
**Fibre ropes for offshore
stationkeeping —**

**Part 1:
General specification**

*Cordages en fibres pour le maintien en position des structures
marines —*

Partie 1: Spécification générale

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 38, *Textiles*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

This first edition of ISO 18692-1, together with ISO 18692-2, cancels and replaces the first edition of ISO 18692:2007, which has been technically revised.

A list of all parts in the ISO 18692 series can be found on the ISO website.

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Fibre ropes for offshore stationkeeping —

Part 1: General specification

1 Scope

This document specifies the main characteristics and test methods of new fibre ropes used for offshore station keeping.

Fibre ropes for stationkeeping can be manufactured from different rope core material.

This document provides general requirements applicable to all materials. The subsequent parts of the ISO 18692 series provide the specific requirements for each (rope core) material that are not addressed within this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1968, *Fibre ropes and cordage — Vocabulary*

ISO 2060, *Textiles — Yarn from packages — Determination of linear density (mass per unit length) by the skein method*

ISO 2062, *Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester*

ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

ASTM D 885, *Standard test methods for tire cords, tire cord fabrics, and industrial filament yarns made from manufactured organic-base fibers*

ASTM D 6611, *Standard test method for wet and dry yarn-on yarn abrasion resistance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1968 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

breaking strength

BS

maximum force applied in straight tension to a rope, which causes it to rupture

3.2

core

central part which is the load-bearing part of the rope

3.3

cover

braided cover or other protective layer, which is placed over the rope core

Note 1 to entry: The cover has no significant contribution to the rope strength.

3.4

dynamic stiffness

ratio of rope load to strain variations between the lower (trough) and upper (peak) stresses imposed during testing, normalized by the rope minimum breaking strength

Note 1 to entry: See [B.3.6.2](#).

3.5

fibre material declaration

document prepared by the fibre producer attesting the type and grade of fibre material and the properties of the fibre

3.6

marine finish

process and substance used on a fibre or yarn to improve the yarn-on-yarn abrasion performance of the product in a marine environment

3.7

marine grade fibre

fibre intended for use in a marine environment and that has demonstrated yarn-on-yarn abrasion performance

3.8

minimum breaking strength

MBS

specified minimum value that the breaking strength of a rope shall achieve when tested following the procedure in this document

Note 1 to entry: In this document, the specified MBS is that of a terminated rope.

3.9

prototype rope

rope fully complying with the rope design specification made for the purpose of testing either before an order is placed or before regular rope production begins for an order

3.10

qualified rope

rope already certified by the manufacturer as complying with the requirements laid down in this document, including all the relevant prototype testing

3.11

recognized classification society

RCS

classification society being a member of the International Association of Classification Societies (IACS), with recognized and relevant competence and experience in fibre rope mooring, and with established rules/guidelines for related classification

3.12**rope construction**

manner in which the fibres, yarns and strands are assembled together in making the rope

Note 1 to entry: In some rope constructions, rope core is made of sub-ropes, i.e. laid or braided ropes, that are assembled together by laying, braiding, or in parallel.

3.13**rope design specification**

document which completely describes the design of the rope, including the numbers and arrangements of strands, the strand pitch, the material chemical composition and the manufacturing method

3.14**rope manufacturing specification**

document which completely describes the process of making the rope, including instructions for each step of the manufacturing process

3.15**rope production report**

document which completely describes the rope product, including rope design, termination design, and assembly length, and which includes the material certificates, material test results and the various checklists

3.16**rope termination**

method by which the rope is attached to the assembly interface

EXAMPLE Splice, potted socket, wedged socket.

3.17**termination specification**

document which completely describes the design of the termination and the process of making that termination, including materials and steps for making or assembling the termination

3.18**torque**

moment that produces or tends to produce a twisting or a rotating motion around rope axis,, when a tension is applied to the rope, or changed

4 Materials**4.1 Rope core material****4.1.1 Fibre tenacity**

The fibre used in the core of the rope shall be in accordance with the specific requirements of each respective part of the ISO 18692 series and shall be qualified and tested according to [Annex A](#).

4.1.2 Marine grade

The fibre used in the core of the rope shall be marine grade fibre. The yarn-on-yarn abrasion performance shall be verified by tests on wet yarn and it shall meet the requirements of [A.4.2](#).

4.2 Rope cover material

When polyester yarn is used in the protective cover, it shall be in accordance with [Annex A](#) and its minimum tenacity shall be 0,73 N/tex.

4.3 Other materials

Other materials employed in rope assembly shall be identified in the rope design/manufacturing specification.

For each material, the following shall be specified, as applicable:

- a) base material;
- b) size (e.g. linear density, mass per unit area);
- c) relevant strength properties (e.g. tenacity, stiffness).

5 Requirements — Rope properties

5.1 Minimum breaking strength

The minimum breaking strength of the rope, when tested according to [Clause 7](#) and [Annex B](#), shall conform to specific requirements of each respective part of the ISO 18692 series.

5.2 Minimum core tenacity

The rope minimum core tenacity, measured according to [Annex B](#), shall be in accordance with specific requirements of each respective part of the ISO 18692 series.

5.3 Dynamic stiffness at end of bedding-in

The dynamic stiffness at the end of the bedding-in sequence shall be measured on the prototype testing in step 8 of the rope test procedure in [B.3.1](#).

5.4 Torque properties

5.4.1 Torque-neutral rope

A rope is considered torque-neutral if it has a torque factor, Q , of less than 0,005, see [Formula \(1\)](#):

$$Q = \frac{T}{d \cdot F} \quad (1)$$

where

Q is the torque factor;

d is the rope diameter, expressed in millimetres (mm);

F is the force applied to the rope, expressed in kilonewtons (kN);

T is the torque generated by the rope, expressed in newton metres (N·m).

The test method to demonstrate torque-neutral behaviour is defined in [B.6.1](#).

Parallel construction ropes having braided sub-ropes or an equal number of left lay and right lay twisted sub-ropes which are all identical in every respect except for twist direction are inherently torque-neutral (see also [6.2](#)). These constructions does not need to have their torque generation verified.

5.4.2 Torque-matched rope

A rope is considered torque-matched if its torsional characteristic over the design load range is essentially the same as that of the wire rope to which it is to be connected.

When tested as described in [B.6.2](#), the angular rotation in the wire rope element shall not exceed 5° per rope lay.

5.5 Cyclic loading performance

The rope shall have demonstrated performance under cycling loading following the requirements of [7.1.6](#) and [B.5](#).

5.6 Particle ingress protection

Unless otherwise specified, the rope shall be constructed with a protection of the core against the ingress of particles having a size greater than 20 µm (microns) or as agreed between involved parties. Testing of the protection shall be performed in accordance with [B.7](#). The tests shall be performed on one rope size.

6 Requirements — Rope layout and construction

6.1 General

The typical section of a rope shall comprise a rope core, providing intended strength and stiffness, and a cover.

6.2 Type of construction

The rope shall be of one of the following types of construction:

- torque-neutral construction (type TF);
- torque-matched construction (type TM).

The type of rope shall be specified by the purchaser.

NOTE Torque-neutral ropes are intended for use in mooring systems together with chain or torque-neutral spiral strand wire ropes. Torque-matched ropes are intended for use in mooring systems together with six-strand wire ropes or other non torque-neutral wire ropes.

6.3 Rope core

6.3.1 The total number of yarns in the rope shall be at least the number specified in the rope design specification.

6.3.2 Splices are not allowed in the rope core nor in sub-rope, except for those at the end terminations.

Strands shall be uninterrupted over the length of the rope, with no splice or strand interchange.

Yarns may be joined if necessary.

6.4 Protective cover

6.4.1 A protective cover shall be provided around the rope core to protect the rope core from mechanical damages (mainly abrasion) during handling and in service.

The protection shall be water-permeable.

6.4.2 A polyester braided protective cover shall have a minimum thickness, t , with:

- $t = 7,0$ mm, for a reference number RN equal or above 100;
- $t = 0,07 \times \text{RN}$, but not less than 4 mm, for a reference number RN less than 100.

Strand interchanges, i.e. the overlapping continuation of an interrupted strand with another identical strand following the same path, are permitted if they are properly staggered.

6.4.3 If an alternative protective cover is used, it shall demonstrate at least a level of protection equal to that of a polyester braided cover as per [4.2](#) and [6.4.2](#).

6.4.4 A braided cover shall include coloured strands forming a pattern so that rope twist during installation or in service can be identified. There shall be a minimum of one "S" coloured strand and one "Z" coloured strand to form a cross on the rope.

An alternative protective cover shall be fitted with an axial stripe of contrasting colour, or other means to identify rope twist during installation or in service.

6.5 Terminations

The terminations shall be made of an eye splice plus abrasion protection materials.

There may be other terminations provided that they do not jeopardize the rope performance.

The dimensions and arrangement of the eye shall match the diameter and groove shape of the thimble (or other interface piece) to be used for end connections, and shall be the same as for the rope prototype testing.

In the splice area, the integrity and the continuity of rope cover and particle-ingress protection, if fitted, shall be preserved or restored.

The eye and the splice area shall be further covered by an abrasion protection coating such as polyurethane.

Each termination shall be made according to the manufacturing practice as described in the termination specification.

6.6 Length of rope

The bedded-in lengths of the rope sections shall be calculated in accordance with [7.2.2](#), under 20 % of MBS, unless otherwise agreed on the purchase order or contract.

The calculated length of supplied rope shall be within ± 1 % of the specified length.

For each supplied rope, the actual length at the reeling tension or during manufacture shall be reported as an indicative value.

The length of short sections, if any, shall be mutually agreed between the purchaser and the manufacturer.

Adequate extra length shall be manufactured in order to prepare the samples for testing, which are considered to be part of the delivery.

7 Rope testing

7.1 Type test

7.1.1 General

Type tests demonstrate that ropes certified by the manufacturer as complying with the requirements laid down in this document possess the properties specified in this document. The purpose of these tests is to verify the design, material and method of manufacture of each size of finished rope, including protective cover and terminations.

All ropes to be type tested shall comply with all the other requirements laid down in this document. The tests specified below shall be carried out on a prototype rope for each size of rope, unless otherwise noted in this clause.

Any change in the design, material, method of manufacture, including protective cover and terminations, which may lead to a modification of the properties as defined in [Clause 5](#) shall require that the type tests specified in this document be carried out on the modified rope.

7.1.2 Sampling and testing

The number of rope samples to be tested shall be in accordance with the specific requirements of each respective part of the ISO 16892 series.

7.1.3 Breaking strength, core tenacity and stiffness tests

7.1.3.1 Samples shall be tested according to the procedure specified in [Annex B](#), and each shall be capable of meeting the specific requirements of each respective part of the ISO 18692 series.

7.1.3.2 The rope core tenacity and dynamic stiffness at end of bedding-in shall be calculated according to the methods defined in [B.3](#).

7.1.3.3 Measurement of the static stiffness and of the dynamic stiffness at other load levels shall be performed within the same tests. These measurements are, however, not required when results are available for another qualified rope of the same design, material and method of manufacture, with a reference number of not less than 150.

NOTE 1 These stiffness measurements are performed for design purposes only. There are no acceptance criteria on these parameters.

NOTE 2 These stiffness measurements can be also performed on a separate rope sample (see [B.3.5](#)).

7.1.4 Torque properties tests

Where applicable, torque properties tests shall be performed according to the procedure specified in [B.6](#).

These tests are, however, not required when results are available for another qualified rope of the same design, material, method of manufacture and termination, with a reference number of not less than 150.

7.1.5 Linear density test

The linear density shall be calculated from the measured weight and length according to the method defined in [B.4](#).

7.1.6 Cyclic loading endurance test

One sample shall be tested for cyclic loading. However, a cyclic loading (endurance) tests performed with one size of qualified rope having the same design, material and method of manufacture including protective cover and terminations, shall be enough to qualify all sizes with an MBS between 50 % and 200 % of the size tested. The test for cyclic loading (endurance) is not required if such data are available.

The cyclic loading endurance test shall be performed according to the procedure specified in [B.5](#).

A load range shall be selected by the manufacturer, and the rope shall withstand, without breaking, at least the number of cycles for that load range, as given in [Figure B.2](#).

7.1.7 Protective cover thickness

The thickness of the protective cover shall be verified.

The thickness of a braided cover shall be measured as twice the thickness of cover strands under the maximum braiding tension.

7.2 Testing of current production

7.2.1 Sampling and testing

For ropes that conform to the requirements of this document, based on type tests in accordance with [7.1](#), the following tests shall be performed on one sample taken from the manufacturing process, for each type and size of rope:

- a) breaking strength and core tenacity, according to the procedure in [Annex B](#);
- b) protective cover thickness verification.

7.2.2 Length measurement

The bedded-in length of each supplied rope section (other than short sections) shall be calculated from the linear density, ρ_t , using [Formula \(2\)](#).

$$L = \frac{(m_T - m_S) \cdot 1000}{\rho_{t,20}} \quad (2)$$

where

- L is the length of the rope in metres (m);
- m_T is the mass of the total rope length in kilograms (kg);
- m_S is the mass of the materials used to form the eyes and the splices in kilograms (kg);
- $\rho_{t,20}$ is the linear density of the rope, in ktex, obtained from the type test.

The length of short rope sections (i.e. sections of less than 20 m) shall be measured at a load of 2 % of MBS as the length between the centres of termination fittings (see [Figure B.1](#)).

8 Report

8.1 Prototype rope

A complete and detailed report of the prototype rope manufacturing shall be supplied, including the fibre manufacturer, the fibre type and finish and all rope characteristics that may influence the mechanical

properties, like design, material specifications, method of manufacture, including protective cover and terminations, with sketches or pictures.

A complete and detailed report of type tests, with sketches or pictures of the test set-up, shall also be provided.

8.2 Current production

The manufacturing report of supplied ropes shall be provided. A complete and detailed report of rope tests with sketches and pictures of the test set-up shall also be provided.

9 Certification

The certificate of approval and control, issued by a recognized classification society (RCS), shall be presented together with the ropes, in order to ensure that testing and fabrication are in accordance with the approved specifications.

The rope manufacturer shall issue a declaration or obtain a certificate including at least the following information:

- a) reference number;
- b) type of construction;
- c) rope core material;
- d) linear density;
- e) MBS;
- f) individual identification number;
- g) length at a specified load;
- h) length at the reeling handling tension.

NOTE A suggestion for manufacturer declaration can be found in [Annex D](#).

10 Marking, labelling and packaging

10.1 Marking

A tape of at least 3 mm wide printed with a reference identifying the manufacturer shall be incorporated into the rope. The maximum distance between two consecutive markings shall be 0,5 m.

10.2 Labelling

An identification plaque or alternative means shall be installed close to the splice with the following information, as a minimum:

- a) purchase identification;
- b) individual identification number;
- c) rope core material;
- d) a reference to the specific part of the ISO 18692 series;
- e) type of construction (TF or TM), in accordance with [6.2](#);

- f) rope MBS;
- g) rope length at a specified load, according to [7.2.2](#).

10.3 Packaging

If the assembly is packed on a spool or a reel, these shall be suitable for the applicable transportation means and of appropriate construction in terms of strength.

The packaging shall be marked with the manufacturer's trademark and with the lot identification number.

The ropes may be delivered in steel reels or in containers. Alternative packaging designs may be provided with the prior approval of the purchaser.

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Annex A (normative)

Fibre qualification and testing

A.1 General

This annex specifies the requirements for fibre qualification and testing.

Additional fibre specific requirement are specified in each respective part of the ISO 18692 series.

The requirements related to yarn-on-yarn abrasion performance are only applicable when a marine grade fibre is required.

A.2 Fibre specification

A.2.1 General information

A fibre specification shall include at least the following information:

- a) identification and general properties of fibre;
- b) detailed specification of physical and mechanical properties;
- c) yarn-on-yarn abrasion performance;

NOTE General properties of material can be found in the material safety data sheet.

A.2.2 Identification and general properties

The following information shall be provided in the fibre specification:

- a) producer of fibres;
- b) fibre designation;
- c) fibre material;
- d) number of filaments;
- e) nominal size (linear density);
- f) average tenacity;
- g) marine finish designation, finish content and finish solubility in water, if present.

A.2.3 Physical and mechanical properties

The following information shall be provided in the fibre specification, including tolerances on specified properties:

- a) linear density;
- b) dry break strength;
- c) dry elongation to break;

d) dry elongation at a specified load level.

These properties shall be documented by results of tests in accordance with [A.4](#).

A.2.4 Yarn-on-yarn abrasion performance

For a marine grade fibre, wet yarn-on-yarn abrasion performance data shall be also specified and documented by results of tests, in accordance with [A.4.2](#).

A.3 Fibre declaration

For each delivery, the fibre manufacturer shall issue a raw material declaration including at least the following information:

- a) fibre designation;
- b) merge number/batch identification;
- c) size (linear density);
- d) dry breaking strength;
- e) dry elongation to break;
- f) test result of finish application (see [A.4.2.2](#)).

For acceptance testing, the above properties shall be obtained from testing on a representative number of samples taken from the delivery, not less than once every 5 000 kg.

For each property, the number of tests, the mean value and the standard deviation or range shall be reported.

A.4 Fibre testing

A.4.1 Fibre linear density and strength

The fibre linear density shall be tested in accordance with ISO 2060.

The fibre strength and elongation shall be determined based on five samples of basic yarn samples taken and tested. These samples shall be conditioned to equilibrium to a temperature of $21\text{ °C} \pm 1\text{ °C}$ and a relative humidity of $(60 \pm 10)\%$. After conditioning, the samples shall be loaded to break in accordance with ISO 2062, ASTM D 885 or a documented equivalent method established by the fibre manufacture and derived from existing standards (see Reference [7]). The testing method to be used shall be identified in the rope design documentation. The same method is then to be used whenever the yarn is tested by the fibre manufacturer. The average yarn breaking strength and elongation shall be determined and recorded.

A.4.2 Yarn-on-yarn abrasion performance

When the fibre is specified to be “marine grade fibre”, testing for efficiency and for persistence of finish shall be performed.

A.4.2.1 Qualification testing

A.4.2.1.1 Qualification testing (efficiency)

Qualification testing for efficiency of finish shall be performed on wet yarns in accordance with ASTM D 6611.

Tests shall be performed at least at three load levels, including one in each of the following ranges:

- a) (20 to 30) mN/tex;
- b) (35 to 45) mN/tex;
- c) (55 to 60) mN/tex.

A minimum of 8 yarns shall be tested for each level.

The results at each load level shall be derived and reported in accordance with the procedure in ASTM D 6611, and shall be kept for reference.

A.4.2.1.2 Qualification testing (persistence)

The persistence of the marine finish in a marine environment shall be demonstrated.

The assessment method shall be duly documented by the fibre producer.

Yarn-on-yarn abrasion tests after artificial ageing may be used.

A.4.2.2 Testing of current production

The effectiveness of the application of the marine finish during fibre production shall be verified by yarn-on-yarn abrasion tests or another documented testing method.

When a yarn-on-yarn abrasion test is used, the testing shall be performed at least at one load level, on a minimum of four yarns at each test, with an acceptance level that shall be specified based on the results of qualification testing.

Any other testing method shall be duly documented by the fibre producer.

Annex B (normative)

Rope testing

B.1 General

This annex specifies the requirements for full-size testing of rope samples, and it addresses the following tests:

- a) strength and stiffness;
- b) linear density;
- c) cyclic loading endurance;
- d) torque measurement;
- e) particle ingress resistance.

B.2 Testing conditions

B.2.1 Rope samples

The rope tests, including strength, cyclic loading endurance and torque measurement shall be performed on samples with terminations that are identical to the supplied ropes. The strength and cyclic loading tests shall be performed with fixed end conditions (without a swivel).

Termination fittings shall be provided, with the same type of material and the same profile and dimensions (radius, groove shape) as the thimbles for the supplied rope.

B.2.2 Ambient conditions

In all tests, the ambient temperature and humidity shall be recorded.

The water used for soaking, wetting and immersing shall be fresh water with no additives.

During the cyclic loading endurance test (see [B.5](#)), the rope shall be wetted by a water spray, or immersed, and the temperature shall be controlled in order to avoid over-heating.

The temperature of the out-flowing water should not exceed 30 °C.

B.2.3 Testing machine

The testing machine shall be of at least class 2 according to ISO 7500-1 and it shall be of such a type that load (or cross-head displacement) can be controlled at all time, during both extension and retraction.

For the breaking test (step 10 in [B.3.1](#)), the use of a test machine with a fixed cross-head speed is acceptable, provided that time to failure is at least 3 min.

B.2.4 Load and elongation measurements

Load shall be measured by a strain gauge system and continuously recorded during each test.

NOTE In the loading sequences specified below, loads are given as a percentage of the specified MBS of the rope.

The measurements of the gauge length elongation of the rope core shall be performed with a system of adequate sensitivity for the intended sequences and the rope core material. Extensometer or video image processing may be used.

The cover and the filter shall be cut for fastening of extensometer ends or for marking of core (in case of measurement by video image processing).

B.3 Strength and stiffness test

B.3.1 Test procedure

The following rope test procedure applies to verify the rope MBS, the minimum core specific strength and the stiffness. The test shall be performed according to the following steps:

- step 1: the sample shall be soaked for at least 4 h in fresh water;
- step 2: the sample shall be installed in the test machine;
- step 3: a load of 2 % of MBS shall be applied;
- step 4: the rope shall be marked at each end, at a distance of three times the rope diameter from the last tuck of splices (see [Figure B.1](#));
- step 5: the extensometer shall be installed in a section of the rope undisturbed by the termination, between these marks;
- step 6: a tension of 50 % of the rope MBS shall be applied at a rate of 10 % MBS per minute and held for 30 min;
- step 7: the tension shall be reduced to 10 % of the rope MBS, at a rate of 10 % MBS per minute;
- step 8: a cycling tension between 10 % and 30 % of the rope MBS shall be applied 100 times, without interruption, at a frequency between 0,03 Hz and 0,1 Hz (bedding-in and measurement of dynamic stiffness after bedding-in);
- step 9: when applicable, a cycling tension between specified limits shall be applied for a specified number of cycles (dynamic or static stiffness measurements; see [B.3.5](#)), and without interruption; otherwise, this step is omitted;
- step 10: the sample shall be unloaded, the extensometer removed, and the rope pulled to failure, at a loading rate of approximately 20 % MBS per minute.

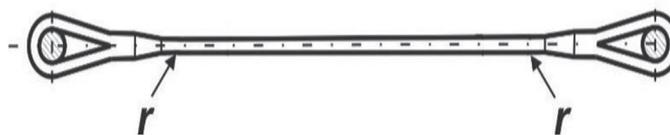


Figure B.1 — Marks “r” on the rope sample

B.3.2 Breaking strength

The tension at break of the rope sample shall be recorded.

All samples tested shall meet the MBS.

If the breaking load of one sample is lower than the MBS, two other samples shall be prepared and tested. The rope is considered to comply with the breaking strength requirement in this document only if the results of both the subsequent two tests meet the MBS.

B.3.3 Load-elongation measurements

The rope test shall include the measurement of the following:

- a) load versus total elongation (stroke), four plots as in the following:
 - 1) steps 5 to 7,
 - 2) step 8,
 - 3) step 9 (when performed),
 - 4) step 10;
- b) gauge length (extensometer) elongation (for the prototype rope), three plots as in the following:
 - 1) load versus elongation encompassing steps 5 to 7,
 - 2) load versus elongation for the last three full cycles at least, in step 8,
 - 3) load versus elongation for the last three full cycles at least, in step 9, dynamic stiffness measurement (whenever performed);
- c) continuous record of load and elongation versus time, during the three cycles of the quasi-static stiffness measurement (whenever performed).

NOTE The step numbers refer to [B.3.1](#).

B.3.4 Dynamic stiffness at end of bedding-in

The dynamic stiffness at end of bedding-in (step 8 of [B.3.1](#)) shall be obtained from the load and gauge length elongation measurements, and shall be calculated according to [B.3.6.2](#).

B.3.5 Quasi-static stiffness and dynamic stiffness

B.3.5.1 The quasi-static stiffness and the dynamic stiffness at other load levels shall be obtained from load and gauge length elongation measurements in step 9 in [B.3.1](#), and calculated according to [B.3.6.3](#) and [B.3.6.4](#).

Additional measurements of dynamic stiffness may be performed when agreed between the purchaser and the manufacturer (see [Annex E](#)).

B.3.5.2 For the measurement of the quasi-static stiffness, the following cycling shall be applied in three full cycles without interruption:

- a) slowly load the rope from 10 % of the rope MBS to 30 % of the rope MBS in a period of time between 2 min and 6 min;
- b) hold the load at 30 % of the rope MBS for 30 min from the start time of a);
- c) slowly unload the rope from 30 % of the rope MBS to 10 % of the rope MBS in a period of time between 2 min and 6 min;
- d) hold the load at 10 % of the rope MBS for 30 min from the start time of c).

This cycling shall be performed during step 9 of [B.3.1](#) above on one sample before the cycling for the dynamic stiffness.

Other load levels may be considered when agreed between involved parties (see [Annex E](#)).

B.3.5.3 For the measurement of the dynamic stiffness, the following cycling shall be applied at step 9 of [B.3.1](#) at a frequency between 0,03 Hz and 0,1 Hz:

- step 9a: on one sample: 100 cycles between 20 % and 30 % of the rope MBS;
- step 9b: on a second sample: 200 cycles between 30 % and 40 % of the rope MBS;
- step 9c: on a third sample: 300 cycles between 40 % and 50 % of the rope MBS.

In the case of an interruption within a set of cycling, this set of cycling shall be repeated.

If the interruption leads to unloading of the rope, step 8 shall be performed again before re-running the interrupted set of cycling.

B.3.5.4 As an alternative to the procedures in [B.3.1](#) to [B.3.5.3](#), measurements may be performed as follows.

- a) All measurements are performed on the same sample, quasi-static stiffness, then dynamic stiffness, as steps 9a, 9b, and 9c (see [B.3.5.3](#)), in ascending order of load. Then, the cycling may be limited to 100 cycles at each level.
- b) These measurements are performed in either wet or dry condition on a separate rope sample or – in case of parallel construction – on a sub-rope, and according to the following steps:
 - 1) the sample shall be installed in test machine;
 - 2) steps 3 to 8 of [B.3.1](#), including measurement of the dynamic stiffness at the end of bedding-in;
 - 3) step 9 of [B.3.1](#) with cycling as per [B.3.5.2](#) for the measurement of the quasi-static stiffness;
 - 4) steps 9a, 9b, 9c of [B.3.5.3](#) with cycling for the measurement of the dynamic stiffness.

B.3.6 Calculation of mechanical properties

B.3.6.1 Core tenacity

The rope core tenacity shall be calculated as given by [Formula \(B.1\)](#):

$$t = \frac{F_{BS}}{\rho_{l,c0}} \quad (\text{B.1})$$

where

t is the rope core tenacity, expressed in newtons per tex (N/tex);

F_{BS} is the actual breaking strength of the rope, expressed in newtons (N), obtained in step 10 of [B.3.1](#);

$\rho_{l,c0}$ is the linear density of the rope core, expressed in tex, at 2 % of MBS, as measured during the linear density test (see [B.4](#)).

B.3.6.2 Dynamic stiffness at the end of bedding-in

The dynamic stiffness at the end of bedding-in is calculated from the load-elongation measurement at the end of step 8 of [B.3.1](#).

The dynamic stiffness is calculated as given by [Formula \(B.2\)](#):

$$K_{rb} = \frac{(F_{30} - F_{10}) / F_{MBS}}{(L_{30} - L_{10}) / L_{10}} \quad (\text{B.2})$$

where

- K_{rb} is the dynamic stiffness after bedding-in;
- $F_{30} - F_{10}$ is the recorded variation of load over the 100th cycle;
- F_{MBS} is the specified minimum breaking strength of the rope;
- $(L_{30} - L_{10}) / L_{10}$ is the elongation (strain variation) between F10 and F30 over the 100th cycle.

NOTE Alternatively, the stiffness can be obtained from the average slope of the load-elongation plot over the last three full cycles.

B.3.6.3 Dynamic stiffness

When required, the dynamic stiffness is calculated, using [Formula \(B.3\)](#), from load-elongation measurements of step 9a, 9b or 9c of [B.3.5.3](#):

$$K_{rd, X \rightarrow Y} = \frac{(F_Y - F_X) / F_{MBS}}{(L_Y - L_X) / L_X} \quad (\text{B.3})$$

where

- $K_{rd, X \rightarrow Y}$ is the dynamic stiffness under cycling between load X and Y;
- $(L_Y - L_X) / L_X$ is the elongation between F_X and F_Y over the last cycle;
- F_{MBS} is the specified minimum breaking strength of the rope;
- $F_Y - F_X$ is the recorded variation of load over the last cycle.

NOTE Alternatively, the stiffness can be obtained from the average slope of the load-elongation plot over the last three full cycles.

B.3.6.4 Quasi-static stiffness

Whenever required, the quasi-static stiffness is calculated from load-elongation measurements, using [Formula \(B.4\)](#):

$$K_{rs, X \rightarrow Y, 1h} = \frac{(F_Y - F_X) / F_{MBS}}{(L_Y - L_X) / L_X} \quad (\text{B.4})$$

where

- $K_{rs, X \rightarrow Y, 1h}$ is the quasi-static stiffness under cycling between loads X and Y , over a period of 1 h;
- $(L_Y - L_X) / L_X$ is the recorded elongation between F_X and F_Y over the last cycle;
- F_{MBS} is the specified minimum breaking strength of the rope;
- $F_Y - F_X$ is the recorded variation of load over the last cycle.

NOTE 1 Alternatively, the quasi-static stiffness can be obtained by averaging the results over the last two cycles.

NOTE 2 The quasi-static stiffness for longer cycling periods can be obtained by extrapolation from the records of load and elongation versus time (see [Annex E](#)).

B.4 Linear density

B.4.1 Test procedure

The linear density is calculated from a dry sample of rope with at least 2 m free length (out of splice area, as for marks, "r", in [B.3.1](#)) taken from the manufacturing process, according to the following procedure, unless otherwise agreed on purchase order or contract:

- a) the sample shall be installed in the test machine;
- b) a suitable fastening shall be provided in order to ensure no slippage between the cover and the core;
- c) the sample shall be submitted to a tension of 2 % of MBS, and a length of about 2 m marked as a reference length, L_{R0} ;
- d) the tension shall be increased to 20 % of the rope MBS, at a rate of 10 % of MBS per minute;
- e) a cycling tension between 15 % and 25 % of the rope MBS shall be applied 100 times at a frequency between 0,03 Hz and 0,1 Hz;
- f) after cycling, the tension shall be maintained at 20 % of the rope MBS and the reference length, L_{R20} , shall be measured, immediately after this tension is reached;
- g) the tension shall be lowered to 2 % of MBS and the reference length, L_{R2} , shall be measured again, immediately after the 2 % tension is reached;
- h) after unloading, the sample shall be cut upon the reference length marks. The cut sections shall be flat and perpendicular to the rope longitudinal axis;
- i) the mass of the segment shall be measured and recorded;
- j) after removing the cover, the mass of the core segment shall be also measured and recorded.

NOTE The linear density includes the dry mass of the coating applied.

B.4.2 Calculation of linear densities

The linear densities shall be calculated using [Formulae \(B.5\)](#) to [\(B.8\)](#):

$$\rho_{1,0} = \frac{m_R}{L_{R0}} \quad (\text{B.5})$$

$$\rho_{1,20} = \frac{m_R}{L_{R20}} \quad (\text{B.6})$$

$$\rho_{1,2} = \frac{m_R}{L_{R2}} \quad (\text{B.7})$$

$$\rho_{1,c0} = \frac{m_{RC}}{L_{R0}} \quad (\text{B.8})$$

where

$\rho_{1,0}$ is the linear density of the rope, expressed in kilotex (ktex), as manufactured, under 2 % of MBS;

$\rho_{1,20}$ is the linear density of the rope, expressed in kilotex (ktex), after the rope has been cycled and under 20 % of MBS;

$\rho_{1,2}$ is the linear density of the rope, expressed in kilotex (ktex), under 2 % of MBS after being mechanically worked to the above procedure;

$\rho_{1,c0}$ is the linear density of the rope core, expressed in kilotex (ktex), as manufactured, under 2 % of MBS;

m_R is the mass of the reference length, expressed in grams (g);

m_{RC} is the mass of the reference length of rope core, expressed in grams (g);

L_{R0} is the (length of the) reference length, expressed in metres (m), as manufactured, under 2 % of MBS;

L_{R20} is the (length of the) reference length, expressed in metres (m), after the rope has been cycled and under a tension of 20 % of MBS;

L_{R2} is the (length of the) reference length, expressed in metres (m), under 2 % of MBS after being mechanically worked to the above procedure.

B.5 Cyclic loading endurance test

B.5.1 Planning

A load range, R , between 40 % and 50 % of MBS shall be selected by the manufacturer.

The corresponding minimum number of cycles shall be obtained from [Figure B.2](#).

The mean load, F_{mean} , during test shall be such that the maximum load, F_{max} , is within 52 % and 55 % of MBS.

NOTE 1 The levels for cycling are then:

$$F_{\min} = F_{\text{mean}} - \frac{R}{2} \quad (\text{B.9})$$

and

$$F_{\max} = F_{\text{mean}} + \frac{R}{2} \quad (\text{B.10})$$

The number of cycles, N , in [Figure B.2](#) is given by [Formula \(B.11\)](#):

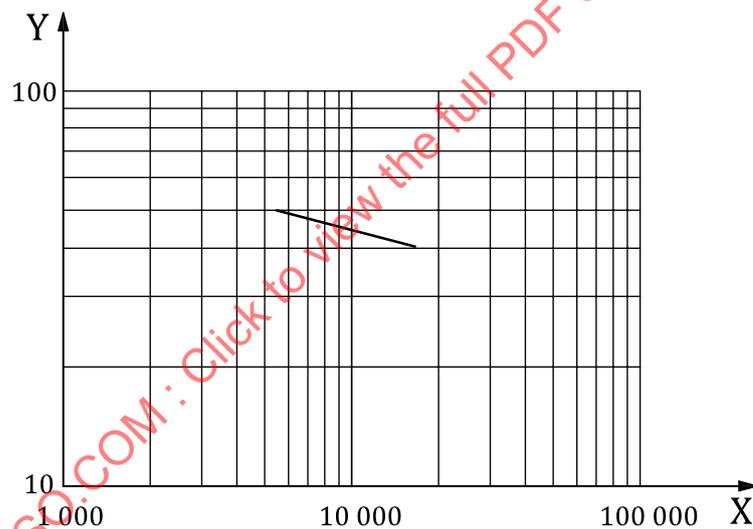
$$N \cdot R^{5,05} = 166 \quad (\text{B.11})$$

where

R is the load range divided by the MBS;

$N = 17\,000$ for $R = 0,4$;

$N = 5\,500$ for $R = 0,5$.



Key

X endurance (number of cycles), N

Y load range, R (% MBS)

Figure B.2 — Minimum requirement for cyclic loading test

B.5.2 Test procedure

- the sample shall be soaked for at least 4 h in fresh water;
- the sample shall be installed in the test machine;
- a load of 2 % of the MBS shall be applied;
- a tension of 50 % of the rope MBS shall be applied at a rate of about 10 % of MBS per minute and held for 30 min;
- the tension shall be reduced to 30 % of the rope MBS at a rate of about 10 % of MBS per minute;

- f) cyclic loading between the selected levels F_{\min} and F_{\max} shall be applied for at least the specified number of cycles at a frequency between 0,01 Hz and 0,1 Hz;
- g) unload the sample, and pull the rope to failure at a loading rate of approximately 20 % of MBS per minute, and record the residual strength of the rope.

B.6 Torque measurement

B.6.1 Torque factor

The torque factor shall be verified by the following procedure:

- a) a sample of rope, as described in [B.2.1](#), shall be installed in the test machine;
- b) a load of 2 % of MBS shall be applied to the sample and the rope diameter, d , measured;
- c) a tension of 50 % of the rope MBS shall be applied at a rate of 10 % of MBS per minute and held for 30 min;
- d) the tension shall be reduced to 10 % of the rope MBS at a rate of 10 % MBS per minute;
- e) a cycling tension between 10 % and 30 % of the rope MBS shall be applied 100 times, without interruption, at a frequency between 0,03 Hz and 0,1 Hz;
- f) the tension shall be released and a friction-compensating swivel shall be introduced between one end of the sample and the test machine pin (preferably the fixed end pin);
- g) a load of 2 % of MBS shall be applied to the sample;
- h) a rigid steel lever shall be firmly attached across the face of the rope end fitting at right angles to the line of applied load;
- i) the load shall be reduced to zero and a compression load cell, mounted on a solid base, placed in touching contact with the extremity of the lever;
- j) the distance of the load cell contact point from the centre line of the rope shall be measured;
- k) the load on the rope, F , shall be increased to 10 % of MBS;
- l) the torque in newton metres (N·m), generated by the rope at 10 % of MBS, shall be calculated by reference to the load cell measurement and lever arm length.

The torque factor, Q , shall be calculated using [Formula \(1\)](#).

B.6.2 Torsional compatibility

The torsional compatibility shall be verified by the following procedure:

- a) equal length samples of the fibre rope and of the wire rope to be matched shall be connected in series and arranged in a test machine with both outer ends fixed;
- b) the sample shall be loaded to 2 % of the wire rope component MBS. The length of each rope and the lay length of the wire rope shall be measured;
- c) in order to settle the sample, the composite sample shall be cycled 10 times between 2 % and 20 % of wire rope component MBS;
- d) the sample shall be held at the 20 % load and the connection between the two ropes shall be provided with means to measure any rotation of the connection, such as a lever;
- e) the sample shall be cycled 10 times with a load of ± 10 % of MBS, and the angular rotation of the connection per cycle shall be noted;

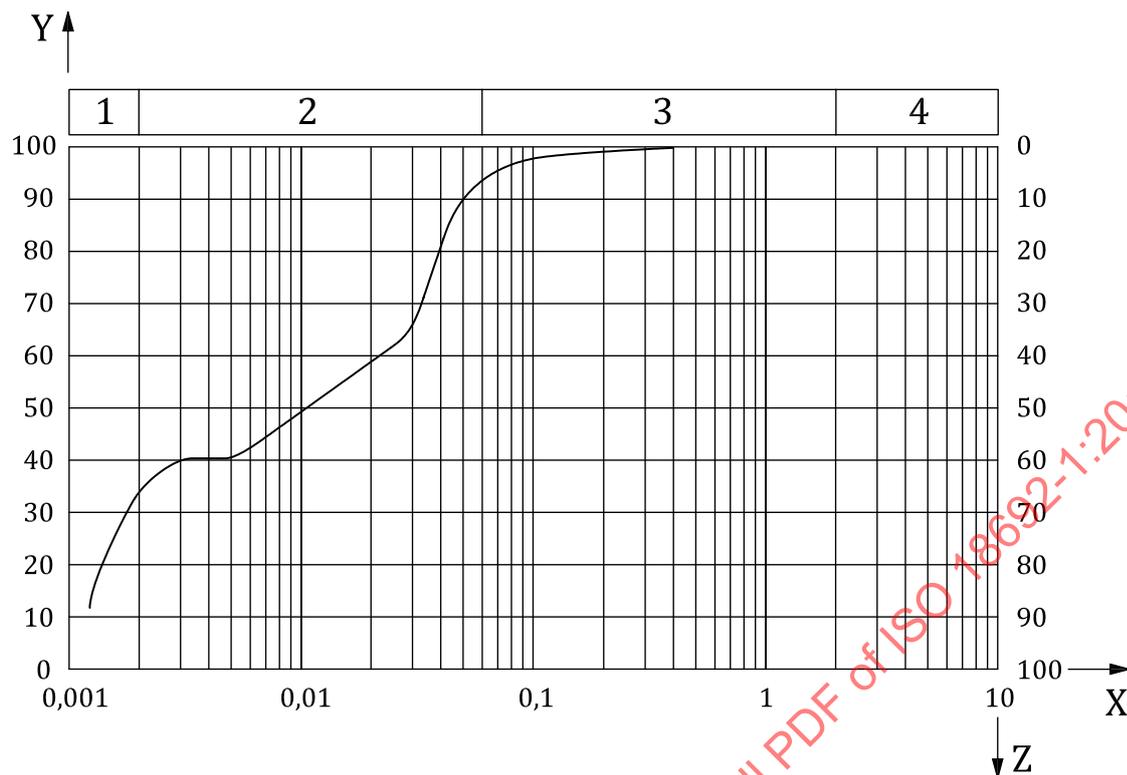
- f) the average cyclic degree of rotation per lay of the wire rope shall be calculated and shall not exceed the value specified in [5.4.2](#).

B.7 Particle ingress resistance

One sample shall be tested as follows:

- a) a specimen from a new rope with useful length of at least two times the rope diameter shall be selected;
- b) the specimen ends shall be sealed with a waterproof compound;
- c) the specimen shall be placed into a hyperbaric chamber and it shall be immersed in tap water with a sufficient volume to cover it. It shall be kept for 60 min at atmospheric pressure;
- d) an amount of soil shall be added at a proportion of 25 % of water mass. The soil shall meet or exceed the grading shown in [Figure B.3](#);
- e) the pressure shall be applied incrementally over 1 hour period from atmospheric to 10 MPa. Total time of test including initial hour shall be 20 hours;
- f) after this period, the pressure shall be removed and the rope core shall be examined by a scanning electron microscope (SEM) to determine the efficiency of the filter in avoiding soil particle ingress with a size equal to, or greater than, the one stipulated.

NOTE Existence of a few particles larger than the specified maximum referred to in [5.6](#) might not indicate deficiency of the filter because these particles could be within the rope prior to contact with the soil.



Key

- 1 clay $\leq 2 \mu\text{m}$
- 2 silt $> 2 \mu\text{m}$ and $\leq 63 \mu\text{m}$
- 3 sand $> 63 \mu\text{m}$ and $\leq 2 \text{ mm}$
- 4 gravel $> 2 \text{ mm}$ and $\leq 63 \text{ mm}$
- X particle size (mm)
- Y passing percentage (%)
- Z retained percentage (%)

Figure B.3 — Grading of soil for particle ingress resistance test

Annex C (informative)

Guidance for rope handling care

C.1 General considerations

Whenever fibre ropes for offshore stationkeeping are being handled, avoid the following:

- a) contact between rope and sharp edges (attention to vessel's drum area and stern roller); see [Figure C.1](#).

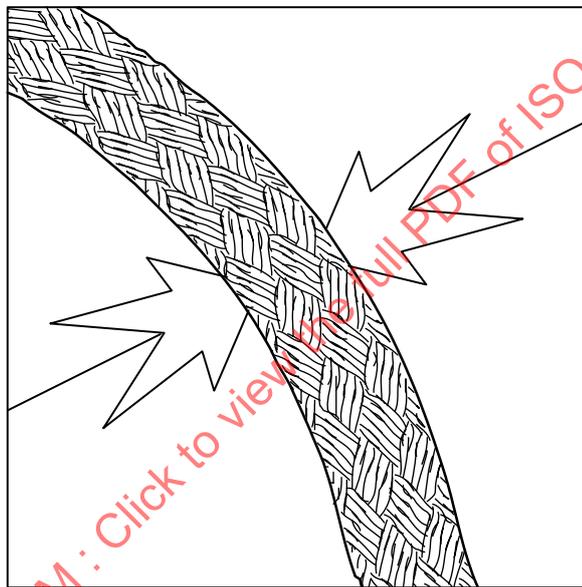


Figure C.1 — Contact with sharp edges

- b) excessive abrasion between rope and rough surfaces (attention to vessel's deck and stern roller); see [Figures C.2](#) and [C.3](#).

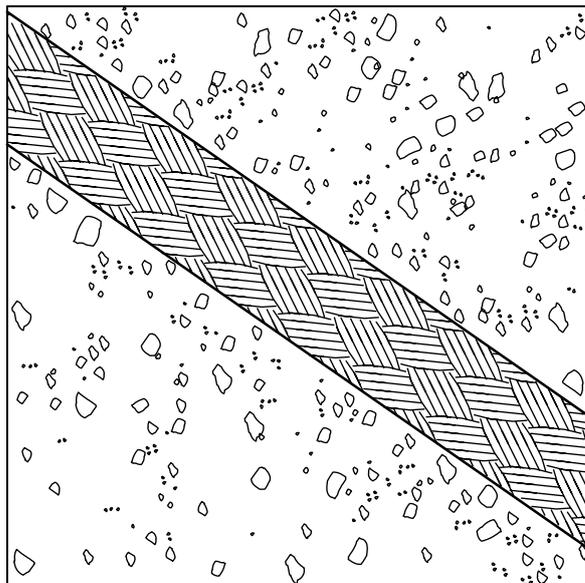


Figure C.2 — Contact with rough surfaces

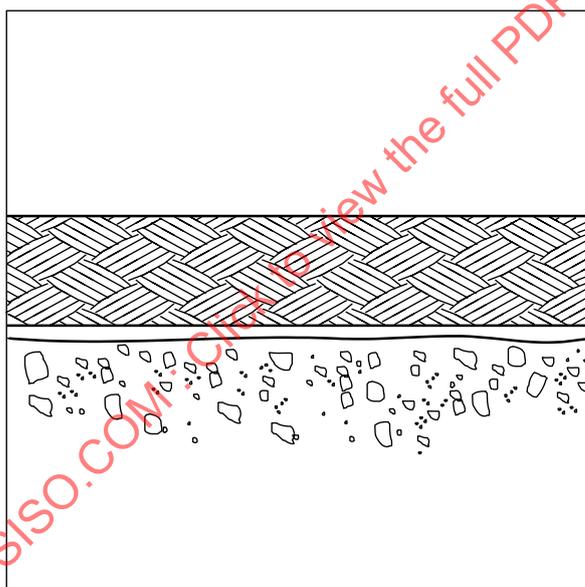


Figure C.3 — Contact with rough surfaces

- c) working or handling with sharp tools (knives, blades, steel cables); see [Figures C.4 to C.6](#).

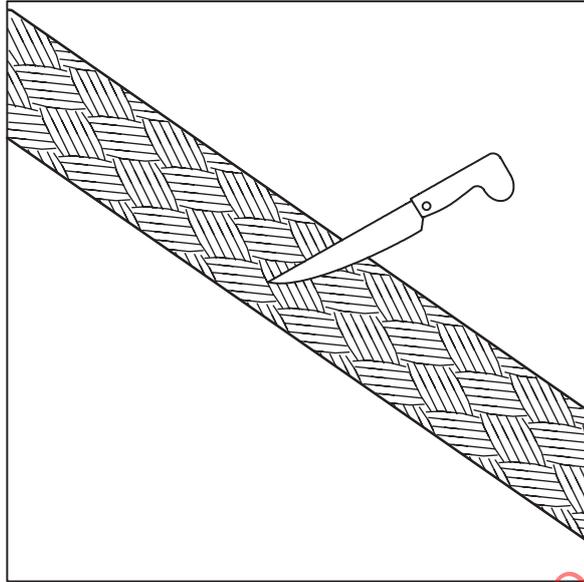


Figure C.4 — Working with sharp tools

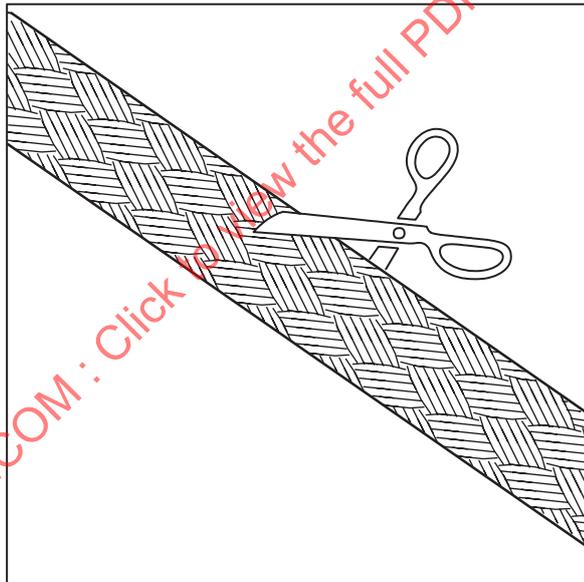


Figure C.5 — Working with shap tools

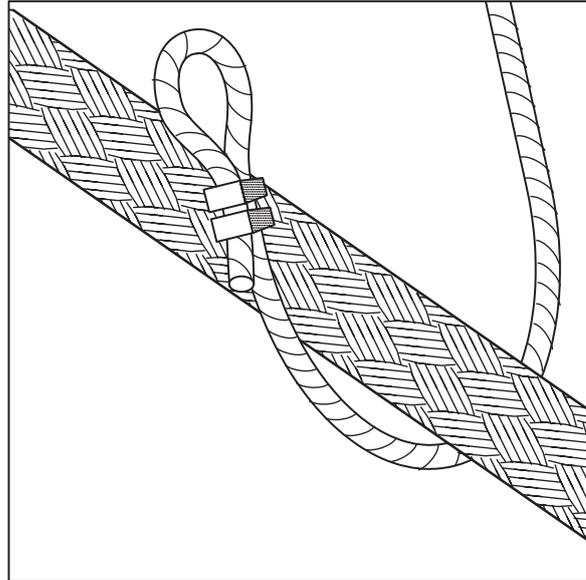


Figure C.6 — Working with sharp tools

- d) excessive dirt in the rope and work area (oil, mud, scraps); see [Figure C.7](#).

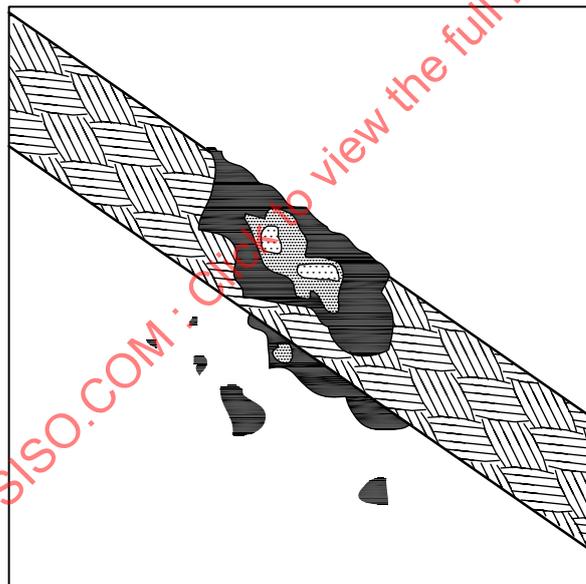


Figure C.7 — Excessive dirt

- e) excessive twist or bending in the rope; see [Figures C.8](#) and [C.9](#).

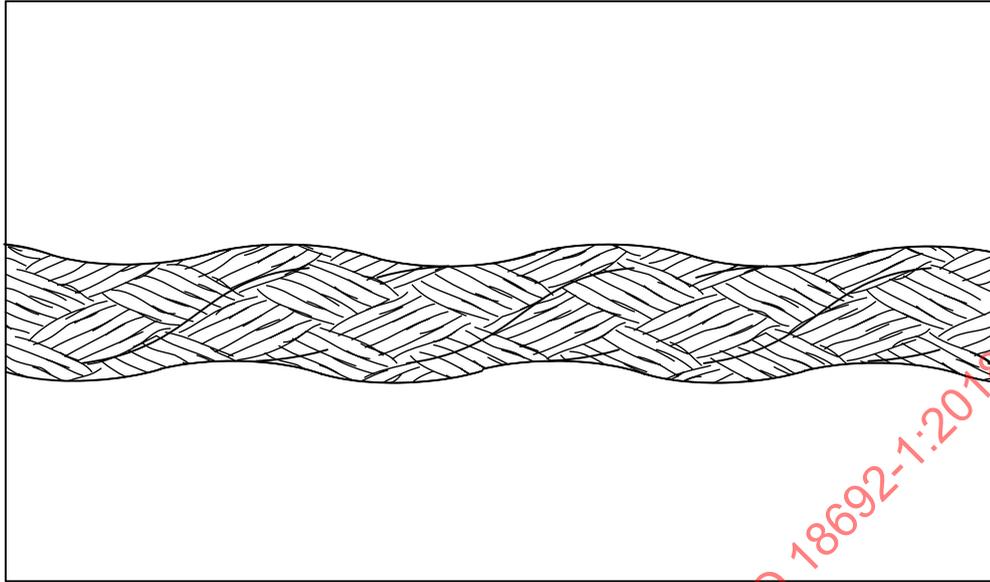


Figure C.8 — Excessive twist

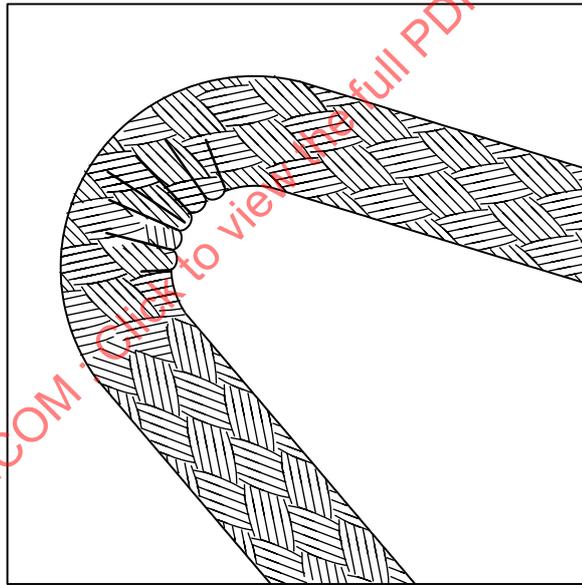


Figure C.9 — Excessive bending

- f) contact with chemicals and prolonged exposure to sunlight.

C.2 Presentation of rope on reels

Fibre ropes for offshore stationkeeping will normally be supplied wound on to steel reels.

Protective packaging material is wound around the main body of the rope to provide protection during transportation.

Packaging material should be carefully removed without cutting or damaging the rope. Strapping around the packaging may be under high tension and can snap back when cut, so extra care should be taken.

Insert segments are likely to be provided in packing crates of considerable dimension. Crates may be handled with a forklift truck of suitable dimension and working load, provided the fork positions enable

safe lifting. Alternatively, the crates may be lifted by a slinging arrangement, provided the slings are connected to the underside of the crate and are positioned to enable equal load distribution and safe lifting. Lifting slings, which risk damaging the crate, thereby exposing the segments packed inside, are not permitted.

C.3 Reel lifting and handling

Where using a crane, reels should be lifted using a specified lifting arrangement.

Whenever lifting reels, the initial load application and final set-down should be conducted as slowly and gently as possible to prevent the imposition of undue acceleration and deceleration forces.

Reels should not be rolled on the floor where loaded with rope. Whenever empty, reels should not be rolled unless it is absolutely essential, and only on flat clear ground and where methods to fully control rolling are applied.

Reels should not be twisted or moved sideways while standing on the ground. Forklift trucks should not be used to lift reels in either the full or empty condition.

Where reel cradles are provided, the reel should not be disconnected from the cradle until just prior to installation into the rope spooling mechanism. The use of the cradle prevents reel rolling, minimizes instability and ensures correct reel orientation whenever in storage.

C.4 Reel storage and maintenance

The ropes should be stored on reels on flat ground in reel cradles, where supplied, or else suitably chocked to prevent any unexpected movement. They should not be stacked on top of each other. The reels should be covered if stored outside to avoid prolonged exposure to sunlight, prevent plant growth on the ropes and prevent abrasive particles from being deposited in the cover. These measures ensure that the rope cover is maintained in as good a condition as possible.

Steel spools and other fittings should not be connected to the rope whenever stored on a reel to avoid chafing of the rope cover.

C.5 Installation

C.5.1 Deployment overboard

- a) Where a new rope is in contact with the vessel's deck and stern roller, spraying water directly on the rope helps to avoid damage caused by external abrasion and reduce rope internal abrasion between fibres. See [Figure C.10](#).

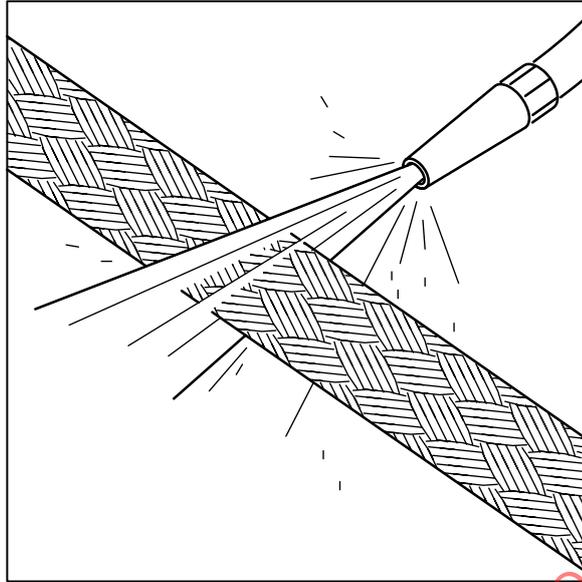


Figure C.10 — Spraying water to avoid abrasion damage

- b) Whenever installing the thimble, avoid excessive opening of the rope eye, which may damage or crack the polyurethane coating. See [Figure C.11](#).

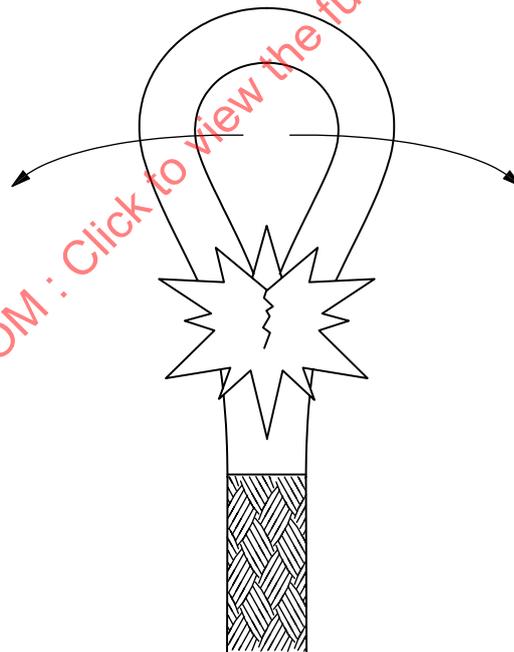


Figure C.11 — Avoid excessive opening of rope eye

- c) Avoid proximity with works involving fire, corrosive chemical products, or excessive heat. If unavoidable, protect the rope. See [Figure C.12](#).

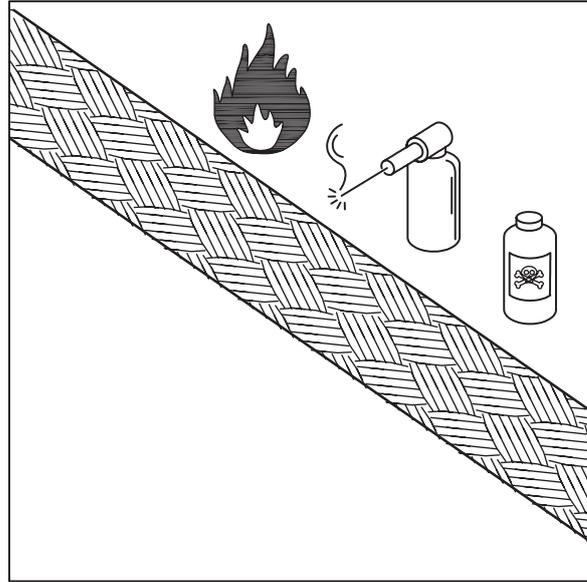


Figure C.12 — Avoid proximity of fire and corrosive chemicals

d) Avoid contact of the rope with the seabed.

C.5.2 Line tensions and re-reeling

The maximum line tension during deployment should be calculated and designed not to exceed 20 % MBS. The deployment of heavy anchors and long lengths of chain may be required. It is recommended that the rope not support the complete mass of these and that they be either pre-deployed or a second line be used. In the latter case, care should be taken to avoid the second line causing damage to the rope both during the deployment and after disconnection. This second work line should ideally be a torque-balanced fibre rope.

The standard reels on which ropes are normally transported cannot withstand line tensions over a few tonnes. It is recommended that the ropes be transferred to a winch drum on an anchor-handling vessel or to a purpose built deployment reel. The lines can then be deployed directly from the winch or from the deployment reel via a dedicated deployment winch. Any temporary connection to the eye during re-reeling should be made using a fibre rope or webbing sling. The load in any connecting rope should be kept to a minimum to avoid cutting into the bearing point of the eye.

To reduce the chances of burying on a drum and possible damage caused to the cover by relative movement of the rope against the layer below, the deployment tension should be designed to be as low as possible. Applying tension during re-reeling on to a winch or storage drum helps avoid burying, along with a good traverse mechanism. As a guide, lines re-reeled at low tension and deployed with a line tension below 5 % of MBS do not experience problems with burying.

C.5.3 Equipment condition

All surfaces with which the rope can come into contact should be smooth and free of sharp edges. Relative movement between the rope and any equipment that it can come into contact with during deployment should be avoided. Special care should be taken to avoid contact between the polyurethane eyes of the rope and metal parts such as winch frameworks.

C.5.4 Rollers and rope bending

Occasional bending and running over rollers is allowable during deployment. The rope should not be repeatedly cycled around rollers for prolonged periods of time. The rope should also not be left curled for prolonged periods around bends under dynamic loading conditions.

Drums, sheaves and rollers should rotate freely.

The minimum storage D/d proportion is given by the barrel diameter of the transport reels. Insert lengths may utilize a lesser D/d proportion whenever packed in the original shipment.

C.5.5 Pre-tensioning and hook-up

In order to test the anchors and to remove initial constructional stretch from the tethers, a tensioning programme may be used. It may also be necessary to re-tension the lines from time to time during the early life of the mooring system and after its first storm loading in order to remove further constructional extension from the rope. Line tensions should continue to be monitored and retensioning should be completed where necessary.

Where applying high tensions to the rope during deployment or hook-up, the rope and terminations should be clear of any bends or obstructions. The rope should be completely outboard of the deployment vessel and fully submerged in the seawater.

C.6 Identifying damage

C.6.1 Damage to the rope cover

Small external damages, such as dirt and minor abrasion, are very common. The objective of the rope cover and filter is to protect the inner cores. The cover and filter are not considered for calculations of rope performance regarding, for example, breaking strength and stiffness. See [Figure C.13](#).

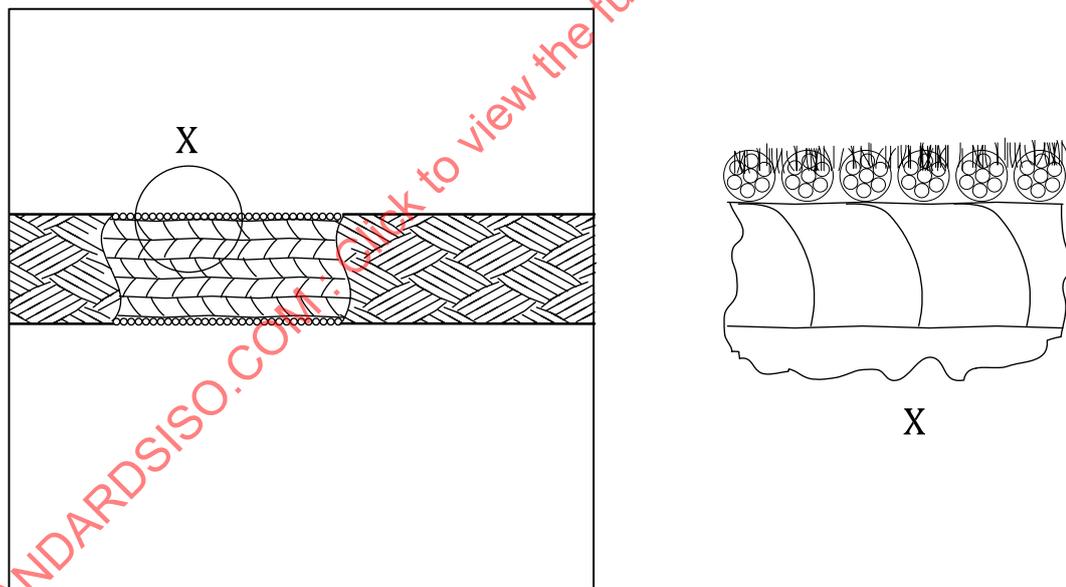


Figure C.13 — Small damage to Rope cover and filter

External damages can be visually identified as the following.

- a) Excess dirt, which does not represent major damage. The objective of the cover is to protect the rope cores. In this case, wash the area with fresh water. See [Figure C.14](#).

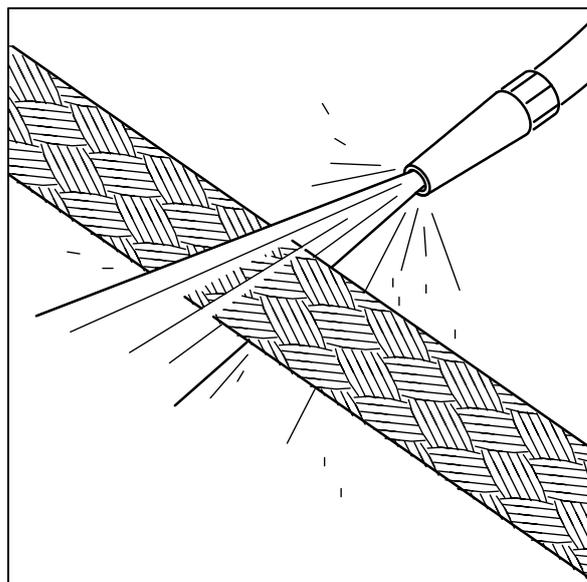


Figure C.14 — Washing out excess of dirt

- b) Cuts in the rope cover exposing the cores. In this case, if the exposed area of the core does not show any signs of cuts or dirt, cover the area with small diameter cords in a spiral array and secure them with reinforced adhesive tape; otherwise, the rope should be rejected. See [Figures C.15 to C.17](#).

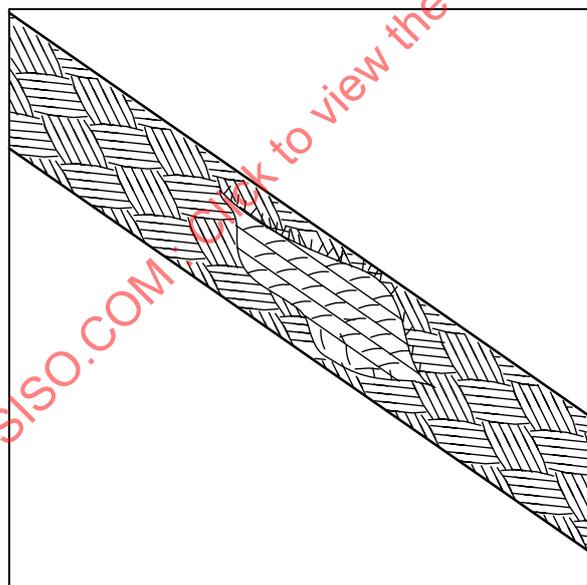


Figure C.15 — Exposed core

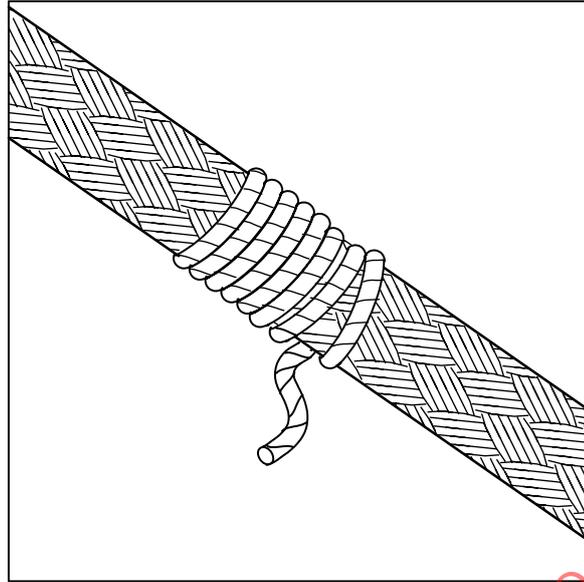


Figure C.16 — Repairing cover

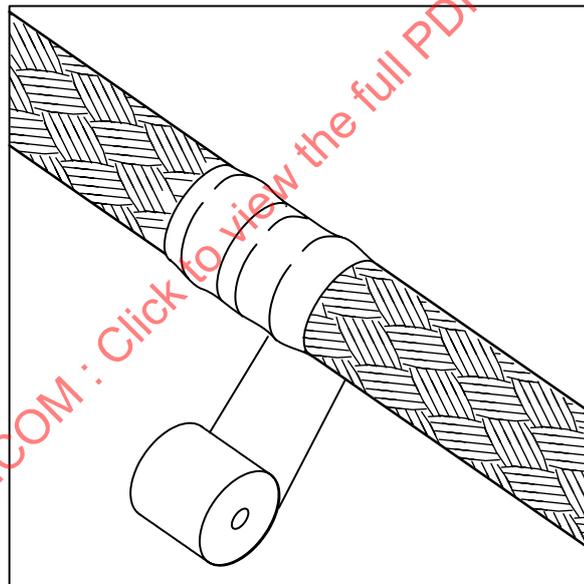


Figure C.17 — Repairing cover

- c) Threadbare cover caused by abrasion, without a cut. In this case, cover the area with reinforced adhesive tape. See [Figures C.18](#) and [C.19](#).

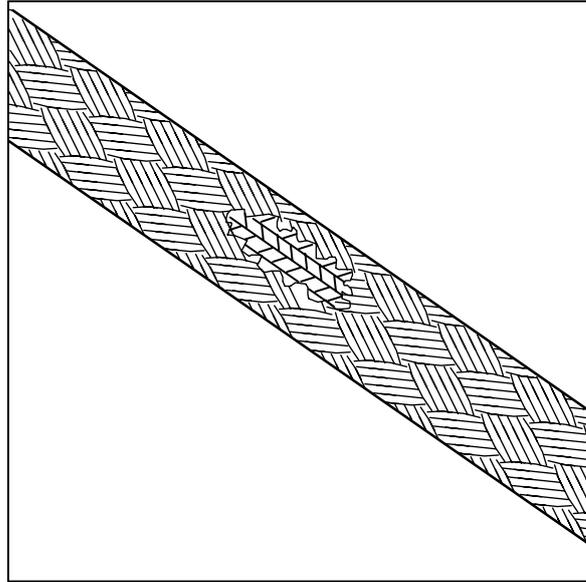


Figure C.18 — Threadbare cover

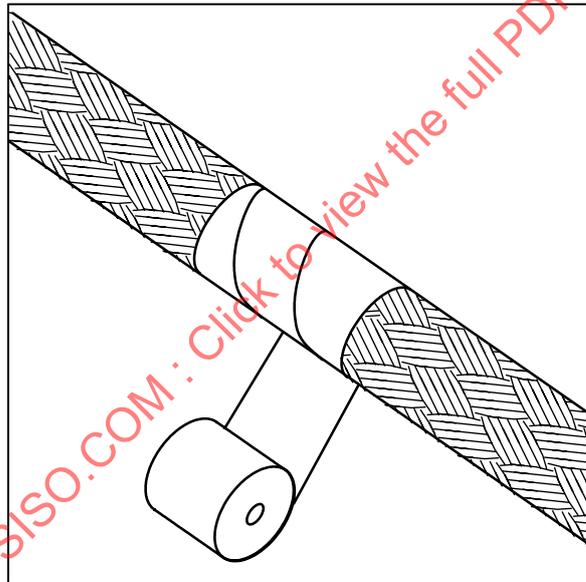


Figure C.19 — Reinforcing threadbare cover

C.6.2 Damage to the rope core

Ropes with damaged cores should be rejected. See [Figure C.20](#).

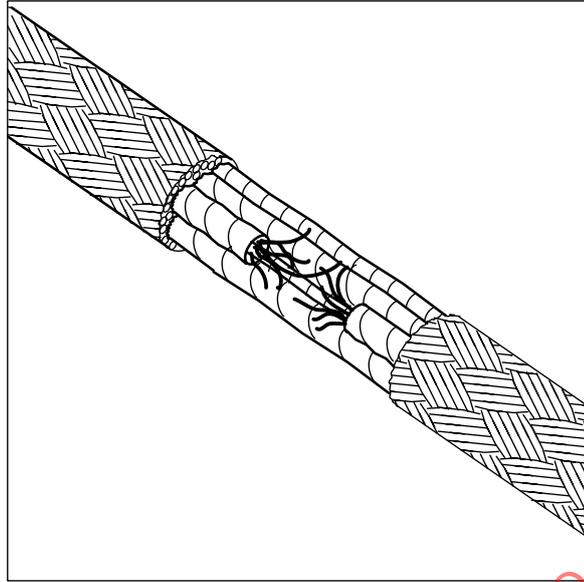


Figure C.20 — Damaged core

It should be noted that only major internal damage can be identified visually. Excessive nonlinearity in the rope surface may represent internal damage. See [Figures C.21](#) and [C.22](#).

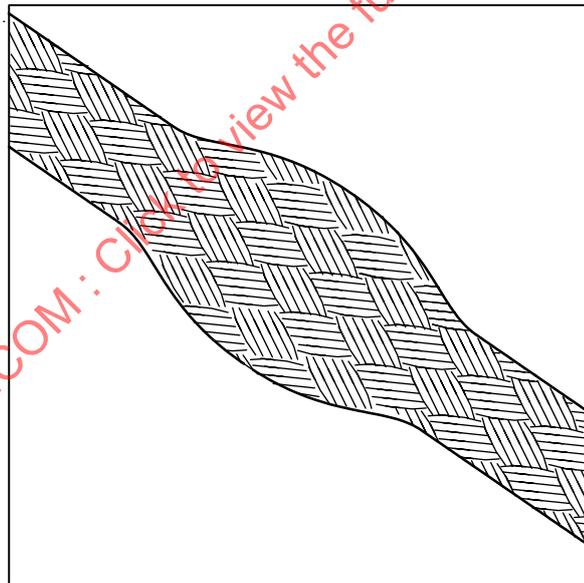


Figure C.21 — Internal damage