Designation: A416/A416M – 16

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

This standard is issued under the fixed designation A416/A416M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification covers two grades of low-relaxation, seven-wire steel strand for use in prestressed concrete construction. Grade 250 [1725] and Grade 270 [1860] have minimum tensile strengths of 250 ksi [1725 MPa] and 270 ksi [1860 MPa], respectively, based on the nominal area of the strand.

1.2 A supplementary requirement (S1) is provided for use where bond strength testing of 0.600-in. [15.24-mm] diameter Grade 270 [1860] strand for applications in prestressed ground anchors is required by the purchaser. The supplementary requirement applies only when specified in the purchase order.

1.3 The text of this specification contains notes or footnotes, or both, that provide explanatory material. Such notes and footnotes do not contain any mandatory information.

1.4 This specification is applicable for orders in either inch-pound units (as Specification A416) or in SI units (as Specification A416M).

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A981/A981M Test Method for Evaluating Bond Strength for 0.600-in. [15.24-mm] Diameter Steel Prestressing Strand, Grade 270 [1860], Uncoated, Used in Prestressed Ground Anchors

A1061/A1061M Test Methods for Testing Multi-Wire Steel Strand

2.2 *U.S. Military Standard:*[3]

MIL-STD-129 Marking for Shipment and Storage

2.3 *U.S. Federal Standard:*[3]

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

3. Terminology

3.1 *Definition of Term Specific to This Specification:*

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.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements to be considered include, but are not limited to, the following:

4.1.1 Quantity (feet [metres]),
4.1.2 Nominal diameter of strand,
4.1.3 Grade of strand,
4.1.4 Specially dimensioned strand (7.4), if desired,
4.1.5 Weldless, if desired (8.1),
4.1.6 Outside inspection, if required (11.1),
4.1.7 Load-elongation curve, if desired (13.2),
4.1.8 Packaging (14.1),
4.1.9 Supplementary Requirement S1, if desired, and
4.1.10 ASTM designation A416 [A416M] and year of issue.

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,

[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, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://dodssp.daps.dla.mil.

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

TABLE 1 Breaking Strength Requirements

Nominal Diameter of Strand, in. [mm]	Minimum Breaking Strength of Strand, lbf [kN]	Steel Area of Strand, in.^{2} [mm^2]	Weight [Mass] of Strand lb/1000 ft [kg/1000 m]
Grade 250 [1725]			
0.250 [6.4]	9 000 [40.0]	0.036 [23]	122 [182]
0.313 [7.9]	14 500 [64.5]	0.058 [37]	197 [294]
0.375 [9.5]	20 000 [89.0]	0.080 [52]	272 [405]
0.438 [11.1]	27 000 [120]	0.108 [69.7]	367 [548]
0.500 [12.7]	36 000 [160]	0.144 [92.9]	490 [730]
0.600 [15.2]	54 000 [240]	0.216 [139]	737 [1090]
Grade 270 [1860]			
0.375 [9.53]	23 000 [102]	0.085 [55]	290 [430]
0.438 [11.1]	31 000 [138]	0.115 [74.2]	390 [580]
0.500 [12.7]	41 300 [184]	0.153 [98.7]	520 [780]
0.520 [13.2]	45 000 [200]	0.167 [108]	570 [840]
0.563 [14.3]	51 700 [230]	0.192 [124]	650 [970]
0.600 [15.2]	58 600 [261]	0.217 [140]	740 [1100]
0.620 [15.7]	62 800 [279]	0.231 [150]	780 [1200]
0.700 [17.8]	79 400 [353]	0.294 [190]	1000 [1500]

TABLE 2 Yield Strength Requirements

Nominal Diameter of Strand in. [mm]	Initial Load, lbf [kN]	Minimum Load at 1.0 % Extension, lbf [kN]
Grade 250 [1725]		
0.250 [6.4]	900 [4.0]	8 100 [36.0]
0.313 [7.9]	1 450 [6.5]	13 050 [58.1]
0.375 [9.5]	2 000 [8.9]	18 000 [80.1]
0.438 [11.1]	2 700 [12.0]	24 300 [108.1]
0.500 [12.7]	3 600 [16.0]	32 400 [144.1]
0.600 [15.2]	5 400 [24.0]	48 600 [216.2]
Grade 270 [1860]		
0.375 [9.53]	2 300 [10.2]	20 700 [92.1]
0.438 [11.1]	3 100 [13.8]	27 900 [124.1]
0.500 [12.7]	4 130 [18.4]	37 170 [165.3]
0.520 [13.2]	4 500 [20.0]	40 500 [180.1]
0.563 [14.3]	5 170 [23.0]	46 530 [207.0]
0.600 [15.2]	5 860 [26.1]	52 740 [234.6]
0.620 [15.7]	6 280 [27.9]	56 520 [251.4]
0.700 [17.8]	7 940 [35.3]	71 500 [318.0]

TABLE 3 Diameter Relation Between Center and Outer Wires

Nominal Diameter of Strand, in. [mm]	Minimum Difference Between Center Wire Diameter and Diameter of Any Outer Wire, in. [mm]
Grade 250 [1725]	
0.250 [6.4]	0.001 [0.025]
0.313 [7.9]	0.0015 [0.038]
0.375 [9.5]	0.002 [0.051]
0.438 [11.1]	0.0025 [0.064]
0.500 [12.7]	0.003 [0.076]
0.600 [15.2]	0.004 [0.102]
Grade 270 [1860]	
0.375 [9.53]	0.002 [0.051]
0.438 [11.1]	0.0025 [0.064]
0.500 [12.7]	0.003 [0.076]
0.520 [13.2]	0.003 [0.076]
0.563 [14.3]	0.0035 [0.089]
0.600 [15.2]	0.004 [0.102]
0.620 [15.7]	0.004 [0.102]
0.700 [17.8]	0.0045 [0.114]

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.

NOTE 1—This product is a composite of seven wires and is produced only to meet the prescribed mechanical properties. 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 reelless pack. Traceability is based on identity of reels or reelless packs as maintained and reported by the manufacturer.

5.3 *Treatment*—After stranding, strand shall be subjected to a continuous thermal-mechanical treatment to produce the prescribed mechanical properties. Temper colors which result from the thermal-mechanical treatment are considered normal for the finished appearance of this strand.

6. Mechanical Property Requirements

6.1 Tests for mechanical properties shall be conducted in accordance with Test Methods A1061/A1061M.

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 pounds [kN] shall be measured at 1.0 % extension under load. The minimum yield strength shall be 90 % 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 in./in. [0.0001 mm/mm] 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 24 in. [600 mm]. It shall be permissible 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*—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 hours of testing.

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.

7. Dimensions and Permissible Variations

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

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

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

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 specially dimensioned strands with nominal diameters up to 0.750 in. [19 mm]. The breaking strength shall be defined, and the yield strength, as defined in 6.3, shall not be less than 90 % of the specified minimum breaking strength. 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 finished 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 150-ft [45-m] section of the finished 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.

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 a person with normal or corrected vision, shall not be cause for rejection.

NOTE 2—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 reel or reelless pack 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 test specimen shall be taken from each 30-ton [27-tonne] 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 reasonable access to the facilities, which concern the manufacture of the material ordered, to satisfy the inspector 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 manufacturer's operations.

12. Rejection

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

12.2 The production lot shall be resubmitted for inspection by testing a specimen from each reel or reelless pack and sorting out non-conforming material.

12.3 If 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 specimens of strand from the same reel or reelless pack, and if failure occurs in either of these tests, the strand shall be rejected.

13. Certification

13.1 If outside inspection is not required, 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 of issue, and revision letter, if any.

13.2 When requested in the purchase order or contract, the manufacturer shall 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 calculate 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 shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the manufacturer. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 3—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 Package Marking

14.1 The strand shall be furnished on reels or in reelless packs having a minimum core diameter of 24 in. [610 mm], unless otherwise specified by the purchaser. The length of strand on reels or in reelless packs shall be as agreed upon at the time of purchase. The strand shall be well protected against

[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, 200 West Adams St., Suite 2100, Chicago, IL 60606.

mechanical injury in shipping as agreed upon at the time of purchase. Each reel or reelless pack shall have two durable tags securely fastened to it showing the length, size, grade, ASTM designation A416 [A416M], and the name of the manufacturer. One tag shall be positioned where it will not be inadvertently lost during transit, such as inside the core of a reelless pack. The other tag shall be placed on the outside of a reelless pack for easy identification.

14.2 When specified in the purchase order or contract, and for direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the purchase order or contract, 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

SUPPLEMENTARY REQUIREMENTS

S1. Bond Strength of 0.600-in. [15.24-mm], Grade 270 [1860] Strand Used in Prestressed Ground Anchors

The following supplementary requirement shall apply only when specified in the purchase order or contract.

S1.1 Bond Strength

S1.1.1 These requirements are not applicable to strand used in prestressed concrete applications.

S1.1.2 The results of bond-strength tests performed in accordance with Test Method A981/A981M 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.

S1.1.3 The average pull force from six pull tests, performed in accordance with Test Method A981/A981M, required to reach the 0.01-in. [0.25-mm] displacement described therein shall be at least 8000 lbf [35.6 kN], with the individual minimum test value not less than 6800 lbf [30.2 kN]. For any future retests, without changes in the manufacturing method and materials used, three tests shall be considered as adequate.

S1.1.4 *Retests* —If the test specimens fail to satisfy S1.1.3, six additional tests shall be performed, and the results shall satisfy the acceptance criteria. Strand that fails the retests shall not be considered acceptable for use in prestressed ground anchors.

S1.1.5 *Annual Tests*—The pull tests shall be performed annually as a minimum or repeated when, in the opinion of the manufacturer, a process change is made which is believed could decrease the bond strength of the strand.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A416/A416M – 15) that may impact the use of this standard. (Approved March 1, 2016.)

(1) Revised 3.1.1.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A416/A416M – 12a) that may impact the use of this standard. (Approved May 1, 2015.)

(1) Deleted "stress-relieved (normal-relaxation)" type of stand, revising the title, 1.1, 4.1.4, 5.3, 6.3, 7.4, 6.5, and Table 2.

(2) Revised 10.1 to update current production capabilities.

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