Test Report

Bearing-Hole Tests for 20" Pole Sections of Fiberglass-Reinforced Composite Poles: Effect of Torque

Submitted to:

POWERTRUSION INTERNATIONAL, Inc.

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Introduction

Hardware is attached to composite utility poles through single or double bolted combinations. It is necessary to determine the maximum load that can be attached to the pole, based on conventional utility industry installation practices. This study will assess the effect of torque on the bearing-hole performance of composite utility poles. The installation standard calls for a not to exceed value of 50 ft-lb of torque, which is more than the three times the maximum torque in the bearing hole tests performed so far (See bearing hole reports). To address the effect of torque levels, an additional set of tests were performed.

This study is being performed by the University of Delaware Center for Composite Materials (UD-CCM) at the request of Powertrusion International, Inc. Founded in 1974, UD-CCM is an internationally recognized, interdisciplinary center of excellence for composites research and education. UD-CCM has been an Army Center of Excellence since 1986 and currently hosts 3 Centers of Excellence in composites: Composite Materials Research (CMR) and Composite Materials Technology (CMT) funded by the Army and the Advanced Materials Intelligent Processing Center (AMIPC) funded by the Navy. UD-CCM currently provides technology transfer, analysis and testing services, processing techniques and educational services to over 30 companies, who are members of the Industrial Consortium. The companies range from large established firms (Boeing, Lockheed etc.), diverse firms (Greene Tweed, Advanced Ceramics etc.) to technical specialty firms (Powertrusion, VersaCore etc.).

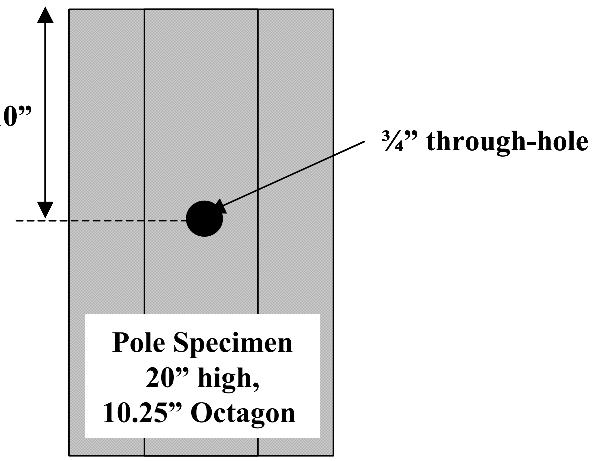
Proposed Approach

The test procedure is identical to the test procedure for bearing strength of pole sections, with different level of torque. The through hole for the bolt is located at the center of the pole section to remove any end effects associated with high torque loading. All tests were performed at 0.625" diameter hole (5/8") with a tolerance of 0.125" (1/8"). It is expected that results for other hole diameters and tolerances will follow similar trends as the selected hole geometry.

Two series of experiments were conducted. The first was to observe and evaluate what happened during the application of torque. The not to exceed requirement was based on current industry practice and there is the question of whether it is necessary to apply that level of torque (50 ft-lb) and what happens to the composite pole when that level of torque is applied. In the second series of tests, bearing hole strengths were measured on both seam and non-seam faces, with the maximum torque levels (50 ft-lb).

Specimen Dimensions

For the bearing hole torque tests, specimen dimensions are shown in the figure below. Each specimen is a 20" section from an octagonal composite pole, with the hole locations as shown below.



Specimen Geometry for Torque Tests

The location of the hole was set at the middle of the pole, for the following reasons:

- Tests with the hole at 6” from the top (configuration for bearing hole) showed significant damage to the pole when the torque was increased to 50 ft-lb. This was due to the hole being close to the edge (top end) of the pole.
- In actual pole installations, there is an end cap provided to prevent damage if holes are drilled close to the top of the pole. Tests showed that the presence of the end cap prevents damage when torqued to 50 ft-lb.

Test Matrix

The proposed test matrix is shown in the Table below. Several trials were performed prior to evaluating the test matrix to ensure that the specimen and hole geometry selected, results in the correct failure mode (local crushing at the hole).

Test Matrix for Torque Tests

Test	Torque (ft-lb)	Hole Dimensions	Number of Tests*
Single hole (Seam)	50	0.625 + 0.125	2
Single hole (Non-Seam)	50	0.625 + 0.125	2

Test Procedure

The test method is identical to ASTM D 953 and is summarized here. A calibrated Instron test frame is used with a displacement rate of 0.05 in/min. A loading fixture of hardened steel is used and is shown in the Figure below. Each specimen is mounted in the loading fixture taking care to align the loading face of the specimen with the centerline of the test fixture. The specimen is then through bolted using the bolt hardware provided and lightly torqued (maximum of 10 ft-lbs). The specimen was loaded at 0.05 in/min of crosshead travel and load and displacement documented till specimen failure.

Test Setup for Bearing Hole Tests

Test Results

In the coupon configuration, torque is not a factor and the measured load represents the crushing strength of the composite. During the non-seam pole test, minimal torque (up to 10 ft-lb compared to the not to exceed 50 ft-lb) was applied to enable a one-to-one comparison between tension and compression configurations. In the test set with seams, a 15 ft-lb torque was applied using load washers (full compression at 15 ft-lb) to assess the effect of torque. Results from these tests show that the torque does not seem to play a significant role in the bearing strength.

Two series of experiments were conducted. The first was to observe and evaluate what happened during the application of torque. The not to exceed requirement was based on current industry practice and there is the question of whether it is necessary to apply that level of torque and what happens to the composite pole when that level of torque is applied. Results from the first experiment are documented in the table below. The presence of the end cap prevented any damage at the maximum torque of 50 ft-lb. When torqued with the end cap removed, there is damage initiation and visible damage at the same torque level. In addition, the damage initiation is usually audible in the form of “pops”, which may not be desirable from the customer point of view.

Observation Summary During Application of 50 ft-lb Torque

Location	End Cap	Inside Diameter at Bolt Location Before (in)	Inside Diameter at Bolt Location After (in)	Observation During/After Torque
Seam	With Cap	9.63	9.3	9.125 diameter of opposite side of cap, no cracks
No Seam	Without Cap	9.686	9.235	started cracking @ 20 lb/ft ; large crack @ nut face
Seam	Without Cap	9.632	9.316	slight pop @ 30 lb/ft ; small crack beginning at seam on inside
No Seam	Without Cap	9.678	9.14	popped @ 20 lb/ft ; large crack at nut and on undrilled side

The same four faces were then tested under bearing hole compression with the results documented in the table below. It is interesting to note that despite the damage sustained during application of torque, the failure loads are statistically the same as in the lower torque cases. As a comparison,

Failure load, Non-Seam, <10 ft-lb torque: 4860 ± 487 lbs (4 tests)

Failure load, Seam, 15 ft-lb torque: 3781 ± 518 lbs (4 tests)

Failure load, Non-Seam, 50 ft-lb torque: 4584 ± 571 lbs (2 tests, Table below)

Failure load, Seam, 50 ft-lb torque: 4290 ± 4 lbs (2 tests, Table below)

Location	End Cap	Torque (ft-lb)	Test Condition	Failure Load (lbs)	Observation During Testing
Seam	No	50	Single Hole 0.625 + 0.125	4180	Severe cracking and splintering along the inside @ connection of drilled hole and test fixture
No Seam	No	50	Single Hole 0.625 + 0.125	4287	Same
Seam	No	50	Single Hole 0.625 + 0.125	4988	Same
No Seam	No	50	Single Hole 0.625 + 0.125	4293	Same

Conclusions for Torque Tests

Based on the tests to assess the affect of torque, the following conclusions are drawn:

- Torque does not appear to significantly affect the bearing hole strength (within statistical bounds).
- Applied torque of up to 15 ft-lb is sufficient. The current practice of 50 ft-lb torque is too high as it leads to visible and audible damage. Damage initiation appears to start at approximately 20 ft-lb, though this can vary significantly from pole to pole.
- It is interesting that the damage sustained during application of 50 ft-lb torque does not seem to affect the bearing hole strength. Usually one expects that any damage initiated should weaken the pole resulting in a lower strength. It may be that increasing torque may actually increase the bearing strength somewhat due to the compression load, which counteracts the damage sustained in the composite, resulting in no change in the bearing strength. Additional tests are recommended if one needs to understand this effect.