Test Report

Bearing-Hole Tests for 20” Pole Sections of Fiberglass-Reinforced Composite Poles

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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. Standard installation practices involve single or double through bolts with diameters of 5/8" or ¾". Previously, strengths of one- and two-hole bearing joints were measured for coupon specimens in accordance with ASTM D 953 test procedure.

This study will perform one- and two-hole bearing tests on 20" sections of the composite pole, to verify and supplement test data from the coupon tests. In addition, tests will be performed on pole faces with and without seams, in compression as compared to tension mode in the coupons.

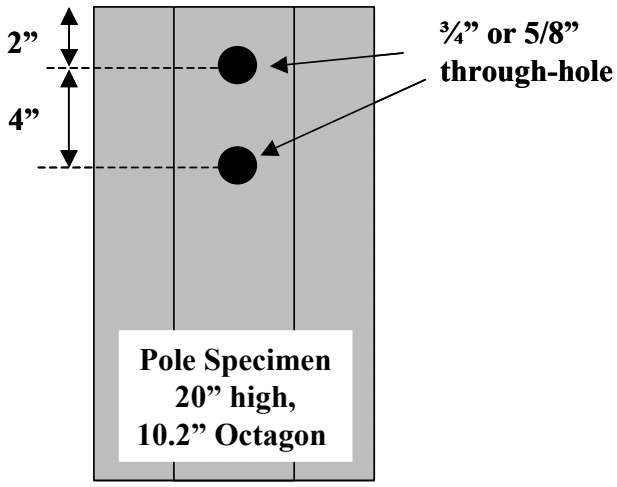
This study is being performed by the University of Delaware Center for Composite Materials (UD-CCM) at the request of Powertrusion International, Inc. Founded in 1974, UD-CCM is an internationally recognized, interdisciplinary center of excellence for composites research and education. UD-CCM has been 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 similar to the test procedure for bearing strength of coupons, with a different test setup to hold the pole section in place. There are two major issues to consider – maximum strength of bearing hole with one and two bolts and effect of dimensional tolerance on the performance of the joint. The tests will determine the maximum strengths of the bearing holes for one and two-hole designs. Two different hole tolerances will be evaluated representing the low (0.064") and high ends (0.125") for strengths and failure behavior. This test procedure will involve compressive loading to failure.

Specimen Dimensions

For the bearing hole pole tests, specimen dimensions are shown in the figure below. Each specimen is a 20" section from an octagonal composite pole, with the hole locations similar to those in the coupon tests documented previously.



Final Specimen Geometry for One and Two-Hole Bearing Tests

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 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 size selected results in the correct failure mode (local crushing at the hole).

Test Matrix for Bearing Hole Tests of Seam and Non-Seam Faces

Test	Hole Dimensions	Number of Tests*
Single hole	0.625 + 0.0625	4
Single hole	0.625 + 0.125	4
Single hole	0.75 + 0.0625	4
Single hole	0.75 + 0.125	4
Double hole	0.625 + 0.0625	4
Double hole	0.625 + 0.125	4
Double hole	0.75 + 0.0625	4
Double hole	0.75 + 0.125	4

* Each pole specimen provided 2 non-seam tests and 2 seam tests

Test Results

Test results are summarized in the Tables below.

Bearing Hole Test Summary

Test	Hole Dimensions (in.)	Coupon Test Failure Load* (lbs)	Non-Seamed – Failure Load** (lbs)	Seams - Failure Load*** (lbs)
Single hole	0.625 + 0.0625	3753 ± 365	4538 ± 312	3883 ± 516
Single hole	0.625 + 0.125	4235 ± 130	4860 ± 487	3781 ± 518
Single hole	0.75 + 0.0625	5506 ± 472	4687 ± 453	4694 ± 546
Single hole	0.75 + 0.125	5113 ± 504	4303 ± 589	4678 ± 1018
Double hole	0.625 + 0.0625	9919 ± 1108	7883 ± 632	8557 ± 656
Double hole	0.625 + 0.125	8890 ± 1314	8495 ± 312	8523 ± 372
Double hole	0.75 + 0.0625	10365 ± 1671	8933 ± 1018	9191 ± 847
Double hole	0.75 + 0.125	8931 ± 828	8708 ± 1050	8305 ± 1169

* Bearing hole tension test on coupon
** Compression test on 20” pole section, < 10 ft-lb torque
*** Compression test on 20” pole section, 15 ft-lb torque

Comments

In all cases, failure occurred due to local crushing at the holes. Typical length of shear ranged between 1/8" to ¼"at the hole and there is generally no damage at the opposing holes.

There are two comparisons that need to be evaluated:

- Tension vs. Compression bearing hole data: A comparison of the failure loads shows somewhat higher loads for the coupon tests, especially in the double hole tests. The average compression-based failure loads are up to 10% smaller in some cases, however given the variability of the failure loads, the loads fall within statistical bounds in all cases.
- Seam vs. Non-Seam data: Prior to testing seamed faces, it was expected that the seamed faces would show lower failure loads. However, the test data does not show significant variation. In fact, in most cases, the average failure load is the same (within statistical bounds) or higher for the seamed faces. Note that the seamed faced had a slightly higher torque compared to the non-seam set.

An important test parameter is the torque applied to the bolts during the test. The current recommendation to utilities is a not to exceed 50-lb torque during installation. The question then arises: does the applied torque affect the bearing strength? Torque tests are documented in a separate report.

Appendix A: Detailed Results for Bearing Hole Coupon Tests

Single 5/8 Bearing Hole with 1/16 Tolerance

Specimen	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.686	0.25	4963	28938.78	4455	25976.68
2	0.686	0.25	4758	27743.44	3120	18192.42
3	0.689	0.25	4236	24592.16	3839	22287.37
4	0.686	0.25	4198	24478.13	4121	24029.15
Average			4538.75	26438.13	3883.75	22621.41
Std. Dev			312.92	1853.18	516.15	2996.38
COV			6.89	7.0	13.29	13.25

* Torqued to 15 ft-lb using load washer

Single 5/8 Bearing Hole with 1/8 Tolerance

Specimen	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.748	0.25	4078	21807.49	3357	17951.87
2	0.748	0.25	5680	30374.33	3631	19417.11
3	0.748	0.25	4901	26208.56	4521	24176.47
4	0.748	0.25	4783	25577.54	3617	19342.25
Average			4860.5	25991.98	3781.5	20221.93
Std. Dev			487.40	2606.43	517.93	2769.68
COV			10.03	10.03	13.7	13.7

* Torqued to 15 ft-lb using load washer

Single 3/4 Bearing Hole with 1/16 Tolerance

Specimen	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.81	0.25	4650	22962.96	4618	22918.11
2	0.81	0.25	4428	21866.67	4958	24185.37
3	0.812	0.25	5224	25733.99	4095	20222.22
4	0.81	0.25	4449	21970.37	5105	24993.88
Average			4687.75	23133.5	4694	23079.9
Std. Dev			453.63	2203.47	545.66	2553.72
COV			9.67	9.52	11.62	11.06

* Torqued to 15 ft-lb using load washer

Single 3/4 Bearing Hole with 1/8 Tolerance*

Specimen	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.875	0.25	3296	14780.27	4409	20132.42
2	0.877	0.25	3979	17963.88	4878	22350.52
3	0.877	0.25	4831	21518.93	5727	26483.24
4	0.875	0.25	5109	22936.03	3699	16718.64
Average			4303.75	19299.78	4678.25	21421.2
Std. Dev			588.79	2561.53	1018.46	4901.43
COV			13.68	13.27	21.77	22.88

* Torqued to 15 ft-lb using load washer

Double 5/8 Bearing Hole with 1/16 Tolerance

Specimen	Hole Dia. (in)	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.686	0.69	0.25	7814	45298.55	8059	46991.25
2	0.686	0.692	0.25	8386	48473.99	8490	49504.37
3	0.689	0.688	0.25	7189	41796.51	8217	47703.92
4	0.686	0.691	0.25	8143	47137.48	9465	55189.5
Average				7883	45676.63	8557.75	49847.26
Std. Dev				632.71	3533.2	656.08	3907.18
COV				8.02	7.73	7.67	7.84

* Torqued to 15 ft-lb using load washer

Double 5/8 Bearing Hole with 1/8 Tolerance

Specimen	Hole Dia. (in)	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.748	0.747	0.25	8363	44781.79	8702	46534.76
2	0.748	0.748	0.25	7527	40251.34	8125	43449.2
3	0.748	0.748	0.25	9438	50470.59	8863	47395.72
4	0.748	0.748	0.25	8655	46283.42	8403	44935.83
Average				8495.75	45446.79	8523.25	45578.88
Std. Dev				960.67	5137.30	372.72	1993.16
COV				11.30	11.30	4.37	4.37

* Torqued to 15 ft-lb using load washer

Double 3/4 Bearing Hole with 1/16 Tolerance

Specimen	Hole Dia. (in)	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.81	0.81	0.25	7606	37560.49	9232	45816.38
2	0.81	0.81	0.25	10320	50962.96	9756	47590.24
3	0.812	0.81	0.25	9511	46967.9	9572	47269.14
4	0.81	0.81	0.25	8296	40967.9	8205	40171.36
Average				8933.25	44114.81	9191.25	45211.78
Std. Dev				1018.76	5030.93	847.36	4193.67
COV				11.40	11.40	9.2	9.27

* Torqued to 15 ft-lb using load washer

Double 3/4 Bearing Hole with 1/8 Tolerance

Specimen	Hole Dia. (in)	Hole Dia. (in)	Thickness (in)	Non-Seam Failure Load (lbs)	Non-Seam Failure Strength (psi)	Seam Failure Load* (lbs)	Seam Failure Strength* (psi)
1	0.876	0.874	0.25	8187	36713	8397	38342.47
2	0.873	0.846	0.25	9332	42178.53	9483	43450.17
3	0.865	0.884	0.25	9633	43197.31	8192	37882.08
4	0.885	0.876	0.25	7682	34487.09	7149	32311.86
Average				8708.5	39143.98	8305.25	37996.65
Std. Dev				1050.35	4762.07	1169.19	5569.15
COV				12.06	12.16	14.07	14.66

* Torqued to 15 ft-lb using load washer