

Recommendation

ITU-T L.100 (01/2024)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Optical fibre cables – Cable structure and characteristics

Optical fibre cables for duct and tunnel application

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Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

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Recommendation ITU-T L.100

Optical fibre cables for duct and tunnel application

Summary

Recommendation ITU-T L.100 describes characteristics, construction, test methods, and performance criteria of optical fibre cables installed by pulling method for duct and tunnel application. Note that Recommendation ITU-T L.10, Ed 3.0, was redesignated as ITU-T L.100/L.10, Ed 3.0, in February 2016.

First, in order to demonstrate the sufficient performance of an optical fibre cable, the characteristics that a cable should possess are described in this Recommendation. Then, the methods of examining whether a cable has the required characteristics are described in this Recommendation. Therein, detailed performance criteria for a cable are recommended.

Recommended technical requirements are detailed by reference to IEC 60794-3-11 on outdoor optical fibre cables for duct, directly buried, and lashed aerial applications. Changes and additions to these requirements suitable to the duct and tunnel cable applications are recommended herein.

Required conditions may differ from the installation environment. Therefore, instances where agreement on detailed conditions should be determined between customer and manufacturer are stated.

This version of Recommendation ITU-T L.100 adds the electrical continuity test for continuous metallic elements. Scope, References, fibre dimensions, Annex A and Bibliography are also updated.

History *

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Duct, environmental condition, mechanical characteristics, optical fibre cable, test method, tunnel.

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FOREWORD

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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.

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Recommendation ITU-T L.100

Optical fibre cables for duct and tunnel application

1 Scope

This Recommendation:

- refers to single-mode optical fibre cables installed by the pulling method to be used for telecommunication networks in ducts and tunnels;
- recommends that optical fibre dimensional and transmission characteristics should comply with one or more of [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656], [ITU-T G.657] and [IEC 60793-2-50];
- deals with mechanical, environmental, and electrical characteristics of optical fibre cables that are installed in the ducts or tunnels;
- refers to the technical specifications of [IEC 60794-3-11] as applicable to the concerned optical fibre cables;
- recommends performance criteria for those tests that are relevant to the duct and the tunnel application space.

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 (2024), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable*.
- [ITU-T G.650.2] Recommendation ITU-T G.650.2 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.
- [ITU-T G.650.3] Recommendation ITU-T G.650.3 (2017), *Test methods for installed single-mode optical fibre cable links*.
- [ITU-T G.652] Recommendation ITU-T G.652 (2016), *Characteristics of a single-mode optical fibre and cable*.
- [ITU-T G.653] Recommendation ITU-T G.653 (2010), *Characteristics of a dispersion-shifted, single-mode optical fibre and cable*.
- [ITU-T G.654] Recommendation ITU-T G.654 (2020), *Characteristics of a cut-off shifted single-mode optical fibre and cable*.
- [ITU-T G.655] Recommendation ITU-T G.655 (2009), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.
- [ITU-T G.656] Recommendation ITU-T G.656 (2010), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.
- [ITU-T G.657] Recommendation ITU-T G.657 (2016), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable*.

- [ITU-T K.29] Recommendation ITU-T K.29 (1992), *Coordinated protection schemes for telecommunication cables below ground.*
- [ITU-T K.47] Recommendation ITU-T K.47 (2012), *Protection of telecommunication lines against direct lightning flashes.*
- [ITU-T L.108] Recommendation ITU-T L.108 (2018), *Optical fibre cable elements for microduct blowing-installation application.*
- [ITU-T L.126] Recommendation ITU-T L.126/L.27 (1996), *Method for estimating the concentration of hydrogen in optical fibre cables.*
- [ITU-T L.161] Recommendation ITU-T L.161/L.46 (2000), *Protection of telecommunication cables and plant from biological attack.*
- [IEC 60304] IEC 60304:1982, *Standard colours for insulation for low-frequency cables and wires.*
- [IEC 60331-25] IEC 60331-25:1999, *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements – Optical fibre cables.*
- [IEC 60332-1-2] IEC 60332-1-2:2004, *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame.*
- [IEC 60332-3-24] IEC 60332-3-24:2018, *Tests on electric and optical fibre cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C.*
- [IEC 60708] IEC 60708:2005, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath.*
- [IEC 60754-1] IEC 60754-1:2011+AMD1:2019 CSV Consolidated version, *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the halogen acid gas content.*
- [IEC 60754-2] IEC 60754-2:2011+AMD1:2019 CSV Consolidated version, *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity.*
- [IEC 60793-1-21] IEC 60793-1-21:2001, *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry.*
- [IEC 60793-1-32] IEC 60793-1-32:2018, *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability.*
- [IEC 60793-1-40] IEC 60793-1-40:2019, *Optical fibres – Part 1-40: Attenuation measurement methods.*
- [IEC 60793-2-50] IEC 60793-2-50:2018, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres.*
- [IEC 60794-1-1] IEC 60794-1-1:2023, *Optical fibre cables – Part 1-1: Generic specification – General.*
- [IEC 60794-1-2] IEC 60794-1-2:2021, *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures – General guidance.*
- [IEC 60794-1-21] IEC 60794-1-21:2015+AMD1:2020 CSV Consolidated version, *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods.*

- [IEC 60794-1-23] IEC 60794-1-23:2019, Optical fibre cables – *Part 1-23: Generic specification – Basic optical cable test procedures – Cable element test methods.*
- [IEC 60794-1-31] IEC 60794-1-31:2021, Optical fibre cables – *Part 1-31: Generic specification – Optical cable elements – Optical fibre ribbon.*
- [IEC 60794-1-215] IEC 60794-1-215:2020, Optical fibre cables – *Part 1-215: Generic specification – Basic optical cable test procedures – Environmental test methods – Cable external freezing test, Method F15.*
- [IEC 60794-1-219] IEC 60794-1-219:2021, Optical fibre cables – *Part 1-219: Generic specification – Basic optical cable test procedures – Material compatibility test, method F19.*
- [IEC 60794-1-310] IEC 60794-1-310:2022, Optical fibre cables – *Part 1-310: Generic specification – Basic optical cable test procedures – Cable element test methods – Strippability, method G10.*
- [IEC 60794-1-403] IEC 60794-1-403:2021, Optical fibre cables – *Part 1-403: Generic specification – Basic optical cable test procedures – Electrical test methods – Electrical continuity test of cable metallic elements, method H3.*
- [IEC 60794-3] IEC 60794-3:2022, Optical fibre cables – *Part 3: Outdoor cables – Sectional specification.*
- [IEC 60794-3-11] IEC 60794-3-11:2010, Optical fibre cables – *Part 3-11: Outdoor cables – Product specification for duct, directly buried, and lashed aerial single-mode optical fibre telecommunication cables.*
- [IEC 60811-202] IEC 60811-202:2012+AMD1:2017+AMD2:2023 CSV Consolidated version, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 202: General tests – Measurement of thickness of non-metallic sheath.*
- [IEC 60811-203] IEC 60811-203:2012, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 203: General tests – Measurement of overall dimensions.*
- [IEC 60811-501] IEC 60811-501:2012+AMD1:2018+AMD2:2023 CSV Consolidated version, *Electric and optical fibre cables – Test methods for non-metallic materials – Part 501: Mechanical tests – Tests for determining the mechanical properties of insulating and sheathing compounds.*
- [IEC 61034-1] IEC 61034-1:2005+AMD1:2013+AMD2:2019 CSV Consolidated version, *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus.*
- [IEC 61034-2] IEC 61034-2:2005/AMD2:2019, Amendment 2 – *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements.*
- [IEC 61196-1-313] IEC 61196-1-313:2009, *Coaxial communication cables –Part 1-313: Mechanical test methods – Adhesion of dielectric and sheath.*
- [ISO 11357-6] ISO 11357-6:2018, *Plastics – Differential scanning calorimetry (DSC) – Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT).*

3 Definitions

3.1 Terms defined elsewhere

For the purpose of this Recommendation, the definitions given in [ITU-T G.650.1], [ITU-T G.650.2], [ITU-T G.650.3] and [IEC 60794-1-1] apply.

Other terms used, particularly in referencing IEC test procedures and specifications, are per [IEC 60794-1-1] and other IEC specifications specifically referenced.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 attenuation and attenuation coefficient: Attenuation is used, herein, for brevity and convenience, with the understanding that values on a per length basis – dB/km – are, most correctly, attenuation coefficient.

3.2.2 cable weight (W): Force (N) exerted from the weight of 1 km of the cable that is suspended vertically.

3.2.3 jacket: One or more polymer coverings comprising the main protection of the fibre cable as part of a sheath; inner jackets or outer jackets may be used, as necessary.

3.2.4 sheath: An assembly of cable elements surrounding and protecting the fibre core; including, but not limited to, jacket(s), strength member(s), armour(s), moisture barrier(s), etc. as necessary.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BoL	Beginning of Life, as applied to cable testing and criteria
d	Outer diameter, as of a cable, core tube, or other element described in the usage (see clause 6.2.3.1)
DS	Detailed Specification
EoL	End of Life, as applied to cable testing and criteria
L _L	Long-term, or residual, load rating of a cable
L _S or L _M	Tensile rating of a cable
OD	Outer Diameter
OIT	Oxidative Induction Time, as applied to polyolefin materials
r or R	Radius of the element described
SZ	Reverse oscillating stranding

5 Conventions

None.

6 Characteristics of optical fibres and cables

6.1 Optical fibre characteristics

The following optical fibre types should be considered for use in the cables of this Recommendation, based on the agreement between manufacturers and customers. Single-mode optical fibres should be used as described in [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656]

or [ITU-T G.657]. The corresponding IEC fibre category designations are shown in Appendix V of [b-ITU-T G Suppl.40].

6.1.1 Transmission characteristics

The typical transmission characteristics are described for each optical fibre in its respective Recommendation. Unless specified otherwise by the users of the Recommendations, those values apply to the corresponding cabled optical fibre.

The maximum point discontinuity at the operating wavelength(s) for fibres should be in accordance with [IEC 60794-1-1].

6.1.2 Fibre microbending loss

Severe bending of an optical fibre involving local axial displacement of a few micrometres over short distances caused by localized lateral forces along its length can result in additional attenuation in the optical fibre and is called microbending loss. This may be caused by manufacturing and installation strains, and also during operation by dimensional variations of cable materials due to temperature changes.

Microbending can cause an increase in the optical loss. In order to reduce microbending loss, stress randomly applied to a fibre along its axis should be minimized during the incorporation of the fibres into the cable, as well as during and after the cable installation.

6.1.3 Fibre macrobending loss

Macrobending is the resulting curvature, typically several mm in the radius of the element described (R), of an optical fibre.

Macrobending of an optical fibre after cable manufacture and installation can cause an increase in the optical loss. The optical loss caused by macrobending typically increases as the bending radius is reduced.

NOTE – [ITU-T G.657] optical fibres are optimized for reduced macrobending loss.

6.1.4 Fibre dimensions

Mode field diameter and cladding diameter are defined by the ITU-T G.65x-series Recommendations.

The overall fibre dimensions and related characteristics such as non-circularity and concentricity are important in the performance of cabled fibre and in the splicing and connectorization of fibres. Accordingly, [IEC 60793-2-50] specifies critical values and measurement methods. The range of fibre outer coating diameter should be in accordance with [IEC 60793-2-50].

6.2 Mechanical characteristics

6.2.1 Evaluation of mechanical characteristics

Cable mechanical characteristics should be evaluated using the test methods and requirements of [IEC 60794-3-11], and applicable recommendations in clause A.3.

6.2.2 Tensile strength

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 (e.g., temperature variation) during operation. Changes in the tension of the cable due to the variety of factors encountered during the service life of the cable can cause differential movement of the cable components. This effect should be considered in the cable design. Excessive cable tensile loading may increase the optical loss and may cause increased residual strain in the fibre if the cable cannot relax. When a cable is subjected to permanent loading during its operational life, the fibre should not experience strain beyond values that adversely affect fibre reliability (see clause A.3.1). To avoid these issues, the maximum tensile

strength determined by the cable construction, especially the design of the strength member, should not be exceeded.

6.2.2.1 Tensile ratings

The standard tensile rating, tensile rating of a cable L_S (or L_M), of cables per this Recommendation should be:

1.5 W , where W is the force (N) exerted from the weight of 1 km of the cable that is suspended vertically.

If the result exceeds 2 700 N, the tensile rating should be 2 700 N.

The long-term or residual, load rating of a cable (L_L) tensile rating, L_L should be 30 per cent of the tensile rating L_S .

6.2.3 Bending

Under the dynamic conditions encountered during installation, the fibre is subjected to strain from both cable tension and bending. The strength elements in the cable and the installation bend diameter should be selected to limit this combined dynamic strain. Routing and storage may result in permanent bends after installation. Any fibre bend radius remaining after the cable installation should be large enough to limit the macrobending loss or long-term strain limiting the lifetime of the fibre.

Minimum bending diameter is an important parameter for the physical integrity of the sheath, for fibre strain limitation, and for fibre attenuation performance due to macrobending loss. Cables with smaller core structures can be bent to relatively smaller bend diameters than cables having larger core structures.

6.2.3.1 Minimum bending diameter

The standard minimum bending diameters for cables should be declared by the manufacturer. Cable bending diameters are defined as:

Residual (installed): $20 \times$ cable OD or $30 \times$ cable OD,

Loaded condition (during installation): $40 \times$ cable OD.

For very small cables such as microduct cables, manufacturers may specify a fixed cable minimum bending diameter that is independent of the cable's outer diameter (OD). It should also be noted that the minimum bending diameter changes depending on the cable structure, such as the design and configuration of the strength members.

NOTE – Some cable tests and specifications declare the bending criteria in terms of the radius of the apparatus or sheave. Care should be taken to avoid incorrect testing.

6.2.4 Crush

A duct or tunnel cable may be subjected to crush both during installation and the operational life. Characteristically, the crushing incident involves a relatively short length of the cable. The crushing may be short-term, as during installation, or may be long-term as over the operational life of the cable.

The cable is constructed to isolate the optical fibres from external compressive forces. The construction and dimensions of the cable affect the resistance of the cable to performance degradation due to crushing.

Crushing may damage the physical integrity of the cable or may increase the optical loss (either temporarily or permanently). Excessive stress may lead to fibre fracture.

6.2.5 Impact

A duct or tunnel cable may be subjected to impact both during installation and the operational life. Although in either case, the impact is a transient event, still it could result in the cable performance deformation and affect the cable over its operational life.

Cable is constructed to isolate the optical fibres from external compressive forces. The construction and dimensions of the cable affect the resistance of the cable to performance degradation due to impact.

Impact may damage the physical integrity of the cable or may increase the optical loss (either temporarily or permanently). Excessive stress may lead to fibre fracture.

Characteristically impact could cause visible cracks, splits, tears, or other openings on the outer surface of the cable jacket.

6.2.6 Torsion

Under dynamic conditions encountered during installation and operation, a duct or tunnel cable may be subjected to torsion. This may be under tension during installation and the torsion may remain after the installation is complete. The torsion may be due to the coiling of the cable during installation and will often remain over the operational life of the cable. Torsion may result in optical loss of the fibres and/or damage to the sheath including the splitting of the sheath. The cable should be sufficiently robust to resist twisting, and its design should accommodate a reasonable number of cable twists per unit length without an increase in optical loss and/or damage to the sheath.

Characteristically torsion could cause visible cracks, splits, tears, or other openings on the outer surface of the cable jacket.

6.2.7 Vibration

Vibration effects on duct and tunnel cables may occur when the cables are installed on structures or in areas where vibrations can be transmitted to the duct or the installed cable.

When optical fibre cable ducts are installed on bridges, they will be subject to relatively high amplitude vibrations of various low frequencies, depending on the bridge construction and on the type of traffic density. Underground optical fibre cables in ducts or tunnels may be subject to persistent vibrations from traffic, railways, etc., or vibrations from infrequent activities such as pile-driving and blasting operations.

In all cases, cables should withstand these vibrations without failure or performance degradation.

Care should be exercised in the choice of the installation method. A well-established surveillance routine can identify the vibration activity, allowing for a careful choice of route to minimize this problem.

6.3 Environmental characteristics

6.3.1 Evaluation of environmental characteristics

Cable environmental characteristics should be evaluated using the test methods and requirements of [IEC 60794-3-11], and applicable discussion in clause A.4.

6.3.2 Temperature variations

During their operational lifetime, cables may be subjected to significant temperature variations. In these conditions, the increase of attenuation of the fibres should not exceed the specified limits.

Duct and tunnel cables will typically experience a less severe range of temperature variations than other outdoor cables. However, parts of these cables may be deployed above ground or may experience freezing within their duct or tunnel. Also, these cables may be deployed in a high