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TS BEND TEST REPORT

EPRI Test Results

1. INTRODUCTION

Introduction

Composite-core conductors are increasingly used in applications where higher operating temperatures, increased power-transfer capability, and reduced sag are required within existing transmission rights-of-way. In these conductors, the composite core provides much of the mechanical strength, while the surrounding aluminum strands provide the primary current-carrying path. Because the composite core is a critical structural component, installation and handling practices must avoid conditions that could introduce hidden or localized core damage.

During construction, conductor cores can be exposed to bending as the conductor is moved, handled, placed in equipment, routed around hardware, or tensioned during installation activities. In most cases, these bending events are controlled through equipment selection, minimum sheave and bullwheel diameters, and manufacturer installation guidance. However, field handling can sometimes expose materials to bend radii that approach or exceed recommended limits. Understanding how bend radius affects visible damage and residual tensile strength is therefore important for assessing installation margin and for identifying bend conditions that may increase the risk of strength loss.

This test program evaluates the mechanical response of TS composite conductor core samples after bend-under-tension exposure at progressively smaller bend radii. The evaluation focuses on two related outcomes: the type and extent of visible damage produced during bending, and the residual tensile capacity of the core after the bend exposure. The results provide a basis for comparing the behavior of bent samples with unbent control samples and for identifying whether reduced bend radii produced measurable changes in tensile performance.

The test approach is based on the bend test described in ASTM B987, which includes bending the core around a mandrel with a diameter equal to 50 times the core diameter while the core is held under tension. The standard condition is intended to confirm that the core can withstand a defined bend-under-tension exposure without a measurable reduction in tensile strength. In this report, the 50x bend condition serves as the baseline reference condition.

To provide additional insight beyond the baseline requirement, the test matrix also included bend radii of 40 times and 30 times the core diameter. These reduced-radius conditions were selected to increase bend severity and to evaluate whether the TS composite core exhibited progressive changes in damage appearance, failure location, or residual tensile strength as the bend radius decreased. Two samples were tested at each bend condition, and two unbent samples were tested as controls.

The report documents the test setup, bend-test observations, tensile-test results, and post-test failure observations for each sample. The discussion and conclusions interpret the results in relation to the conductor rated breaking strength, the ASTM B987 baseline condition, and the practical implications for installation and handling practices.

2. TEST SETUP

Test Assembly

The test assembly was configured to evaluate the response of the TS composite core during bend-under-tension loading and to support subsequent tensile testing of the same samples. The assembly was intended to reproduce the general loading condition described in ASTM B987 while also allowing the bend severity to be varied by changing the mandrel diameter.

1. Document the type and extent of visible damage produced in the core during bend-under-tension exposure at three bend radii.
2. Determine the residual tensile strength of the core after exposure to each bend condition and compare the results with unbent control samples.

New conductor core samples were used for all tests. For each bend test, the core was wrapped 180 degrees around a mandrel with the specified diameter, and both ends of the sample were secured to a yoke-plate assembly. The assembly was then loaded to 15% of the core rated breaking strength and held at that tension for one minute. After the hold period, the load was released, and the sample was removed from the yoke plate and mandrel for visual inspection and later tensile testing.

Test Apparatus

The bend-under-tension apparatus consisted of a horizontal tensile test frame, conductor grips, yoke plates, and interchangeable mandrels. The mandrels were sized relative to the TS composite core diameter so that the bend severity could be controlled for each sample group. Three bend radii were evaluated:

1. 50 times the core diameter
2. 40 times the core diameter
3. 30 times the core diameter

Two samples were assigned to each mandrel size: 50x, 40x, and 30x the core diameter. Two additional core samples were not subjected to bend testing and were retained as unbent control samples for the subsequent ultimate tensile-strength tests. This arrangement allowed the residual tensile strength of the bent samples to be compared with both the conductor rated breaking strength and the measured strength of the unbent controls.

Test Object

The test object was the TS (Jackson) M3 8.5 (28.727) Aluminum Encapsulated Carbon Core (AECC) conductor. This conductor uses a high-strength TS composite core as the primary tensile member and fully annealed trapezoidal aluminum strands as the current-carrying component. For this evaluation, the bend-under-tension and tensile tests focused on the response of the composite core after removal from the conductor assembly, while the conductor rating and geometry were used as the basis for test setup and performance comparison. A photograph of the conductor is shown in Figure 1, and the relevant conductor specifications are summarized in Table 1.



Figure 1. TS conductor tested

Table 1. TS conductor specification

Parameter	Value
Aluminum Material	Fully Annealed Aluminum
Number of Al Strands	32
Overall Conductor Diameter	1.131 in
Core Diameter	0.335 in
Rated Breaking Strength (entire conductor)	42,510 lb.
Weight	1095 lb. / 1000 ft

3. TESTS CONDUCTED

Bend Tests

Eight conductor samples were prepared for the test program. Each sample was cut to a length of 20 ft to fit within the bend-under-tension and tensile-test apparatus. Six samples were assigned to bend testing, with two samples tested at each mandrel ratio: 50x, 40x, and 30x the core diameter. The remaining two samples were retained as unbent controls for comparison during the ultimate tensile-strength testing. The sample assignments, mandrel ratios, mandrel sizes, and sample lengths are summarized in Table 2.

Table 2. Variations in bending stress of the carbon fiber core

Sample No.	Mandrel Ratio	Mandrel Size (in)	Sample Length (ft)
1 & 2	50 x Core Diameter	16.73	20
3 & 4	40 x Core Diameter	13.38	20
5 & 6	30 x Core Diameter	10.04	20
7 & 8	Control Samples	N/A	20

For each bend test, the selected sample was installed in the horizontal tensile tester and routed around the assigned mandrel. The sample ends were secured in the grips and connected to the yoke-plate assembly so that the core could be tensioned while maintaining a 180-degree wrap around the mandrel. The test configuration is shown in Figure 2.



Figure 2. Horizontal Tensile Tester

After installation, the sample was loaded to 15% of the core rated breaking strength and held at that load for one minute. The load was then released, and the sample was removed from the mandrel and yoke-plate assembly for visual inspection. The conductor grip and yoke-plate arrangement used during the bend tests is shown in Figure 3.



Figure 3. Conductor Grip and Yoke Plate

The mandrels were mounted on the fixed back plate of the test frame and were selected according to the assigned bend condition. Using interchangeable mandrels allowed the same sample support, gripping, and loading arrangement to be used for all bend tests while varying only the bend radius. The 50x, 40x, and 30x mandrels are shown in Figure 4.



Figure 4. 50x Mandrel; 40x Mandrel; 30x Mandrel

Following each bend exposure, the samples were visually examined for changes in surface condition, localized deformation, audible events noted during testing, and any evidence of permanent set after removal from the mandrel. These observations provided the basis for the bend-test results discussed in the following section.

4. BEND TEST RESULTS

Test Observations

Bend-under-tension testing was performed on the three sample groups in increasing order of bend severity. The 50x core-diameter mandrel was tested first, followed by the 40x and 30x mandrels. During each test, observations were recorded for audible events, visible surface damage, fiber disruption, localized deformation, and any permanent set remaining after the sample was removed from the mandrel. Representative images of the test configuration and post-bend sample condition are provided in Figures 5 through 8.

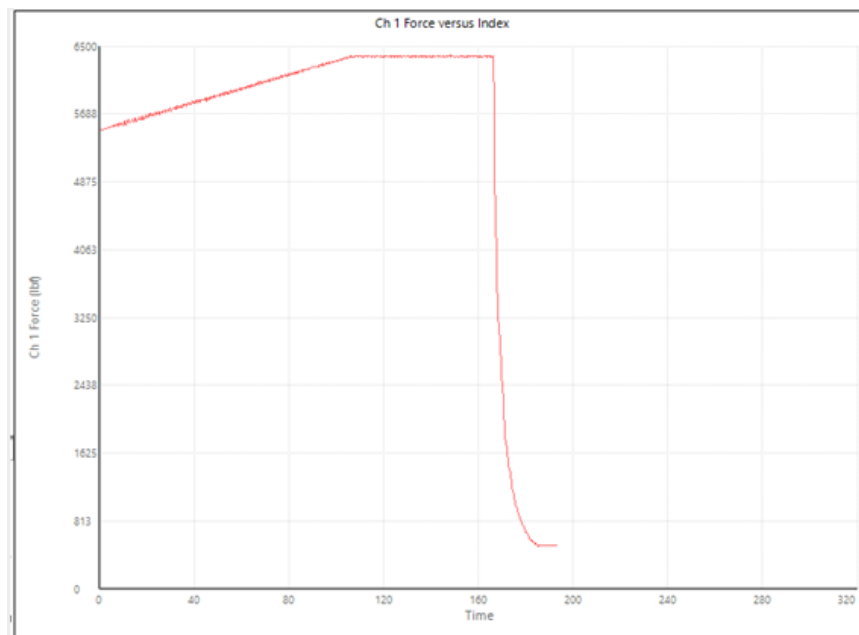


Figure 5. Example of Test Procedure

Figure 5 shows the general bend-under-tension configuration during loading. The image illustrates the use of the grips, yoke-plate assembly, and mandrel wrap used to maintain a repeatable sample position and loading path across the bend-test conditions.



Figure 6. 50x Sample after bend

Samples tested on the 50x mandrel exhibited minimal visible damage after the bend exposure. Minor scuffing and small surface imperfections were observed near the mandrel contact region, but no major visible cracking, fiber disruption, or permanent deformation was noted. The post-bend condition was consistent with expectations for the ASTM B987 baseline bend radius.



Figure 7. 40x Sample after bend

Samples tested on the 40x mandrel showed visual characteristics similar to the 50x samples. Minor surface marks and localized imperfections were observed, but no significant visible damage or permanent set was evident after removal from the mandrel. These observations indicate that reducing the bend radius from 50x to 40x did not produce a clear change in the visual condition of the tested samples.



Figure 8. 30x Sample after bend

Samples tested on the 30x mandrel showed the most visible response among the bend-test groups. Localized flexing was observed at the mandrel contact region during loading, and audible popping sounds were noted during the bend exposure. After unloading and removal from the mandrel, the samples remained intact but showed a visible permanent bend. The audible events could not be attributed to a specific mechanism based on visual inspection alone; however, the post-bend deformation indicates that the 30x condition imposed a more severe bend exposure than the 50x and 40x conditions.

Overall, the visual observations indicate that bend-test severity increased as bend radius decreased, with the most notable response occurring at the 30x condition.

5. TENSILE TEST RESULTS

Test Observations

The tensile portion of the test required preparation work on all eight samples. The conductor ends used during the bend test were removed, and the previously bent section was positioned near the center of each prepared tensile sample.

The aluminum strands were removed from each end of the TS conductor to expose the composite core. The exposed core surface was cleaned, and threaded steel tubes were crimped onto both ends. A dead-end eye was attached to each threaded tube. The prepared samples were installed in the same horizontal tensile test rig used for the bend test, with the dead-end eyes connected to the rig using shackles. Each sample was then loaded in tension at a crosshead rate of 19 mm/min until failure.



Figure 9. Prepared TS Composite Core with Steel Tube



Figure 10. Tensile sample installed in the horizontal tensile test rig

Test Results

The breaking load recorded for each sample is provided in Table 3. The TS AECC Jackson conductor has a rated breaking strength of 42,510 lbs.

Table 3. Tensile breaking load results

Sample Name and Bend Radius	Breaking Load (lbf)	% RBS
TS Sample 1 – 50x Bend Radius	43868.1	103
TS Sample 2 – 50x Bend Radius	44085.6	104
TS Sample 3 – 40x Bend Radius	44564.2	105
TS Sample 4 – 40x Bend Radius	43862.1	103
TS Sample 5 – 30x Bend Radius	38529.9	91
TS Sample 6 – 30x Bend Radius	7138.7	17
TS Sample 7 – Control Sample	43612.8	103
TS Sample 8 – Control Sample	42508.8	100

The 50x samples produced breaking loads of 43,868.1 and 44,085.6 lbf, with an average of 43,976.9 lbf. The 40x samples produced breaking loads of 44,564.2 and 43,862.1 lbf, with an average of 44,213.2 lbf. Both groups were comparable to the control average, indicating that the 50x and 40x bend conditions did not produce a measurable reduction in residual tensile strength within the limits of this test.

The 30x samples showed substantially greater variation. Sample 5 reached 38,529.9 lbf, which was approximately 89% of the control average and was higher than expected for the

most severe bend condition. Sample 6 failed at 7,138.7 lbf, approximately 17% of the control average. A visible defect was observed on Sample 6 before tensile loading, and an early failure was anticipated. The low result is consistent with the severe damage observed at the 30x bend radius; however, the location and characteristics of the pre-existing defect should be documented when the post-test inspection is completed.

During each tensile test, the sample response was similar. A small audible pop was generally heard immediately before the composite core separated, at which point the test concluded. The exact failure location and post-failure condition varied among samples and are documented below.

Overall, the tensile-test results show that the 50x and 40x bend conditions retained tensile capacity comparable to the unbent control samples and exceeded the conductor rated breaking strength. The 30x bend condition produced a more variable response, with one sample retaining most of the rated capacity and the second sample failing at a substantially lower load. This contrast indicates that the tighter 30x bend radius can introduce localized damage that may not affect each sample uniformly but can significantly reduce residual tensile strength when severe damage is present.

Sample Failure Observations

Sample 1, which was subjected to the 50x bend condition, reached a maximum tensile load of 43,868.1 lbf before failing near the center of the sample. The failure occurred within the previously bent region; however, the measured load exceeded the conductor rated breaking strength of 42,510 lbf by 1,358.1 lbf, or approximately 3.2%. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 11. Based on the retained tensile capacity, the failure location alone does not indicate a measurable strength reduction associated with the 50x bend condition.



Figure 11. Post-test condition of Sample 1

Sample 2, also tested at the 50x bend condition, reached a maximum tensile load of 44,085.6 lbf before failing between the sample centerline and the actuator. The fracture was located near, but not clearly within, the previously bent region. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 12. The sample exceeded the conductor rated breaking strength by 1,575.6 lbf, or approximately 3.7%, indicating that the 50x bend condition did not produce an observable reduction in residual tensile capacity for this sample.

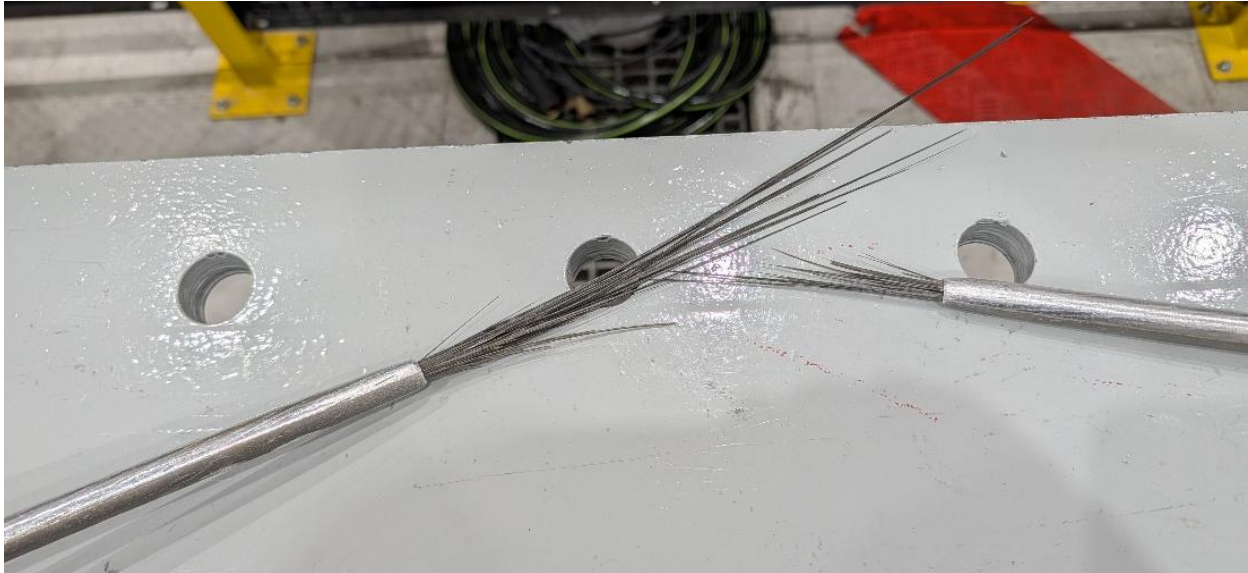


Figure 12. Post-test condition of Sample 2

Sample 3, tested at the 40x bend condition, reached the highest measured tensile load in the test set at 44,564.2 lbf. The sample failed between the center of the sample and the actuator, near the region subjected to the 40x bend radius. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 13. The measured load exceeded the conductor rated breaking strength by 2,054.2 lbf, or approximately 4.8%, indicating that this sample retained tensile capacity after the 40x bend-under-tension exposure.

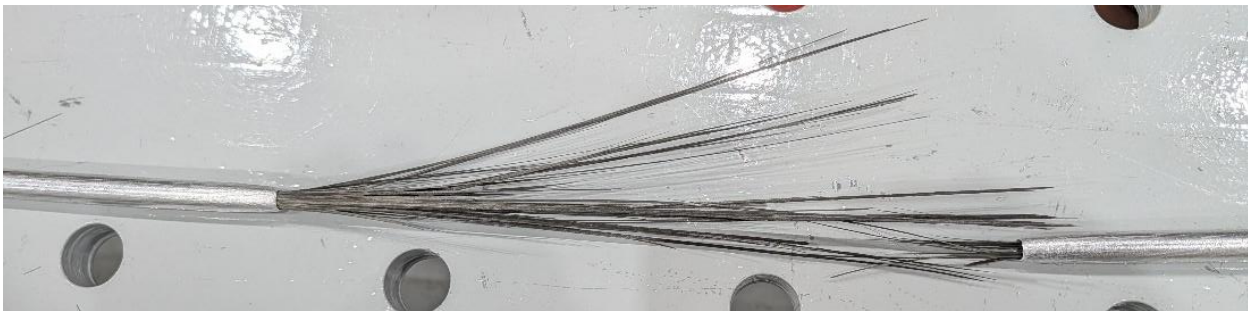


Figure 13. Post-test condition of Sample 3

Sample 4, also tested at the 40x bend condition, reached a maximum tensile load of 43,862.1 lbf before failing near the center of the sample. The fracture was located within the previously bent region. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 14. The sample exceeded the conductor rated breaking strength by 1,352.1 lbf, or approximately 3.2%, indicating that the observed center-region failure did not correspond to a measurable loss of tensile capacity under the 40x bend condition.

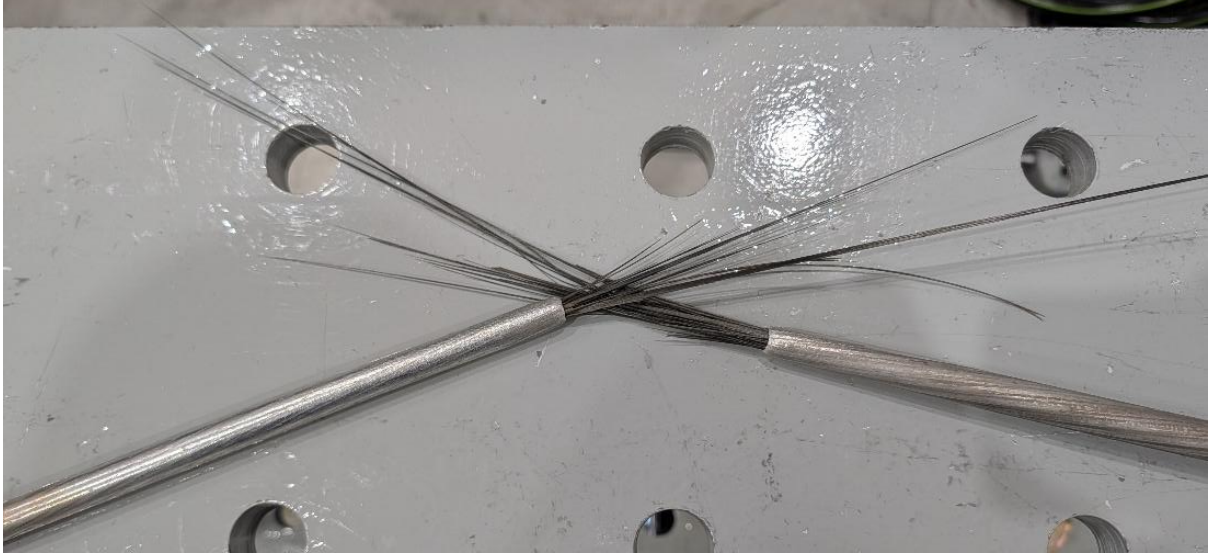


Figure 14. Post-test condition of Sample 4

Sample 5, tested at the 30x bend condition, reached a maximum tensile load of 38,529.9 lbf before failing near the center of the sample. The fracture occurred within the previously bent region. Post-test inspection showed ductile deformation of the aluminum encapsulation and fracture of the carbon core, as shown in Figure 15.



Figure 15. Post-test condition of Sample 5

The measured load was 3,980.1 lbf below the conductor rated breaking strength, corresponding to approximately 90.6% of rated capacity. This result indicates a reduction

in residual tensile strength after the 30x bend exposure, although the sample retained substantially more capacity than Sample 6.

Sample 6, also tested at the 30x bend condition, reached a maximum tensile load of 7,138.7 lbf before failing near the center of the sample. The fracture was located within the previously bent region, where visible damage had been observed before tensile loading. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 16. The measured load was 35,371.3 lbf below the conductor rated breaking strength, corresponding to approximately 16.8% of rated capacity. This early failure is consistent with severe localized damage introduced during or before the 30x bend-under-tension exposure.

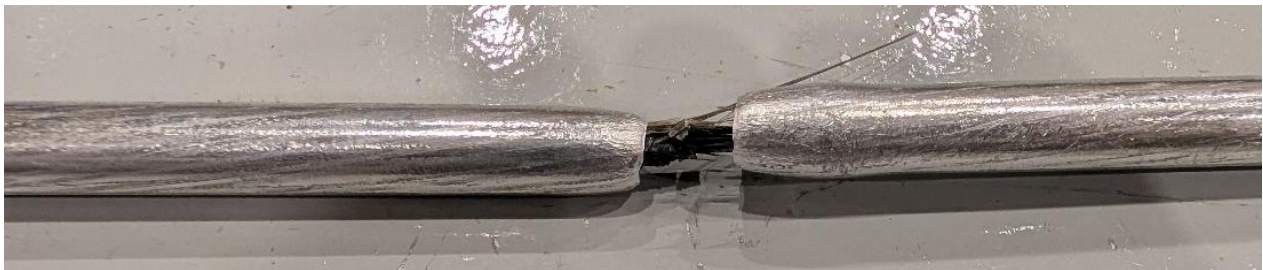


Figure 16. Post-test condition of Sample 6

Before the samples was tensile tested, it was noted that bulge had formed in the aluminum encapsulation as shown in Figure 17. The core broke at this bulge location.

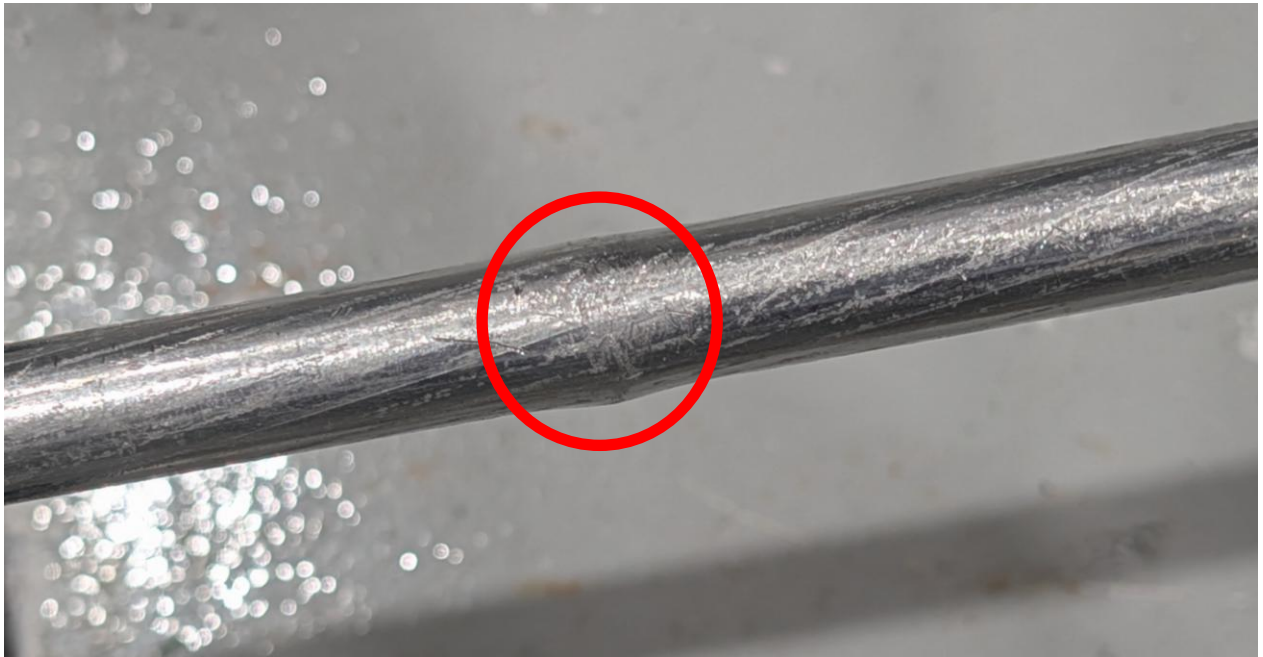


Figure 17. Pre tensile test condition of Sample 6

Sample 7 was an unbent control sample and reached a maximum tensile load of 43,612.8 lbf before failing near the center of the sample. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 18. The sample exceeded the conductor rated breaking strength by 1,102.8 lbf, or approximately 2.6%, confirming that the control sample met the expected tensile-strength requirement.

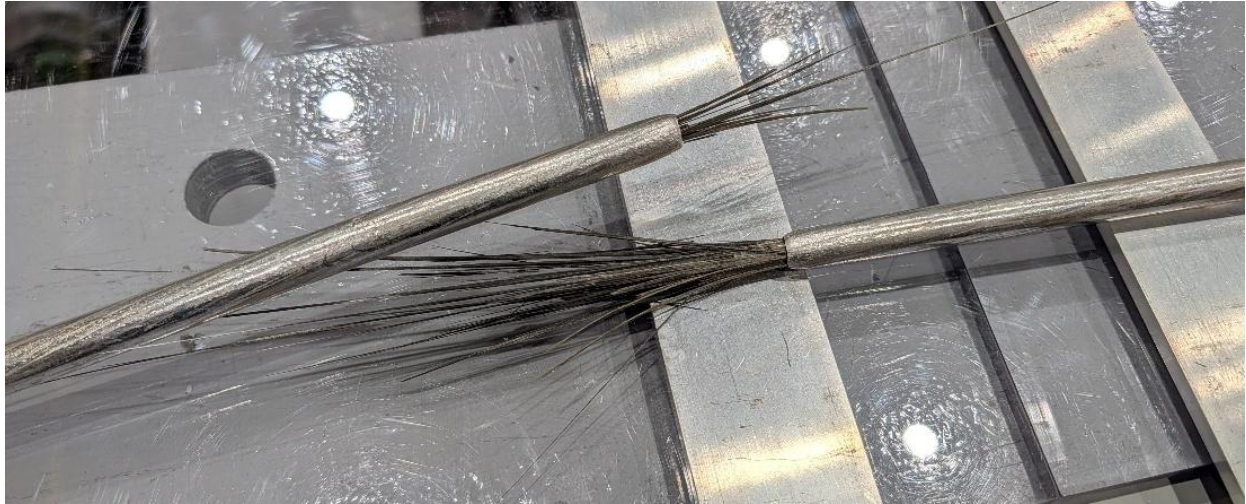


Figure 18. Post-test condition of Sample 7

Sample 8 was the second unbent control sample and reached a maximum tensile load of 42,508.8 lbf before failing near the holding side of the sample. Post-test inspection showed ductile deformation of the aluminum encapsulation and separation of the carbon core, as shown in Figure 19. The measured load was essentially equal to the conductor rated breaking strength and above the 95% acceptance threshold used for comparison, confirming that the second control sample met the expected tensile-strength requirement.



Figure 19. Post-test condition of Sample 8

Overall, the post-test observations indicate that the 50x and 40x bend conditions produced failure characteristics similar to the unbent control samples, with tensile failures occurring at or above the conductor rated breaking strength and no clear evidence of bend-induced strength loss. The 30x samples showed a different response, with both failures occurring within the previously bent region and with substantially reduced or variable residual tensile capacity. The contrast between Samples 5 and 6 suggests that damage at the 30x bend radius may be localized, with the severity of the defect strongly influencing the remaining tensile strength.

6. DISCUSSION AND CONCLUSIONS

Discussion

The bend-under-tension and tensile-test results show a clear dependence on bend severity. The 50x and 40x bend conditions produced only minor visible surface effects and retained tensile capacity comparable to the unbent control samples. The 30x condition produced a more pronounced response, including visible permanent deformation, audible events during bending, and substantially greater variation in residual tensile strength. This trend indicates that the TS composite core tolerated the ASTM B987 baseline bend condition in this test program, while tighter bend radii increased the likelihood and consequence of localized damage.

The tensile results for the 50x and 40x samples were consistent with both the conductor rated breaking strength and the measured control-sample performance. The 50x samples averaged 43,976.9 lbf, and the 40x samples averaged 44,213.2 lbf, compared with an average of 43,060.8 lbf for the two unbent control samples. These results do not indicate a measurable reduction in residual tensile strength for either the 50x or 40x bend condition within the limits of the sample set tested. The failure locations observed in some samples within or near the previously bent region therefore should not be interpreted by themselves as evidence of bend-induced strength loss when the retained tensile capacity remained at or above the rated breaking strength.

The 30x condition produced a different response. One sample reached 38,529.9 lbf, corresponding to approximately 90.6% of the conductor rated breaking strength, while the second sample failed at 7,138.7 lbf, or approximately 16.8% of rated capacity. Both 30x samples failed within the previously bent region, and Sample 6 had visible damage before tensile loading. The wide spread in results indicates that damage at this bend radius can be localized and highly consequential. Although the limited number of samples does not define a statistical threshold for failure, the test results show that bending at 30x the core diameter can reduce residual tensile capacity below the conductor rating when severe localized damage is introduced.

Conclusions

The TS composite core met the expected performance for the ASTM B987 baseline bend condition in this test program. Both 50x samples exceeded the conductor rated breaking strength after bend-under-tension exposure and showed only minor visible surface effects. The tested 40x samples also exceeded the rated breaking strength and performed comparably to the unbent control samples, indicating no measurable strength reduction for the 40x condition within this limited test set.

The 30x bend condition did not provide the same level of retained performance. Both 30x samples failed within the previously bent region, and the measured tensile results were

lower and more variable than the 50x, 40x, and control-sample results. The severe reduction observed in Sample 6 demonstrates that tight-radius bending can introduce localized damage capable of materially reducing remaining tensile strength. The difference between Samples 5 and 6 also indicates that the severity and location of the defect strongly influence residual capacity.

For installation and handling practices, the results support maintaining bend radii at or above the 50x core-diameter requirement specified in ASTM B987 unless additional project-specific qualification testing supports an alternate limit. The 40x results provide useful margin information for the samples tested, but they should not be generalized as a reduced installation limit without broader testing. The 30x results indicate that tighter bend radii can create localized damage with significant strength consequences.

Field procedures and installation equipment should therefore be selected and reviewed to avoid tight-radius bending of the composite core. Sheaves, bullwheels, reels, blocks, hardware transitions, pulling arrangements, and temporary supports should be checked against applicable minimum bend-radius requirements before installation. If a conductor or exposed core is suspected of being bent below the recommended limit, the condition should be documented and evaluated through inspection and engineering review before the conductor is placed in service.

Recommendations

The recommendations focus on maintaining conservative bend-radius controls during installation, identifying locations where localized bending could occur, and establishing a defined response process for suspected over-bending events. Additional qualification testing is recommended before any reduced bend-radius limit is adopted for field use.

Use the ASTM B987 50x core-diameter bend condition as the default minimum bend-radius requirement for installation and handling unless a project-specific qualification program establishes an alternate limit. Do not use the limited 40x results from this test program alone to reduce field bend-radius requirements.

Before installation, review the planned stringing, handling, clipping, dead-ending, and hardware installation sequence to identify where the conductor or exposed core could be forced into a localized bend. Examples include conductor transfer points between reel stands and stringing blocks, routing around temporary supports, transitions through running grounds or traveler hardware, core exposure during dead-end preparation, and tight bends that can occur during clipping or spacer installation. Confirm that equipment, temporary supports, hardware transitions, and work methods maintain the required bend radius under both unloaded and tensioned conditions. Include the minimum bend-radius requirement in construction documents, pre-job briefings, inspection checklists, and field quality checks.

Establish a field response process for suspected over-bending events. Examples of events that should trigger review include a conductor being pulled sharply over a small-diameter edge, an exposed core being bent during hardware preparation, a conductor becoming trapped or kinked during handling, or a visible permanent set remaining after a bend is released. At a minimum, the process should require documenting the location, estimated bend radius, tension state, exposure duration, visible damage, permanent set, and any audible or handling observations. The affected section should be held from service until inspection and engineering review determine whether it can remain in place, requires supplemental testing, or should be removed.

If a reduced bend-radius limit is needed for future installation guidance, conduct a dedicated qualification program before adopting the lower limit. The program should include a larger sample set, repeated 40x and 30x bend-under-tension exposures, controlled replication of the observed 30x damage response, and post-test forensic inspection of failed samples. Example variables to document include mandrel diameter, applied tension, hold time, loading rate, sample orientation, visible surface condition before and after bending, permanent set after unloading, failure location, and fracture characteristics. The objective should be to define the transition between acceptable bend exposure and strength-reducing damage under controlled and repeatable conditions.