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Fibre ropes — General specifications

Cordages en fibres — Spécifications générales

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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 of 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 www.iso.org/iso/foreword.html.

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

This fourth edition cancels and replaces the third edition (ISO 9554:2010), which has been technically revised. The main changes compared to the previous edition are as follows:

— methodology for rope design and strength realization factor has been introduced;

— strand interchanges have been introduced;

— Table A.1 has been updated;

— Annex C has been updated.

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.

Fibre ropes — General specifications

IMPORTANT — It is the responsibility of the user to select a rope that is fit for purpose, i.e. of the right size and with the physical properties that meet the requirements of the application and to determine the limitations prior to its use.

1 Scope

This document specifies the general characteristics of fibre ropes and their constituent materials. It is intended to be used in conjunction with the standards for the individual types of fibre rope, which cover the physical properties and specific requirements for that particular product type.

This document also gives some information on the use of fibre ropes and also on their inspection and retirement criteria.

This document does not intend to address all of the safety matters associated with its use.

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 2307, *Fibre ropes — Determination of certain physical and mechanical properties*

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
strand interchange
overlapping continuation, in a braided rope, of a single interrupted strand (or multiple strand) with another identical strand which follows an identical path in the braid

3.2
minimum breaking strength
MBS
force a fibre rope shall at least achieve when tested following a recognized procedure/test method

Note 1 to entry: The MBS is set by each manufacturer, as per their own internal statistical methods based on breaking tests. In Annex D, two statistical methods are given that can be used to determine the MBS.

4 Manufacture

4.1 Constituent materials

The following materials are considered in this document:

a) natural fibres:

— sisal;

— manila;

— hemp;

— cotton.

b) man-made fibres:

— polyamide, PA;

— polyester, PES;

— polypropylene, PP;

— polyethylene, PE;

— mixed polyolefin, PP/PE;

— polyester/polyolefin dual fibres;

— high modulus polyethylene, HMPE;

— Para-Aramid, AR;

— Polyarylate, LCP;

— Polybenzobisoxazole, PBO.

Typical characteristics for these materials are given in Annex A. Specific applications should involve technical discussions with rope manufacturers.

4.2 Construction and structure

4.2.1 Laid ropes

Unless otherwise specified, 3-, 4- and 6-strand laid ropes shall be Z-twist (right-hand lay), their strands S-twist and their roping yarns Z-twist.

4.2.2 Braided ropes

The 8-strand braided ropes shall consist of four S-twist strands and four Z-twist strands arranged so that S-twist strands alternate (individually or in pairs) with Z-twist strands (individually or in pairs).

The 12-strand braided ropes shall consist of six S-twist strands and six Z-twist strands arranged so that S-twist strands alternate (individually or in pairs) with Z-twist strands (individually or in pairs).

4.2.3 Double-braided ropes

A double-braided rope shall consist of a number of strands that are braided to form a core, around which additional strands are braided to form a sheath. The core lies coaxially within the sheath. The number of strands varies, based upon the size of the rope.

4.2.4 Covered ropes

A covered rope consists of a core protected by a non-load bearing cover. A parallel rope construction is a covered rope where the core consists of a number of sub-ropes.

4.2.5 Strands

Each strand shall consist of an equal number of rope yarns sufficient to provide the characteristics specified in the International Standard for the relevant product. For ropes of reference number 36 or higher, the number of yarns in each strand may differ by one yarn or ±2,5 % from the intended number of yarns in the strand.

The ropes and their strands should be continuous, without splice for standard delivered lengths or shorter lengths. However, some lengths or methods of manufacture impose limitations. To overcome these limitations, strand interchanges can be used, these shall be in accordance with 4.4.3.

Yarns may be joined as necessary.

The strands can be assembled yarns.

4.2.6 Lay length or braid pitch

The manufacturer shall establish the lay length or the braid pitch of the rope according to its intended use, or based upon the purchaser's acceptance.

NOTE For a given reference number of rope, the smaller the lay length or braid pitch, the harder the rope will be. This hardness can affect the estimated breaking strength of the rope.

4.3 Treatment

4.3.1 Polyamide and polyester ropes

4.3.1.1 Polyamide and polyester laid ropes that are required to be heat set to ensure lay and dimensional stability are designated as type 1 ropes in the relevant product standard.

4.3.1.2 In other cases, polyamide and polyester laid ropes that are not required to have a heat setting on the rope are designated as type 2 ropes in the relevant product standard.

If type 1 or 2 are not specified in a particular product standard, it shall be understood that heat setting is not considered for that particular product.

4.3.1.3 The fibre producer or the rope manufacturer may apply a finish to the fibre to control friction, fibre tension and reduce fibre damage during manufacturing. The total amount of additives or extractable materials shall not exceed 2,5 % in mass.

4.3.1.4 Upon request of the purchaser, the manufacturer may use a coating or impregnation of the product for special applications.

4.3.2 Polypropylene and polyethylene ropes

Polypropylene and polyethylene ropes shall be protected against deterioration due to sunlight (UV).

The inhibiting system used should ensure the expected performance in usage under the foreseen geographical areas for applications, provided that the manufacturer is kept informed by the user.

4.3.3 High modulus polyethylene ropes

4.3.3.1 High modulus polyethylene ropes are typically coated.

4.3.3.2 High modulus polyethylene ropes may be subject to a heat setting process. Heat set ropes of HMPE are designated as type 1 ropes in the relevant product standard.

4.3.3.3 High modulus polyethylene ropes which have not been heat set are designated as type 2 ropes in the relevant product standard.

Heat setting usually enhances the breaking strength of a high modulus polyethylene rope. However, the overall life time of the rope may be decreased.

4.3.4 Manila and sisal

4.3.4.1 General

All ropes of manila and of sisal shall be made exclusively of new fibres.

4.3.4.2 Manila

A cordage oil lubricant of suitable quality shall be applied. The lubricant shall not impart an offensive odour to the finished rope. The percentage of extractable matter based on the dry weight of the rope shall not be less than 11,5 % nor more than 16,5 %.

When specified, the rope shall have a mildew-resistant treatment.

Anti-bacterial additives for manila may be added to extend the performance of the natural fibre when requested by the purchaser.

4.3.4.3 Sisal

A cordage oil lubricant of suitable quality shall be applied. The lubricant shall not impart an offensive odour to the finished rope. The percentage of extractable matter based on the dry weight of the rope shall not be more than 11,5 % for an un-oiled product and not more than 16,5 % for an oiled product.

When specified, the rope shall be free from any oils and sold as un-oiled rope.

Anti-bacterial additives for sisal may be added to extend the performance of the natural fibre when requested by the purchaser.

4.4 Workmanship

4.4.1 The finished rope shall contain no cuts, kinks or soft spots caused by change in lay or pitch length, hockles, chafed or damaged sections, or broken, loose or projecting ends in the rope or the strands.

4.4.2 The unspliced ends of all ropes shall be cut off squarely and shall be securely whipped, taped or heat-sealed.

4.4.3 Strand interchanges, when present in 12-strand ropes or sub ropes, shall be staggered along the length of the rope and at sufficient distance apart. The interrupted and replacement strands are arranged in parallel over some distance and are buried or tucked into the braid so as to secure them into the braid. To maintain strength, the strands shall overlap one another for a sufficient distance.

A test sample including a strand interchange in one strand shall achieve 100 % of the specified minimum breaking strength (MBS) when tested in accordance with ISO 2307.

NOTE For strand interchanges in double braid ropes, see the relevant product standard.

The process of strand interchange shall be completely documented. Documentation shall contain at least the following information and shall be available to an inspector upon request:

— length of one strand interchange;

— minimum distance between two strand interchanges;

— total length of the strand interchange;

— positions of the strand interchanges from beginning to end in the rope.

If required, every splice of a strand/part shall be permanently marked (for example by paint) on the rope in order to enable early detection of a strand interchange slipping apart, and to distinguish a strand interchange from damage. Strand interchanges are allowed only in 12-strand braided ropes.

5 Rope design

Ropes of different sizes are considered to be of the same design when the following rope parameters remain constant across the size range:

a) rope yarn;

b) dimensionless lay of strand is fixed (= lay of strand divided by diameter of the strand);

c) dimensionless lay length or braid pitch is fixed (= lay of rope divided by diameter of the rope);

d) type of equipment used;

e) coating type, pick-up and penetration (when applicable);

f) quality control and splicing.

The design should be reported in a design specification sheet containing general information on the company, independent inspector, rope design and prototype tests done to validate the design. This specification should be made available to interested parties on request. See D.3.1.

The details of rope design and prototype tests should be given in a second sheet (see D.3.2). Details of the fibre used for the design are specified in D.3.3. These last two sheets should be made available for inspection by independent inspectors on request of interested parties.

6 Requirements

The main requirements shall be those specified in the relevant International Standard for the product and shall include the following:

a) reference number;

b) linear density;

c) minimum breaking force.

The test methods for b) and c) are specified in ISO 2307.

Other requirements, for example the lay length, the braid pitch, the diameter of the circumscribed circle, and the elongation of the rope under specific tensile conditions, may be specified, subject to agreement between the manufacturer and the purchaser.

7 Marking and labelling

7.1 Marking

7.1.1 General

The identification of the material, quality and origin of a fibre rope conforming to this document shall be marked using a tape placed within the article (see 7.1.3) so as to remain recognizable despite soiling, soaking or discoloration during use.

The tape shall be at least 3 mm wide, and shall be printed with the number of the relevant International Standard, and a reference identifying the manufacturer. The maximum distance between two consecutive markings shall be 0,5 m.

7.1.2 Ropes of reference number less than 14

These do not need to be marked, unless specified in a product standard.

7.1.3 Ropes of reference number equal to or greater than 14

A marker tape as defined in 7.1.1 shall be incorporated into the centre of one strand for 3-, 4-, and 8-strand ropes. 12-strand ropes can either have a marker in the centre of one strand or in the centre of the rope. Double-braided ropes shall have a marker tape in or outside the core.

For covered ropes, the marking tape shall be incorporated between the cover and the core or within the core.

7.2 Labelling

Each coil shall have a label, which is firmly fixed in place, giving the following information:

— constituent material;

— identification of manufacturer and country of origin;

— reference number;

— delivered length;

— reference to the relevant product standard.

8 Packaging, invoicing and delivered length

8.1 Packaging and invoicing

8.1.1 The packaging unit may be a reel, a coil, a hank, a box, a bag or as specified by the purchaser.

8.1.2 The finished rope shall be supplied in a package, so that it can be dispensed freely without entanglement of any kind.

8.1.3 Either the unit mass or the length may be used to invoice the rope. When the gross mass is used for invoicing, the mass of the packaging shall not exceed 1,5 % of the gross mass of the rope.

8.2 Delivered length

8.2.1 Standard delivered length

The length of the coil shall be determined by dividing the mass of the coil by the mass per metre of the rope, determined in accordance with ISO 2307.

The limit deviation on delivered length shall be

— −5 % for ropes with a reference number less than or equal to 14, or

— −3 % for ropes with a reference number greater than 14.

However, the gross mass corresponding to the delivered length shall not be less than the product of the minimum linear density and the theoretical delivered length.

Standard delivered lengths are the following:

— 100 m;

— 183 m;

— 200 m;

— 220 m;

— 366 m.

Other lengths may be supplied for special orders.

8.2.2 Shorter delivered length due to sampling

To carry out testing at the request of the purchaser, test pieces may be taken from the ordered length of rope. The length of rope delivered shall then be less than the ordered length because of these test pieces (which are considered to be part of the delivery).

In the event that a specific length and testing are required, the purchaser may be invoiced the additional length or mass of the rope required to perform such testing.

9 Testing

9.1 The minimum breaking strength shall be taken from a relevant ISO standard, or as agreed to between parties, the manufacturer may use his own internal statistical methods.

The testing of the finished rope shall be conducted as specified in the applicable International Standard and in the purchase order or contract.

9.2 The required length and number of test samples shall be removed from the selected test reels as outlined in 8.2.2, if required.

9.3 Test reports shall be prepared in accordance with the contract or the purchase order.

10 Visual quality control

10.1 Responsibility for inspection

Unless otherwise specified in the contract or in the purchase order, the rope manufacturer is responsible for the performance of all quality-control requirements specified in this document and in the applicable fibre rope standard. The purchaser shall have the option to have a representative present during the control by the manufacturer. The purchaser, at his/her expense, reserves the right to perform or have a third party perform any of the controls set forth in the specification where controls are deemed necessary to ensure that ropes conform to specifications. A representative of the rope manufacturer shall have the option to be present during these controls.

10.2 Finished-rope visual control

Each sample shall be subject to visual examination. The samples shall be selected at random. If any defects are noted in the original test units, an equal number of additional test units shall be selected at random and, if any specified defects are noted, the entire lot shall be rejected. See Annex B.

11 Manufacturer declaration

When requested by the purchaser, the manufacturer of the rope shall issue declarations of conformity with the relevant International Standard when invoicing. These declarations shall always be available for any of the phases of the distribution and/or usage of the rope.

If manufacturing declaration is required, it shall be requested at the time of placing the order.

12 Instructions for use

The manufacturer shall provide the purchaser with a set of instructions for the use and maintenance of fibre ropes.

NOTE Recommendations on information for the use and maintenance of fibre ropes to be provided by the manufacturer are given in Annex C.

Annex A
(informative)

Typical characteristics of the yarns for man-made and natural fibres used in ropes, slings and netting

Table A.1 — Typical characteristics of the yarns for man-made and natural fibres

Fibre	International Standard for rope type	Physical properties								Environmental properties	
		Approximate density	Tenacity		Elongation at break	Abrasion resistance[a,b]	Creep resistance[b]	Melting point	Moisture regain	Sunlight (UV) resistance[b,d]	Effects of chemical exposure[e]
		kg/dm³	gf/denier	N/tex	%			°C	%		
Polyamide[f] PA 6 PA 6,6	ISO 1140 ISO 10554	1,14	7,5 to 10,5	0,66 to 0,93	14 to 28	dry 5 wet 2	2 to 3	218 to 258	4 to 6	3 to 5	Resistant to weak acids, alkalis and organic solvents. Decomposed by strong mineral acids. Soluble in phenols and formic acid.
Polyester[f] PES	ISO 1141 ISO 10547	1,38	7 to 10	0,62 to 0,88	10 to 18	4 to 5	4	254 to 260	<1	4 to 5	Resistant to mineral acids and organic solvents. Decomposed by strong sulfuric acids and strong alkalis at a high temperature. Soluble in phenols.
Polypropylene PP	ISO 1346	0,91	split 4,5 to 5,0 mono 6,0 to 6,5 multi 6,0 to 6,5 multi 7,2 to 9,5[g]	0,40 to 0,44 0,53 to 0,57 0,53 to 0,57 0,63 to 0,84[g]	8 to 12 12 to 18 20 to 24 16 to 20[g]	2	2	165	0	2 to 3	Resistant to acids, alkalis and organic solvents. Soluble in chlorinated hydrocarbons.

[a] Over-applied finishes can enhance abrasion resistance under both dry and wet conditions.

[b] These columns are graded on a scale of 1 to 5, considering that 1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent.

[c] Resistant to rotting, mildew and other microbiological actions.

[d] Special additives, protective coatings and jackets can greatly reduce the harmful effects of sunlight (UV).

[e] For specific service conditions of time, temperature and concentrations, contact the rope manufacturer.

[f] Polyamide and polyester ropes shall contain not more than 0,05 % by mass of titanium dioxide.

[g] Polypropylene multifilament of high tenacity.

[h] Synthetic fibres are susceptible to UV degradation. When a fibre is used in a rope, the UV resistance can vary depending on the construction and other factors. Specific values should be obtained from the individual fibre companies and the rope manufacturers.

Table A.1 *(continued)*

Fibre	International Standard for rope type	Physical properties								Environmental properties	
		Approximate density	Tenacity		Elongation at break	Abrasion resistance[a,b]	Creep resistance[b]	Melting point	Moisture regain	Sunlight (UV) resistance[b,d]	Effects of chemical exposure[e]
		kg/dm³	gf/denier	N/tex	%			°C	%		
Polyethylene PE	ISO 1969	0,95	5,5 to 9,0	0,49 to 0,79	16 to 24	3	1	140	0	3 to 5	Resistant to acids, alkalis and organic solvents. Soluble in chlorinated hydrocarbons.
Mixed polyolefin PP/PE	ISO 10572	0,92	6,5 to 8,5	0,57 to 0,75	12 to 18	3	2	140	0	2 to 4	Resistant to acids, alkalis and organic solvents. Soluble in chlorinated hydrocarbons.
Polyester/ polyolefin dual fibres	ISO 10556	0,98 to 1,15	6,6 to 7,9	0,58 to 0,69	12 to 18	3 to 5	3	140	<1	2 to 4	Same effects as those of polyester and polypropylene.
High modulus polyethylene	ISO 10325	0,97	25 to 44	2,2 to 3,9	2,58 to 3,9	5	1 to 3	144 to 155°	0	4 to 5	Resistant to most concentrated industrial acids, bases, oxidizers, and organic solvents at room temperature.
Polyarylate LCP	—	1,4	20 to 31	1,8 to 2,7	2,5 to 4,0	3	5	310 to 340°	<0,1	2 to 3	Stable to acids <90 % concentration and bases <30 % concentration

[a] Over-applied finishes can enhance abrasion resistance under both dry and wet conditions.

[b] These columns are graded on a scale of 1 to 5, considering that 1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent.

[c] Resistant to rotting, mildew and other microbiological actions.

[d] Special additives, protective coatings and jackets can greatly reduce the harmful effects of sunlight (UV).

[e] For specific service conditions of time, temperature and concentrations, contact the rope manufacturer.

[f] Polyamide and polyester ropes shall contain not more than 0,05 % by mass of titanium dioxide.

[g] Polypropylene multifilament of high tenacity.

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Table A.1 *(continued)*

Fibre	International Standard for rope type	Physical properties								Environmental properties	
		Approximate density	Tenacity		Elongation at break	Abrasion resistance[a,b]	Creep resistance[b]	Melting point	Moisture regain	Sunlight (UV) resistance[b,d]	Effects of chemical exposure[e]
		kg/dm^3	gf/denier	N/tex	%			°C	%		
Para Aramid AR	—	1,44 to 1,47	22 to 28	1,9 to 2,5	1,5 to 4,4	dry 4 wet 3 to 4	5	Decomposes at 500°	2 to 7	3 to 4	Resistant to weak acids, bases, water and salt water. Degradation can be induced by strong acids and bases in high concentration or high temperature.
Para Aramid copolymer	—	1,39	26 to 28	2,3 to 2,5	3,9 to 4,5	dry 5 wet 4 to 5	5	Decomposes at 500°	1,9	3 to 4	Very resistant to acids, bases, organic solvents and salt water.
Polybenzo-bisoxazole PBO	—	1,54 to 1,56	42	3,7	2,5 to 3,5	5	5	Decomposes at 650°	0,6 to 2	1	Resistant to bases and organic solvents at room temperature. Degradation induced by acids

[a] Over-applied finishes can enhance abrasion resistance under both dry and wet conditions.

[b] These columns are graded on a scale of 1 to 5, considering that 1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent.

[c] Resistant to rotting, mildew and other microbiological actions.

[d] Special additives, protective coatings and jackets can greatly reduce the harmful effects of sunlight (UV).

[e] For specific service conditions of time, temperature and concentrations, contact the rope manufacturer.

[f] Polyamide and polyester ropes shall contain not more than 0,05 % by mass of titanium dioxide.

[g] Polypropylene multifilament of high tenacity.

[h] Synthetic fibres are susceptible to UV degradation. When a fibre is used in a rope, the UV resistance can vary depending on the construction and other factors. Specific values should be obtained from the individual fibre companies and the rope manufacturers.

Table A.1 — *(continued)*

Fibre	International Standard for rope type	Physical properties								Environmental properties		
		Approximate density	Tenacity		Elongation at break	Abrasion resistance[a,b]	Creep resistance[b]	Melting point	Moisture regain	Environmental resistance[bc] (natural fibres)	Sunlight (UV) resistance[b,d]	Effects of chemical exposure[e]
		kg/dm³	gf/denier	N/tex	%			°C	%			
Cotton	—	1,54	2,0 to 3,0	0,18-0,26	2 to 3	2	5	Chars at 148	100	1 to 2	3 to 4	Degradation by acids in high concentration or high temperature. Resistant to alkalis. Degradation by organic solvents and sea water.
Sisal	ISO 1181	1,38	2,0 to 2,5	0,18 to 0,22	6 to 12	2	5	Chars at 148	100	1	3 to 4	Resistant to alkalis and organic solvents. Degradation by acids of high concentration or at a high temperature.
Manila	ISO 1181	1,35	2,5 to 3,0	0,22 to 0,26	6 to 10	2	5	Chars at 148	100	1 to 2	3 to 4	Resistant to organic solvents. Degradation by acids of high concentration or at a high temperature.
Hemp	EN 1261	1,35	2,5 to 3,5	0,26 to 0,31	6 to 12	2 to 3	5	Chars at 148	100	1 to 2	3 to 4	Resistant to organic solvents. Degradation by acids of high concentration or at a high temperature.

[a] Over-applied finishes can enhance abrasion resistance under both dry and wet conditions.

[b] These columns are graded on a scale of 1 to 5, considering that 1 = poor; 2 = fair; 3 = good; 4 = very good; 5 = excellent.

[c] Resistant to rotting, mildew and other microbiological actions.

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[f] Polyamide and polyester ropes shall contain not more than 0,05 % by mass of titanium dioxide.

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[h] Synthetic fibres are susceptible to UV degradation. When a fibre is used in a rope, the UV resistance can vary depending on the construction and other factors. Specific values should be obtained from the individual fibre companies and the rope manufacturers.

Annex B
(informative)

Information on defects and variances

B.1 Major defects

Major defects include the following:

a) any cuts, snags, pulled yarns or strands, and/or kinks;

b) any damaged sections;

c) uneven (overly tight or loose) braiding, resulting in braid discontinuity, or soft spots;

d) any rope ends knotted or spliced to make a continuous standard length;

e) yarns (fibres) per strand or number of strands not as specified;

f) braid pattern not as specified;

g) lay or braid pitch not within specification required by the customer;

h) identification marker, if required, omitted or incorrect;

i) colour not as specified;

j) more-than-allowable strand interchanges.

B.2 Minor defects

Minor defects include the following:

a) broken, loose or projecting ends in the rope or strand;

b) excessive loose fibre ends on the surface or in gaps between strands;

c) ends not cut off squarely, or not securely whipped, taped or heat-sealed;

d) clearly visible and excessive stains;

e) any chaffed sections.

B.3 Unit and/or packaging variances

B.3.1 Unit

Variances with regard to length or mass exists if any of the following are determined during inspection:

a) length of unit is less than specified;

b) net mass of unit is exceeding permitted tolerance;

c) package units not in continuous length for standard lengths, unless otherwise agreed to on the purchase order or contract.

B.3.2 Packaging

Variances with regard to packaging exists if the following are determined during inspection:

a) improperly or not firmly wound, resulting in slippage or otherwise affecting the free unhampered, unwinding (uncoiling) of the rope;

b) improper identification or labelling of the product.

The manufacturer should correct such variances or the purchase order or contract may be cancelled. These variances should be determined prior to the shipment.

Annex C
(informative)

Information for use and maintenance to be provided by the manufacturer

C.1 General

The information in this annex on the use and maintenance of fibre ropes should be provided by the manufacturer to purchasers.

This annex also provides some detailed information for the use and maintenance of used ropes.

It is recommended that the manufacturer provide warning labels, wherever reasonable, to alert users to dangerous practices.

C.2 Basic information on use and maintenance of fibre ropes

C.2.1 Uncoiling

When removing a rope from a coil, one should start with the end from the inside. The rope should run out counter clockwise. If the rope is pulled out clockwise, kinks will occur. If that happens, replace the length of rope back into the coil, turn the coil over and pull from the centre again. The rope should then run out counter-clockwise and be kink-free.

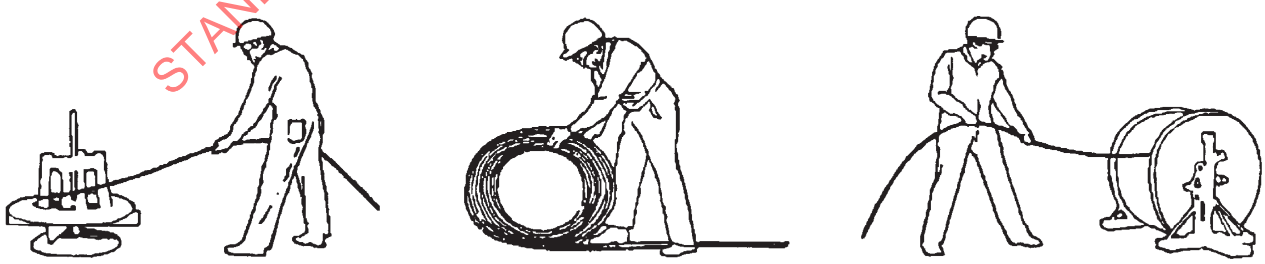
An even better way of uncoiling is by using a turntable. The rope can be uncoiled from the outside end, as shown in Figure C.1 a).

A short length of rope can also be rolled out over the ground as shown in Figure C.1 b).

C.2.2 Unreeling

When rope is removed from a reel, the reel itself should be free to rotate. This can easily be accomplished by passing a pipe through the reel centre, as shown in Figure C.1 c).

Never remove rope from a reel lying on its side.



a) Uncoiling **b) Uncoiling** **c) Unreeling**

Figure C.1 — Uncoiling and unreeling

C.2.3 Storing

C.2.3.1 Storing in a coil (circular shape)

A right-hand-laid rope should always be coiled in a clockwise direction and a left-hand-laid rope should always be coiled counter-clockwise, i.e. with the lay of the rope. Instead of laying all layers on top of each other, it is best to lay the rope in a spiral shape by moving each layer by a few centimetres (see Figure C.2).

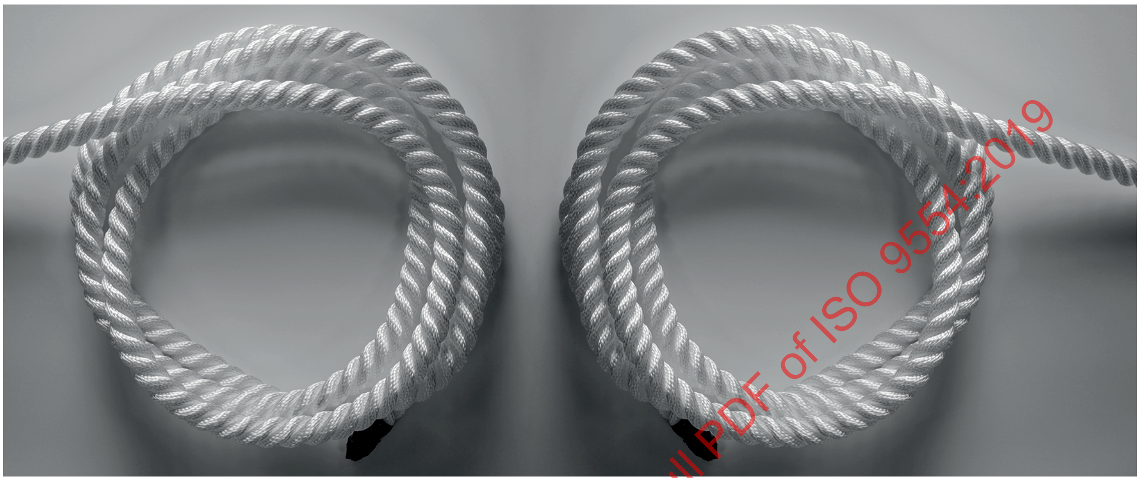


Figure C.2 — Storing on a coil

C.2.3.2 Storing in a figure of 8 shape

Storing the rope in a figure of 8 shape (see Figure C.3) is possibly better than storing in a coil.

NOTE This method is suitable for both laid and braided ropes. It avoids the build-up of twist in both directions.

For laid ropes, the rope should be turned over the line's axis every second turn, otherwise there will still be tension within the rope.

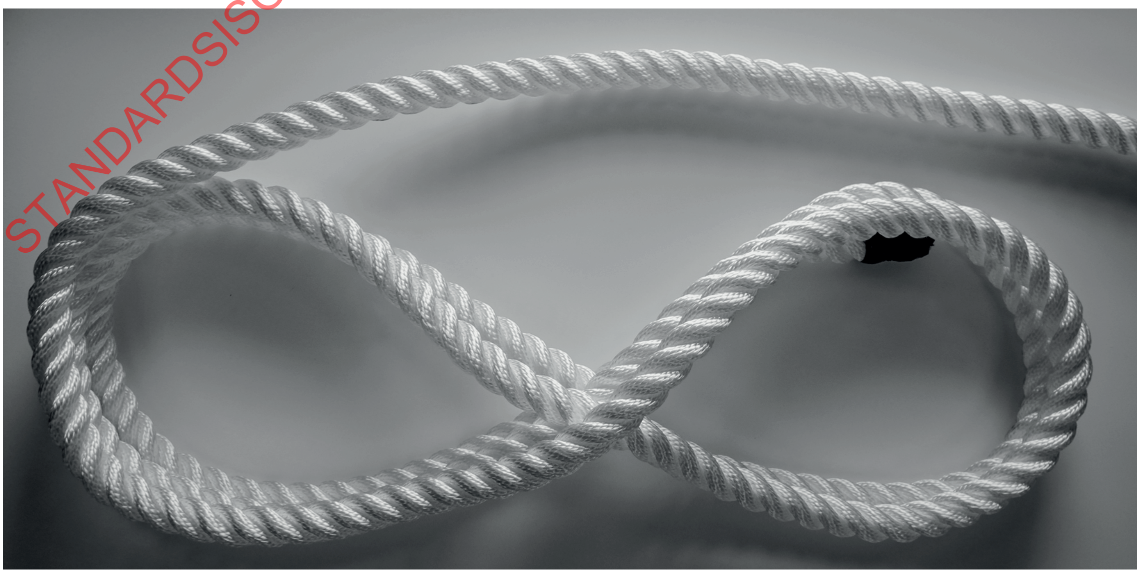


Figure C.3 — Storing in a figure of 8 shape

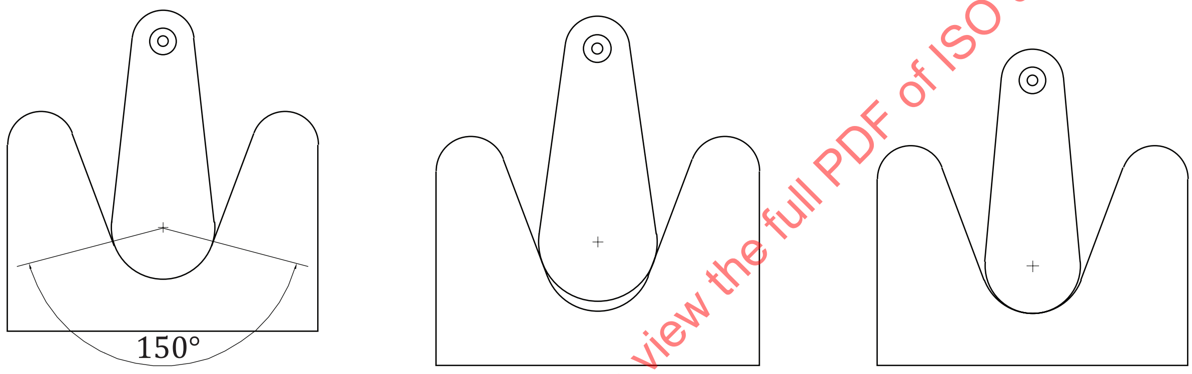
C.2.4 Sheaves

The *D*/*d* ratio, where *D* is the diameter of the sheaves and *d* is the diameter of the rope, should exceed 5 in all cases, but may be as high as 20 for certain high-performance fibres. Many applications or rope types require a high *D*/*d* ratio. Especially for lifting operations, higher design factors are appropriate.

Apart from the sheave diameter, the lifetime of the rope also depends on the design and dimensions of the groove. If the groove is too narrow, the rope gets wedged, the strands and fibres cannot move as required for bending and this is detrimental to the rope's lifetime. On the other hand, a groove that is too wide also has an adverse effect on the lifetime of the rope due to flattening out of the strands and yarns.

For synthetic rope, it is recommended that the groove diameter be 10 % to 15 % larger than the nominal diameter of the rope. The rope is supported in the best possible manner if the arc of contact with the groove contour is 150°. The height of the flanges should be at least 1,5 times the rope diameter, in order to prevent the rope from running off the sheave.

The sheaves should be inspected in accordance with Figure C.4.



a) Correct **b) Too tight** **c) Too loose**

Figure C.4 — Inspection of sheaves

Bearings should be maintained at regular intervals in order to ensure smooth rotation of the sheaves.

C.2.5 Knotting

The practice of knotting eyes into ropes, or knotting ropes to shorten them, should be avoided. Knots reduce strength.

C.2.6 Kinking and hockling

Excessive turns can cause kinking (see Figure C.5) in any rope but hockles (see Figure C.7) only occur in basic twisted (laid) ropes. Braided ropes cannot be hockled as their interlocking strand construction prevents unlaying. Strands run in both directions creating a torque-free balance, thus eliminating any inherent tendency towards twist or rotation.

Excessive turns (kinking) in a rope should be removed by “counter rotating” the rope in a relaxed condition as soon as possible. Once the hockles are formed, the rope has lost breaking strength, even when the hockle has been unlaid. The damage is irreversible, and the loss of strength could be as high as 30 %.

Kinks should never be allowed to form in the rope (see Figure C.5). If kinks do form, this is a sign that turn has been gained or lost in the rope, and the kinks should be taken out of the rope from one end. This recommendation applies equally to laid and braided ropes.

Kinks are especially serious with laid ropes, as serious damage can result if attention is not paid to them. Attempts to eliminate kinking should never involve pulling the rope in an attempt to force the kink out. The result might be to cause the strand to distort as shown in Figure C.6.

Figure C.5 — Kinking

The rope has lost approximately 15 % of its strength. While it may be possible to correct this distortion of the rope so that the original location of the site is lost, a weakness has been created in the rope at this point, and future kinks will tend to settle there.

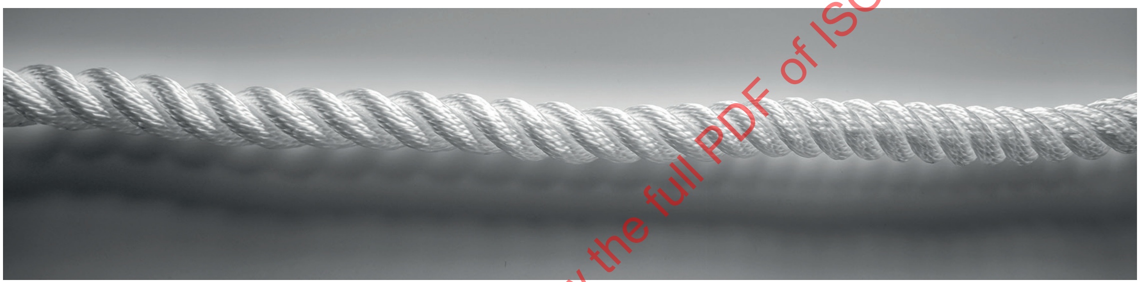


Figure C.6 — Pulling out kinks

If the practice of pulling kinks out of the rope persists, the next stage will be reached quickly.

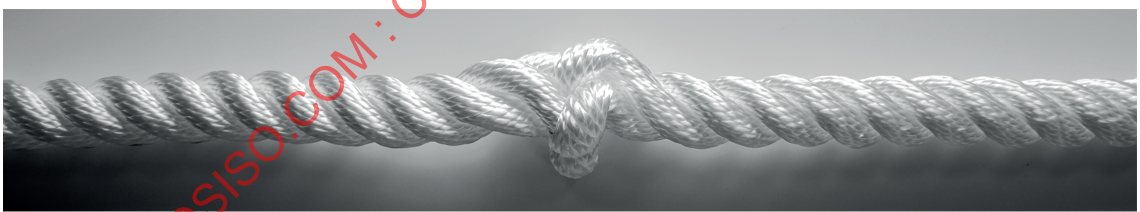


Figure C.7 — Formation of hockle

This is the formation of the complete hockle (see Figures C.7 and C.8). The rope has lost approximately one-third of its strength at this point, and more importantly perhaps, has completely lost its resistance to absorb twist at this point.

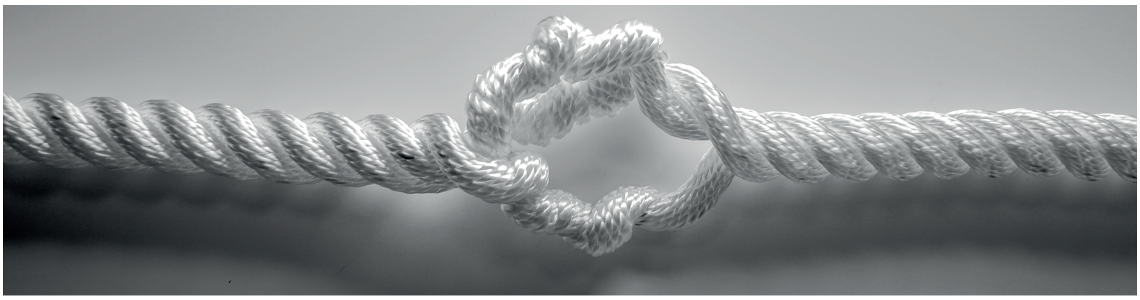


Figure C.8 — Complete hockle

If cyclic loading continues, the hockle will run until the rope has once again reached a position of torsional balance but, clearly, the defect makes the rope unusable.

C.2.7 Snapback safety warning

A dangerous situation occurs if personnel are in line with a rope under excessive tension. Should the rope fail, it will likely recoil with considerable force. Death might result. Persons should be warned against standing in line with the rope or in its bight.

C.3 Fit for purpose of fibre ropes based on context requirements

The context requirements during use need to be considered during design, manufacturing and use of fibre ropes. The aspects to be assessed are aspects such as, but not limited to:

a) resistance to chemicals;

b) restrictions due to temperature;

c) susceptibility to cutting and abrasion;

d) degradation due to ultraviolet radiation;

e) static bending over, e.g. available hardware;

f) repeated bending-unbending when passing over sheaves;

g) axial compression;

h) tension fatigue; and

i) irreversible elongation over time induced by constant loading (creep).

Before each period of use, refer to the rejection criteria in Table C.1.

C.4 Periodic thorough examination and maintenance

The following are aspects to be considered regarding examination and maintenance:

a) retirement criteria, including missing/damaged label and illegible marking;

b) records of examination.

C.5 Fibre rope inspection and retirement criteria

C.5.1 Inspection of cordage

C.5.1.1 General

Before a length of rope is issued for use, the entire length, including eye splices and/or long splices, should be inspected by a competent person. This examination should be undertaken to look for the types of damage described in C.5.1.2 to C.5.1.8.

The details of every inspection should be recorded as to date, damage, location and conclusions.

C.5.1.2 External wear

Some types of ropes will develop a fur or pile on their surface as the result of dragging over rough surface. This is quite normal and will not cause weakening of the rope to any significant extent. Excessive wear is indicated by a major portion of the cross-sections of the yarns on the outside of the rope being removed. Such wear is usually seen most clearly on the strand crowns and on the inside of eye splices, in particular underneath a rope thimble, if incorporated (see Figure C.9).

Figure C.9 — External wear

C.5.1.3 Internal wear

Where ropes have been used in a gritty environment, sharp grit may penetrate into their centre. It is important to open the rope and examine between the strands to establish whether such damage is occurring (see Figure C.10). This examination should be undertaken very carefully to prevent buckling and distortion of the strands which can themselves cause trouble at a later date. The presence of large quantities of fibre dust in the centre of the rope indicates that replacement may be necessary.

Figure C.10 — Internal wear

C.5.1.4 Axial compression and kink bands

Ropes can be subject to axial compression, especially ropes that have a braided or extruded jacket over an inner, load bearing core are subject to axial compression, as manifested by kink bands. This occurs mostly in ropes with long lay (braid) cores and a very tight cover when they are subject to bending while under tension (as occurs on bitts and chocks). In severe cases, the rope will have bulges in zones where kinks are concentrated (bulges often repeat at a uniform cycle length). If the inner core can be inspected, bands of kink fibres or yarns that have a Z appearance may be seen. If damage is severe, the filaments at the Z points will be severed as with a knife. If the cover cannot be opened for internal inspection, destructive inspection or testing may be the only means of evaluation.

Kink bands can also appear in splices of very high strength, high modulus ropes. This is an indication that serious damage could be present. Destructive testing may be the only means of evaluation. See Figure C.11.

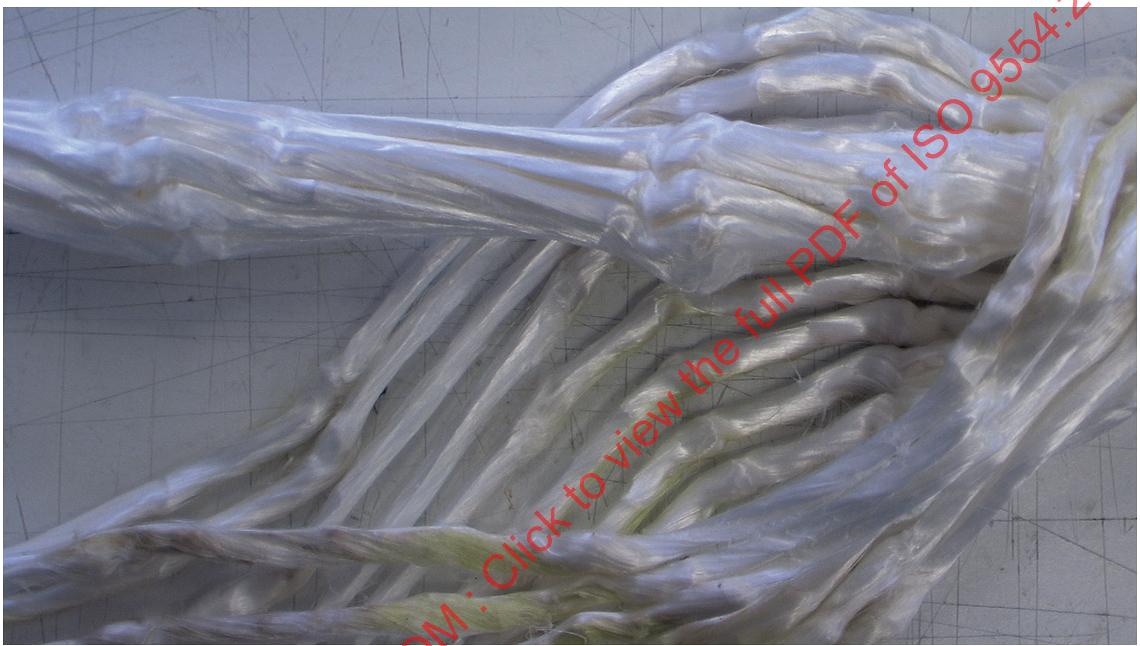


Figure C.11 — Kink bands

C.5.1.5 Cuts, chafes and other mechanical damage

Mechanical damage (see Figure C.12) will always weaken a rope. The weakening will depend upon the severity of the damage. It should be remembered that mechanical damage, especially chafing, will always have a more pronounced effect on a smaller rope than on a larger one.

Cuts require close examination to establish their depth, and hence how much of the cross-section of the rope has been damaged.

For covered ropes where the cover is non-load bearing, a cut that does not damage the core will probably not affect the strength. However, core deformation or herniation could occur on subsequent use if the cover is not repaired. Cores can shift relative to the cover; further inspection in the vicinity of the damages should be performed to ensure integrity of the core. Cuts to covers may cause other adverse effects such as handling difficulties, inability to slide through fittings smoothly, and exposing the core to grit.

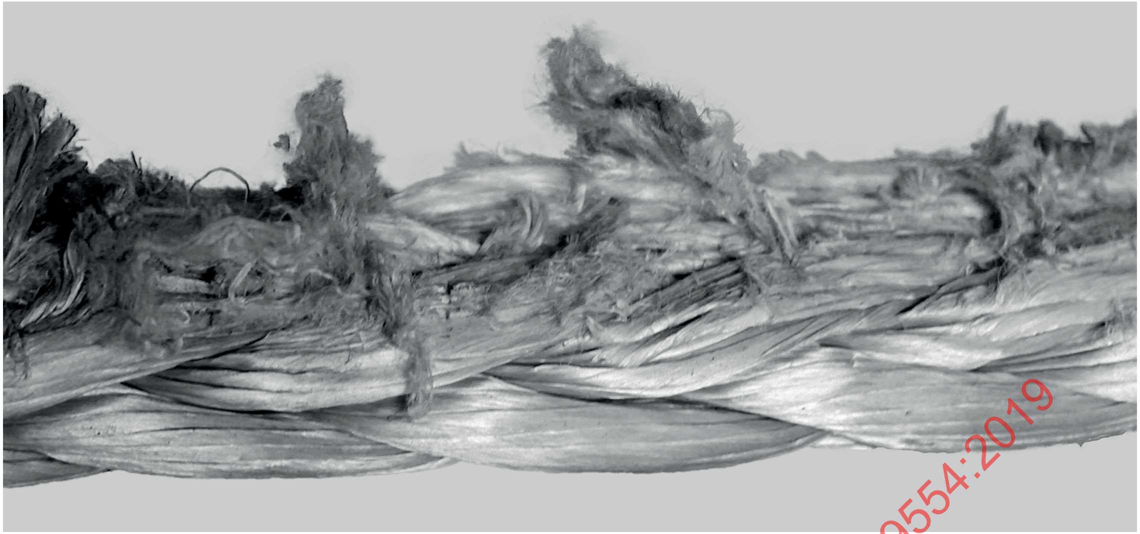


Figure C.12 — Mechanical damage

C.5.1.6 Damage by chemicals

Deterioration of cordage by chemical means is not usually the result of the rope having been contaminated in a manner that could have been anticipated by the user, i.e. rope supplied for use in known chemical environments is usually that which offers the highest resistance to the anticipated conditions. Deleterious contamination frequently occurs by accidental contact with chemicals whose presence was not anticipated.

C.5.1.7 Sunlight damage

Ultraviolet (UV) radiation from direct sunlight causes brittle and weak outer rope yarns. UV degradation is difficult to inspect visually. Discoloration and brittleness in the filaments may be observed in some cases. Strength testing of a few surface fibres or the entire rope is required for a definitive assessment.

C.5.1.8 Thermal damage

The friction generated in synthetic-fibre ropes under high tension during work can generate enough heat to melt or fuse fibres, yarns or strands together.

The examination should determine whether any areas of fusion or carbonization are present. If in doubt, discard the rope.

C.5.1.9 Wetting

Wet or damp natural-fibre ropes should not be left on the ground, as this causes the start of rot and also the adhesion of particles of grit. Even ropes of man-made fibres that are not affected by wet or damp are liable to be damaged by particles of grit. All wet ropes should be hung in freely circulating air or festooned over pegs and allowed to dry naturally. If this cannot be done, the ropes should be loosely stacked on pieces of timber or any other suitable substance, clear of the damp ground or sweating concrete. Coils of new rope should be stacked in a similar manner. On no account should the ropes be dried by any form of heat.

C.5.1.10 Mildew

Mildew does not attack man-made fibres, although surface contamination can, under certain circumstances, provide a nutrient which permits the growth of moulds. While these are unpleasant, they do not affect the strength of the rope. They may be removed by washing in water. The use of harsh detergents should be avoided.

Mildew will attack natural-fibre cordage if it is stored wet in stagnant air. The mould will live on the cellulose of the rope and a loss of strength will inevitably occur as a consequence.

C.5.2 Estimating damage and strength degradation with different rope constructions

The following guidelines are suggested for use in estimating damage and strength degradation, brought on by normal wear.

It is important to understand that a rope will lose strength during use in any application. Ropes are serious working tools and if used properly will give consistent and reliable service. The cost of replacing a rope is extremely limited when compared to the physical damage or personnel injury that a worn-out rope can cause.

— Before inspection, identify the rope by its label or permanent marking, and consult any previous inspection records.

— Visually inspect the rope over its entire length, identifying any areas requiring in-depth investigation.

— Splice terminations should also be inspected to ensure they are in the "as-made" condition.

In synthetic-fibre ropes, the amount of strength loss due to abrasion and/or flexing is directly related to the amount of broken fibre in the rope's cross-section. After each use, look and feel along the length of the rope, inspecting for abrasion, glossy or glazed areas, inconsistent diameter, discoloration, inconsistencies in texture and stiffness.

It is important to understand the design of the rope in use. Most ropes are designed to have features specifically tailored to their application. These features can lead to misconceptions during visual inspections. When a rope has a braided cover, it is only possible to visually inspect the cover.

In laid and 8-strand rope constructions, all strands have an intermittent prominent surface exposure, usually referred to as the "crowns". Thus, they are susceptible to damage.

12-strand braided ropes are similar to the 8-strand rope mentioned above. However, the "crowns" of the strands are less prominent and therefore less susceptible to surface damage.

Double-braided rope construction has an independent inner core, possessing approximately 50 % of the total rope strength. This core, since it is not subjected to surface abrasion and wear, tends to retain a larger percentage of its original strength, over a longer period of time. Thus, wear on surface strands does not constitute as large a percentage of strength loss as in other constructions.

In a parallel rope construction, the core represents 100 % of the rope strength. The outer braided cover acts as a protection against external abrasion for the strength member, and therefore massive damage to this outer braid does not dramatically reduce the overall strength of the rope. See also ISO 18692-1:2018, C.6.

Ropes are also subject to internal abrasion.

C.5.3 Acceptance or rejection

C.5.3.1 General

Reaching a decision on whether or not the cordage is fit for further use should be based on the conditions of the cordage and what defects have been observed during the examination. The examination should be undertaken only by someone who is competent and who has had considerable experience in carrying out this work. There is no substitute for experience, and the examiner should be familiar with the defects already discussed and their likely effect on the performance of the gear. In forming a decision, the examiner should adopt a fail-safe policy. If there is any doubt that the cordage may not sustain the stresses that it is likely to bear, then it should not be used.

Criteria to repair or retire the ropes are shown in Table C.1.

Repairing ropes requires expertise and training. It should be restricted only to cases where the damage is localized. Whenever the ends of the rope are to be joined again by a splicing operation, the splice instructions of the rope manufacturer shall be followed. It should be considered that aged ropes might be hardened or worn to an extent that resplicing will not yield a rope fit-for-service.

Finally, the user should be aware that even carefully used ropes will wear out if they receive sufficient use, and care should be taken to withdraw them from service before this time is reached, rather than allowing them to continue in use until they fail.

Table C.1 — Criteria to repair or to retire the ropes

Rope type and condition	Repair	Retire
For all ropes		
— bulk of surface yarns or strands reduced by 50 % or more for a linear distance equal to the rope diameter	X	X
— rope suspected of being shock loaded		X
— exposure to excess temperature as specified for type of fibre		X
— burns or melting visible for a length of over four rope diameters	X	X
— abrasion on inside radius of eye, with bulk of surface yarns or strands reduced by 50 % or more	X	X
— rust on polyamide (might indicate chemical damage)	X	X
— oil and grease	wash in mild detergent	
— heavy surface fuzz (progressive)	X	X
	remove source of abrasion	
— UV degradation, splinters on yarn surface		X
For covered ropes (see also C.5.3.2)		
— more than four consecutive pulled cover strands (which cannot be reincorporated into cover braid)	X	X
— more than three cut cover strands	X	X
— multiple cut yarns or filaments within distance of one pitch length	X	X
— core visible through cover, because of cover damage		X
— core damage-pulled, cut, abraded, powdered, or melted strands		X
— herniation-core pokes through cover		X
— Body of rope shows distinctive periodic bulges along its length. Internal inspection is not possible		X
— Internal inspection reveals distinctive Z shaped kink bands in portions of the load bearing core. More than 10 % of the cross section is affected. These tend to repeat in a regular pattern along the length (Axial compression and kink bands).		X
For 3-strand, 8-strand (braided) and 12-strand (braided) ropes		
— 10 % of yarns cut or badly abraded in score between strands	X	X
— outer yarns cut or abraded more than 50 % on one or more crowns of rope	X	X
— strand cut to 5 % of diameter within one lay length	X	X
— powdering between adjacent strand contact surfaces	X	X
— hockle or backturn	X	X
— 10 % abrasion of one strand within one lay length	X	X
— For double-braided ropes: see C.5.3.3.		
Thermal damage		
— hard, melted, flattened areas of the rope which can indicate serious damage to the rope	X	X

Table C.1 *(continued)*

Rope type and condition	Repair	Retire
— melting or fusing affecting 20 % or more of rope yarns		
— if within one lay length	X	
— if over more than one lay length		X
Short-term exposure to temperature above fibre working temperature		
— polyolefins, over 65 °C		X
— polyamide, over 100 °C		X
— polyester, over 100 °C		X
— polyester/polyolefin dual fibres, over 65 °C		X
— HMPE, over 70 °C		X
— Aramid over 300 °C		X
— Polyarylate over 150 °C		X
— manila, over 100 °C		X
— sisal, over 100 °C		X
— hemp, over 150 °C		X
Chemical exposure (see Annex A)		
— Chemical damage Discard in principle but separate advice should be given by the rope manufacturer		X
Splices		
— Splices in ropes made of high modules fibre may exhibit kink bands. Damage is very difficult to access without destructive testing (Axial compression and kink bands).		X

C.5.3.2 Covered ropes

For covered ropes where the core is the strength member, it may be possible to repair the cover. The manufacturers' or other governing guidelines or directions of a qualified person should be followed. See also ISO 18692-1:2018, Annex C.

C.5.3.3 Double-braided rope

The double-braided ropes, among other aspects, differ from other rope formats due to their constructive uniqueness, core and cover. A visual inspection may reveal damage on the cover, but it is impossible to assess eventual data in its core.

So, when establishing a detailed criterion concerning double-braided rope inspection, it is important to understand that these ropes' inspection process can't follow the same criterion and procedure of a rope that is twisted, braided or with protective covers.

Double-braided ropes are harmonically braided so that their breaking force can remain appropriately distributed between the cover and the core, so that the latter can represent up to 55 % of the total rope mass. Due to the difficult access to the ropes core it is recommended that the inspection be concentrated on the rope's outer part paying attention to the signs of wear that may come from its interior.

Inspection recommendations concerning the use of double-braided ropes.

a) They should be inspected whenever possible.

b) Excessive torsion should be avoided.

c) The rope should be washed whenever possible.

d) Wear due to external abrasion will not necessarily lead to the rope's retirement, but it is an indication of how long it has been used (strength loss due to fatigue and degradation due to exposure to UV).

e) Hardening indicates overload and, in these cases, the rope should be externally inspected in a proper way.

f) Nodule along the length may denote internal damage and, in such cases, the rope should be either properly inspected or discarded.

g) Damage on the cover (cuts on the strands) changes the structure of the rope negatively and affects the distribution of the rope's resistance. In such cases, one should either reclassify it for use in operations of a lesser responsibility or one discards it.

h) Whenever possible, even if the visual appearance does not indicate signs of malfunction, reinforcing the splice region's protection may be a very cost-effective alternative.

Annex D
(informative)

Determining minimum breaking strength

D.1 General

D.1.1 Overview

This annex gives guidance on a statistical method that can be used by rope manufacturers to define the MBS of their specific rope product. The MBS of the product should meet or exceed the applicable MBS of that rope product specified in the applicable ISO standard or purchaser's specification.

A prerequisite is to decide on the probability that an individual test is above the MBS (so called confidence level). Typical values are 95 %, 99 % or 99,9 %.

From the results of break tests, the average strength and standard deviation are calculated, according to one of the following methods:

a) Method 1 is applicable for single diameters.

This method is used if no other test results are available for a given rope or different ropes from the same design. If few test results are available, the margin is to be increased to meet selected confidence level (see D.1.2 and Table D.1).

b) Method 2 is applicable over a range of diameters (see Clause 5).

The minimum amount of break tests to be performed should be as specified in ISO 2307:2019, B.3.2.

When available, test data for other diameters should be included in the evaluation.

The strength is interpolated based on the linear density of the rope. For covered ropes, the linear density of the rope core should be used.

Data should only be interpolated within the range of diameters tested.

The margin is a function of the total number of break tests for the considered rope design.

Then, with the average strength, the standard deviation and the selected confidence level, the minimum breaking strength can be calculated following method 1 or method 2.

Table D.1 — Student's t-table

DOF	Confidence level		
	95 %	99 %	99,9 %
1	6,314	31,82	63,66
2	2,920	6,965	22,33
3	2,353	4,541	10,21
4	2,132	3,747	7,173
5	2,015	3,365	5,893
6	1,943	3,143	5,208
7	1,895	2,998	4,785
8	1,860	2,896	4,501

Table D.1 *(continued)*

DOF	Confidence level		
	95 %	99 %	99,9 %
9	1,833	2,821	4,297
10	1,812	2,764	4,144
11	1,796	2,718	4,025
12	1,782	2,681	3,930
13	1,771	2,650	3,852
14	1,761	2,624	3,787
15	1,753	2,602	3,733

D.1.2 Method 1: MBS for single diameters

a) The average breaking strength *AS* and the standard deviation *SD* are calculated with Formulae (D.1) and (D.2):

$$AS = \frac{1}{n}\sum_{i=1}^{n} BF_i \tag{D.1}$$

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(BF_i - AS)^2}{n-1}} \tag{D.2}$$

where

BF_i are measured breaking strength results for that rope;

n is the number of tests done.

b) The number of degrees of freedom (DOF) = n–1.

With the DOF and the required confidence level, p is read from Table D.1.

The minimum breaking strength is calculated by Formula (D.3):

$$\text{MBS} = \text{Average} - (p \times \text{SD}) \tag{D.3}$$

NOTE Historically, p = 2 is used for five tests, i.e. DOF = 4: this is corresponding to a confidence level of about 94 %.

D.1.3 Method 2: MBS for a rope design (see Clause 5)

a) Plot the log10 (break force) vs log10 (linear density) for all tests results, then perform a linear regression to obtain the values of a and b in Formula (D.4).

$$\log_{10}(\mathrm{BF}) = a\left[\log_{10}(\mathrm{LD})\right] + b \tag{D.4}$$

where

LD_i is the linear density of each rope sample tested;

BF_i is the breaking force of each rope sample tested;

a = line slope;

b = line intercept at y-axis.

b) The standard deviation of y, can then be calculated as per Formula (D.5):

$$SD_y = \left[\Sigma\left[y_i - y(x_i)\right]^2 \big/ (n-2)\right] 1/2 \tag{D.5}$$

where

y_i = [log10 (BF_i)] for each rope sample tested;

$y(x_i)$ = [a (log10(LD_i))+b] for each rope sample tested;

n = total number of samples tested.

c) The number of degrees of freedom (DOF) is equal, in this case, to n−2.

With DOF and the required confidence level, *p* is read from Table D.1.

d) Calculate the average and minimum break force for all rope diameters using Formulae (D.6) and (D.7):

$$BF_{average} = 10^b \times LD^a_{average} \tag{D.6}$$

$$BF_{minimum} = 10^{(b - p \cdot SDy)} \times LD^a_{average} \tag{D.7}$$

where LD is the linear density for the rope diameter considered.

e) The results can then be reported in a prototype test data sheet or similar document. See D.3.

D.2 Example

A ropemaker wants to have confidence that 95 % of his tests are above the minimum breaking load. He has the following results from twelve (12) break test on three different rope diameters of the same design, see Table D.2.

Table D.2 — Results of break tests

Diameter (mm)	Actual linear density (ktex)	Actual break force; spliced (kN)
20	300	62,1
	325	65,2
	288	58,5
	310	61,8
	305	59,0
40	1 200	240
	1 225	238
	1 210	225
	1 245	244
	1 250	220
80	5 050	898
	4 880	850

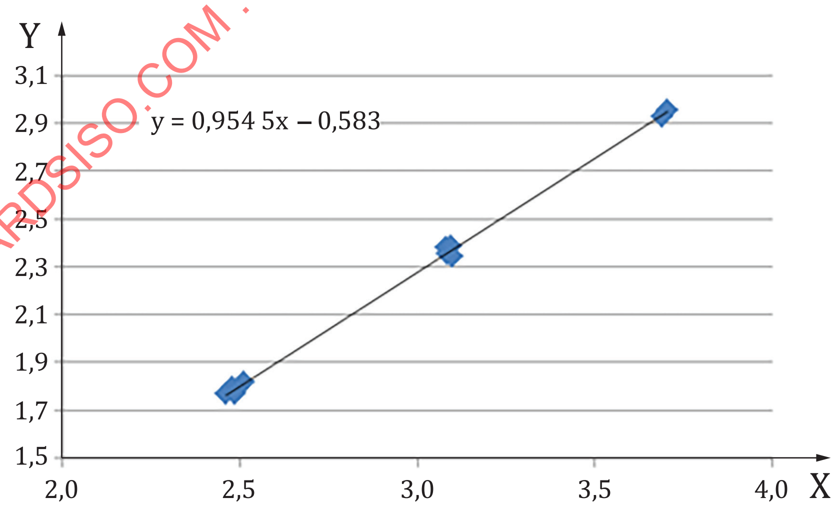
Method 1

For 20 mm and 40 mm there are 5 tests, giving a p of 2,132 (95 %). For 80 mm there are 2 tests, giving a p of 6,314 (95 %).

Method 2

From Table D.1 (95 % confidence level, DOF = 12 – 2 = 10): P = 1,812.

Plot $\log_{10}$ (BF_i) vs $\log_{10}$ (LD_i) and perform a linear regression to obtain a and b in the Formula D.4. For the results in Table D.2 a = 0,954 5 and b = −0,583.



Key

Y log (BF)

X log (LD)

Figure D.1 — Breaking force (BF) versus linear density (LD) (log-log scale)