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RESULTS OF SOME TESTS OF MANILA ROPE

BY

AMBROSE H. STANG, Associate Physicist
LORY R. STRICKENBERG, Assistant Mechanical Engineer
Bureau of Standards

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RESULTS OF SOME TESTS OF MANILA ROPE

By Ambrose H. Stang and Lory R. Strickenberg

ABSTRACT

This paper summarizes the results of tensile tests of 368 specimens of manila rope. Most of the material was submitted on purchase orders for Government departments. They were all 3-strand, regular lay manila rope having diameters from ½ inch to 4½ inches.

A summary of the results is given in tables and graphically. A formula is given for determining the average breaking load as a function of the diameter of the rope. The test results cover sufficient range and show such consistency that it is believed that the formulas may be used safely for 3-strand, regular lay manila rope of the sizes indicated. The ropes showed a continually varying modulus of elasticity and no well-defined proportional limit.

CONTENTS

I. INTRODUCTION

The results of tests on manila rope discussed in this paper represent some of the data obtained at the Bureau of Standards during the past few years. The tests were made under the supervision of J. H. Griffith, J. G. Bragg, W. H. Virgin, and others.

Most of the specimens were submitted by various rope manufacturers on purchase orders for Government departments.

Although the purchase specifications until recently were not identical for all departments, a fixed procedure was adopted by the laboratory for all rope tests. On April 4, 1918, a standard specification for manila rope was adopted at a joint conference between the representatives of the various Government departments and of the rope manufacturers. This has since been used by many of the departments, as, for example, by the Panama Canal (No. 307–C, Standard Specifications for Manila Rope, 1920).

As the method of testing adopted by the laboratory was the same as that required by the standard specifications (paragraph 9), these results may be considered representative of those which would be obtained on commercial rope if tested under the Government standard specifications. Due to the fact that the tests were not part of an investigational program, the effect of many of the variables on the properties of rope was not determined.

II. SCOPE OF TESTS

The samples of rope ranged in diameter from ½ to 4½ inches, inclusive, and consisted of commercial 3-strand, regular lay ropes.

The breaking loads were observed in all the tensile tests, and observations were made upon a considerable number of the samples for weight per linear foot, number of yarns, and the "lay" of the rope and strands. Measurements of elongation were also made upon 18 specimens of special "hard-laid" ropes, ¾, 1¼, 1½, and 1¾ inches in diameter.

III. CONSTRUCTION OF ROPE

1. NUMBER OF YARNS

All kinds of rope and cordage are composed of 1 or more yarns, which are also known as plys or threads, depending upon the kind of rope in which they are used. In regular lay 3-strand rope the number of these yarns may be expected to vary with the diameter; that is, a rope of large diameter will have more yarns than one of small diameter if the yarns are the same or about the same size in each rope. This investigation showed that ropes of small diameter, as a rule, have smaller sized yarns than those of large diameter and that even those of the same diameter from different makers vary somewhat in the number. The yarns were counted in many of the ropes, the results being given later in the paper.

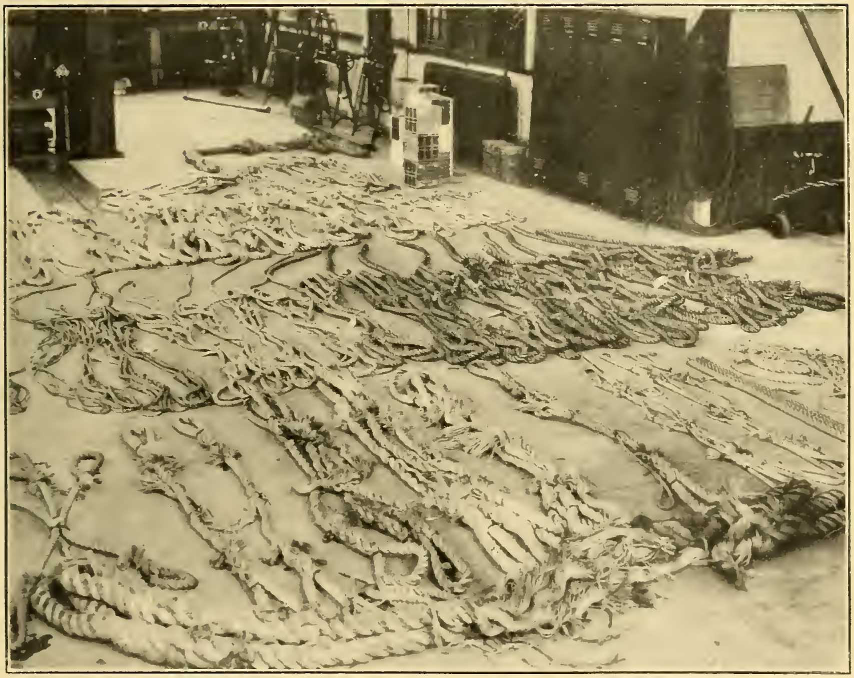

FIG. 1.—*One lot of manila rope samples representing a year's purchase of rope for one storage depot of the U. S. Army*

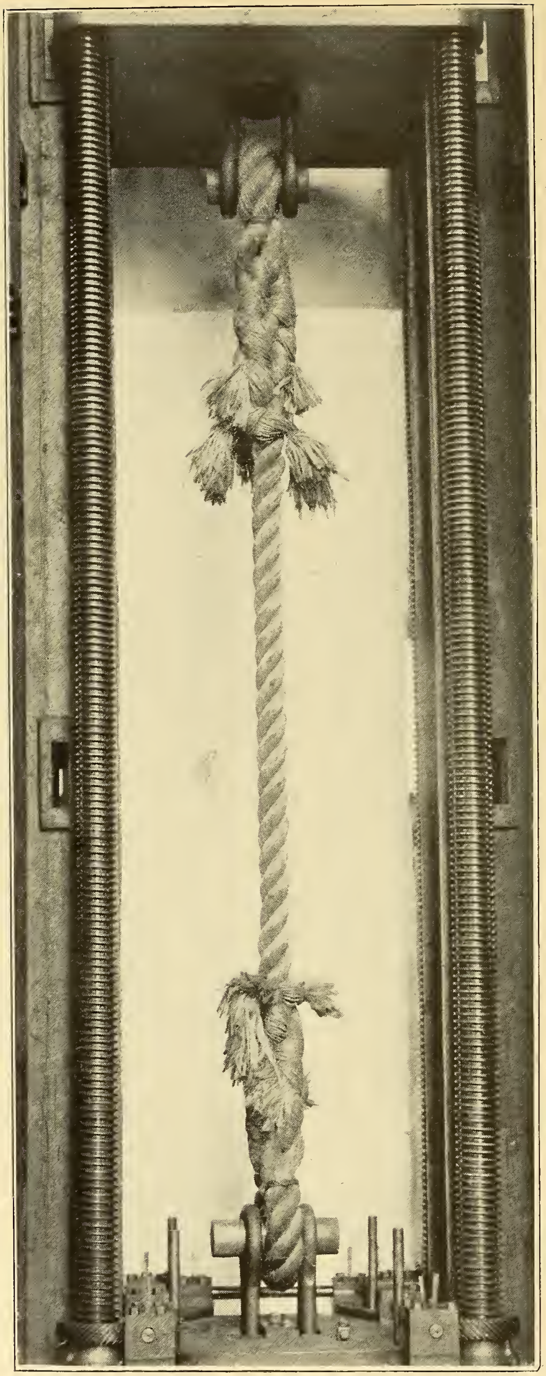

FIG. 2.—*A rope specimen in position for tension test in a 600 000 pound testing machine*

2. LAY OF ROPE AND STRANDS

The distance along the axis of the rope in which the rope makes one complete turn is called the "lay" or "jaw" of the rope. The distance along the axis of the strand in which the yarn makes one complete turn is called the "lay" of the strand. When the yarns twist in one direction about the axis of the strands and the strands twist in the opposite direction about the axis of the rope, the rope is known as regular "lay." The hardness of a rope is determined by the amount of twist given to the strands, and consequently it may be referred to as hard or soft laid.

IV. METHOD OF TESTING

1. PREPARATION OF ROPE

All specimens for tensile tests were prepared with an eye splice in each end, the inside diameter of the eye being about 7 inches, and the length between splices not less than 5 feet. Splices were carefully made in an effort to cause the specimen to break in the body of the rope. To prevent slipping at the splice, the specimens were soaked in water overnight. However, in spite of the precautions, about 50 per cent of those tested broke at or near a splice.

2. MACHINES USED FOR TESTING

Most of the specimens were broken in a 600 000 pound testing machine, although a few of the smaller sizes (under 1 inch in diameter), for which the distance between the splices would permit, were broken in a 100 000 pound machine. The machine was operated so that the speed of the moving head was not more than 4 inches per minute. Fig. 2 shows a rope specimen in position in the larger machine.

3. DESCRIPTION OF TESTS

(*a*) TENSION.—Fig. 2 shows the method of fastening the ends of the rope in the machine. The beam of the weighing apparatus was kept balanced as the load was gradually applied, and the breaking load was indicated on the beam at the completion of the test.

(*b*) WEIGHT.—To determine the weight of the rope, the specimen was subjected to a load of (P) pounds, equal to 200 times the square of the diameter of the rope in inches ($P = 200\ D^2$). With the specimen under this load, a certain length was marked off on the rope, and this length was then cut out of the specimen after the load was removed. This portion was weighed, and the weight per foot was calculated.

(*c*) SIZE.—The size was determined on the rope specimens when under the same load as was used in determining the weight. The circumference was measured by passing a fiber snugly around the rope and cutting it at the point of intersection. The length of fiber was then measured to obtain the circumference. The lay, in number of turns per foot, of both rope and strands was also measured directly upon the rope specimen, and the number of strands and yarns was counted.

V. RESULTS OF TESTS

TABLE 1.—Tests of Manila Rope. (Sample Log Sheet)

Sample number	Length		Diameter	Weight of sample		Weight of rope	Number of strands
	Feet	Inches	Inches	Pounds	Ounces	Lb./ft.	
1	15	0	1 1/4	4	1.5	0.273	3
2	14	10	1 1/8	3	9.2	.241	3
3	15	9 1/2	1 1/8	4	3	.265	3
4	14	6	1 1/4	3	15.2	.272	3
5	14	9	1 1/8	3	15	.267	3
6	14	10	1 1/4	3	15.8	.269	3
7	15	1 1/2	1 1/4	4	8	.298	3
8	13	7	1 1/8	3	8	.258	3
9	14	8	1 1/8	4	8.5	.309	3
10	15	0	1 1/4	4	5.8	.291	3
11	15	1 1/2	1 1/8	3	15.5	.263	3
12	14	8	1 1/8	3	11.2	.252	3
13	14	8	1 1/8	3	10	.247	3

Sample number	Number of yarns in rope	Lay of rope	Lay of strand	Lay of yarn	Breaking load	Remarks [a]
		Turns/ft.	Turns/ft.	Turns/ft.	Pounds	
1	54	3.7	3	7.2	13 600	
2	74	3.7	3.8	8.7	9 950	Marked "Whitlock pure manila"
3	69	4	3.5	9.2	10 500	
4	96	3.3	3	11.3	11 700	Two strands broke near splice
5	54	4	4	7.2	9 500	
6	99	3.7	3.5	10.2	10 500	Two strands broke about 6 inches from splice
7	85	3.7	3	9.9	10 800	
8	83	4	3.2	7.9	11 700	
9	72	4	3.2	9.3	8 700	
10	84	3.7	3	9.8	10 500	
11	84	4	3.5	7.8	10 700	
12	87	3.5	4	10.4	9 950	
13	90	3.3	3.8	8.7	10 400	

[a] Except where noted, one strand of each rope broke at or near splice.

TABLE 2.—Breaking Loads for Manila Rope

Dimensions of ropes in inches: Diameters	Dimensions of ropes in inches: Circumferences	Number of tests	Observed breaking loads: Maximum	Observed breaking loads: Minimum	Observed breaking loads: Average	Values of breaking load calculated from $L=cd\ (d+1)$ $c=6300$......3700......5000: Maximum	Minimum	Average	Government standard specifications
			Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
½	1 57	23	3 920	2 300	3 250	4 725	2 775	3 750	2 450
⅝	2	17	6 550	4 250	5 300	6 400	3 750	5 100	4 000
¾	2 2	14	7 020	5 180	6 350	8 270	4 850	6 565	4 900
13/16	2 90	26	8 730	5 850	7 100	9 275	5 450	7 360	5 900
1	3 14	72	12 700	7 800	9 770	12 600	7 400	10 000	8 200
1 ⅛	3 5	9	12 900	8 700	11 480	15 060	8 850	11 950	11 000
1 ¼	3 93	76	17 600	10 420	13 650	17 725	10 410	14 060	12 500
1 ½	4 71	48	24 800	13 280	18 440	23 630	13 875	18 750	17 500
1 ⅝	5 07	14	25 210	16 410	21 830	26 875	15 800	21 325	21 500
1 ¾	5 5	14	31 130	20 000	24 400	30 325	17 800	24 060	25 500
2	6 28	5	27 200	23 140	26 140	37 800	22 200	30 000	30 000
2 ½	7 85	8	54 700	32 300	44 000	55 100	32 350	43 750	43 500
3	9 42	22	74 000	45 000	59 300	75 600	44 400	60 000	61 000
3 ½	10 10	17	105 000	58 100	85 800	99 230	58 275	78 750	....
4	12 57	2	115 700	87 500	101 600	126 000	74 000	100 000	....
4 ½	14 14	1	110 000	110 000	110 000	155 900	91 600	123 750	....

TABLE 3.—Number of Yarns in Manila Rope

Diameter of ropes in inches	Number of tests	Number of yarns in rope: Maximum	Minimum	Average	Number calculated from formula $N=50d(d+0.4)$
½	21	21	18	20	22
⅝	15	36	30	33	32
¾	11	39	39	39	43
13/16	26	51	39	42	49
1	70	96	54	72	70
1 ¼	76	162	72	105	103
1 ½	46	225	129	144	143
1 ⅝	12	225	150	174	165
1 ¾	12	201	150	189	188
2	5	234	150	222	240
2 ½	8	354	315	339	362
3	22	582	435	504	510
3 ½	16	720	645	690	683
4	2	915	846	885	880

VI. DISCUSSION OF RESULTS

The average tensile strengths of 368 specimens of manila rope, ranging from ½ to 4½ inches in diameter, are shown in Table 2, and have been plotted in Fig. 3 as a function of the diameters of the ropes. The breaking load is approximately a quadratic function of the diameter, and may be closely expressed by the formula:

$$L=cd(d+1),$$

where L is the breaking load in pounds, d the diameter of the rope in inches, and c is a constant that is equal approximately to 6300 for the strongest ropes tested, 5000 for the average, and 3700 for the weakest ropes. In other words, with the observed loads from the individual tests plotted for the various diameters of ropes as

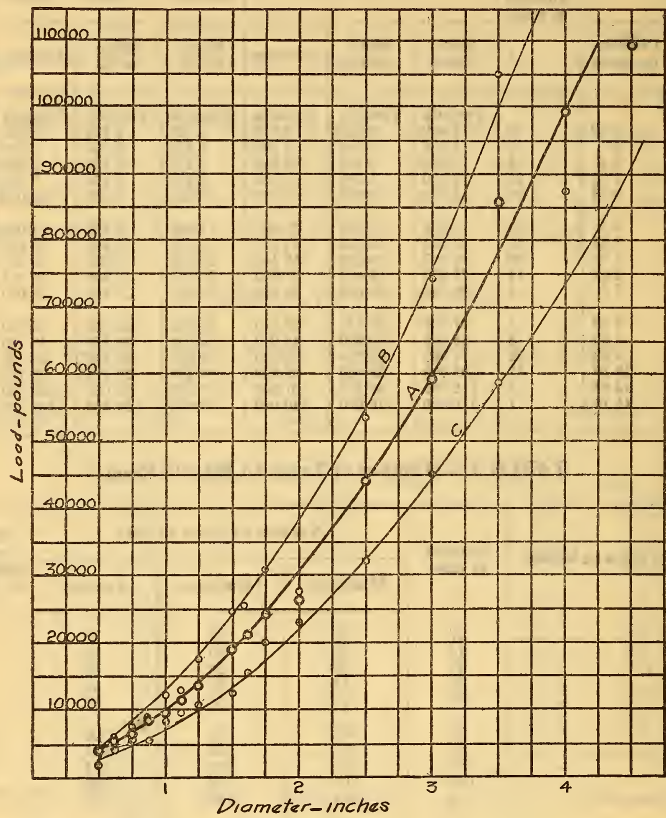

FIG. 3.—*Relation between breaking load and diameter of manila rope*

The plotted points show the close agreement of the experimental values with those computed from the formulas

shown in Fig. 3, the curve for the average results conforms very closely to the equation (see curve A, Fig. 3):

$$L = 5000\, d\, (d+1).$$

The minimum results are very closely expressed by the equation (see curve C, Fig. 3):

$$L = 3700\, d\, (d+1);$$

and the maximum values are expressed by the equation (see curve B, Fig. 3):

$$L = 6300\, d\, (d+1).$$

These equations apply only to 3-strand, regular lay manila rope over ½ inch in diameter.

It should be noted (see Table 2) that the average values given by the formula:

$$L = 5000\, d\, (d + 1),$$

and from the tests agree closely with those obtained from the standard specifications. An attempt to plot all three of these values in

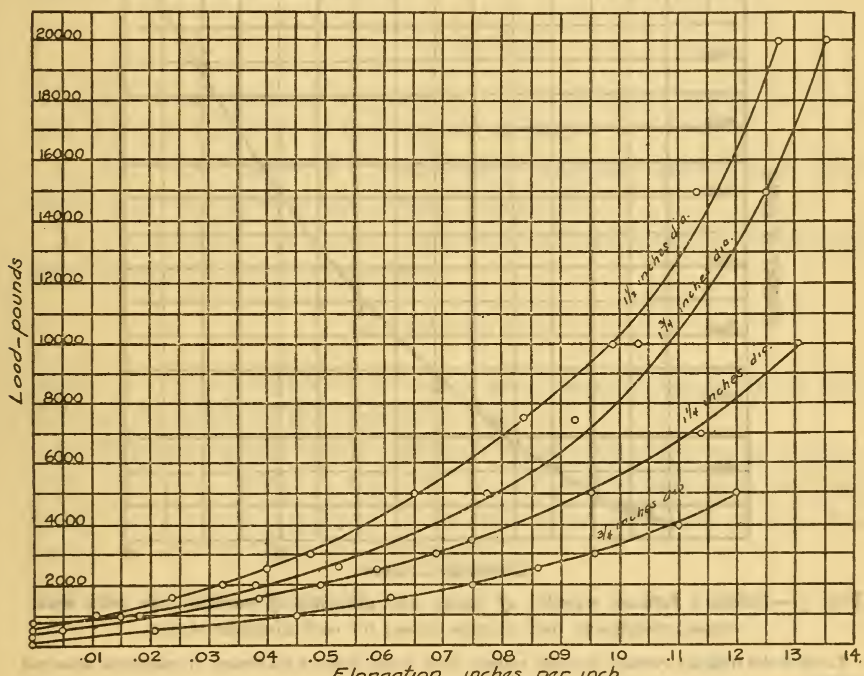

Fig. 4.—*Load-elongation curves for hard laid ropes of various diameters*

The plotted points are the averages of the observed elongations for specimens having the same diameter, the highest value in each case being the average breaking load

Fig. 3 showed that the curves practically coincided with the curve *A* which was drawn.

In Fig. 4 load-elongation curves have been plotted for 18 specimens of hard-laid rope of 4 different diameters. The plotted points are the averages of the observed elongations at a given load for specimens having the same diameter, the highest value in each case being the average breaking load. It is readily noted from the curves that rope has a variable modulus of elasticity and no well-defined proportional limit.

Table 3 shows the relation between the number of yarns in a rope and the diameter of the rope. The number of yarns was counted, and the maximum, minimum, and average number found in the different sized ropes is given here. These values have been plotted in Fig. 5 against the diameter of the rope. The average

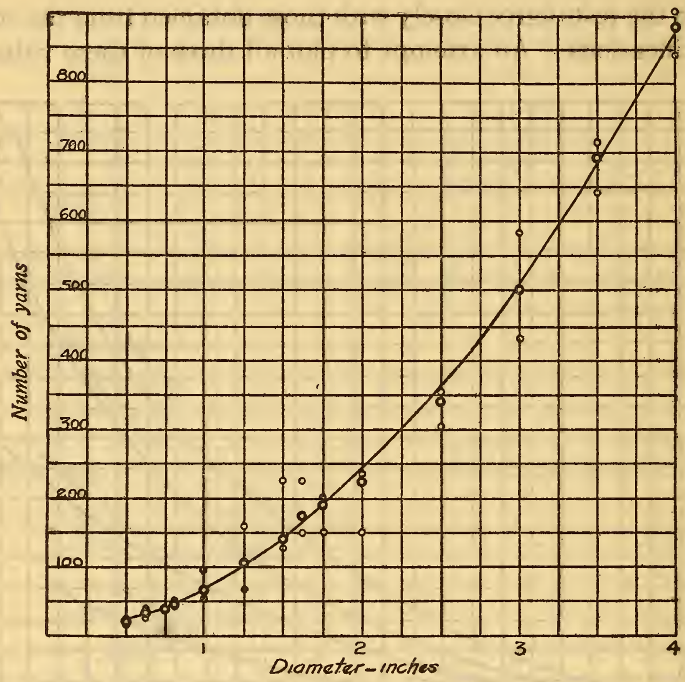

FIG. 5.—*Relation between number of yarns and diameter of manila rope with maximum, minimum, and average values for each diameter shown*

Large circles indicate average observed values; small circles indicate maximum or minimum observed values

number of yarns composing a rope may be approximately represented by the formula:

$$N = kd\ (d + 0.4),$$

where N is the number of yarns, k is a constant equal to 50, and d is the diameter of the rope in inches. The last column in Table 3 shows the number of yarns as represented by this formula. This formula is represented also graphically by the curve of Fig. 5, from which the agreement between the experimental values and those obtained from the equation may be judged.

As stated, this is only approximate, since the actual number of yarns composing a rope may vary as much as 30 per cent either above or below the number expressed by this empirical equation. However, it gave results in this work having a probable error of about 10 per cent for the average values.

VII. SUMMARY

1. The average breaking load was found to be approximately a quadratic function of the diameter of the rope. It is expressed quite closely by the equation:

$$L = cd\ (d + 1),$$

in which L is the load in pounds, c is a constant equal to 5000, and d is the diameter of the rope in inches.

2. The ropes showed a continually varying modulus of elasticity and no well-defined proportional limit.

3. The number of yarns composing a rope may be expressed approximately by the equation:

$$N = kd\ (d + 0.4),$$

where N is the number of yarns, k is a constant equal to 50, and d is the diameter of the rope in inches.

4. The test results cover sufficient range and show such consistency that it is believed that the formulas deduced may be used safely for 3-strand, regular lay manila rope for sizes of rope between ½ and 4½ inches in diameter.

WASHINGTON, February 26, 1921.