Cordage Institute

International Guideline

Determination of Cordage Institute Minimum Breaking Strengths

CI 2002-14
May 2014

1. Scope

1.1 This guideline is intended for use by the Cordage Institute (CI) Technical Committee to determine recommendations for the Minimum Break Strength (MBS) of various fiber rope products for publication in the CI Cordage and Rope Standards. This Guideline is not intended for use with Life Safety Ropes.

1.2 A subcommittee for a particular rope category may deviate from this procedure after review and approval of the Technical Operating Committee and General committee.

1.3 These guidelines are not intended for routine use in testing of rope products for compliance with CI Rope Standards. It is the responsibility of individual manufacturers to establish and to follow suitable testing procedures to assure that rope products comply with CI Standards.

1.4 Ropes of a particular size designation may be significantly stronger than the MBS given in CI Standards.

1.5 For rope products designed and intended for a specific application, such as Life Protection, performance may be determined based on the requirement of the particular application

2. Reference

2.1 CI 1500: Test Methods for Fiber Rope.

3. Terminology

3.1 Measured Diameter (D_m): The actual diameter measured of a tested specimen.

3.2 Measured Linear Density (LD_m): The actual linear density measured of a tested specimen.

3.3 Measured Break Strength (BS_m): The actual break strength measured of a tested specimen.

3.4 Proposed Nominal Diameter (D_{prop}): The Nominal Diameter of a proposed new rope type

3.5 Proposed Linear density (LD_{prop}): The linear density proposed for a given Nominal Diameter value.

3.6 Predicted Break Strength (BS_{pred}) The Break Strength predicted based on regression analysis of BS_m vs. $LD_{m.}$

3.7 Proposed Minimum Break Strength (MBS_{prop}): The minimum break strength for a given nominal rope size.

3.8 Minimum Strength Tolerance Band (MSTB): The percentage subtracted from the Predicted Break Strength to determine the (MBS_{prop}). A MSTB of 10% is used for non-life safety products. 10% is used as a simplified value to represent two standard deviations, which has been accepted as a typical distribution on cordage testing.

3.9 Sample: A set of ropes taken from production by a manufacturer.

3.10 Specimen: A particular rope taken from the sample and tested.

3.11 Rope Category: A classification of rope based on its construction and generic fiber content as defined in the relevant CI Standard.

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4. Summary of Procedure

4.1 Rope samples of a specific product of several sizes from various manufacturers are tested. Regression analysis is then used to determine the best fit curves for Measured Diameter vs. Measured Linear Density and Measured Linear Density vs. Measured Break Strength. The Proposed Linear Density for a given rope category is then determined by the best fit of Diameter vs. Linear Density. The proposed Break strength for each size of a given rope category is then determined by subtracting the MSTB (10%) from the best fit prediction of Break Strength.

5. Sample Collection

5.1 When a rope category is under consideration for strength determination, the Cordage Institute membership shall be notified, along with any other manufacturers known to produce the particular type of rope. The CI Technical Subcommittee shall provide directions for testing or for submitting rope samples for testing, to all respondents who indicate an interest in the project.

6. Sampling

6.1 Test samples shall be selected from standard production runs. Where feasible, selection shall be done from production over several or many non-consecutive runs of the particular product.

6.2 As many different sizes as feasible should be sampled.

6.3 At least four test specimens shall be tested from each test sample, one for testing linear density and three for testing break strength.

6.4 Each rope test specimen shall be of sufficient length to prepare a test specimen with splices as described in CI 1500 Test Methods for Fiber Rope

7. Testing

7.1 The testing may be conducted by the manufacturer, a testing laboratory chosen by the manufacturer or a testing laboratory designated by the CI Technical Subcommittee to perform such tests.

7.2 Test at least one specimens from each sample for the Linear Density(LD_m) and Diameter (D_m). For each rope test sample, determine the Linear Density and Diameter in accordance with CI 1500 Test Methods for Fiber Rope.

7.3 Test at least three specimens from each sample for the Breaking Force. For each rope test sample, determine the Breaking Force in accordance with CI 1500 Test Methods for Fiber Rope, after cycling to either 20% or 50% of the rope's breaking strength as instructed by the CI Technical Subcommittee for that category of rope.

7.4 For each test, the Measured Linear Density (LD_m), Measured Diameter (D_m), Measured Break Strength (BS_m), Cycle Load History, and the location and nature of the break shall be reported.

8. Data Analysis

8.1 Linear Density

8.1.1 Use least squares best fit regression analysis to determine a best fit curve of D_m vs. LD_m using D_m as the independent variable, and LD_m as the dependent variable. A power function shall be used to normalize the data. The Formula used is:

$$LD_m = a \times (D_m)^b$$

a and b are constants determined by the regression analysis.

8.1.2 Calculate a proposed Linear Density for each Nominal Diameter that will be specified by the standard under development. The Formula used is:

$$LD_{prop} = a \times (D_{prop})^b$$

Where: a & b are the constants determined by the regression analysis in 8.1.1 above.

Note: Diameter is considered to be nominal by CI standards, with a +/- tolerance stated in the footnotes of the applicable rope standard.

8.2 Break Strength

8.2.1 Use regression analysis to determine a best fit curve of BS_m versus LD_m using LD_m as the independent variable, and BS_m as the dependent variable. A power function shall be used to normalize the data. The Formula used is:

$BS_m = c \times (LD_m)^d$

c and d are constants determined by the regression analysis.

8.2.2 Calculate a Predicted Break Strength for each Nominal Diameter that will be specified by the standard under development. The Formula used is:

$BS_{pred} = c \times (LD_{prop})^d$

Where: c & d are the constants determined by the regression analysis in 8.2.1 above.

8.3 Calculate a Proposed Minimum Break Strength for each Nominal Diameter that will be specified by the standard under development. The Formula used is:

$MBS_{prop} = BS_{pred} \times (1- MSTB)$

8.4 The CI Technical Subcommittee may propose the development of a regular and high performance standard for the category of rope under consideration. This may be appropriate in cases where different grades of fiber are used, or other technologies such as heat setting or pre-stretching are used.

9. Determination of Cordage Institute Rated Strengths

9.1 The Chair of the CI Technical Subcommittee shall conduct (or arrange for conducting) the data analysis called for above in order to establish the equation for use in calculating rated strengths.

9.2 The CI Technical Subcommittee shall then use the specified equation to calculate a rated strength for each rope size that is to appear in the designated CI rope standard.

9.3 Upon approval by the CI Board of Directors, the resulting rope strength value(s) are used in Cordage Institute technical documents.

10. Handling of Confidential Data

10.1 The manufacturers shall submit their test data directly to the Cordage Institute's Technical Director, or to a designated person or organization that has an appropriate confidentiality agreement with the Cordage Institute.

10.2 The recipient of the data shall code the identities of the manufacturers and then submit the data sets to the Chair of the appropriate Subcommittee of the CI Technical Committee.

11. Report

11.1 The responsible CI Technical Subcommittee shall prepare a report giving the data sets (without manufacturers' identifies), detailing the data analysis, and providing the resulting table of rope strengths.

11.2 The report shall be retained by the Cordage Institute for the duration of the standard or until it is superseded by another report.

EXAMPLE:

This provides an example of the calculations involved in determining CI standard strength values.

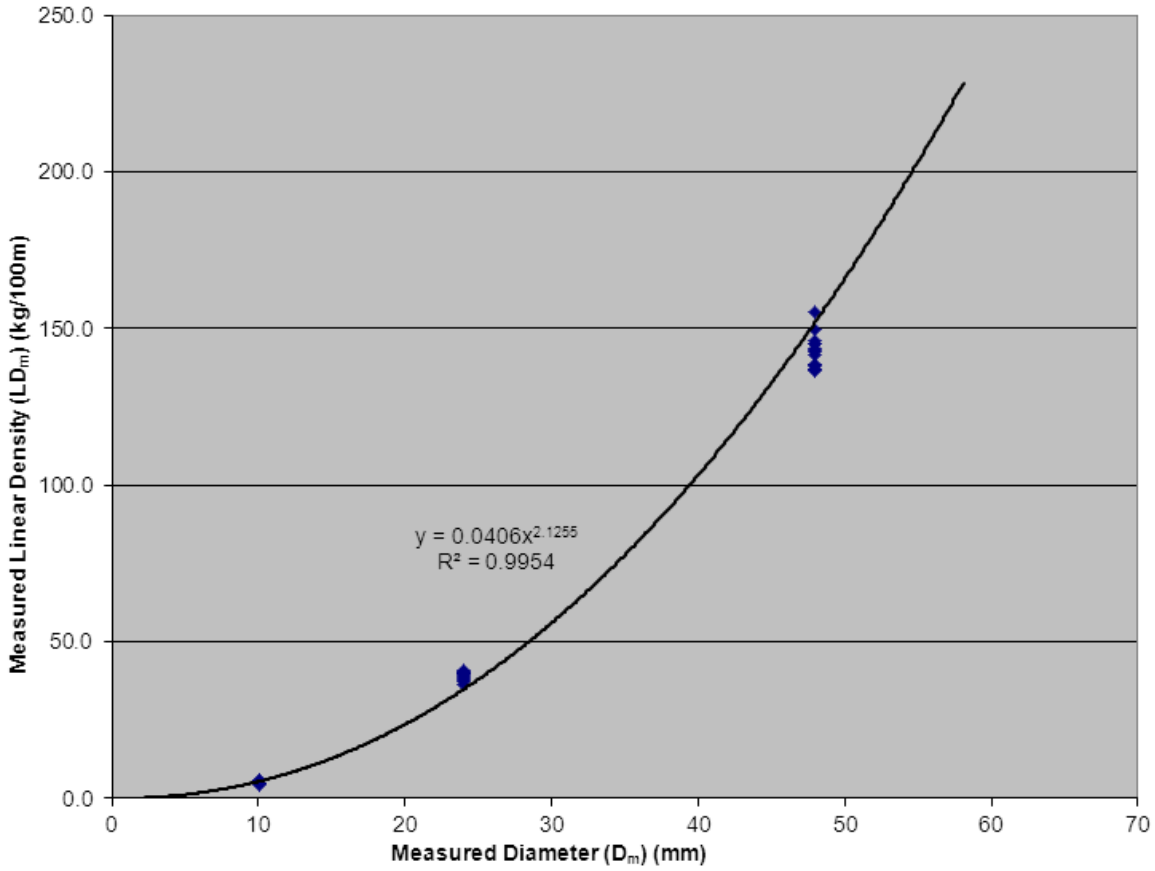
Three manufacturers of nylon 3-strand rope submit test data for three rope sizes.

Testing per Section 7 yields the following test results:

Manufacturer	Index	Measured Diameter (D_m) (mm)	Measured Linear Density (LD_m) (kg/100m)	Measured Break Strength (BS_m) (kN)
Mfg. A	specimen 1	10	5.1	20.9
Mfg. A	specimen 2	10	4.5	17.3
Mfg. A	specimen 3	10	5.2	19.6
Mfg. A	specimen 4	10	4.9	20.0
Mfg. A	specimen 5	10	5.3	16.9
Mfg. B	specimen 1	10	5.1	17.3
Mfg. B	specimen 2	10	5.2	18.7
Mfg. B	specimen 3	10	5.5	16.8
Mfg. B	specimen 4	10	5.4	16.9
Mfg. B	specimen 5	10	5.2	18.5
Mfg. C	specimen 1	10	5.2	17.1
Mfg. C	specimen 2	10	5.2	16.1
Mfg. C	specimen 3	10	5.2	16.2
Mfg. C	specimen 4	10	5.1	14.9
Mfg. C	specimen 5	10	5.2	16.4
Mfg. A	specimen 1	24	39.9	114.5
Mfg. A	specimen 2	24	37.5	137.9
Mfg. A	specimen 3	24	37.7	133.4
Mfg. A	specimen 4	24	38.4	120.1
Mfg. A	specimen 5	24	39.7	122.8
Mfg. B	specimen 1	24	40.4	106.1
Mfg. B	specimen 2	24	39.9	107.2
Mfg. B	specimen 3	24	39.0	104.3
Mfg. B	specimen 4	24	40.5	105.0
Mfg. B	specimen 5	24	39.7	105.2
Mfg. C	specimen 1	24	39.4	113.9
Mfg. C	specimen 2	24	36.5	111.7
Mfg. C	specimen 3	24	39.7	137.9
Mfg. C	specimen 4	24	40.0	119.2
Mfg. C	specimen 5	24	41.2	122.8
Mfg. A	specimen 1	48	149.7	441.3
Mfg. A	specimen 2	48	146.3	434.8
Mfg. A	specimen 3	48	142.7	439.2
Mfg. A	specimen 4	48	155.4	442.6
Mfg. A	specimen 5	48	145.2	403.9
Mfg. B	specimen 1	48	138.0	384.3
Mfg. B	specimen 2	48	142.6	381.4
Mfg. B	specimen 3	48	143.5	383.0
Mfg. B	specimen 4	48	145.1	387.0
Mfg. B	specimen 5	48	141.2	377.9
Mfg. C	specimen 1	48	138.4	458.2
Mfg. C	specimen 2	48	137.7	471.5
Mfg. C	specimen 3	48	136.9	440.4
Mfg. C	specimen 4	48	136.8	438.6
Mfg. C	specimen 5	48	137.2	467.1

Use regression analysis to determine a best fit curve of D_m vs. LD_m using D_m as the independent variable, and LD_m as the dependent variable. A power function shall be used to normalize the data. The Formula used is: $LD_m = a \times (D_m)^b$

Measured Diameter (D_m): vs. Measured Linear Density (LD_m)



Constants a & b are determined to be:

a=0.0406

b=2.1255

Calculate a proposed Linear Density for each Nominal Diameter that will be specified by the standard under development.

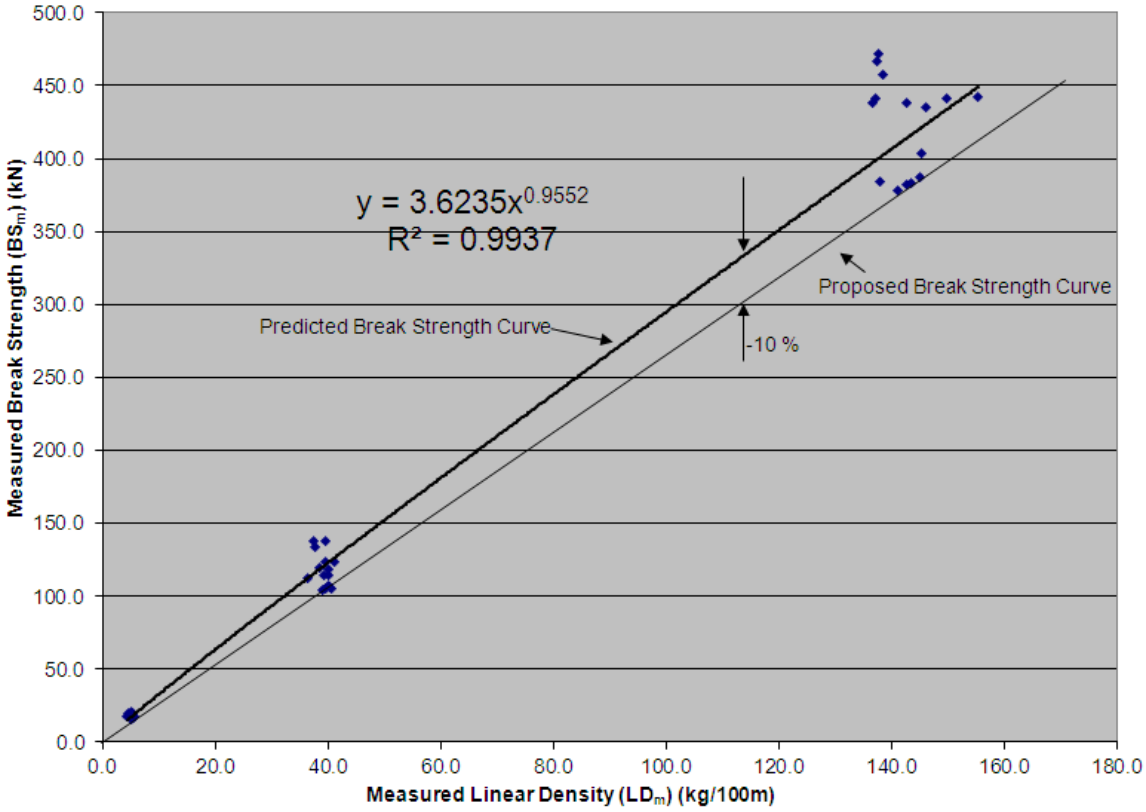
For example:

The Proposed Linear Density (LD_{prop}) for a rope with a 14mm Proposed Nominal Diameter (D_{prop})

$LD_{prop} = a \times (D_{prop})^b = 0.0406 \times (14)^{2.1255} = 11.1$ kg/100m

Use regression analysis to determine a best fit curve of BS_m versus LD_m using LD_m as the independent variable, and BS_m as the dependent variable. A power function shall be used to normalize the data. The Formula used is: $BS_m = c \times (LD_m)^d$

Measured Linear Density (LD_m) vs. Measured Break Strength (BS_m)



Constants c & d are determined to be:

c=3.6235

d=0.9552

Calculate a Predicted Break Strength for each Nominal Diameter that will be specified by the standard under development.

For example:

The Predicted Break Strength (BS_{pred}) for a rope with a Proposed Linear Density (LD_{prop}) of 11.1kg/100m is

$$BS_{pred} = c \times (LD_{prop})^d = 3.6235 \times (11.1)^{0.9552} = 36.1 \text{ kN}$$

Calculate a Proposed Minimum Break Strength for each Nominal Diameter that will be specified by the standard under development.
For example:

$$MBS_{prop} = BS_{pred} \times (1 - MSTB) = 36.1 \times (1 - 0.1) = 32.4 \text{ kN}$$

So, for the proposed standard, a 14mm rope would be 11.1 kg/100m with a MBS of 32.4kN

⚠ WARNING

The use of rope and cordage products has inherent safety risks which are subject to highly variable conditions and which may change over time. Compliance with standards and guidelines of the Cordage Institute does not guarantee safe use under all circumstances, and the Institute disclaims any responsibility for accidents which may occur. If the user has any questions or uncertainties about the proper use of rope or cordage or about safe practices, consult a professional engineer or other qualified individual.