Designation: A 416/A 416M – 06

Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete[1]

This standard is issued under the fixed designation A 416/A 416M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers two types and two grades of seven-wire, uncoated steel strand for use in pretensioned and post-tensioned prestressed concrete construction. The two types of strand are low-relaxation and stress-relieved (normal-relaxation). Low-relaxation strand shall be regarded as the standard type. Stress-relieved (normal-relaxation) strand will not be furnished unless specifically ordered, or by arrangement between purchaser and supplier. Grade 1725 [250] and Grade 1860 [270] have minimum ultimate strengths of 1725 MPa [250 ksi] and 1860 MPa [270 ksi], respectively, based on the nominal area of the strand.

1.2 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 The supplementary requirements in S1 shall be specified for 15.2-mm [0.600-in.] diameter uncoated seven-wire steel strand if needed for applications in prestressed ground anchors.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 981 Test Method for Evaluating Bond Strength for 15.2 mm (0.6 in.) Diameter Prestressing Steel Strand, Grade 270, Uncoated, Used in Prestressed Ground Anchors

E 328 Test Methods for Stress Relaxation for Materials and Structures

2.2 *U.S. Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[3]

MIL-STD-163 Steel Mill Products Preparation for Shipment and Storage[3]

2.3 *U.S. Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *strand*, *n*—a group of wires having a center wire enclosed tightly by six helically placed outer wires with uniform pitch of not less than 12 and not more than 16 times the nominal diameter of the strand.

3.1.1.1 *Discussion*—The direction of lay may be either right- or left-hand, however, strands of different lays should not be spliced together.

4. Ordering Information

4.1 Orders for seven-wire low-relaxation or stress-relieved (normal-relaxation) strand under this specification should include the following information:

4.1.1 Quantity (meters [feet]),

4.1.2 Diameter of strand,

4.1.3 Grade of strand,

4.1.4 Type of strand,

4.1.5 Packaging,

4.1.6 ASTM designation and year of issue, and

4.1.7 Special requirements, if any.

NOTE 1—A typical ordering description is as follows: 25 600 m [84 000 ft], 13 mm [0.5 in.], Grade 1860 [270] low-relaxation strand, in 3600-m [12 000-ft] reelless packs to ASTM A 416/A 416M– _____.

5. Materials and Manufacture

5.1 *Base Metal*—The base metal shall be carbon steel of such quality that when drawn to wire, fabricated into strand, and then thermally treated, shall have the properties and characteristics prescribed in this specification.

5.2 *Wire*—The wire from which the strand is to be fabricated shall be round and have a dry-drawn finish.

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

***A Summary of Changes section appears at the end of this standard.**

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NOTE 2—This product is a composite of seven wires and is produced to mechanical properties only. The chemical composition of all wires or any individual wire is not pertinent to this application, and heat identity is not necessarily maintained. It is possible that wire from more than one heat may be used in the manufacture of a reel or pack. Traceability is based on pack identity as maintained and reported by the manufacturer.

5.3 *Treatment*—After stranding, low-relaxation strand shall be subjected to a continuous thermal-mechanical treatment to produce the prescribed mechanical properties. For stress-relieved (normal-relaxation) strand, only thermal treatment is necessary. Temper colors which result from the stress-relieving operation are considered normal for the finished appearance of this strand.

6. Mechanical Properties

6.1 Methods of testing for mechanical properties are described in Annex A7 of Test Methods and Definitions A 370. Low-relaxation strand shall also be tested as prescribed in Methods E 328.

6.2 *Breaking Strength*—The breaking strength of the finished strand shall conform to the requirements prescribed in Table 1.

6.3 *Yield Strength*—Yield strength in kN [pounds] shall be measured at 1 % extension under load. The minimum yield strength shall be 90 % for low-relaxation strand and 85 % for stress-relieved (normal-relaxation) strand of the breaking strength listed in Table 1. Initial loads for the test and minimum yield strengths are listed in Table 2.

6.3.1 The extension under load shall be measured by an extensometer calibrated with the smallest division not larger than 0.0001 mm/mm [0.0001 in./in.] of gage length.

6.4 *Elongation*—The total elongation under load shall not be less than 3.5 % using a gage length of not less than 600 mm [24 in.]. It shall be permissable to determine the total elongation value by adding, to the 1.0 % yield extension, the percent extension or movement between the jaws gripping the strand after yield determination. The percent is calculated on the new base length of jaw-to-jaw distance.

6.5 *Relaxation Properties*—Low-relaxation strand shall have relaxation losses of not more than 2.5 % when initially loaded to 70 % of specified minimum breaking strength or not more than 3.5 % when loaded to 80 % of specified minimum breaking strength of the strand after 1000 h tested under the conditions listed in 6.5.1 through 6.5.7.

6.5.1 If required, relaxation evidence shall be provided from the manufacturer's records of tests on similarly dimensioned strand of the same grade.

6.5.2 The temperature of the test specimen shall be maintained at 20 ± 2°C [68 ± 3.5°F].

6.5.3 The test specimen shall not be subjected to loading prior to the relaxation test.

6.5.4 The initial load shall be applied uniformly over a period of not less than 3 min and not more than 5 min, and the gage length shall be maintained constant; load relaxation readings shall commence 1 min after application of the total load.

6.5.5 Over-stressing of the test specimen during the loading operation shall not be permitted.

6.5.6 The duration of the test shall be 1000 h or a shorter period of at least 200 h, provided it can be shown by records that an extrapolation of the shorter period test results to 1000 h will provide similar relaxation values as the full 1000 h test.

6.5.7 The test gage length shall be at least 60 times the nominal diameter. If this gage length exceeds the capacity of the extensometer or testing machine, then it shall be permitted to substitute a gage length of 40 times the nomimal strand diameter.

7. Dimensions and Permissible Variations

7.1 The size of the finished strand shall be expressed as the nominal diameter of the strand in millimetres [inches].

7.2 The diameter of the center wire of any strand shall be larger than the diameter of any outer wire in accordance with Table 3.

7.3 *Permissible Variations in Diameter*:

7.3.1 All Grade 1725 [250] strand shall conform to a size tolerance of ±0.40 mm [±0.016 in.] from the nominal diameter measured across the crowns of the wires.

7.3.2 All Grade 1860 [270] strand shall conform to a size tolerance of +0.65, – 0.15 mm [+0.026, –0.006 in.] from the nominal diameter measured across the crowns of the wire.

TABLE 1 Breaking Strength Requirements

Strand Designation No.	Diameter of Strand, mm [in.]	Minimum Breaking Strength of Strand, kN [lbf]	Steel Area of Strand, mm^2[$in.^2$]	Weight of Strand kg/1000 m [lb/1000 ft]
		Grade 1725 [250]		
6	6.4 [0.250]	40.0 [9 000]	23.2 [0.036]	182 [122]
8	7.9 [0.313]	64.5 [14 500]	37.4 [0.058]	294 [197]
9	9.5 [0.375]	89.0 [20 000]	51.6 [0.080]	405 [272]
11	11.1 [0.438]	120.1 [27 000]	69.7 [0.108]	548 [367]
13	12.7 [0.500]	160.1 [36 000]	92.9 [0.144]	730 [490]
15	15.2 [0.600]	240.2 [54 000]	139.4 [0.216]	1094 [737]
		Grade 1860 [270]		
9	9.53 [0.375]	102.3 [23 000]	54.8 [0.085]	432 [290]
11	11.11 [0.438]	137.9 [31 000]	74.2 [0.115]	582 [390]
13	12.70 [0.500]	183.7 [41 300]	98.7 [0.153]	775 [520]
13a	13.20 [0.520]	200.2 [45 000]	107.7 [.0167]	844 [568]
14	14.29 [0.563]	230.0 [51 700]	123.9 [.0192]	970 [651]
15	15.24 [0.600]	260.7 [58 600]	140.0 [0.217]	1102 [740]
18	17.78 [0.700]	353.2 [79 400]	189.7 [0.294]	1487 [1000]

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TABLE 2 Yield Strength Requirements

Strand Designation No.	Nominal Diameter of Strand mm [in.]	Initial Load, kN [lbf]	Minimum Load at 1 % Extension, kN [lbf]	
			Low-Relaxation	Normal-Relaxation
		Grade 1725 [250]		
6	6.4 [0.250]	4.0 [900]	36.0 [8 100]	34.0 [7 650]
8	7.9 [0.313]	6.5 [1 450]	58.1 [13 050]	54.7 [12 300]
9	9.5 [0.375]	8.9 [2 000]	80.1 [18 000]	75.6 [17 000]
11	11.1 [0.438]	12.0 [2 700]	108.1 [24 300]	102.3 [23 000]
13	12.7 [0.500]	16.0 [3 600]	144.1 [32 400]	136.2 [30 600]
15	15.2 [0.600]	24.0 [5 400]	216.2 [48 600]	204.2 [45 900]
		Grade 1860 [270]		
9	9.53 [0.375]	10.2 [2 300]	92.1 [20 700]	87.0 [19 550]
11	11.11 [0.438]	13.8 [3 100]	124.1 [27 900]	117.2 [26 350]
13	12.70 [0.500]	18.4 [4 130]	165.3 [37 170]	156.1 [35 100]
13a	13.20 [0.520]	20.0 [4 500]	180.1 [40 500]	170.1 [38 250]
14	14.29 [0.563]	23.0 [5 170]	207.0 [46 530]	195.5 [43 950]
15	15.24 [0.600]	26.1 [5 860]	234.6 [52 740]	221.5 [49 800]
18	17.78 [0.700]	35.3 [7 940]	318.0 [71 500]	300.2 [67 500]

TABLE 3 Diameter Relation Between Center and Outer Wires

Strand Designation No.	Nominal Diameter of Strands, mm [in.]	Minimum Difference Between Center Wire Diameter and Diameter of Any Outer Wire, mm [in.]
	Grade 1725 [250]	
6	6.4 [0.250]	0.025 [0.001]
8	7.9 [0.313]	0.038 [0.0015]
9	9.5 [0.375]	0.051 [0.002]
11	11.1 [0.438]	0.064 [0.0025]
13	12.7 [0.500]	0.076 [0.003]
15	15.2 [0.600]	0.102 [0.004]
	Grade 1860 [270]	
9	9.53 [0.375]	0.0508 [0.002]
11	11.11 [0.438]	0.0635 [0.0025]
13	12.70 [0.500]	0.0762 [0.003]
13a	13.20 [0.520]	0.0762 [0.003]
14	14.29 [0.563]	0.0889 [0.0035]
15	15.24 [0.600]	0.1016 [0.004]
18	17.78 [0.700]	0.1143 [0.0045]

7.3.3 Variation in cross-sectional area and in unit stress resulting therefrom shall not be cause for rejection provided that the diameter differences of the individual wires and the diameters of the strand are within the tolerances specified.

7.4 It shall be permitted to furnish, under this specification, specially dimensioned low-relaxation and stress-relieved (normal-relaxation) strands with nominal diameters up to 19 mm [0.750 in.]. The breaking strength shall be defined, and the yield strength, as defined in 6.3, shall not be less than 90 % and 85 % of the specified minimum breaking strength for low-relaxation and stress-relieved (normal relaxation) strands, respectively. All other requirements shall apply.

8. Workmanship, Finish, and Appearance

8.1 *Joints*:

8.1.1 There shall be no strand joints or strand splices in any length of the completed strand unless specifically permitted by the purchaser.

8.1.2 During the process of manufacture of individual wires for stranding, welding shall be permitted only prior to or at the size of the last thermal treatment, for example, patenting or controlled cooling. There shall be no welds in the wire after it has been drawn through the first die in the wire drawing except as provided in 8.1.3.

8.1.3 During fabrication of the strand, butt-welded joints are permitted in the individual wires, provided there shall not be more than one such joint in any 45-m [150-ft] section of the completed strand.

8.1.4 When specifically ordered as “Weldless,” a product free of welds shall be furnished. When “Weldless” is specified, the strand is produced as one continuous length with no welds as allowed by 8.1.3.

8.2 The finished strand shall be uniform in diameter and shall be free of imperfections not consistent with good commercial strand practices.

8.3 When the strand is cut without seizings, the wire shall not fly out of position. If any wire flies out of position and can be replaced by hand, the strand shall be considered satisfactory.

8.4 The strand shall not be oiled or greased. Slight rusting, provided it is not sufficient to cause pits visible to the unaided eye, shall not be cause for rejection.

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NOTE 3—Guidance for evaluating the degree of rusting on prestressed concrete strand is presented in Sason.[4]

9. Sampling

9.1 Test specimens cut from either end of the strand package are permitted. Any specimen found to contain a wire joint shall be discarded and a new specimen obtained.

10. Number of Tests

10.1 One specimen for test shall be taken from each 18-Mg [20-ton] production lot of finished strand, and tested for breaking strength, yield strength, and elongation.

11. Inspection

11.1 If outside inspection is required, the manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy that the material is being furnished in accordance with this specification. All tests and inspections shall be made at the place of manufacture prior to shipment, unless otherwise agreed upon at the time of purchase, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

NOTE 4—The purchaser should state, at the time of order, whether outside inspection is required or waived.

12. Rejection

12.1 Failure of any test specimen to comply with the requirements of the specification shall constitute grounds for rejection of the lot represented by the specimen.

12.2 The lot shall be resubmitted for inspection by testing a specimen from each reel or pack and sorting out nonconforming material.

12.3 In case there is a reasonable doubt in the initial testing as to the ability of the strand to meet any requirement of this specification, two additional tests shall be made on a specimen of strand from the same reel or pack, and if failure occurs in either of these tests, the strand shall be rejected.

13. Certification

13.1 If outside inspection is waived, a manufacturer's certification that the material has been tested in accordance with and meets the requirements of this specification shall be the basis of acceptance of the material. The certification shall include the specification number, year-date of issue, and revision letter, if any.

13.2 The manufacturer shall, when requested in the order, furnish a representative load-elongation curve for each size and grade of strand shipped.

13.3 When the modulus of elasticity of a seven-wire strand is provided, the cross-sectional area used to compute that modulus also shall be provided. The area provided in the certification shall be the area used to calculate the modulus of elasticity.

13.4 A material test report, certificate of inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 5—The industry definition as invoked here is: EDI is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

14. Packaging and Marking

14.1 The strand shall be furnished on reels or in reelless packs having a minimum core diameter of 610 mm [24 in.], unless otherwise specified by the purchaser. Lengths on reels or in reelless packs shall be as agreed upon at the time of purchase. The strand shall be well protected against mechanical injury in shipping as agreed upon at the time of purchase. Each reel or reelless pack shall have two strong tags securely fastened to it showing the length, size, type, grade, ASTM designation A 416/A 416M, and the name or mark of the manufacturer. One tag shall be positioned where it will not be inadvertently lost during transit, such as the core of a reelless pack. The other tag shall be placed on the outside for easy identification.

14.2 *For Government Procurement Only*— When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. government, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

15. Keywords

15.1 prestressed concrete; seven-wire strand (tendon); steel wire

[4] Sason, A.S., "Evaluation of Degree of Rusting on Prestressed Concrete Strand,'' *PCI Journal*, Precast/Prestressed Concrete Institute, Vol. 37, No. 3, May-June 1992, pp 25–30. Reprints of this paper are available from the Precast/Prestressed Concrete Institute, 209 West Jackson Blvd., Suite 500, Chicago, IL 60606.

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SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall apply only to 15.2-mm [0.600-in.] diameter strand, Grade 270 used in prestressed ground anchors or similar applications and shall be specified at the time of order placement. These requirements are not applicable to strand used in prestressed concrete applications.

S1. Bond Capacity

S1.1 The results of bond-capacity tests performed in accordance with Test Method A 981 shall be submitted to the purchaser. The strand specimens, on which tests were performed, shall be from different lots and shall be representative for the strand ordered.

S1.2 The average pull force from six pull tests, performed in accordance with Test Method A 981, required to reach the 0.25-mm [0.01-in.] displacement described therein shall be at least 35.6 kN [8000 lbf], with the individual minimum test value not less than 30.2 kN [6800 lbf]. For any future retests, without changes in the manufacturing method and materials used, three tests shall be considered as adequate.

S1.3 *Retests* —If the test specimens fail to satisfy S1.2, six additional tests shall be performed, and the results shall satisfy the acceptance criteria. Strand that failed the retest shall not be considered acceptable for the use in prestressed ground anchors.

S1.4 *Annual Tests*—The pull tests shall be performed annually as a minimum or repeated when, in the opinion of the producer, a process change is made which is believed could decrease the bond capacity of the strand.

SUMMARY OF CHANGES

Committee A01 has identified the location of the following changes to this standard since the last issue (A 416/A 416M–05) that may impact the use of this standard. (Approved April 1, 2006.)

(1) Sections 6.4, 7.4, and 13.2 were revised to eliminate permissive language.
(2) Revised Table 1, Table 2, and Table 3 to include Strand Designation No. 14 and No. 18.
(3) Editorial changes were made throughout.

Committee A01 has identified the location of the following changes to this standard since the last issue (A 416/A 416M–02) that may impact the use of this standard. (Approved June 1, 2005.)

(1) Revised Table 1, Table 2, and Table 3 to include Strand Designation No. 13a.

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