Designation: D8019 – 15

Standard Test Methods for Determining the Full Section Flexural Modulus and Bending Strength of Fiber Reinforced Polymer Crossarms Assembled with Center Mount Brackets[1]

This standard is issued under the fixed designation D8019; 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.

1. Scope

1.1 These test methods cover the determination of the flexural modulus and bending strength of both tangent and deadend arms bent about their minor and major axes. One method covers testing of assembled tangent crossarms including the tangent bracket and relative hardware. The other method covers testing of assembled deadend crossarms with a deadend bracket and relative phase loading hardware. The failure modes and associated stresses can be used for predicting the phase load capacities of pultruded crossarms specific to certain conductor loading scenarios.

1.2 The test methods described in this standard can be used for predicting the vertical and horizontal component loads of deadend and tangent arms. Both deadend and tangent crossarms shall be tested in the two configurations described in Figures 1 and 2. This will permit the manufactures to publish both vertical and horizontal design capacities for deadend crossarm configurations so that two way bending stresses, caused by catenary effects, can be considered when developing the capacity of the deadend crossarms by utility design engineers and manufacturers.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. 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 nonconformance with the standard.

1.4 This standard will not address all factors that affect the phase loading capacity.

1.5 This standard does not address the use of core materials that are added to increase the structural capacity of the crossarms. Core material shall not be considered in the calculations provided in this standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D4968 Practice for Annual Review of Test Methods and Specifications for Plastics

E4 Practices for Force Verification of Testing Machines

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 Definitions of variables used in the calculations as shown in Section 11 are as follows:

a = distance from phase hardware to the center mount bolt through the crossarm, in. (m),
A_w = area of the webs in shear in.^{2} [m^2],
E = flexural modulus, psi (Pa),
I = moment of inertia about the neutral axis of the crossarm, in.^{4} [m^4],
L = support span, in. [m],
M = moment at failure, lbf-in [N•m],
P = ultimate or failure load acting through a single center mount bolt, lbf [N],
S_x = section modulus about the neutral axis of the crossarm, in.^{3} [m^3],
V = in-plane shear force, lbf [N],
σ = bending stress at failure, psi [Pa],
δ = deflection relative to the applied load, in. [m],
τ_{max} = maximum transverse shear stress, psi [Pa],

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.18 on Reinforced Thermosetting Plastics.

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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.

Q = static moment of area in.^{3} [m^3],
t = thickness of region or regions under consideration in. [m].

4. Summary of Test Methods Including Deadend and Tangent Crossarm Configurations with Commercial Hardware Attached

4.1 *Deadend Crossarms:*

4.1.1 The assembled deadend crossarm, including two phase single sided position hardware and a center mount bracket fabricated to the specifications as detailed by the manufacturer, is positioned in a three point bend apparatus and loaded until failure occurs.

4.1.2 A center mount bracket or a fabricated test bracket, matching the bolt size and dimensional specifications of the manufacturers commercial bracket, is attached to the arm as detailed by the manufacturer.

4.1.3 A three point bend load is then induced into the cross arm assembly until a structural failure of the hardware or crossarm occurs.

4.1.4 The bracket is to be loaded or constrained, depending on the load apparatus, such that no eccentric loading occurs.

4.1.5 Load and deflection data are to be recorded at set intervals or continuously until failure occurs.

4.2 *Tangent Crossarms:*

4.2.1 The assembled tangent crossarm, including two phase single sided deadend position hardware and a center mount tangent bracket fabricated to the specifications as detailed by the manufacturer, is positioned in a three point bend apparatus and loaded until failure occurs.

4.2.2 A tangent bracket, matching the specifications, of the manufacturers commercial bracket, is attached to the arm as detailed by the manufacturer.

4.2.3 A three point bend load is then induced into the crossarm assembly such that the bracket and phase hardware is loaded until failure.

4.2.4 The bracket is to be loaded or constrained, depending on the load apparatus, such that the load produces eccentric loading into the bracket and arm mimicking the tangent connection to a wood, fiberglass, steel or concrete pole.

4.2.5 Load and deflection data are to be recorded at set intervals or continuously until failure occurs.

5. Significance and Use

5.1 Determination of the flexural modulus, beam bending strength and full assembly strength, by this test method is especially useful for product validation, design and specification purposes.

5.2 Calculated values for flexural modulus, bending strength and full assembly strength will vary with specimen depth, span length, hole configurations, loading rate, and ambient test temperature. A minimum span to depth ratio of 16:1 is required for establishing the flexural modulus.

5.3 *Validity*—Stress at failure, σ, is only valid for crossarm failures due to local compression buckling. Other controlling modes of failure will dictate the ultimate phase loading capacities. For example, in-plane shear, fastener pin bearing, position hardware, center mount failures and fastener pull out will dictate the failure mode and ultimately the crossarm capacity.

6. Apparatus

6.1 *Testing Machine*—A properly installed and operated load actuator, ideally one which can be operated at constant rates of load or deflection, used in combination with a properly calibrated load cell. Error in the load measuring system shall not exceed ±1 % of the maximum load expected to be measured. The test setup shall also be equipped with deflection measuring devices. The stiffness of the testing apparatus shall be such that the total elastic deformation of the load frame does not exceed 1 % of the total deflection of the test specimen during testing, or appropriate corrections shall be made. The accuracy of the testing machine shall be calibrated and verified in accordance with Practices E4.

6.2 *Loading Noses and Supports:*

6.2.1 The manufacturer's deadend crossarm shall be either loaded through the center mount, or through the phase hardware. In the event of loading through the center mount, the manufacturer's deadend crossarm shall be assembled with a production mount or fabricated replica. Load shall be applied through the back of the center mount bracket. The deadend crossarm shall be fully fabricated, representing the finished product, with the phase position deadend hardware attached. The crossarm test fixture supports shall connect directly to the phase position hardware.

6.2.2 For deadend crossarm testing loaded through the phase hardware, and for tangent crossarm testing, the manufacturer's center mount shall be mounted to a rigid structure that represents a pole structure in the proper orientation. The crossarm shall be loaded by pulling on the phase hardware in an appropriate direction for the test method. For tangent crossarm testing, this would be in an apparent vertical direction. For deadend crossarm testing, this would be in an apparent horizontal direction.

6.3 *Deadend Crossarm Test Set Up*—The test fixture shall allow for various lengths of crossarms to be tested. The crossarm length range shall be dictated by typical industry offerings. The fixture shall permit the loading of the arm in one of two ways: such that the load is applied through the center mount bracket, into the arm and resisted by the phase loading eyenut hardware representing a two phase single sided deadend crossarm fabrication, or such that the load is applied through the phase loading eye nut hardware representing two phase single sided deadend crossarm fabrication, into the arm, and resisted by the secured center mount bracket. The loading configuration described is shown in Fig. 1.

6.4 *Tangent Crossarm Test Set Up*—The test fixture shall allow for various lengths of tangent crossarms to be tested. The crossarm length range shall be dictated by typical industry requirements. The fixture shall permit the tangent bracket to be solidly mounted to a structural member that represents a pole.

6.5 In absence of specific insulator hardware requirements for application, the tangent crossarm shall be loaded by applying an apparent vertical force through two eyenuts, hoist

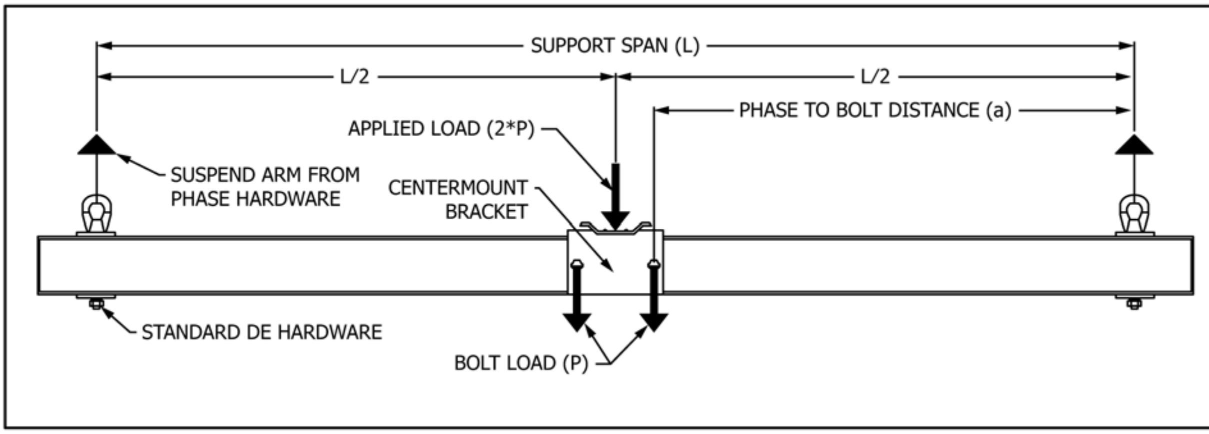

FIG. 1 Three-Point Bend Dead End Crossarm Test Set Up

rings, or other securing hardware connected to the load apparatus using a threaded rod or bolt at the appropriate conductor location, in a configuration which represents typical tangent arm usage. The load path shall propagate from the eyenut or other securing hardware, through the threaded rod or bolt, to washers which span the entire width of the crossarm. The load shall then be distributed from the washer, through the crossarm, where it is then distributed to the tangent bracket and into the mount. It is critical that the mount used in the commercial sale of the tangent arm be used in the test, as the arm strength will be influenced by the hardware or center mount. The loading configuration described is shown in Fig. 2.

6.6 *Deflection Measuring Device*—A properly calibrated device to measure the deflection of the crossarms shall be used. The device shall automatically and continuously record the deflection during the test. In the absence of an automated data acquisition system, a properly calibrated deflection dial gauge shall be used. A minimum of ten manual recordings shall be taken at approximately the same load increments throughout the duration of the test. The deflection dial gauge shall be accurate to ±0.001 in. [±0.0254 mm].

7. Sampling and Test Specimens

7.1 *Sampling*—A minimum of five specimens, per each test method described in 4.1 and 4.2, shall be tested for each arm length that displays a different failure mode. Alternatively, the minimum quantity as required by the agency or the appropriate codes and standards.

7.2 *Specimens*—Specimens shall be full-scale samples, fabricated in accordance with the manufacturer's specifications and outfitted with standard deadend or tangent crossarm hardware and tested at the desired span length.

7.3 *Specimen Preparation*—Specimens shall be of the same material composition, geometric characteristics, and manufactured by the same process as those described in the manufacturer's specifications and as available commercially.

7.4 *Labeling*—Label the test specimens (date, batch number, line number) so that they will be distinct from each other and traceable back to the specimen of origin, and will neither influence the test nor be affected by it.

NOTE 2—Non-load bearing accessories such as identification (I.D.) tags, end caps and commercial markings are not required for test specimens.

8. Calibration and Standardization

8.1 The accuracy of all testing and measuring equipment shall have certified calibrations that are current at the time of use of the equipment.

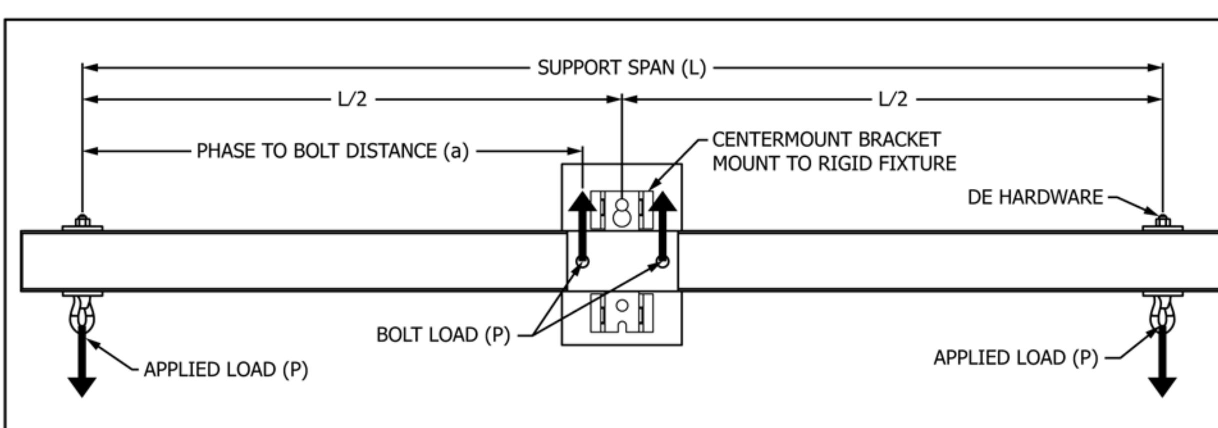

FIG. 2 Three-Point Bend Tangent Crossarm Test

9. Conditioning

9.1 If the test requestor does not explicitly specify a pre-test conditioning environment, conditioning is not required and the test specimens shall be tested at normal room temperature (20-25°C or 68-77°F).

9.2 If no explicit conditioning process is performed the specimen conditioning process shall be reported as "unconditioned."

10. Procedure and Test Setup

10.1 If needed, condition test specimens as required. Store the test specimens in the conditioned environment until test time if the test environment is different than the conditioning environment.

10.2 Before testing, measure and record the cross-sectional shape and dimensions as necessary. Record the dimensions to three significant figures.

10.3 Measure and record the length of the unsupported span.

10.4 *Rate of Testing*—The load rate shall be between 1,500 lbf [6,672 N] and 2,500 lbf [11,120 N] per minute.

10.5 *Fixture Installation*—Arrange the loading fixture as shown in Fig. 1 for a deadend crossarm test or as shown in Fig. 2 for a tangent crossarm test.

10.6 *Specimen Insertion and Alignment*—Place the specimen into the test fixture. Align the fixture and specimen so that the initial starting longitudinal axis of the specimen is perpendicular (within 1°) to the longitudinal axis of the loading nose, and that the resultant load carried by the phase supports is perpendicular (within 1°) of the initial starting longitudinal axis of the specimen.

10.7 *Loading*—Apply a force while continuously recording data. Load the specimen until failure occurs. Load shall be applied so that the loading axis and phase support loading axes remains perpendicular within 3.5° to the initial starting longitudinal axis of the specimen through the entirety of the test.

10.8 *Data Recording*—Record load and vertical displacement until failure occurs.

11. Calculation of the Determination of Mechanical Properties

11.1 The full section flexural modulus shall be calculated by rearranging Eq 1 and solving for E.

$$\delta = \frac{Pa(3L^2 - 4a^2)}{24EI} \quad (1)$$

where:

a = distance from phase hardware to the center mount bolt through the crossarm. in. [m],
E = flexural modulus, psi [Pa],
I = moment of inertia about the neutral axis of the crossarm, in.^{4} [m^4],
L = support span, in. [m],
P = load acting through a single center mount bolt, lbf [N], and
δ = deflection relative to the applied load. in. [m].

11.2 *Calculation of the Moment at Failure*—The failure moment shall be calculated by solving Eq 2.

$$M = Pa \quad (2)$$

where:

a = distance from phase hardware to the center mount bolt through the crossarm, in. (m),
M = moment at failure, lbf-in. [N·m], and
P = load acting through a single center mount bolt, lbf [N].

11.3 The bending stress at failure shall be calculated by solving Eq 3 for σ.

$$\sigma = \frac{M}{S} \quad (3)$$

where:

σ = bending stress at failure, psi [Pa],
M = moment at failure, lbf-in. [N·m],
S = section modulus about the neutral axis, in.^{3} [m^3].

11.4 The in-plane shear stress at failure, for a thin walled tube, shall be calculated by solving Eq 4 for τ_{max}.

$$\tau_{max} = \frac{VQ}{It} \quad (4)$$

where:

τ_{max} = maximum transverse shear stress, psi [Pa],
I = moment of inertia, in.^{4},
Q = static moment of area, in.^{3} [m^3],
t = thickness of region or regions under consideration, in. [m],
V = in-plane shear force, lbf [N].

12. Report

12.1 Parameters to be specified before test:

12.1.1 The specimen cross-sectional geometry.

12.1.2 Testing span length.

12.1.3 Conditioning process (if required).

12.1.4 The section properties and data reporting format desired.

12.2 Report the following information:

12.2.1 Identification of product being tested.

12.2.2 Conditioning procedure (if required).

12.2.3 Cross-sectional dimensions.

12.2.4 Span length(s) tested.

12.2.5 Rate of loading.

12.2.6 Experimental values.

12.2.7 Calculated values for the flexural modulus shall be taken as the average of at least five data points in the range between 30 % and 70 % of the ultimate crossarm capacity.

12.2.8 Calculated moment at failure.

12.2.9 Calculated stress at failure.

12.2.10 Any deviations from this test method, whether intentional or inadvertent.

12.2.11 All failure modes.

13. Precision and Bias[3]

13.1 The precision of this test method is based on an intralaboratory study of ASTM Work Item WK49793, Standard Test Method For Determining the Full Section Flexural Modulus, Bending Strength and the Ultimate Phase Load Capacity of Fiber Reinforced Polymer Crossarms Assembled with Center Mount Brackets, conducted in 2015. A single laboratory participated in this study, testing four crossarm lengths for several properties. Every "test result" represents an individual determination. The laboratory was instructed to report as many as 20 replicate test results for each testing combination. Except for the use of only one laboratory, Practice E691 was followed for the design and analysis of the data.

13.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

13.1.1.1 Repeatability can be interpreted as maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

13.1.1.2 Repeatability limits are listed in Tables 1-5.

13.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

13.1.2.1 Reproducibility can be interpreted as maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

13.1.2.2 Reproducibility limits cannot be calculated from a single laboratory's results.

13.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

[3] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1264. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Deadend—Flexural Stress at Failure (psi)

Crossarm in.	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
60	47132	2509	7026
96	83650	1761	4929
120	88277	2944	8242
144	87661	2577	7216

[A] The average of the laboratories' calculated averages.

TABLE 2 Deadend—Average E-modulus (Msi)

Crossarm in.	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
60	3.72	0.28	0.77
96	5.34	0.16	0.44
120	5.91	0.05	0.14
144	6.03	0.10	0.28

[A] The average of the laboratories' calculated averages.

TABLE 3 Deadend—Bearing Stress at Failure (psi)

Crossarm in.	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
60	27799	1480	4144
96	28193	593	1662
120	23141	772	2160
144	18801	553	1548

[A] The average of the laboratories' calculated averages.

TABLE 4 Deadend—Failure Load (lb)

Crossarm in.	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
60	20849	1110	3108
96	21145	445	1246
120	17355	579	1620
144	14101	415	1161

[A] The average of the laboratories' calculated averages.

TABLE 5 Tangent—Flexural Stress at Failure (psi)

Crossarm in.	Average[A] $\bar{x}$	Repeatability Standard Deviation S_r	Repeatability Limit r
60	29790	1772	4961
96	49903	4699	13157
120	61717	3251	9103
144	67524	1184	3315

[A] The average of the laboratories' calculated averages.

13.1.4 Any judgment in accordance with statement 7.1 would normally have an approximate 95 % probability of being correct, however the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of laboratories reporting replicate results essentially guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with considerably greater or smaller frequency than the 95 % probability limit would imply. Consider the repeatability limit as a general guide, and the associated probability of 95 % as only a rough indicator of what can be expected.

14. Keywords

14.1 deflection; flexural modulus