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Fibre ropes — Determination of certain physical and mechanical properties

Cordages en fibres — Détermination de certaines caractéristiques physiques et mécaniques

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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 fifth edition cancels and replaces the fourth edition (ISO 2307:2010), which has been technically revised. The main changes compared to the previous edition are as follows:

— inclusion of diameter in the scope, and describe methods to measure it;

— changes in test length;

— changes in test speed;

— inclusion of another method for determination of realization factor in Annex B;

— addition of a sample of a test report (Annex D).

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 — Determination of certain physical and mechanical properties

1 Scope

This document specifies, for ropes of different kinds, a method of determining each of the following characteristics:

— linear density;

— diameter;

— lay length;

— braid pitch;

— elongation;

— breaking force.

This document also provides a method for measuring water repellence, lubrication and finish content, when requested by the customer.

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 139, *Textiles — Standard atmospheres for conditioning and testing*

ISO 1968, *Fibre ropes and cordage — Vocabulary*

ISO 9554, *Fibre ropes — General specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1968 in ISO 9554 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
unspliced breaking force
breaking force which is obtained by application of the method described in 9.7.2

3.2
spliced breaking force
force at which the rope breaks, by application of the method described in 9.7.3

4 Principle

4.1 Calculation of the linear density

The linear density is obtained by measurement of the mass and the length, under the reference tension specified in Annex A, of a conditioned test piece.

4.2 Measurement of the diameter, lay length and braid pitch

These measurements are taken at the time of application of the reference tension.

4.3 Measurement of the elongation of the rope

This measurement is taken by comparing the lengths of a section of the test piece that has been subjected successively to

a) the reference tension (this length is called l_0, see Figures 1, 2 and 3), and

b) a tension equal to 50 % of the minimum specified breaking force for the rope. Alternatively, additional elongation measurements may be made in increments of, for example, 10 % tension, from 10 % to 50 % of the minimum specified breaking force of the rope. See 9.6 for procedures and safety recommendations.

4.4 Measurement of the breaking force

This measurement is carried out by increasing the maximum tension achieved in 4.3 b) to the breaking point.

Alternatively, the methods described in Annex B can be used, subject to agreement between the parties involved. In such case, a mention shall be made in the test report that the breaking strength was calculated from yarn test results

5 Apparatus

5.1 Tensile testing machine, accommodating the assumed breaking force of the rope, which allows a constant rate of traverse of the moving element, in accordance with 9.5, and measurement of the breaking force to an accuracy of ±1 %.

The stroke and bed length should be long enough to extend the specimen to rupture in one continuous pull.

NOTE In case a specimen is pulled to break to rupture in more than one pull, the result can be affected.

Different types of tensile testing machines may be used:

— bollard-type grip testing machine;

— testing machine with pins for eye splices;

— wedge-grip testing machine.

In the case of a bollard-type tensile testing machine, the diameter of the bollard or capstan holding down the test pieces shall be equal to at least 10 times that of the rope being tested.

In the case of a testing machine with pins, the diameter of the pins passing through the eye-spliced test pieces shall be of an adequate size so that the rope does not break in the eye, in principle at least twice the diameter of the rope being tested.

5.2 Balance, allowing measurement of mass to an accuracy of ±1 %.

6 Sampling

6.1 Composition of the batch to be sampled

Samples shall be taken from a homogeneous manufacturing batch, i.e. consisting of ropes of the same size and same dimensions and which have been subject to the same series of manufacturing operations and the same control procedure.

If additional information is required, test samples shall be taken from each shipping unit (manufacturing batch), with the necessary characteristics to perform the specified tests. The samples shall be included in the delivered mass or length.

As an alternative, the manufacturer's production and inspection records may be used if agreed upon between the purchaser and the manufacturer.

6.2 Sample size

Batch samples for acceptance testing shall be taken at random in accordance with 6.3 or as per a sampling plan defined and accepted by both the purchaser and the manufacturer.

6.3 Selection of samples

Take the number N_S of samples at random from the batch in accordance with Formula (1):

$$N_S = 0,4\sqrt{N} \tag{1}$$

where N is the batch size, expressed as the number of continuous lengths or coils.

NOTE A typical coil size is 220 m.

When the calculated value of N_S is not a whole number, the number obtained shall be rounded to the nearest whole number.

EXAMPLE 27,5 and 30,35 are rounded to 28 and 30, respectively.

Where $N_S < 1$, take one sample length.

7 Test pieces for tensile testing and force-elongation measurements

7.1 Length

The test piece shall be of adequate length to give an effective length, L_u (see 9.3), between terminations which is at least equal to 5 pitches or lays or 400 mm, whichever is greater.

7.2 Number of test pieces

Take one test piece from each sample.

7.3 Taking the test pieces

7.3.1 Take the test piece either from one end of the samples, or from the body of the samples if they are intended to be cut. Take all necessary steps to prevent unlaying. If necessary, remove slightly unlaid ends.

An alignment line should be marked along the rope specimen surface, parallel to its axis, using a suitable marking device. When the rope specimen is mounted on the test bed, it shall be arranged such that the marked line is straight.

7.3.2 When testing the rope on pins, eye splices shall be made in accordance with the rope manufacturer's instructions. In case of a deviation of the manufacturer's instructions, the result can be different. The splice method used shall then be documented with the report. The splice shall be suitable for general rope service and should not be a special design intended to enhance performance during testing.

Eye splices shall be of sufficient size that the rope does not break in the eye. In principle, the eyes shall have a minimum internal length of 6 times the rope diameter when closed.

8 Conditioning

Ropes shall be tested in the ambient atmosphere, except in cases of dispute, when the test piece shall be placed in the atmosphere specified in ISO 139 for at least 48 h, immediately prior to testing.

9 Procedure

9.1 General

For the measurement of force-elongation and breaking force, perform the procedures specified in 9.2 to 9.7 sequentially.

For the linear density, perform the procedures specified in Clause 10.

9.2 Initial measurements

Lay the test piece out straight on a flat surface by pulling with a slight force of the hand (not exceeding 20 % of the reference tension) (see Annex A).

Make two "*w*" marks on the test piece, spaced symmetrically with regard to its mid-point, and at a distance apart of l_0 that is greater than 400 mm.

In exceptional circumstances, when L_u < 400 mm, l_0 and l_2 (see 9.4) are measured on a separate test piece, with a minimum length of 400 mm, following the same procedure; the value l_2 is obtained by applying the appropriate tension by means of weights and a pulley.

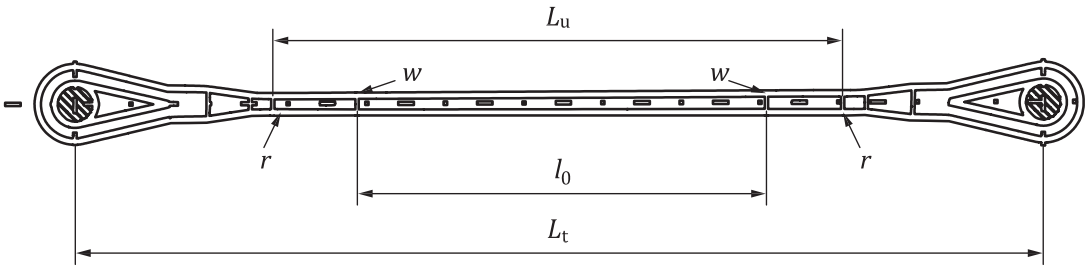
9.3 Mounting the test piece on the testing machine

Fix the ends of the test piece onto the machine, in order to obtain the effective length of the test piece specified in 7.1.

Outside the segment l_0, make two "*r*" marks on the test piece, delimiting the section in which a rupture is considered as normal, as shown in Figures 1 to 3.

The distance from each mark "*r*" to the end of the splice (or to the tangent point in the case of a bollard) shall be a minimum of twice the diameter and a maximum of three times the diameter of the rope.

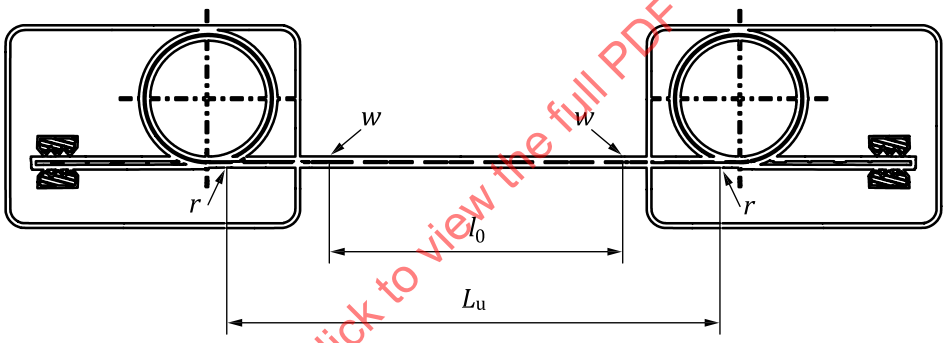
For testing a sample with a braider splice (see ISO 9554:2019, 4.4.3), the marked braider splice shall be located in the middle of the test specimen, with a minimum of 400 mm of undisturbed rope between the ends of the braider splice and the "*r*" marks on either side of it.



Key

r limiting marks for the standard test
l_0 length measured with no tension
L_u effective length measured with no tension
L_t length from the middle of the pin to the middle of the pin measured at reference tension
w limiting marks for l_0

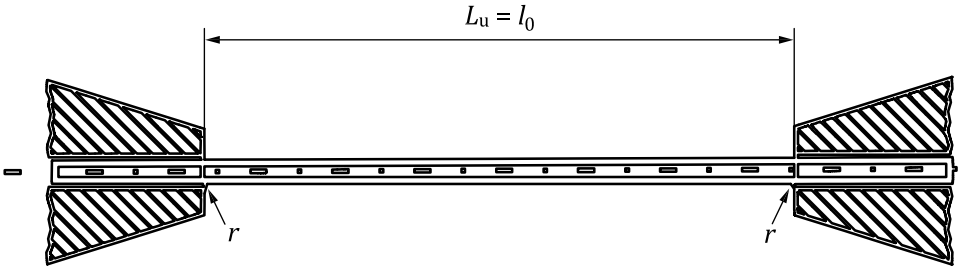
Figure 1 — Effective length, L_u, for testing machines with pins for eye splices applied to ropes of reference number 20 and above



Key

r limiting marks for the standard test
l_o length measured with no tension
L_u effective length measured with no tension
w limiting marks for l_0

Figure 2 — Effective length, L_u, for bollard-type grips testing machine applied to ropes of reference number < 20 mm



Key

r limiting marks for the standard test

l_o length measured with no tension

L_u effective length measured with no tension

Figure 3 — Effective length, L_u, for wedge-grip testing machine applied to ropes of reference number < 20 mm

9.4 Measurement of diameter, lay length or braid pitch and gauge length

Apply the reference tension specified for the type of rope being tested (refer to Annex A) to the test piece and measure the following.

a) Diameter or circumference. The circumference can either be measured with a suitable tape or a low-stretch yarn.

   — With a measuring tape, wrap it around the rope, apply a moderate tension, and read the circumference while it is still in contact with the rope.

   — With a low-stretch yarn, wrap it once around the rope. Apply moderate tension and mark the yarn at the point of overlap. Then remove the marked portion of the yarn from the rope. Measure the circumference as the length of the marked portion.

   Do this measurement on at least three positions more than 2 lay lengths or braid pitches apart.

   Alternatively, a suitable caliper may also be used. A caliper is considered suitable for measuring rope diameter if it has sufficient wide or long measuring jaws to make contact with at least two strand crowns along each side of the rope. Apply a moderate compression. Secure the caliper feet in this position. Remove the calipers from the rope and read the value.

   This measurement should also be done at least three positions more than 2 lay lengths or plait pitches apart. At each position two measurements should be taken, which are 90° apart.

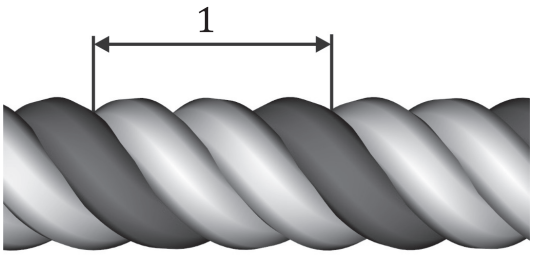
   The resulting diameter or circumference is the average of the three measurements.

b) The length of the maximum number of lays possible (or braid pitch) within L_u, expressed in millimetres.

   Do this measurement on at least three positions more than 2 lay lengths or plait pitches apart.

   NOTE The length of lay for laid ropes, and plait pitch for 8- and 12-strand ropes, are shown in Figures 4, 5 and 6, respectively.

c) The distance between the two "w" marks. Let this distance be l_2, the gauge length, expressed in millimetres, under the reference tension.

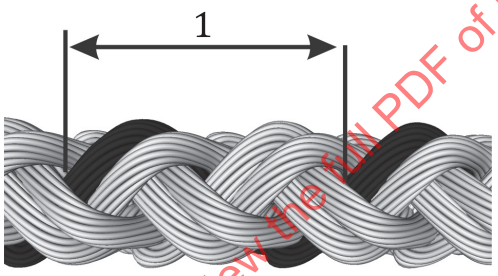


Key

1 one lay of a 3-strand rope

NOTE This also applies to 4- and 6-strand ropes, and this Figure 4 showing one lay of a 3-strand rope is provided as an example.

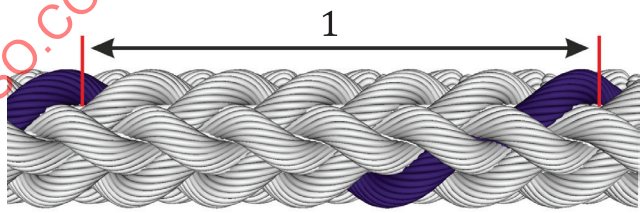
Figure 4 — Length of lay for 3-, 4- and 6-strand ropes



Key

1 one-plait pitch

Figure 5 — Braid pitch for 8-strand braided rope



Key

1 one-braid pitch

Figure 6 — Braid pitch for 12-strand braided rope

9.5 Bedding-in of the test piece

Before testing to the breaking point, subject the sample 10 times to a cyclic load between the reference tension and 50 % of the minimum breaking force of the rope. Alternatively, three cycles may be used. The number of bedding-in cycles shall be recorded in the test report.

When testing with wedge grips or bollard grips the test speed should be 250 mm/min +/−50 mm/min, unless otherwise specified and documented in the test report.

When testing spliced ropes, the test speed should be between 2 and 12 % of L_t per minute, unless otherwise specified and documented in the test report. See also Figure 1, for the definition of L_t.

9.6 Measurement of the elongation of the rope

Increase the tension again by moving the moving element of the testing machine. The test shall be carried out at the speeds defined in 9.5, unless otherwise specified in a specific rope standard.

When the tensile force reaches 50 % of the minimum breaking force, measure the distance between the "*w*" marks (the stoppage necessary for measurement shall be as brief as possible). Designate this distance as l_3, the gauge length, expressed in millimetres, for a tensile force equal to 50 % of the specified minimum breaking force.

This measurement shall always be done in a safe and responsible manner. The practice of approaching a rope while under load shall be avoided. Whenever possible, elongation shall be measured through an optical tracking system, or a linear voltage displacement transducer with the required accuracy.

By previous agreement between the purchaser and supplier, a force-elongation curve, recorded during the tensile tests up to 50 % of the minimum breaking force of the rope, may be supplied.

It may be requested that the elongation be determined on a particular test piece. In this case, the procedure given in Annex C shall be followed to obtain the force-elongation coordinates.

9.7 Measurement of the breaking force

9.7.1 Continue to increase the tension, at the same speed, until the rope breaks.

Record the maximum force and the place on the test piece where the break occurs.

9.7.2 If an unspliced breaking force is specified, the specimen shall be deemed to meet the requirement if the break occurs

a) within the "*r*" marks and at a force equal to or higher than the specified value, or

b) outside the "*r*" marks and at a force equal to or higher than 90 % of the specified value.

In the latter case, it should not be assumed that the true breaking force of the specimen would be represented by multiplying the result by 10/9.

For other terminations the manufacturer shall be contacted for an estimate of the strength loss from the termination if the failure occurs outside the "*r*" marks.

9.7.3 If a spliced minimum breaking force is specified, the specimen shall be deemed to meet the requirement if it breaks at a force equal to or higher than the value for ropes with eye-spliced terminations, as indicated in the relevant standard.

9.7.4 If a single test falls below the MBS, then the manufacturer is allowed to do two additional tests. The rope is deemed to pass if both these tests are above the MBS.

10 Linear density

Take a new sample by drawing a length of rope of 2 m or more plus the length required for tensioning from the reel or coil and lay it out in a straight line on a flat surface. Tension the test length to the reference tension and maintain the tension for 1 min. Place two marks on the rope 2 m apart, then

remove the tension and detach the sample from the parent length by cutting cleanly at the two marks. Determine the mass, *m,* of the test piece and calculate the mass per metre from the result.

NOTE This process can be assisted by lapping the rope with adhesive tape at the approximate position of the marks and then placing the marks on top of this tape while the rope is under tension. The tape will hold the rope together when it is subsequently cut at these marks and will assist in the presentation of a cleanly cut specimen.

11 Expression of results

11.1 General

For the linear density, lay length or braid pitch, and elongation (see 11.2 to 11.4), the numerical result of a test is the arithmetic mean of the individual values obtained on each test piece in the batch. As far as the tensile strength is concerned, the result is expressed by giving the breaking force (see 11.5) for each of the test pieces in the batch, without calculating the mean value.

The individual values are obtained as given in 11.2 to 11.5.

11.2 Linear density, ρ_1

The linear density (net mass per unit length), expressed in kilotex, is given by Formula (2):

$$\rho_1 = \frac{m}{l_1} \tag{2}$$

where

m is the mass, in grams, of the test piece;

l_1 is the measured length, in metres, of the test piece under the reference tension.

11.3 Diameter, lay length or braid pitch

The diameter is expressed in millimetres. The resulting diameter or circumference is the average of the three measurement. When the circumference has been measured, the diameter is calculated by dividing the circumference by Pi (3.14).

The lay, l_p, expressed in millimetres, is given by Formula (3):

$$l_p = \frac{l_n}{n} \tag{3}$$

where l_n is the length of n complete turns of the same strand or, in the case of plaited ropes, the length between n successive plait points (see 9.4).

11.4 Elongation

The value of the elongation, E, expressed as a percentage, is given by Formula (4):

$$E = \frac{(l_3 - l_2) \times 100}{l_2} \tag{4}$$

where

l_2 is the gauge length, expressed in millimetres, under the reference tension (see 9.4);

l_3 is the gauge length, expressed in millimetres, for a tensile force equal to 50 % of the specified minimum breaking force (see 9.6).

11.5 Actual breaking force

Express the breaking force in kilonewtons, indicating whether or not the reported breaking force is spliced or unspliced according to 9.7.

12 Determination of water repellency

12.1 General

The determination of water repellency applies to ropes made from natural fibres.

12.2 Principle

The increase in mass of the rope is determined after immersion in water for a given period.

12.3 Test pieces

12.3.1 General

Place two marks 450 mm apart on the length of rope, clear of its ends.

12.3.2 Whipping

Place a tight and secure whipping over each mark. The length of these whippings shall not exceed the values specified in Table 1.

Table 1 — Length of whipping

Reference number of rope	Maximum length of whipping mm
≤24	15
>24 but ≤48	20
>48	25

12.3.3 Cutting the samples

Detach the samples from the parent length by cutting cleanly across the rope with a sharp knife at right angles to its longitudinal axis at the seizings, so that a suitably seized sample is obtained.

12.3.4 Sealing

To prevent absorption by capillary action, seal the ends off so that the whipping is just covered.

A suitable sealing material is pitch with a small amount of tar added to prevent cracking. Any other suitable sealing material may be used.

12.4 Procedure

12.4.1 First weighing

Carefully weigh each conditioned specimen after whipping and sealing, and then place it in tap water at a temperature of (20 ± 2) °C, taking care that the specimen is fully submerged, if necessary by weighting down, to a depth of 150 mm.

Do not add water after the specimens have been submerged.

In order to avoid the variations in mass due to atmospheric conditions, carry out the weighing immediately before immersion. Do not carry out the test until at least 24 h after the completion of manufacture of the rope.

12.4.2 Second weighing

After a total immersion of 1 h, take the specimens out of the water and, before weighing, dry them in the following manner. Shake each specimen six times to remove the superfluous water and then roll the sample on blotting paper until no wetting of the paper is observed. Finally, draw the specimens three times through an absorbent cloth, such as towelling. Then weigh the specimens and resubmerge in the water.

12.4.3 Third weighing

After a further 5 h immersion period (making a total of 6 h in all), dry the specimens as described in 12.4.4 and weigh them.

12.4.4 Drying the specimens

Thoroughly dry each specimen by gentle heating, if necessary. Take care that the sealing is not affected by the temperature, and that the temperature does not exceed 50 °C. Dry the specimens to a mass slightly less than that obtained at the first weighing, so that, after exposure for at least 4 h to normal room atmospheric conditions, the specimens shall return as nearly as possible to their original mass.

12.4.5 Fourth, fifth and sixth weighing

Repeat the procedure described in 12.4.1 to 12.4.4 using the same specimens.

12.5 Results of tests

Record the gain in mass in each of the specimens as a percentage of the original mass (first and fourth weighing), for the 1 h immersion (second and fifth weighing), and for the 6 h immersion (third and sixth weighing).

13 Determination of lubrication and finish content

13.1 General

The determination of lubrication and finish content applies to ropes made from natural fibres.

13.2 Reagents

In this test, use reagents of laboratory reagent quality or equivalent.

13.3 Preparation of samples

Unlay the rope into its component yarns. Select, at random, representative yarns from the unlaid rope. Form these into a hank weighing between 30 g and 50 g.

13.4 Determination of water content

13.4.1 Weigh the hank prepared in 12.3 to the nearest 10 mg. Designate this mass as m_1.

13.4.2 Distil the water contained in the sample after the addition of a suitable quantity of petroleum ether, and condense it in a graduated receiver.

13.4.3 Continue the distillation until the condensate in the graduated receiver becomes constant. Measure the volume of water to the nearest 0,1 ml. Designate this volume as V.

13.5 Determination of lubrication and finish content

13.5.1 Transfer the hank of yarn into a Soxhlet apparatus, and reflux with petroleum ether (boiling range 60 °C to 80 °C) until the extraction medium flows off in a colourless form or, if colourless impregnating agents are present, until a specimen taken from the extract evaporates without residue.

13.5.2 Remove the hank from the Soxhlet apparatus, and place it in an oven at a temperature of 120 °C until all the solvent has evaporated. Transfer the hank to a desiccator until it has cooled to room temperature.

13.5.3 Re-weigh the sample to the nearest 10 mg. Designate this mass as m_2.

13.6 Calculation of lubrication and finish content

13.6.1 Calculate the percentage of lubrication or finish using Formula (5):

$$L = \frac{m_1 - m_2}{m_1} \times 100\% \tag{5}$$

13.6.2 Express the result to the nearest 1 %.

14 Test report

The test report shall contain the following information:

a) a reference to this document, i.e. ISO 2307:2019;

b) results obtained, expressed in accordance with 11.1 to 11.5;

c) individual values which were used to calculate the results [except for breaking force values, which will already have been given in b)];

d) particular test conditions (conditioning of the test pieces, type of tensile testing machines used, type of clamp and D/d-ratio, if tested with bollards, testing speed, free testing length L_u, procedure used for determination of elongation, use of the procedure described in Annex B, where applicable);

e) details of procedures not stipulated in the method and incidents which are likely to have affected the results.

NOTE See also Annex D for an example.

Annex A
(normative)

Reference tension

The reference tension defined in this annex is to be applied to ropes when measuring linear density and lay length or braid pitch.

The reference tension, F_T, expressed in kilonewtons, applied to the specimen shall be calculated from Formula (A.1):

$$F_T = \frac{n_{ref}^2}{8} \times 0{,}01 \quad \text{(A.1)}$$

where n_{ref} is the reference number.

See Table A.1 for the calculated nominal values of the reference tension to be applied to the ropes and their tolerance, as a function of the reference number of the rope.

Table A.1 — Reference tension

Reference number	Reference tensions		Reference number	Reference tension	
	Nominal value kN	Tolerance %		Nominal value kN	Tolerance %
4	0,020		44	2,42	
4,5	0,025		48	2,88	
6	0,045		52	3,38	
8	0,080		56	3,92	
9	0,101		60	4,50	
10	0,125		64	5,12	
12	0,180		72	6,48	
14	0,245		80	8,00	
16	0,320		88	9,68	
18	0,405	±5	96	11,5	±5
20	0,500		104	13,5	
22	0,605		112	15,7	
24	0,720		120	18,0	
26	0,845		128	20,5	
28	0,980		136	23,1	
30	1,13		144	25,9	
32	1,28		152	28,9	
36	1,62		160	32,0	
40	2,00		—	—	

Annex B
(informative)

Alternative procedures for ropes with high breaking forces

B.1 General

The methodology given in this annex may be applied for verification in between regular full-size tests. It is an approximation of the rope breaking strength.

The factors quoted in Tables B.1 and B.2 relate to the materials and constructions as specified in B.2.

For specific designs and/or materials not addressed in B.2, the rope maker may generate his own realization factors in accordance with B.3.

B.2 Realization factors for current ropes

B.2.1 Overview

The method indicated in B.2 may only be used for 3-, 4-, 8- and 12-strand ropes and double-braid construction ropes of reference ≥44 and made of a single material and of yarns with the same linear density without lubrication, only by agreement between the parties involved, and only on condition that, before determining the breaking force of the yarns, the rope fulfils the specified conditions in all other respects.

B.2.2 Sampling

In order to obtain the rope yarns necessary for the test, a sufficient length of rope should be untwisted, avoiding any rotation of the individual rope components (yarns, strands) above their own axe.

In the case of 3- or 4-strand ropes, 15 yarns should be tested, of which three should be selected from the centre of the strands.

In the case of 8-strand and 12-strand braided rope, eight yarns in the two directions of twist S and Z should be tested (i.e. a total of 16 yarns).

In the case of double-braid ropes, 15 yarns from core and 15 yarns from cover should be tested.

B.2.3 Testing

The rope yarns selected are mounted in turn on the testing machine. During this process, the necessary steps should be taken to prevent the yarns untwisting before testing. The yarn test should be according to ISO 2062, note especially ISO 2062:2009, 5.1 (no cutting, slipping or breaks at the jaws).

B.2.4 Rope breaking strength

The mean of the results thus obtained should be used to determine the breaking force, F_c, or F_s, of the rope from which the yarns were taken, by applying Formula (B.1) or Formula (B.2):

$$F_c = F_y \times n \times \mathrm{RF} \quad \text{for unspliced ropes} \tag{B.1}$$

$$F_c = F_y \times n \times \mathrm{RF} \times 0{,}9 \quad \text{for spliced ropes} \tag{B.2}$$

where

F_y is the mean break force of the yarns;

n is the number of yarns in the rope;

RF is the realization factor (see Tables B.1 and B.2).

Table B.1 — Realization factors

Reference number	Realization factors, RF[a], for					
	polyester (PES)	polyamide (PA)	polypropylene (PP)	mixed polyolefin (PP/PE)	manila (abaca), sisal or hemp	polyethylene (PE)
44	0,499	0,613	0,829	0,684	0,598	0,694
48	0,495	0,605	0,820	0,674	0,597	0,688
52	0,492	0,597	0,811	0,663	0,593	0,684
56	0,488	0,591	0,803	0,652	0,590	0,681
60	0,486	0,585	0,795	0,640	0,588	0,677
64	0,484	0,579	0,787	0,640	0,586	0,673
68	0,480	0,575	0,783	0,636	0,583	0,670
72	0,478	0,569	0,775	0,631	0,580	0,667
76	0,475	0,565	0,771	0,629	0,579	0,663
80	0,474	0,560	0,764	0,627	0,577	0,661
88	0,470	0,552	0,757	0,621	0,573	0,656
96	0,467	0,544	0,745	0,615	0,569	0,650
104	0,463	0,538	0,739	0,599	—	—
112	0,460	0,532	0,732	0,596	—	—
120	0,457	0,526	0,725	0,596	—	—
128	0,455	0,521	0,718	0,596	—	—
136	0,452	0,517	0,714	0,595	—	—
144	0,451	0,512	0,707	0,594	—	—
160	0,446	0,507	0,702	0,586	—	—

[a] The realization factors apply for 3-, 8- and 12-strand ropes. The realization factors for 4-strand ropes are 10 % lower.

Table B.2 — Realization factors for double-braid construction

Reference number	Realization factor, RF , for	
	polyester	polyamide
48	0,580	0,790
56	0,580	0,690
64	0,570	0,660
80	0,570	0,650
88	0,560	0,620
greater than 88	0,560	0,610

B.3 Realization factors for a specific rope design

B.3.1 General

The rope maker should demonstrate the strength performance of his rope design, as specified in ISO 9554 by making and testing prototype ropes. These prototype ropes should be identical in every aspect, such as material, structure, manufacturing and splicing, to the production ropes he intends to make.

The methodology described here can only be used to interpolate realization factors in-between the sizes tested by the producer.

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

The validity of the prototype test is limited to 10 years.

B.3.2 Prototype tests

The test schedule according to Table B.3 can be used where a minimum of 3 diameters are tested.

Table B.3 — Break tests needed

Rope diameter mm	Break test
Smallest	5
Midsize	5
Largest	2

The midsize should be determined by first estimating the weight of the midsize with Formula (B.3):

$$\log\left(LD_{\text{mid}}\right)=\frac{\log\left(LD_{\text{smallest}}\right)+\log\left(LD_{\text{largest}}\right)}{2} \tag{B.3}$$

Then the rope diameter whose linear density is close to the calculated linear density shall be taken as the midsize. See also example in B.4.

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

For each diameter tested, individual results and averages should be reported for linear density (see Clause 10 spliced break force (see 11.5), and rope yarn break force (see B.2.3).

B.3.3 Testing rope yarn strength

To measure the yarn breaking force, sample yarns should be taken out of a rope from the same production as the prototype rope. For subsequent tests, sample yarns should be taken from the same production as the delivered rope, and tested according to the same procedure using the same equipment as used in the prototype testing.

Sampling and testing of yarns should be performed in accordance with B.2.2 and B.2.3.

B.3.4 Calculating realization factor

Calculate the realization factor for each break test done on the three (or more) rope diameters using Formula (B.4):

$$\mathrm{RF} = F_{\mathrm{rope}} / \left(F_{\mathrm{y}} \times n\right) \tag{B.4}$$

where

RF is the realization factor;

F_{rope} is the break force of the rope;

F_{y} is the break force of the yarns;

n is the number of yarns in the rope.

Plot the $\log_{10}$(realization factor) vs $\log_{10}$(linear density) for all rope tests, then perform a linear regression to obtain the values of a and b in Formula (B.5):

$$\log_{10}\left(\mathrm{RF}\right) = \mathrm{a}\left[\log_{10}\left(\mathrm{LD}\right)\right] + \mathrm{b} \tag{B.5}$$

where

LD_i is the linear density of each rope sample tested;

RF_i is the realization factor of each rope sample tested.

Calculate the realization factor for all rope sizes using the Formula (B.6):

$$\mathrm{RF}_{(\mathrm{rope})} = 10^{\mathrm{b}} \times \mathrm{LD}_{(\mathrm{rope})}{}^{\mathrm{a}} \tag{B.6}$$

Calculate the resulting estimated actual rope break strength for the intermediate rope size using Formula (B.7):

$$F_{\mathrm{rope}} = F_{\mathrm{y}} \times n \times \mathrm{RF}_{(\mathrm{rope})} \tag{B.7}$$

The results are to be reported in a prototype test realization data sheet or similar document.

B.4 Validating changes for a specific rope design

When a prototype has already been tested according to B.2, but an alternative grade or material supplier and or splice design is to be used, then the tests on the midsize need to be redone to validate the change. It is deemed acceptable if the breaking force and realization factor are the same or higher than the original tests. If the test equipment for the rope yarns is changed it needs to be demonstrated with a comparable yarn (same fibre grade and total yarn count) that the breaking strength for the new equipment is the same with a tolerance of ±5 %.

NOTE If the realization factor for the midsize is higher than the original tests, it cannot be assumed that the realization factor for the product can be adjusted based on this individual verification test.

B.5 Example calculation

A rope maker produces polyester ropes from 20 mm to 80 mm. The 20 mm rope has an actual average linear density of 306 ktex, the 80 mm rope of 4 965 ktex.

First the midsize is calculated as Formula (B.8):

$$\log_{10}(\mathrm{LD}_{\mathrm{mid}}) = ½ \times \left[\log_{10}(306) + \log_{10}(4\,965)\right]$$
$$\mathrm{LD}_{\mathrm{mid}} = 1\,232 \text{ ktex} \tag{B.8}$$

From the rope manufacturer's specifications, the rope with the closest linear density is a 40 mm. This rope has an actual average linear density of 1 226 ktex. Thus, the following sizes have been tested to determine the realization factors: 20 mm, 40 mm and 80 mm, with the results shown in Table B.4.

Table B.4 — Results of break test for rope samples

Diameter (mm)	**Actual linear density** (ktex)	**Actual rope break force; spliced** (kN)	**Actual average yarn break strength** (kN)
20	300	62,1	1,95
	325	65,2	
	288	58,5	
	310	61,8	
	305	59	
40	1 200	240	
	1 225	238	
	1 210	225	
	1 245	244	
	1 250	220	
80	5 050	898	
	4 880	850	

Plot $\log_{10}(\mathrm{RF}_i)$ vs $\log_{10}(\mathrm{LD}_i)$ (see Figure B.1) and perform a linear regression to obtain a and b as shown in Formula (B.5).

a	b
−0,032 4	−0,200 1