Mechanical Reliability and Optical Performance of Field-Aged Optical Fiber Cable

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Author: Nick Karagiannis

Introduction

The technology to instantly share voice, video, and data globally continues to push communication networks to expand and evolve. New generations of optical fiber technology are pioneering the global expansion of broadband connectivity. Optical performance of these cabled fibers is vital to the overall system, but what tends to go unnoticed is the long-term reliability to ensure high performance over a potential installed lifetime of several decades in sometimes extreme environments.

Laboratory environmental tests are used to simulate and predict long-term field performance of optical fiber cables. However, the correlation between a test environment and actual field exposure may not be perfect. Supporting the findings of lab tests, genuine field data from an optical fiber cable provides solid evidence of its integrity and ability to survive its environmental influences.

In this case study, a 34-year-old field-aged aerially installed outdoor cable was removed from operation, extracted, and tested to determine change in mechanical performance over the installed life. The cable is an armored loose-tube hybrid single-mode and multimode fiber design. The cable, installed in 1986 in Hickory, North Carolina bridged communication between Corning Cables Headquarter building and its cables manufacturing plant. A short section of cable was removed and tested. A series of tests were performed, in accordance to industry standards, on the cable and fibers extracted from within. Tests include dynamic fatigue of the optical fiber, strip force, color clarity, and coating geometry of the fibers coating material.

Field Environment/Climate

North Carolina has a humid, sub-tropical climate. In the summer months the temperatures will average 80-90°F and in the winter will drop to low 30-40°F. Average rainfall is about 3-4 inches per month [1]. Figure 1 below represents a yearly depiction of Hickory's weather. Hickory experienced several Category 3 hurricanes (winds of 111 to 129 mph) during the deployment of the cable without any impact to its connectivity or reliability. The climate chart in Figure 1 provides a general concept on its environmental exposure.

CORNING

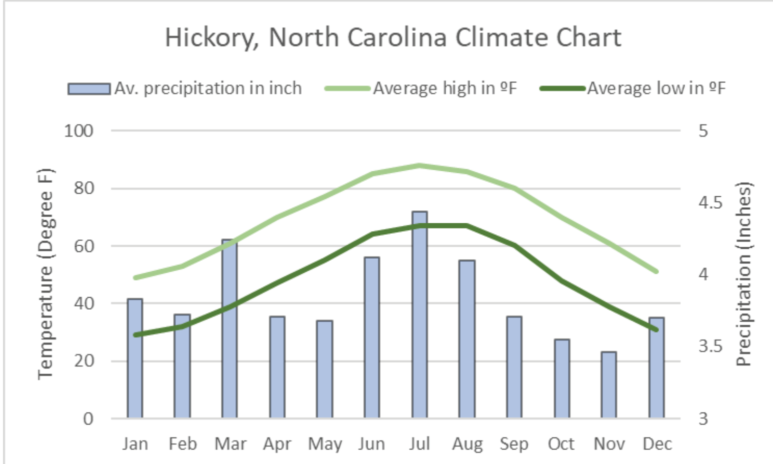

Figure 1. Average Weather in Hickory, North Carolina

Fiber Testing and Results

The fiber samples were carefully removed from the cable and subjected to a variety of evaluations. Testing options were limited owing to the short length of cable made available from the extraction but included visual examination, color permanency, strip force, and fiber fatigue

Of the samples received, each fiber was first examined for any visual signs of abuse and deterioration. Senior technicians analyzing the samples indicated the fibers appeared normal and no issues were observed during the handling or testing of each of the fibers through their respective tests. This observation supports an expectation that maintenance and repair of cables can be achieved without special precautions, even on installations that are several decades old.

Coating and Cladding Diameter

Coating and cladding diameters of the samples were measured and were compared to fiber specification active during the 1980s to determine if any swelling occurred over the years of deployment. All cladding diameters were within the 125 ± 2 microns target, with an average of 126 microns and coating diameter within the allowable 250 ± 15 microns target, with an average of 249 microns. The coating diameter of the extracted fibers is consistent with the coating geometry specifications prevailing in 1986.

Fiber	Coating Diameter	Cladding Diameter
Black	250	No Measurement Obtained
White	249	126.6
Grey	246	126.1
Brown	252	126.7
Blue	251	126.9
Red	246	126.7
Green	251	125.8
Orange	248	125.3
Avg.	249	126.3

Table 2. Coating and Cladding Diameter

Color Permanency

Color clarity and permeance were tested for each of the fiber samples. All colors were within the Munsell color tolerance and were clearly distinguishable and continuous in color, both around the circumference of the fiber and down the length of the fiber. This indicates that the cable and jacketing material was successful in protecting the fibers within. Field technicians would still be able to distinguish fibers apart during maintenance and repair of the cable, if still in service.

Strip Force

Peak and average strip force was measured to determine the fiber coating strippability and integrity after field aging. Strip force testing was completed in accordance to *IEC 60793-1-32 Measurement methods and test procedures – Coating strippability*. Strip force indicates the ability to remove coating from the glass without inducing fiber stress or breakage. In this test, fiber samples were tested for peak and average strip force, recorded in Newtons (N).

A summary of the findings is listed in tables 3 and 4 below. The results show the fiber strip force for the field-aged cable are comparable to similar generation fiber, not deployed in a cable, tested under the same conditions. All fibers met industry standards and requirements. This test indicates that the coating performance is maintained so that preparation for field repair would be allowed even after extended field deployment.

Single-mode Field Aged Optical Fiber				
Fiber ID	Mean Peak Force (N)	Std. Dev.	Avg Strip Force (N)	Std. Dev.
SM Sample 1	3.17	0.26	2.37	0.22
SM Sample 2	3.29	0.43	2.53	0.31
SM Sample 3	3.83	1.81	2.43	0.50
Lab Fiber (Not deployed)	3.47	0.48	2.09	0.08
Sample Min	3.17		2.37	
Sample Max	3.83		2.53	
Sample Average	3.43		2.44	

Table 3. Single-mode Strip Force

Multimode Field Aged Optical Fiber				
Fiber ID	Mean Peak Force (N)	Std. Dev.	Avg Strip Force (N)	Std. Dev.
MM Sample 1	3.70	0.52	2.69	0.32
MM Sample 2	3.78	0.36	2.67	0.18
MM Sample 3	3.96	0.42	2.84	0.18
MM Sample 4	3.54	0.22	2.63	0.21
Sample Min	3.54		2.63	
Sample Max	3.96		2.84	
Sample Average	3.75		2.71	

Table 4. Multimode Strip Force

Fiber Fatigue

Fiber fatigue measurements were performed on sample fibers from the field aged cable. Tests were performed on the usual 0.5 m gauge length samples. Due to limitations on the fiber length available within the cable, only 5 samples per pulling stress could be extracted rather than the minimum of 15 defined in *IEC 60693-1-33 Measurement methods and test procedures – Stress corrosion susceptibility*. All samples were preconditioned in the test environments to 50% relative humidity, 23°C before testing. Fibers were tested using four strain ratings ranging from 30%/min. to 0.09%/min. Results can be viewed in Figure 2 below with comparison to similar generation single-mode fiber, never deployed in a cable and stored since manufacture in a laboratory warehouse. Stress corrosion parameter (n_d) calculated from the available data remains within specification and does not indicate degradation over the period of installation compared to the laboratory fiber.

There is no difference in the mean breaking stress at the second highest stress rate (i.e. the stress rate used to determine the characteristic fiber strength by IEC 60793-1-31 Measurement methods and test procedures - Tensile strength) between the single-mode fiber removed from installation and the single-mode fiber taken from the laboratory warehouse.

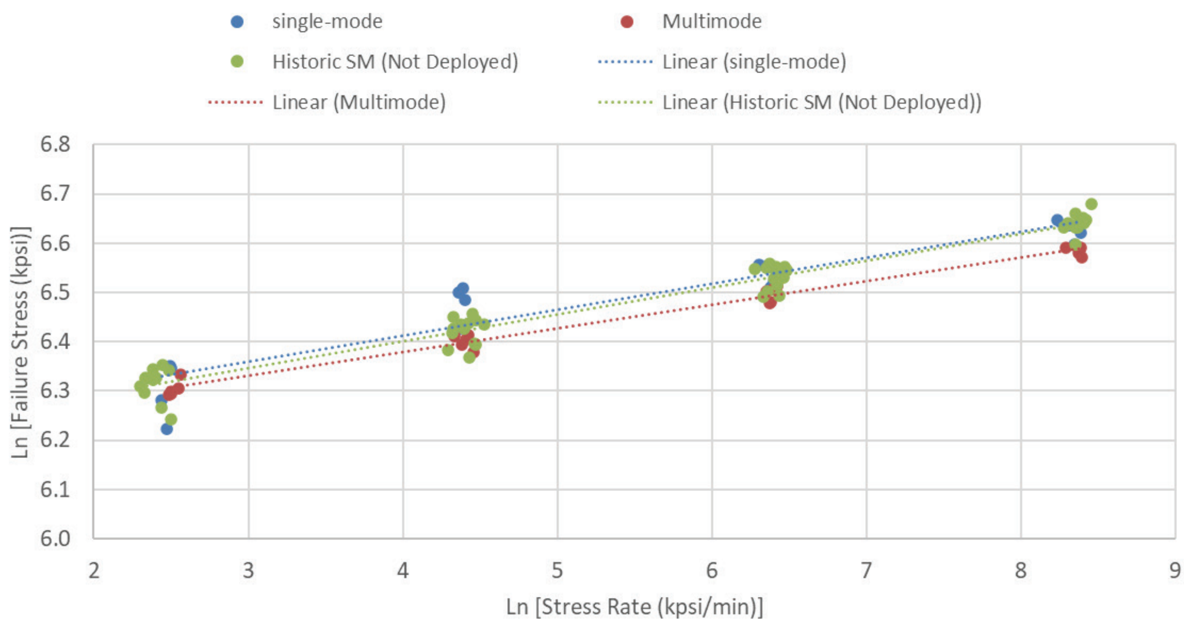

Figure 2. Dynamic Fatigue

Discussion and Conclusion

Tests performed on the field aged optical fiber samples provide proof on the reliability of the fibers over an extended period. The cable provided consistent communication between Corning's facilities for 34 years until decommissioned. The test results validated that Corning's cable designs provide excellent fiber protection under cyclical environmental conditions and fibers do not degrade significantly as a result of deployment. As optical fiber and cable designs continue to improve in quality and effectiveness, these optical fiber cables will continue to maintain high quality transmission for decades.

References

[1] *Climate North Carolina - Temperature, Rainfall and Averages*. (2022). US Climate Data. Retrieved July 15, 2021, from https://www.usclimatedata.com/climate/north-carolina/united-states/3203

Corning Incorporated
www.corning.com/opticalfiber

One Riverfront Plaza
Corning, New York
USA

Phone: +1-607-248-2000 (U.S. and Canada)
Email: cofic@corning.com