Determining Appropriate Proof Test Level for G.657 Fiber (Designed for Tight Bending)

Application Note

AN7080
Issued: February 2020
Supersedes: February 2009
Author: Ian Davis

Summary

- Where fiber is exposed to elevated stress that is highly localized, increasing the proof stress to 200 kpsi imparts negligible improvement in mechanical reliability. This is true of FTTH applications where regions of a few millimeters are typically exposed to bend radii down to 5 mm while the great majority of fiber is essentially straight.
- This is because very few of the flaws susceptible to failure through fatigue during the lifetime of the deployment are actually eliminated by 200 kpsi proof testing.
- The probability of failure in bends to 5 mm is low (2 ppm per full turn) because failure demands the exact coincidence of a susceptible flaw to be positioned on the outside of tight bend circumferentially, close to the location of maximum bend tension.
- Increased proof stress to 200 kpsi is an appropriate method to enable higher stress deployment only where all or most of the fiber is exposed to elevated stress. This is true of submarine applications (where elevated tensile stress is encountered during cable installation and deployment), certain terrestrial cable applications that introduce elevated long-term fiber strain, and some photonic applications (where elevated bending stress is created by deployment in multiple small radius coils).

Introduction

ITU-T Recommendation G.657 defines two classes of bend resistant fibers that are used in fiber to the home (FTTH) applications. Optical performance in bending is defined as low as 7.5 mm radius for Class G.657.A2/B2 and 5 mm radius for Class G.657.B3.

Proof testing is the process where the full fiber length is stressed (typically 100 kpsi tensile stress for terrestrial fiber applications) to assure a lower limit on the strength of the fiber prior to cable processing installation and deployment. Divergent opinion has been expressed as to whether G.657 fibers should be proof tested to 100 kpsi (as required in the standard) or whether the elevated stress imparted to the fiber in the tightest allowed bends demands an increase in the proof test to 200 kpsi. This application note explains why Corning has determined that 100 kpsi proof testing remains appropriate even for highly bend insensitive products that are deployed to 5 mm bend.

CORNING

Explanation

200 kpsi proof stress is sometimes defined to allow application of higher tensile stress during installation or long-term deployment of optical fiber cable. This is particularly true of submarine cables in which any non-zero failure rate is considered unacceptable due to the high density of traffic carried, the large number of subscribers that may be supported by a single fiber, and the high cost associated with cable recovery and repair. Safe (i.e. zero failure probability) stress limits are defined around the weakest flaw that might be present in the fiber after proof testing (the flaw that just survives the proof stress). If safe stress levels are adhered to, the strength of the weakest flaw will never fatigue to below the applied stress so the lowest strength flaw (and therefore the full fiber length) will survive throughout the deployment lifetime. Similarly, Photonic fiber, when used for component manufacturing in which most of the length is permanently deployed in multiple tight coils, can benefit from increasing the proof test level to 200 kpsi to enable tighter zero failure bending deployment.

Corning has determined that the safe deployment stress level is one fifth of the applied proof test level[1]. The weakest surviving flaw of a 200 kpsi proof tested fiber is twice as strong as a 100 kpsi proof tested fiber. A 200 kpsi proof tested fiber consequently has a safe stress limit that is twice that of a 100 kpsi fiber for long length, tensile stress conditions and is therefore more resilient to higher stress events.

While it is tempting to follow the same logic in specifying G.657 fiber and require 200 kpsi proof testing for fibers designed to operate to 5 mm bend radii (which imparts bending stress at ~130 kps over a very small arc along the maximum strain plane) in FTTH applications, this would be misguided. Unlike fiber which is uniformly subject to increased tensile stress in cable, G.657 fibers are exposed to elevated bending stress only in the isolated regions actually under bend (i.e. a quarter turn of 5 mm radius consists of < 8 mm of fiber actually under bend). As with all G.657 fibers, these regions under bend have both a deterministic and very low failure probability.

Knowing the distribution of low strength flaws in the fiber (through extensive mechanical reliability testing using Continuous Rotating Capstan Fiber Tester, CRCFT[2]) Corning has determined the probability that a flaw with initial strength below a particular critical value coincides with a region of fiber under tight bend. The critical value is the initial flaw strength that can fatigue to failure under the bending stress imparted. At 5 mm bend radius, an initial flaw of up to 600 kpsi is susceptible to fatigue to failure over a 40 year installed lifetime.

According to Corning's fiber reliability model, for 100 kpsi proof tested fiber, the likelihood of failure for a full turn of 5 mm radius results in failure probability of 2 ppm. If the proof test is increased from 100 kpsi to 200 kpsi, very few further flaws in the susceptible region are removed and the modeled probability of failure is reduced.

Since the introduction of bend insensitive fiber, Corning has hundreds of thousands of kilometers of G.657.B3 fiber installed in the field with no reported breaks due to sustained bends.

Further Reading

A more detailed discussion of this subject can be found in Corning's White Paper "The Mechanical Reliability of Corning Optical Fiber in Small Bend Scenarios".

References

1. Corning White Paper 5030 – Mechanical Reliability: Applied Stress Design Guidelines
2. Corning White Paper 5050 – Optical Fiber Mechanical Testing Techniques

Corning Incorporated
www.corning.com/opticalfiber

One Riverfront Plaza
Corning, New York
USA

Phone: (607) 248-2000
Email: cofic@corning.com