to be the result of thread failure. The stitching was clearly pulled out of two of the three plies constituting the single load-bearing splice in this sling type. Thus, the principal objective of this work was to determine why this specific mode of failure had occurred in at least one of the legs during launch of the rescue boat. Considering the three-point lifting arrangement of the boat [2] and the fact that all three legs have indeed failed it appears that the failure of a single leg during operation necessarily created a sudden shifting of load to the remaining legs which notably exceed the *residual* strength of these legs thereby causing their almost concurrent failure.

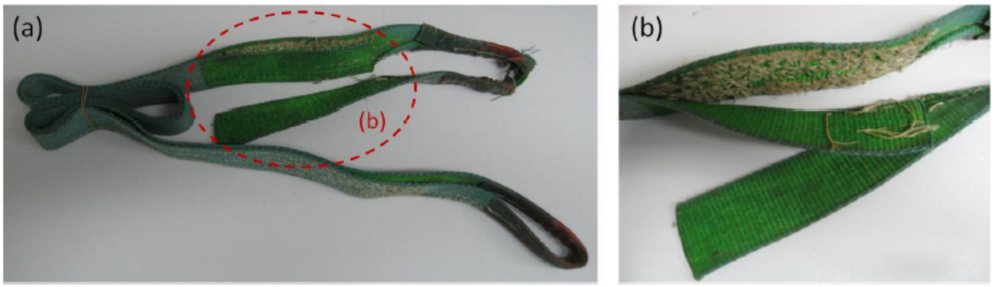


**Figure 1 (a) One of the three sling legs, showing web splice failure and (b) load bearing splice region showing lap pulled apart.**

Firstly, the three sling legs were examined for evidence of mechanical damage and wear, particularly focusing on the splice area. The examination of the entire length of the three sling legs showed no visible cuts or gouges, abrasion or scuffing damage, punctures, snags, melted or charred regions. Similarly, no weft thread damage nor warp thread separation was noticed in the web material. Thus, it appears that the slings were not in long-term contact with edges, protrusions or abrasive surfaces which could have reduced the expected lifetime of the rigging. If this was the case one should be able to observe localised signs of damage, instead the slings appear to be rather evenly aged along their entire length.

Secondly, visual inspection showed that the stitching thread was severely damaged along large portions of the sling body – including the splice region; however, more detailed investigation was needed to establish whether this was present prior to the failure event or whether the sling failure and consequent instantaneous overloading episode could have ruptured at least part of the stitching.

Microscopical investigation was necessary to recognize whether damage to the stitching fibres had happened over an extended period of time or had occurred as a result of the abrupt failure incident. It is proposed that the change in colour of the webbing material when exposed to sunlight can be used as an indication of how recent stitching threads had been removed. While webbing material which was not being exposed to direct sunlight - such as inside the eye loop surfaces or between plies – has a bright greenish colour, most external surfaces appear bleached out to a cyan-like colour. Micrographic imaging shows that underneath intact regions of the stitching pattern the sling webbing was sufficiently protected from the elements allowing the yarn of the former to maintain its original green colour, Figure 2a, b.

Several locations where the (white) sewing thread should have been masking the underlying webbing filaments appeared discoloured, suggesting that local breaking of the stitching had been occurring for some time (Figure 2c). Such sites could easily be distinguished from others where the stitching was more recently removed and thus still appeared markedly greener in colour (Figure 2d).

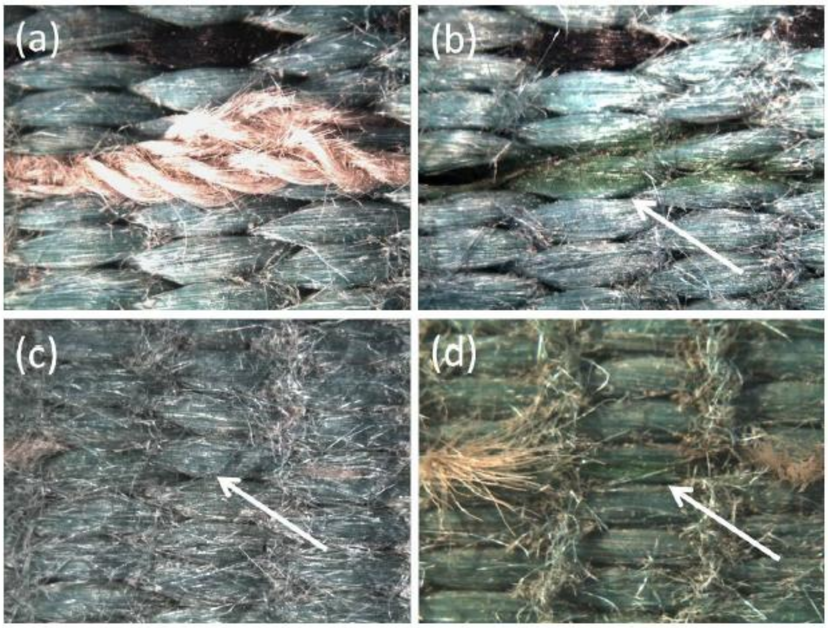


**Figure 2 (a) Webbing section with superimposed unbroken stitch; (b) Same sling portion shown in (a) after stitch has been removed; (c) Recently broken stitch exposing underlying webbing; (d) Sling portion where stitching has been completely removed for some considerable amount of time. Arrows mark regions which were originally crossed over by a stitching thread.**

Extensive fibre damage and breakage could be observed along major parts of the sling body such that the entire rope appears to be covered with fuzz or whiskers and complete absence of light green patches (where the stitching should have been) shows that stitching has been absent for a considerable amount of time. Figure 3 shows different segments of the sling; section (1) shows virtually intact webbing and stitching, section (2) shows significant broken and worn stitching, while in section (3) almost no stitching is remaining and the two plies constituting this section were completely detached. It is important to highlight that sling sections such Figure 3 (1) and (2) were often two faces of the same stretch of sling, suggesting that the a particular side of each leg was more often exposed to direct sunlight. Clearly, substantial degradation of the stitching does not need to be from both sides of the webbing to render it useless.

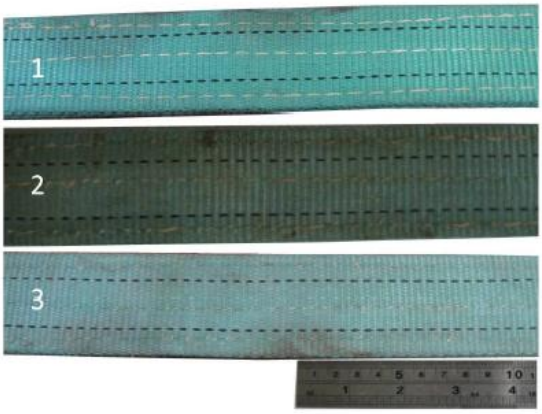


Figure 3 Three sections of the sling showing different level of stitching damage.

Interestingly higher magnification imaging (Figure 4) of the section shown in Figure 3 (1) shows that individual yarn fibres forming apparently 'healthy' stitches may still be damaged, while the same cannot be said for threads forming the sling webbing (Figure 4c). The latter shows no sign of wear and tear, except for the presence of salt crystals and other fine grit. Furthermore, during examination of more extensively degraded sections, such as those shown in Figure 3 (2) and (3), no ruptured yarns were observed in the webbing and damage was limited to individual broken fibres (Figure 2). In contrast, as already described the stitching was extensively damaged.

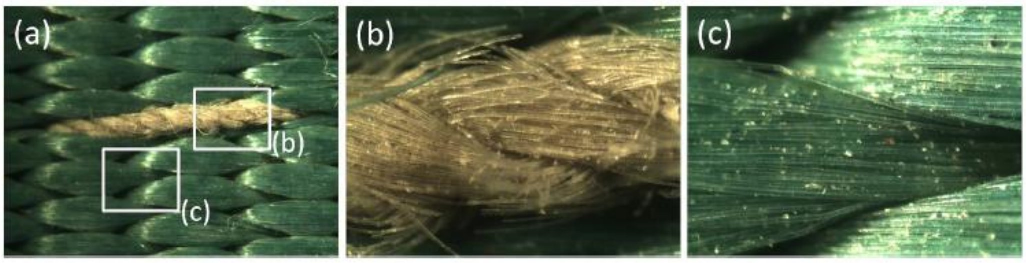


Figure 4 Optical micrographs of relatively undamaged regions of the sling.

Considering that damage to the stitching could not be attributed to say attrition against other bodies one can therefore conclude that the stitching present prior to the sling failure, most importantly at the splice, was already severely degraded. In fact, stitching at the other end of the sling i.e. of the remaining unbroken loop eye was also observed and this showed that the vast majority of the stitches were completely broken or significantly worn (encircled region in Figure 5). The broken stitching is evidently prone to slip through the webbing when relatively low loads are applied.

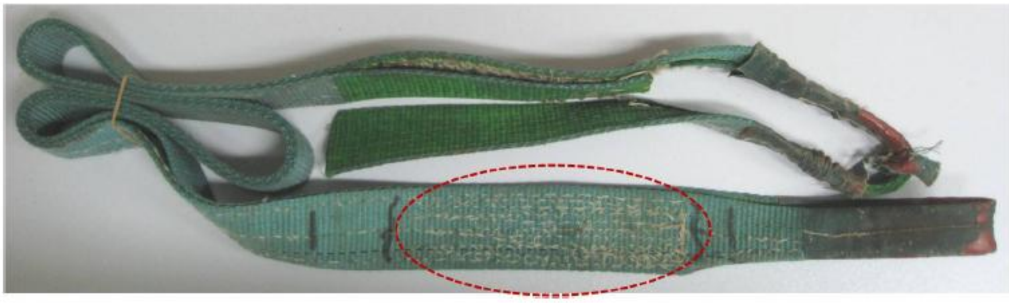

**Figure 5 Sling leg used for tensile testing.**

## Tensile Testing

In order to determine the residual strength of the stitched webbing plies, the remaining unbroken ends of the three legs were modified to replicate a stitched load-bearing lap. It is reasonable to assume that that the stitching fibres on the failed end of the slings were at least as damaged as the ones on the surviving side of the sling, and therefore failure would have occurred in a similar fashion.

Tensile tests were conducted in such a way as to measure the (shear) loading which could be sustained by the stitches along the sling splice prior to these being pulled through the webbing. In order to design such an experiment the leg ends were cut at the loop eye and at around 30cm into the length of the sling. This allowed the stitching portion to be tested. The clamping arrangement is shown in Figure 6.

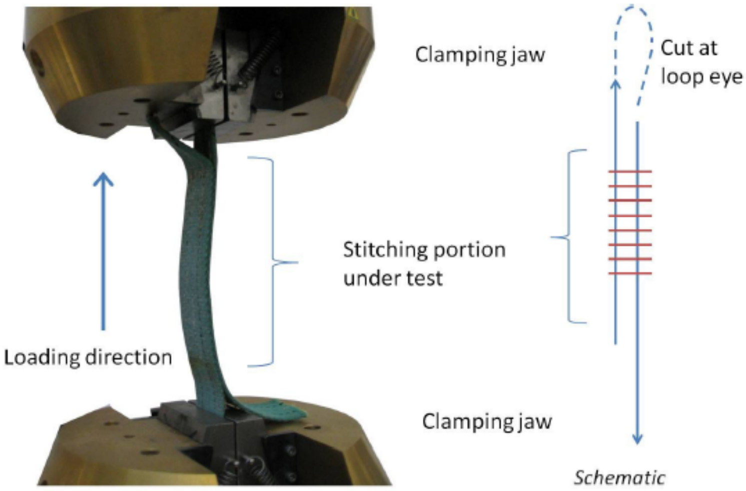


Figure 6 Tensile testing setup.

Clearly, neither loading parameters nor the sample condition and layout precisely replicated those experienced by the sling during operating; however, this test could demonstrate how the degree of thread damage largely affected the residual strength of the stitched lap. Figure 7 shows the results obtained for all three tensile tests. The samples obtained from the three sling legs show markedly different maximum loading prior to failure. The sample with the stitching in the poorest condition (sample 3) showed a massive reduction in the load required to separate the two plies. Once the load applied reached around 253 kg the stitching thread pulled clean through the webbing material. Indeed very few stitches had to break before this could happen since for the most part the stitches were partly or broken altogether.

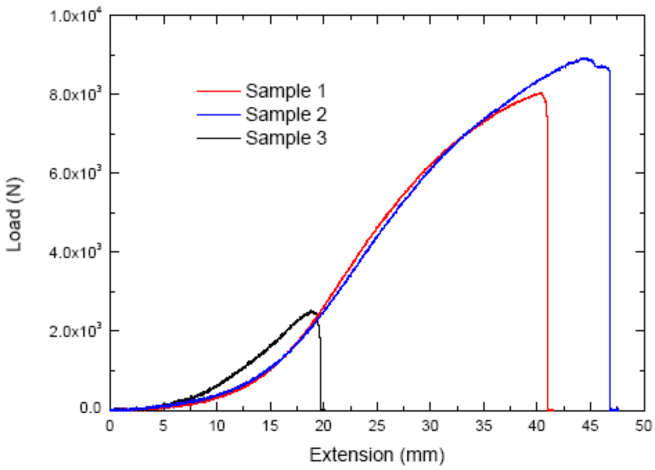


Figure 7 Load-Extension plots for samples 1, 2 and 3 with measured maximum loads of 8.93 kN, 8.04 kN and 2.53 kN respectively.

One should also note that these samples were tested along their principal axis; while multi-legged slings necessarily have to be used at an angle and this angle between sling leg and the horizontal line decreases, the rated capacity of the sling also decreases. In other words, the load which would have been safely supported by this leg would have been less than that measured here. Also, although a breaking load of 253 kg is clearly well below the working load limit of this type of sling, it would have been (just) sufficient (together with the other two legs) to lift the unmanned rescue boat. It is likely that the failed splices had similar residual strength values which upon experiencing some sudden thrust during the relatively rapid deployment of the safety vessel could have easily been exceeded.

## Material Analysis

Yarns from both the sling webbing and stitching were also analysed in order to determine the material used for each. This was considered essential in order to understand whether the sling was made of appropriate materials capable of withstanding the environmental conditions to which it was exposed. Furthermore, the severe degradation of the stitching threads, which ultimately led to the failure of the load-bearing spliced lap(s), and its apparent inferiority in terms of resistance to the environment suggested that the webbing and stitching materials could be dissimilar. This contrasted with the information provided by the vessel's master [3] who reported that the sling was made out of "100% polyester". Indeed, although all fibres are susceptible to ultraviolet light (UV) degradation; the degree of degradation still largely depends on the fibre type. For this reason, synthetic web slings are not usually recommended where extensive and continuous exposure to sunlight is expected.

Initially, a simple burn test [7] was conducted in order to check whether the webbing and thread material could indeed be made of different materials. A small portion of each was burned and the reaction and smoke given off was observed. The webbing material released black smoke while the stitching thread clearly did not. Thus, XRD and ATR-FTIR were carried out in order to identify the exact nature of the two materials.

X-ray diffraction of the sling webbing and thread sample materials was performed using a Bruker D8 Advance diffractometer. Diffraction patterns were obtained in symmetrical Bragg geometry with Cu$K_\alpha$ radiation in the 15 to 60° $2\theta$ range. The results of XRD analysis are shown in Figure 8. Firstly, the peaks found beyond a $2\theta$ angle of 30° can be indexed to marine salt i.e. sodium chloride (NaCl); while the broad peaks below this angle are indicative of semi-crystalline polymers. These characteristic broad features are consistent with 'incoherent scatter' from the amorphous component of the solid. Then diffraction patterns generated were correlated with literature for synthetic polymer fibres to *polyester* and *nylon* for the webbing and stitching respectively [4-6].

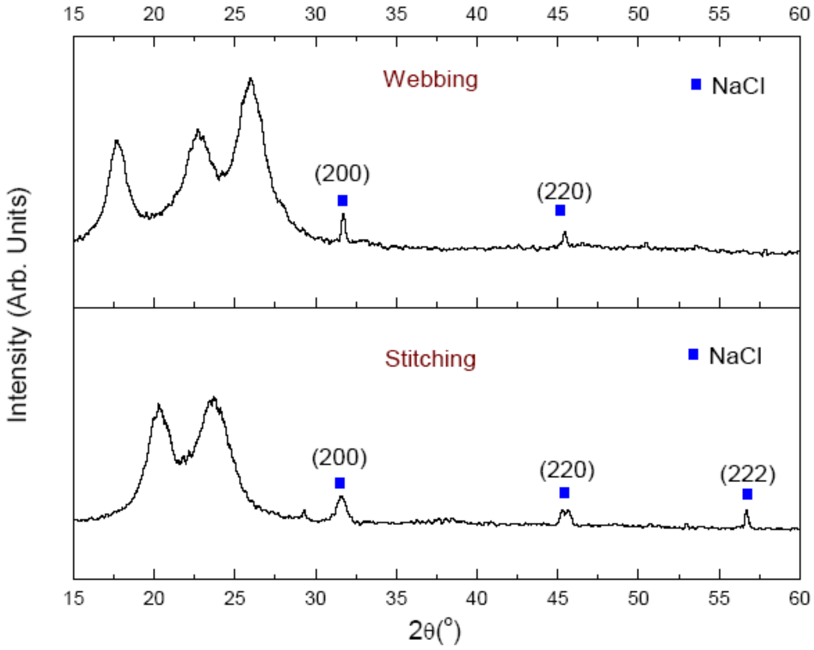


**Figure 8 X-ray diffraction patterns of webbing and stitching fibre samples.**

FTIR was conducted using a Shimadzu IRAffinity-1 spectrometer which is an ideal analytical tool for screening and profiling polymer samples. An attenuated total reflectance (ATR) attachment allowed for 'in-situ' measurement of the two fibre samples in the spectral range of 500cm$^{-1}$ to 4000cm$^{-1}$. The resultant spectra for both samples are shown in Figure 9. Comparing the two with reference spectra using the positions of the strongest peaks which dominate the respective spectrum, the materials were identified as polyamide (nylon) and polyester for the stitching and webbing respectively [8, 9].

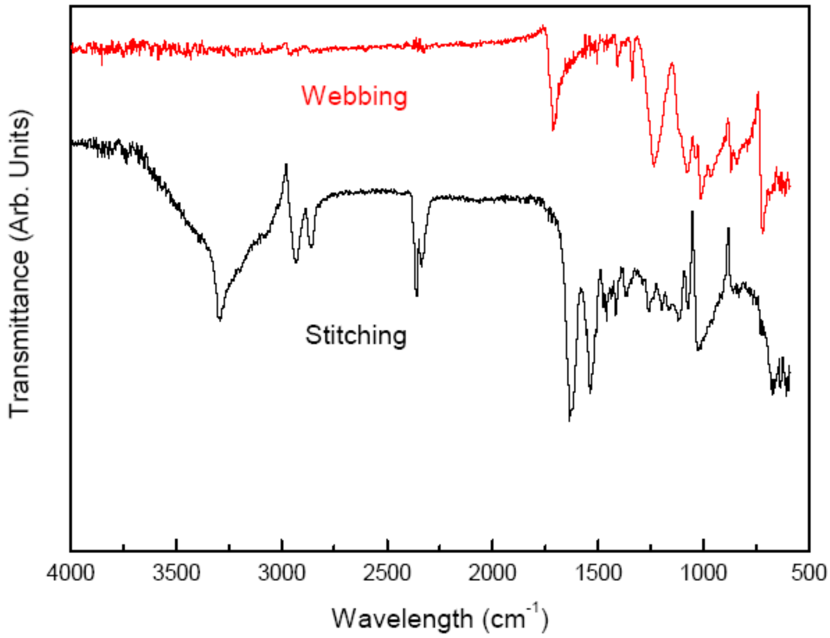


**Figure 9 ATR-IR spectra of webbing and stitching fibre samples.**

The different materials used to manufacture the sling could explain why the degradation was more severe on the thread stitching rather than on the sling. Weathering of synthetic fibres can occur by the synergistic effects of (UV-induced) photodegradation and exposure to air, humidity, water and salt crystallisation. The process of photodegradation can cause polymer chain scission (decomposition of the polymer chain into smaller, weaker segments), throughout which small molecules, such as ketones and acids, are formed. These can then either evaporate or be washed away by moisture contact. As the fibres lose thickness, shrinkage, embrittlement and cracking occur which eventually leads to fibre rupture and loss of tensile strength. In this respect, the resistance of polyester fibres is well known to be superior to that of nylon fibres. Furthermore, the darker pigment of the webbing could also have contributed to the higher UV resistance of the webbing; while the initial thickness of the individual yarn fibres used was unlikely to play a role since both fibres were measured to be around 30 μm in diameter.

Furthermore, nylon is known to absorb water and weakens drastically when wet. Conversely, polyester does not lose strength as a result of moisture absorption. However, both synthetic polymers are susceptible to degradation by hydrolysis over time i.e. the scission of chemical backbone bonds (depolymerisation) due to cleavage induced by absorbed water molecules. It is known that the presence of water can also accelerate the photodegradation processes of polymers described above.

## Conclusions

The analysis and testing conducted on the sling showed that stitching pull-out at the splice(s) during boat-launching was the most likely reason for the sling failure. It was shown that the stitching was substantially degraded along at least one side of the webbing for almost the entire length of the sling - prior to the attempted deployment of the rescue. The degree of degradation observed is congruent to the fact that the sling was presumably permanently exposed to outdoor conditions at least since the ship was delivered on January 2009 [3]; while a service life of 100% polyester slings is unlikely to exceed two years in such circumstances. Clearly, it is impossible to state with utmost certainty that had the sling been manufactured in accordance with standard WSTDA-WS-1 [10] (such that the stitching thread and webbing yarn were of the same type) the failure would have not occurred. However, it can be said that the use of nylon stitching, as opposed to polyester which experiences very little UV degradation, reduced the service-life-expectancy of the sling.

Good practice in the use of synthetic webbing slings and the relevant WSTDA standard [10] dictate that long-term exposure to such harsh conditions requires periodic inspection (against detailed retirement criteria set by the manufacturer), and proof testing (say twice a year) of the sling. The detection of broken and worn stitches particularly at the load-bearing splices should alert the user for immediate replacement of the sling.

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