International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.87

(07/2010)

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Optical fibre cables for drop applications

Recommendation ITU-T L.87

ITU-T

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Optical fibre cables for drop applications

Summary

Recommendation ITU-T L.87 describes the characteristics, construction and test methods of optical fibre cables for drop applications. Optical fibre drop cables are used to connect customer and optical access networks. Access points may be located both outdoors or indoors, depending on the access network configuration. When access points are located outdoors, optical drop cables are exposed to both outdoor and indoor environments. In this case the optical drop cable should be designed for both environments.

This Recommendation also describes the characteristics that a cable requires for an optical fibre to perform appropriately. Moreover, a method is described for determining whether or not the cable has the required characteristics. The required conditions may differ according to the installation environment; detailed test conditions must be agreed upon between the user and manufacturer as regards the environment in which the cable is to be used (in case of applying small bends during and after installation, especially).

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.87	2010-07-29	15

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

Optical fibre drop cables are used to connect the customer and optical access networks. For office users, conventional underground and aerial cables can be employed. However, household users usually require one or more fibre cables. Therefore, cables are often designed specifically for this purpose. Access points may be located both outdoors or indoors, depending on the access network configuration. When access points are located outdoors, optical drop cables are exposed to both outdoor and indoor environments. In this case, optical drop cables should be designed for both environments. The required characteristics may also differ from those of standard underground or aerial cables. This Recommendation has been developed to deal with this situation.

Recommendation ITU-T L.87

Optical fibre cables for drop applications

1 Scope

This Recommendation:

– refers to optical fibre cables to be mainly used for connecting a household customer and an optical access network;

– deals with the mechanical and environmental characteristics of optical fibre cables for drop applications. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with [ITU-T G.652] or [ITU-T G.657], which deal with single-mode optical fibres. When using multi-mode or plastic fibres, [IEC 60793-2-10] and [IEC 60793-2-40] are suitable standards, respectively;

– deals with fundamental considerations related to optical fibre cables from mechanical and environmental standpoints;

– acknowledges that some optical fibre cables may contain metallic elements, for which reference should be made to other L-series Recommendations;

– recommends that an optical fibre cable should be provided with cable end-sealing and protection during cable delivery and storage, as used for metallic cables. If splicing components have been factory installed they should be adequately protected.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.650.1] Recommendation ITU-T G.650.1 (2010), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.

[ITU-T G.652] Recommendation ITU-T G.652 (2009), *Characteristics of a single-mode optical fibre cable*.

[ITU-T G.657] Recommendation ITU-T G.657 (2009), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network*.

[ITU-T L.1] Recommendation ITU-T L.1 (1988), *Construction, installation and protection of telecommunication cables in public networks*.

[ITU-T L.46] Recommendation ITU-T L.46 (2000), *Protection of telecommunication cables and plant from biological attack*.

[IEC 60189-1] IEC 60189-1 (2007), *Low-frequency telecommunication cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods*.

[IEC 60332-1] IEC 60332-1 (1979), *Tests on electric cables under fire conditions – Part 1: Test for vertical insulated wire or cable*.

[IEC 60332-3-24] IEC 60332-3-24 (2000), *Test on electric cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C*.

[IEC 60754-1] IEC 60754-1 (1994), *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the amount of halogen acid gas*.

[IEC 60754-2] IEC 60754-2 (1991), *Test on gases evolved during combustion of electric cables – Part 2: Determination of degree of acidity of gases evolved during the combustion of materials taken from electric cables by measuring pH and conductivity*.

[IEC 60793-1] IEC 60793-1 (2001), *Optical fibres – Part 1: Generic specification*.

[IEC 60793-1-32] IEC 60793-1-32 (2001), *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*.

[IEC 60793-2-10] IEC 60793-2-10 (2007), *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*.

[IEC 60793-2-40] IEC 60793-2-40 (2009), *Optical fibres – Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres*.

[IEC 60794-1-1] IEC 60794-1-1 (2003), *Optical fibre cables – Part 1-1: Generic specification – General*.

[IEC 60794-1-2] IEC 60794-1-2 (2005), *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures*.

[IEC 61034-1] IEC 61034-1 (2005), *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus*.

[IEC 61034-2] IEC 61034-2 (2005), *Measurement of smoke density of cables burning under defined conditions – Part 1: Test procedure and requirements*.

[IEC/TR 62048] IEC/TR 62048 (2002), *Optical fibres – Realibility – Power law theory.*

3 Definitions

For the purpose of this Recommendation, the definitions given in [ITU-T G.650.1] apply.

4 Abbreviations and acronyms

None.

5 Conventions

None.

6 Characteristics of the optical fibres and cables

6.1 Optical fibres

6.1.1 Single-mode fibres

[ITU-T G.652] or [ITU-T G.657] should be used.

6.1.2 Multimode fibres

[IEC 60793-2-10] should be used.

6.1.3 Plastic fibres

[IEC 60793-2-40] should be used.

6.2 Mechanical characteristics

If mechanical forces (e.g., longitudinal strain, buckling, bending, torsion, crush and kink) are applied, they may affect the performance of a fibre and a cable. This clause describes the relationship between typical mechanical forces and cable performance.

6.2.1 Bending

Cable bending during installation and operation may impose strain on fibres, and this may affect fibre reliability. Bending also causes a loss increase. Therefore, the cable bending radius must be kept large enough to avoid any loss increase or fibre lifetime degradation when designing a tensile member or limiting the installation conditions.

In case of using bending loss insensitive fibres, fibre lifetime calculation should be done carefully based on actual installation conditions. Therefore, it is important for manufacturers and users to agree upon typical, general or harsh (worst case) installation conditions.

[IEC/TR 62048] describes two regions of mechanical reliability. One is the low strength tail of the distribution or extrinsic region which covers large flaws in the glass optical fibre. The other region is the intrinsic strength portion which describes the high strength bulk of the fibre.

When the fibre bending radius is small, there are two considerations to avoid risks of fibre degradation. One is to increase the fibre proof stress level to limit extrinsic flaws on the fibre. The second is to limit the small bend portions along the route where the cable is installed. The random flaws that limit the extrinsic strength have a very low probability distribution in glass optical fibres manufactured with modern materials using well controlled processes. Therefore, it is negligible that a small bend will occur at the exact location of a random flaw.

The cable structure is also an important issue when fibre lifetime calculation and fibre loss estimation are done, because fibre bending radius is strongly dependent on the cable structure. Generally, the cable bending radius is determined by its inner radius. Therefore, when the fibre is located in the centre of the cable, with cable diameter D and cable bending radius r, the fibre bending radius is $r + D/2$. In case of a small cable bending radius, such as when r is nearly equal to D, the above calculation cannot be neglected.

6.2.2 Tensile strength

The optical fibre cable is subjected to short-term loading during manufacture and installation, and may be affected by continuous static loading and/or cyclic loading during operation (e.g., temperature variation). Changes to the tension of the cable as a result of the various factors encountered by a cable during its service life can cause the differential movement of the cable components. This effect needs to be considered in the cable design. Excessive cable tensile loading increases the optical loss and may cause increased residual strain in the fibre if the cable cannot relax. To avoid this, the maximum tensile strength determined by the cable construction, especially as regards the design of the strength member, should not be exceeded.

NOTE – Where a cable is subjected to permanent loading during its operational life, the fibre should preferably not experience additional strain.

6.2.3 Bending with tension (axial strain)

It may happen that small bending and residual strain are applied to the fibres simultaneously. In this case, precise analyses for fibre degradation will be described in [IEC/TR 62048] edition 2. However, in order to estimate fibre lifetime, a calculation model which is agreed between manufacturers and users should be required. If any kind of test will be done for this purpose, the test condition should be agreed between manufacturers and users.

6.2.4 Crush and impact

The cable may be subjected to crushing and impact both during its installation and operational life.

This crushing and impact may increase the optical loss (permanently or during the time the stress is applied) and excessive stress may lead to fibre fracture.

6.2.5 Torsion

Under the dynamic conditions encountered during installation and operation, the cable may be subjected to torsion, resulting in residual strain on the fibres and/or sheath damage. If this is the case, the cable design should allow a specified number of cable twists per unit length without any increase in fibre loss and/or sheath damage.

6.3 Environmental conditions

This clause describes expected environmental conditions that must be considered when designing optical fibre cables for drop applications.

6.3.1 Temperature variation

Temperature variation strongly depends on the climatic conditions at the location where optical fibre drop cables are installed. Therefore, it is important to examine the expected temperature range during their operational lifetime. It is recommended that the optical fibre cable structure be designed so that no increase in fibre attenuation exceeds the specified limits under those conditions.

6.3.2 Rodent attack

Rodents may be found in areas where optical fibre drop cables are installed. Where those rodents cannot be excluded, a suitable and effective protection should be provided. Further information is described in [ITU-T L.46], "Protection of telecommunication cables and plant from biological attack".

Common methods of rodent protection are performed by applying a barrier made of GRP, glass yarns or metallic tapes/wires. Armouring with metallic elements can provide most effective protection.

6.3.3 Water immersion

When an optical fibre cable is soaked in water, moisture permeation and water penetration may result, depending on the cable structure. When there is a crack in the cable sheath, water may soak into the cable core. Water causes fibre strength degradation more rapidly than high humidity. If there is a possibility that the cable will be soaked in water, it is recommended that water-blocking materials be used to prevent the cable core from becoming immersed in water.

6.4 Fire safety

Fire safety is an important problem in buildings and houses. There are two major issues. The first is that the cables and cable elements should be difficult to burn. In other words, the cables and cable elements should have flame retardant characteristics. The second is that the cables and cable elements should not generate toxic gases or smoke when burning. Fire performance requirements may differ from country to country. Optical cables for drop applications should comply with the fire safety regulations of each country or telecommunication carrier.

7 Cable construction

7.1 Fibre protection

7.1.1 Fibre primary coating

Primary coated fibres must comply with the relevant ITU-T G.65x-series Recommendations.

7.1.2 Buffered fibre

When using a tight or semi-tight buffer (loosely applied), the following characteristics are required:

– a tight buffer should be easily removable over a length of 10 to 25 mm for fibre splicing;

– a semi-tight buffer should be easily removable over a length of 300 to 500 mm for fibre splicing;

– with a tight buffer, the nominal diameter should be between 300 and 1300 µm, based on an agreement between the user and supplier. The tolerance should be ± 100 µm;

– with a semi-tight buffer, the nominal diameter should be between 300 and 1300 µm, based on an agreement between the user and supplier. The tolerance should be ± 100 µm.

7.1.3 Further protection

When a buffered fibre requires further protection, a sheath that includes one or two non-metallic strength members can be used. The sheath should be made of a suitable material.

7.2 Cable element

The make-up of the cable, in particular the number of fibres, the methods used for their protection and identification, and the location of strength members, should be clearly defined.

7.2.1 Tube

A tube construction is used for packaging one or more optical fibre(s). The tube may contain filling material. A composite wall can be used for reinforcement.

7.2.2 Strength member

The cable should be designed with sufficient strength members to meet installation and service conditions so that the fibres are not subjected to strain levels exceeding those agreed between manufacturers and customers. The strength member may be either metallic or non-metallic.

The cable for drop applications may be classified as a self-supporting type, when it has, for example, a figure-of-eight construction, or when the strength members are located in the cable core and/or in the sheath. Alternatively, the cable may be supported by attaching it to a supporting strand.

Knowledge of span, sag, wind and ice-loading is necessary to design a cable for use in aerial applications.

7.3 Sheath

The cable core shall be covered with a sheath or sheaths suitable for the relevant environmental and mechanical conditions associated with storage, installation and operation. The sheath may be of a composite construction and may include strength members.

Considerations as regards the sheaths for optical fibre cables are generally the same as those for metallic conductor cables. Consideration should also be given to the amount of hydrogen generated from a metallic moisture barrier. The minimum acceptable thickness of the sheath should be stated, together with any allowable overall maximum and minimum diameters for the cable.

The selection of the sheath material is an important issue in terms of satisfying fire safety requirements. Polyethylene is widely used as a cable sheath material. However, it may not be suitable for drop cables from the viewpoint of fire safety.

7.4 Armour

Armouring is provided where additional tensile strength or protection from external damage (crush, impact, rodents, etc.) is required.

Armouring considerations for optical cables are generally the same as for metallic conductor cables. However, hydrogen generation as a result of corrosion must be considered. It should be remembered that the advantages of optical fibre cables, such as lightness and flexibility, will be reduced when an armour is provided.

Armouring for metal-free cable may consist of aramid yarns, fibreglass reinforced strands or strapping tape, etc.

7.5 Water-blocking materials

Filling a cable with water-blocking material or wrapping the cable core with layers of water-swellable material are two means of protecting the fibres from water ingress. A water-blocking element (tapes, filling compound, water swelling powder or combinations of materials) may be used. None of the materials used should be harmful to human beings. The materials in the cable should be compatible, and in particular should not adversely affect the fibre. These materials should not hinder splicing and/or connection.

7.6 Cable identification

Embossing, sintering, imprinting, hot foil or surface printing can be used to identify cables by agreement between the user and supplier.

8 Test methods

In this clause, if the word (optional) follows the test title, it means that the test is not mandatory.

8.1 Test methods for cable elements

8.1.1 Tests applicable to optical fibres

This clause describes optical fibre test methods related to splicing. Methods for testing the mechanical and optical characteristics of optical fibres are described in [ITU-T G.650.1] and the [IEC 60793-1] series.

8.1.1.1 Dimensions

[IEC 60189-1] shall be used for measuring buffered fibres, tubes, and cable diameters. This method can be employed to measure the thickness of a cable sheath.

8.1.1.2 Coating strippability

[IEC 60793-1-32] shall be used for measuring the strippability of primary or secondary fibre coatings.

8.1.1.3 Compatibility with filling material

When fibres contact a filling material, the stability of the fibre coating and the filling material should be examined.

The stability of the coating stripping force shall be tested in accordance with method E5 in [IEC 60794-1-2].

Dimension stability and coating transmissivity should be examined by using a test method agreed upon by the cable manufacturer and buyer.

8.1.2 Tests applicable to tubes

8.1.2.1 Tube kink

Method G7 of [IEC 60794-1-2] shall be used for measuring the kink characteristics of a tube.

8.2 Test methods for mechanical characteristics of cable

This clause recommends appropriate tests and test methods for verifying the mechanical characteristics of optical fibre cables. For test methods, reference shall be made to the [IEC 60794-1] series.

8.2.1 Tensile strength

This test method applies to optical fibre cables installed under all environmental conditions.

Measurements are made to examine the behaviour of the fibre attenuation as a function of the load on a cable during installation.

The test should be carried out in accordance with method E1A of [IEC 60794-1-2].

The amount of mechanical decoupling of the fibre and cable can be determined by measuring the fibre elongation with optical phase shift test equipment, together with cable elongation.

This method may be non-destructive if the tension applied is within the operational values.

Test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.2 Bending

This test method applies to optical fibre cables installed under all environmental conditions.

The purpose of this test is to determine the ability of optical fibre cables to withstand bending around a pulley, simulated by a test mandrel.

This test shall be carried out in accordance with method E11A of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.3 Flexing

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method E8 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.4 Crushing

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method E3 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.5 Torsion

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method E7 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.6 Impact

This test method applies to optical fibre cables installed under all environmental conditions.

This test shall be carried out in accordance with method E4 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.7 Kink

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method E10 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.8 Vibration

This is a subject for further study.

8.2.9 Repeated bending

This test shall be carried out in accordance with method E6 of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.10 Repeated bending at low temperature (optional)

This test should be carried out in accordance with method E11A of [IEC 60794-1-2].

The test conditions should be agreed upon by the cable manufacturer and buyer.

8.2.11 Bending with tension (optional)

The test procedure and conditions should be agreed upon by the cable manufacturer and buyer.

8.3 Test methods for environmental characteristics

This clause recommends appropriate tests and test methods for verifying the environmental characteristics of optical fibre cables.

8.3.1 Temperature cycling

This test method applies to optical fibre cables installed under all environmental conditions.

Testing involves temperature cycling to determine the stability of the attenuation of a cable in the presence of ambient temperature changes, which may occur during storage, transportation and operation.

This test shall be carried out in accordance with method F1 of [IEC 60794-1-2].

8.4 Test methods for fire safety

This clause recommends appropriate tests and test methods for verifying the fire safety characteristics of optical fibre cables.

8.4.1 Flame retardant characteristics

This test shall be carried out in accordance with method [IEC 60332-1] or [IEC 60332-3-24], unless there is an agreement between the cable manufacturer and buyer.

8.4.2 Toxic gases characteristics

This test shall be carried out in accordance with method [IEC 60754-1] or [IEC 60754-2], unless there is an agreement between the cable manufacturer and buyer.

8.4.3 Smoke characteristics

This test shall be carried out in accordance with method [IEC 61034-1] or [IEC 61034-2], unless there is a different agreement between the cable manufacturer and buyer.

Appendix I

United States' experience – Cable installation conditions in multi-dwelling units (MDUs) when using bending-loss insensitive fibre

(This appendix does not form an integral part of this Recommendation)

Currently, the test that has the widest acceptance is the MDU simulation described in the Verizon NEBS Document [b-Verizon TPR 9424]. This test describes an attenuation requirement at 1550 nm that should be ≤ 0.4 dB after the following simultaneous conditions as an MDU simulation:

- Ten 90º corner bends unloaded.
- One 90º corner bend w/2 kg load.
- One 90º corner bend w/14 kg (30% of the cable tensile strength).
- Two 10 mm mandrel wraps.
- Thirty T25 staples.

I.1 Mechanical reliability of optical fibre

Mechanical reliability of optical fibre is described in the document on power law reliability [IEC/TR 62048]. This document describes two regions of mechanical reliability. One is the low strength tail of the distribution or extrinsic region which covers large flaws in the glass optical fibre. The largest acceptable flaw in an optical fibre is on the order of about 0.5 microns and is removed in the 100 kpsi proof-test of the optical fibre. Understanding this low strength tail is essential in understanding the performance of long lengths of fibre in strain as often found in outside plant cables.

The other region is the intrinsic strength portion which describes the high strength bulk of the fibre. For short lengths of fibre such as what would be encountered with fastening, the intrinsic strength is the important metric. The random flaws that limit the extrinsic strength have a very low probability distribution in glass optical fibres manufactured with modern materials using well-controlled processes. There is a near zero failure probability that fastening (i.e., stapling) would induce a small bend occurring at the exact location of a random flaw. The details of this failure probability are described in detail in [IEC/TR 62048] and require measurements of several parameters utilized to characterize the mechanical strength. The intrinsic strength is found by testing short lengths of fibre to mechanical failure. Typical values for modern glass fibres are greater than 550 kpsi. Thus, when determining long-term reliability of fibres in tight bends, the rule of thumb is the long term stress should be no more than one third the proof-test strength is conservative. It is more appropriate to look at either 2-point bend tests or short length test to failure when addressing this critical region of fibre strength. Figure I.1 shows 2-point bend data for 125 micron solid glass optical fibre with an acrylate coating.

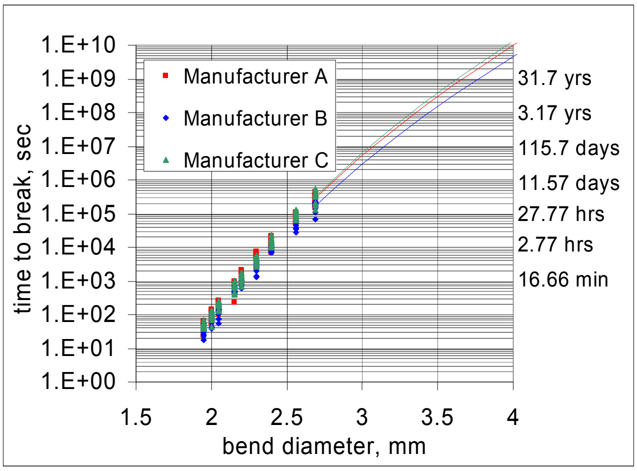
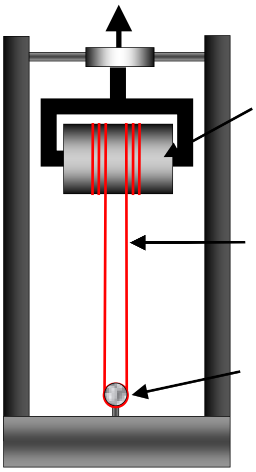


Figure I.1 – Results of 2-point bend static fatigue tests for optical fibres from three manufacturers
Solid lines denote extrapolation of average from the experimental data [b-Mazzarese]

When bends and tension are present at the same time, the two forces are additive. Figure I.2 shows a summary of an experiment that was developed to show this relationship. The results show the linear and additive nature of these forces on the optical fibre.



Bottom mandrel diameter (mm)	Median tensile strength (GPa)	Bending stress (GPa)	Total stress (GPa)
50.4	5.56	~0	5.56
13	4.84	0.71	5.55
9.4	3.97	0.99	4.96
4.8	3.10	1.99	5.09

Figure I.2 – Fibre testing: Bending with axial load with summary results [b-Mazzarese]

I.2 Comments on mechanical reliability of optical cables used in MDUs

It is desirable for MDU cables used in MDU deployments to have a small diameter to drive down costs and simplify installation. Unfortunately, these conditions could lead to optical fibres in these cables to be subjected to both bends and tension after installation. For example, when the MDU installation practices described above are combined with the understanding of optical fibre reliability, one can develop mechanical reliability requirements for optical drop cables that can be met in these demanding environments. It was shown using x-ray images that it is plausible to have bend radii on the order of 5 mm for 4.8 mm optical cables around corners and at places where the cable is fastened. The conditions shown in those images are similar to what can be observed in the field and it is essential that the fibre specifications include the 5 mm bend radius requirement to enable cable designs that can be deployed in the MDU application space. Without a fibre that has a 5 mm radius optical loss bend requirement many novel innovations that would facilitate rapid deployment may suffer from unpredictable performance.

The role of the optical cable is to protect the optical fibre. In traditional terrestrial long haul, metropolitan, and submarines deployments, one looks at axial strain and limits the bend radius to several cable diameters. In an in-building deployment optical cables will have a different set of conditions where they may be pulled around tight corners and fastened (i.e., stapled). It has been shown as illustrated in Amendment 1 to [ITU-T G.657], in an optical cable with a bend and tension, the amount of strain on the optical fibre is several times greater than the strain expected for pure axial tension. It is essential that the cable being used in these demanding applications be characterized to appropriately assure that mechanical reliability of the optical fibre is preserved over the expected life of the optical cable in the configurations that are expected to be encountered in the field, such as described in the demanding deployment configuration above.

I.3 Reliability requirement for optical drop cables

The target for mechanical reliability of terrestrial long-haul, metropolitan, or submarine cables used in the telecom industry is usually stated as less than 1 ppm failure in 30 years. With about 30 years of deployment, evidence is that, other than some unforeseen early failures, current cable designs when properly deployed meet these stringent requirements. The expected lifetime for copper drop cables used to connect individual subscribers is on the order of ten years. Both these numbers have been considered acceptable for their targeted application space, and may support thousands of users, while a copper drop supports a single customer.

It is expected that the installation practices will impact the reliability of optical drop cables as compared to terrestrial long-haul, metropolitan, or submarines cables, but the optical drop cable will still provide substantially better performance than the copper drop cables. Comparing mechanical performance of the optical drop cables in the configurations described in the demanding MDU deployment is a way to have a common reference point that addresses many of the deployments that may occur around the world. Though each service provider may have differing network requirements, properly designed optical cables should provide a minimum reliability of less than 20 ppm failures in 20 years of service.

Appendix II

Draka's experience – Reliability and handling concerns for cables using bending loss insensitive fibres

(This appendix does not form an integral part of this Recommendation)

A safety issue concerning reliability is proposed by means of an increased proof stress value (1.38 GPa or 2% strain). Such ultra bend-insensitive fibres do not show so-called self-diagnosing of risky bends (< 5 mm radius) in post-installation optical time-domain reflectometry (OTDR) or power meter testing. Draka and others fear that such risky bends are a realistic possibility applying "aggressive" installation techniques.

NOTE – A proof stress level of 1.38 GPa or 2% strain corresponds (for a fibre with glass diameter of 125 µm) to a bend radius of slightly more than 3 mm or a pulling force of around 17 N; a 1% proof test level corresponds to a bend radius of slightly more than 6 mm or a pulling force of around 8.5 N.

Using the well-known power-law theory of optical fibre reliability (see, e.g., [IEC/TR 62048]) it is clear that the risky bend area (< 5 mm radius) still can be controlled by limiting extrinsic flaws, which can be filtered by means of a higher proof test level. From 2.4 mm bend radius and smaller, the failure probability explodes, because here the intrinsic failure mode takes over, dominating over the weak spots, as shown in Table II.1.

Table II.1 – Failure probability in 25 years lifetime versus minimum bend radius R_{min} (proof test stress 0.69 Gpa)

	R_{min} (mm)	**15**	**10**	**7.5**	**5**	**2.5**	**2.4**
Extrinsic	F (ppm)	0.08	0.32	0.69	1.84	9.36	10.3
Intrinsic	F (ppm)	0	0	0	0	0.43	33.3

Appendix III

Japanese experience – Test conditions for optical fibre drop cables using bending loss insensitive fibres for indoor application

(This appendix does not form an integral part of this Recommendation)

III.1 Repeated bending test

Procedure: E11A of [IEC 60794-1-2]

Condition:

Cable bending radius is equal to or less than 2.5 mm.

Measurement wavelengths are 1310 ± 10 nm and 1550 ± 20 nm.

Number of repeat is 10 times.

Acceptance criteria:

Loss increase is less than 0.1 dB.

III.2 Crush test

Procedure: E3 of [IEC 60794-1-2]

Condition:

Lateral load is 1200 N/25 mm.

Loading time is 1 minute.

Measurement wavelength: 1310 ± 10 nm and 1550 ± 20 nm.

Acceptance criteria:

Loss increase is less than 0.1 dB.

No sheath breakage.

III.3 Torsion test

Procedure: E7 of [IEC 60794-1-2]

Condition:

Sample length is 1 m.

Rotation angle is ±90 degrees.

Measurement wavelengths are 1310 ± 10 nm and 1550 ± 20 nm.

Acceptance criteria:

Loss increase is less than 0.1 dB.

No sheath breakage.

III.4 Impact test

Procedure: E4 of [IEC 60794-1-2]

Condition:

Hammer weight is 0.3 kg.

Fallen length of a hammer is 1 m.

Impact surface radius of hammer is 10 mm.

Measurement wavelengths are 1310 ± 10 nm and 1550 ± 20 nm.

Acceptance criteria:

Loss increase is less than 0.1 dB after the test.

No sheath breakage.

III.5 Folding test

Procedure: No international standard procedure for this test.

To measure loss change between not folded cable and 180-degree folded cable as shown in Figure III.1.

Condition:

Measurement wavelengths are 1310 ± 10 nm and 1550 ± 20 nm.

Acceptance criteria:

Loss increase is less than 0.1 dB.

No sheath breakage.

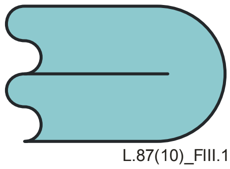


Figure III.1 – 180-degree folded cable

Appendix IV

Chinese experience – Optical fibre cables for drop applications

(This appendix does not form an integral part of this Recommendation)

IV.1 Introduction

The optical broadband network construction is a hot topic all over the world, while it is in a rapid development stage in China. Many network patterns can be adopted in the construction to meet the market needs in order to make the fibres approach the customers as much as possible. The optical fibre cables for drop applications will be employed in this construction on a large scale. Therefore, the Chinese government has issued a corresponding product standard. This contribution introduces the requirements stated in this Chinese standard for the optical fibre cables for drop applications.

IV.2 Scope

This product standard is worked out for optical fibre cables for drop applications used in FTTH networks, also for those cables deployed in FTTO and FTTB networks. Other cables for drop applications with different structures can also refer to this standard.

IV.3 Requirements

IV.3.1 Cable structure

IV.3.1.1 Summary

The selection of cable structures and materials should consider their expected applications as well as installation conditions, especially in respect of flame-retardant requirements. The standard recommends a dry-core structure, while other cable structures can also be adopted as long as they can meet the mechanical, environmental and transmission requirements stated in the standard.

IV.3.1.2 Fibre

The single-mode fibres used in the cable should comply with [ITU-T G.652] and [ITU-T G.657]. The fibre count can be 1, 2 or 4, or other numbers as required by customers.

The identification of fibres in the cable can be implemented with the aid of a full colour spectrum. Unless specified, the fibre colours shall be chosen according to the priority illustrated in Table IV.1, while natural colour can replace any one in the table.

Table IV.1 – Fibre colour spectrum

Sequence	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Colour	Blue	Orange	Green	Brown	Grey	White	Red	Black	Yellow	Violet	Pink	Aqua

IV.3.1.3 Fibre ribbon

The structures and the dimensions of fibre ribbons should comply with [b-IEC 60794-3].

IV.3.1.4 Strength member

The strength members can be either metallic or non-metallic, which should be embedded in the cable sheath. No joint is permitted along the cable delivery length.

IV.3.1.5 Messenger

Besides strength members, a messenger can be added in order to bear most of the tension imposed on the cable for aerial installation. The messenger may consist of one steel wire, stranded steel wires or a fibre reinforced plastic (FRP) rod. No joint is permitted along the cable delivery length.

IV.3.1.6 Sheath

– A layer of protective sheath should be extruded onto the cable core (with a messenger). The sheath material can be LSZH polyolefin or PVC. Other materials can be also adopted according to the requirements of customers, as long as their characteristics can meet the needs in this standard.
– The minimum thickness of the cable sheath should be no less than 0.4 mm.
– For indoor cables, light colours can be used for the sheath, while for outdoor cables, a black sheath is preferred due to its good UV-resistant property. The sheath should be smooth with uniform colour, and without cracks, bubbles or stains.

IV.3.2 Standard manufacture length

The standard manufacture length of the cable should be in accordance with Table IV.2. The cable delivery length shall be in accordance with the standard manufacture length, unless agreed otherwise with the customer. No fibre joint is permitted along the cable delivery length.

Table IV.2 – Standard cable manufacture length

Nominal Value (m)	Tolerance (%)
500	0~+5
1000	
2000	

IV.3.3 Performance

IV.3.3.1 Cabled fibre performance

IV.3.3.1.1 Single-mode fibre

The dimension parameters, mode field diameter, cut-off wavelength and macro-bending loss of the fibres should comply with [ITU-T G.652] and [ITU-T G.657].

IV.3.3.1.2 Fibre ribbon

The characteristics of fibre ribbons should comply with [b-IEC 60794-3].

IV.3.3.1.3 Attenuation attributes of cabled fibres

The maximum attenuation of cabled fibres should be in accordance with Table IV.3, or no more than the value agreed upon between the customer and the manufacturer.

Table IV.3 – Maximum attenuation of cabled fibres

Fibre type	Wavelength (nm)	Maximum attenuation (dB/km)
ITU-T G.657A, ITU-T G.652B and ITU-T G.652D	1310	0.40
ITU-T G.657B	1310	0.50
	1550	0.40

IV.3.3.2 Cable sheath performance

The mechanical and physical characteristics of the cable sheath should comply with Table IV.4. Other materials which can meet customer needs can be also used.

Table IV.4 – Mechanical and physical characteristics of cable sheath

	Item	Unit	Required value	
			PVC	LSZH Polyolefin
1	Tensile strength before heat ageing treatment (minimum value)	MPa	12.5	10.0
	Rate of change after heat ageing treatment (maximum value)	%	20	
	Temperature of heat ageing treatment	ºC	100 ± 2	
	Duration of heat ageing treatment	h	24 × 10	
2	Elongation before heat ageing treatment (minimum value)	%	150	125
	Elongation after heat ageing treatment (minimum value)	%	125	100
	Rate of change after heat ageing treatment (maximum value)	%	20	
	Temperature of heat ageing treatment	ºC	100 ± 2	
	Duration of heat ageing treatment	h	24 × 10	
3	Heat shock resistance		No crack	–
	Temperature of heat treatment	ºC	150 ± 2	–
	Duration of heat treatment	h	1	
4	Environmental stress crack resistance (50ºC, 96h)	piece	–	0/10

IV.3.3.3 Mechanical performance of the cable

IV.3.3.3.1 General requirements

Mechanical performances include separability, tensile strength, crush, impact, repeated bending, torsion, etc., which can be proved by the corresponding test methods under specific test conditions.

IV.3.3.3.2 Separability

– the test is carried out for the cable part only. For self-supporting cables, the messenger should be removed from the cable part before the test;

– the cable should be able to be separated 200 mm long from the opening and the minimum tear load should be no less than 3 N while the maximum value should be no more than 10 N;

– after separation, the fibres can be fully exposed and the colouring layer should not flake off. The separated fibres should not be able to be extracted from the cable by hand. Moreover, the sheath over the strength member should be kept intact, without cracks.

IV.3.3.3.3 Tensile strength

The allowable long-term tensile strength of the cable should be no less than 40 N, while the short-term value should be no less than 80 N. The fibre strain under the long-term load should not exceed 0.2% with no obvious attenuation increase while that under short-term load ought to be less than 0.4% with no obvious attenuation increase and no visual sheath cracks.

IV.3.3.3.4 Crush resistance

The long-term crush resistance of the cable should be no less than 500 N while the short-term value should be no less than 1000 N.

IV.3.3.3.5 Bending radius of the cable

The minimum bending radius of the cable should comply with Table IV.5.

Table IV.5 – Minimum bending radius of the cable

Fibre type	Static (during operation)	Dynamic (during installation)
ITU-T G.652B and ITU-T G.652D	(10*D)	(20*D)
ITU-T G.657A	(7.5*D)	(15*D)
ITU-T G.657B	(5*D)	(10*D)
NOTE – D is the diameter of cables.		

IV.3.3.4 Environmental characteristics

IV.3.3.4.1 General requirements

Environmental characteristics include fibre attenuation at extreme temperatures, flame retardancy, cold bend, etc., which can be proved by the corresponding test methods under specific test conditions.

IV.3.3.4.2 Temperature ranges and attenuation attributes at these temperatures

The temperature ranges for the cables as well as the allowable attenuation increases at these temperatures should comply with Table IV.6.

Table IV.6 – Temperature ranges and allowable attenuation increase

Grade	Temperature Range (ºC)		Allowable attenuation increase (dB/km)	Cable application
	Lowest temperature TA	Highest temperature TB		
A	–5	+50	≤0.20	Indoors
B	–10	+60	≤0.30	Outdoors
C	–40	+60	≤0.40	Outdoors
NOTE – The attenuation increase means the fibre attenuation augments at the extreme temperature compared with the attenuation at 20ºC.				

IV.3.3.4.3 Flame retardancy

The flame retardancy of the cable should comply with the following:

Fire retardancy: The cable should pass the test on a single vertical insulated wire or cable under fire conditions. If required by customers, the cables deployed vertically in the shaft should pass the test for vertical flame spread of vertically-mounted bunched wires or cables-Category C.

Smoke density: The light transmittance should be no less than 50%.

Corrosiveness: The PH value of the gas emitted from the cable during its combustion should be no less than 4.3 and the electrical conductivity should not exceed 10 μs/mm.

IV.3.3.4.4 Cold bend

The cables of Grade C listed in Table IV.6 should pass the cold bend test at –15ºC. After the test, there should be no visual sheath cracks or fibre breakage.

Bibliography

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Printed in Switzerland
Geneva, 2010