International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.78
(05/2008)

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

Optical fibre cable construction for sewer duct applications

Recommendation ITU-T L.78

ITU-T

Recommendation ITU-T L.78

Optical fibre cable construction for sewer duct applications

Summary

Recommendation ITU-T L.78 describes the characteristics, construction and test methods for optical fibre cables to be installed in sewer ducts and drainpipes. The characteristics that a cable should have for an optical fibre to perform appropriately are described. Also, 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 need to be agreed upon between the user and manufacturer for the environment in which the cable is to be used.

Source

Recommendation ITU-T L.78 was approved on 29 May 2008 by ITU-T Study Group 6 (2005-2008) under Recommendation ITU-T A.8 procedure.

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.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

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/.

CONTENTS

Introduction

With the growth of fibre-to-the-home (FTTH) services, there is an increasing demand for ducts and tunnels in which to install optical fibre cables. However, in metropolitan areas it is difficult to increase the number of ducts and/or tunnels because of the cost and interference with traffic that it would involve. To install optical fibre cables in sewer ducts is one possible way to solve the duct shortage problem. However, the sewer pipe environment is different from that of ducts designed for telecommunication. Therefore, the required characteristics also differ from those for standard underground cables. This Recommendation is developed for this reason.

Recommendation ITU-T L.78

Optical fibre cable construction for sewer duct applications

1 Scope

This Recommendation:

– refers to optical fibre cables to be used for telecommunications networks in sewer ducts and/or drainpipes;

– deals with the mechanical and environmental characteristics of optical fibre cables for sewer applications. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with [IEC 60793-2-10], [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656] and [ITU-T G.657], which deal with a multi-mode graded index optical fibre and single-mode optical fibres, respectively;

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

– acknowledges that some optical fibre cables may contain metallic elements, for which reference should be made to [b-ITU-T Plant] (see [ITU-T L.1]), and 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 (2002), *Definitions and test methods for linear, deterministic attributes of single-mode fibre and cable.*

[ITU-T G.651.1] Recommendation ITU-T G.651.1 (2007), *Characteristics of a 50/125 µm multimode graded index optical fibre cable for the optical access network.*

[ITU-T G.652] Recommendation ITU-T G.652 (2005), *Characteristics of a single-mode optical fibre cable.*

[ITU-T G.653] Recommendation ITU-T G.653 (2003), *Characteristics of a dispersion-shifted single-mode optical fibre and cable.*

[ITU-T G.654] Recommendation ITU-T G.654 (2004), *Characteristics of a cut-off shifted single-mode optical fibre and cable.*

[ITU-T G.655] Recommendation ITU-T G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable.*

[ITU-T G.656] Recommendation ITU-T G.656 (2004), *Characteristics of a fibre and cable with non-zero dispersion for wideband optical transport*.

[ITU-T G.657] Recommendation ITU-T G.657 (2006), *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 cables and wires with PVC insulation and PVC sheath – Part 1: General test and measuring methods.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/038026?opendocument>

[IEC 60793-1] IEC 60793-1 (in force), *Optical fibres – Part 1: Measurement methods and test procedures.* <http://webstore.iec.ch/webstore/webstore.nsf/searchview/?searchView=&Query=iec%2060793-1>

[IEC 60793-1-32] IEC 60793-1-32 (2001), *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/027456?opendocument>

[IEC 60793-2-10] IEC 60793-2-10 (2007), *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/038047?opendocument>

[IEC 60794-1-1] IEC 60794-1-1 (2001), *Optical fibre cables – Part 1-1: Generic specification – General.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/027459?opendocument>

[IEC 60794-1-2] IEC 60794-1-2 (2003), *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/030610?opendocument>

[IEC 60794-2] IEC 60794-2 (2002), *Optical fibre cables – Part 2: Indoor cables – Sectional specification.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/029611?opendocument>

[IEC 60794-2-10] IEC 60794-2-10 (2003), *Optical fibre cables – Part 2-10: Indoor cables – Family specification for simplex and duplex cables.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/029687?opendocument>

[IEC 60332-1] IEC 60332-1 (1979), *Tests on electric and optical fibre cables under fire conditions – Part 1: Test for vertical flame propagation for a single insulated wire or cable.* <http://webstore.iec.ch/webstore/webstore.nsf/searchview/?searchView=&Query=iec%2060332-1>

[IEC 60332-3-24] IEC 60332-3-24 (2000), *Tests on electric cables under fire conditions – Part 3-24: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category C.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/026437?opendocument>

[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.* <http://webstore.iec.ch/webstore/webstore.nsf/artnum/019243?opendocument>

[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*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/017216?opendocument>

[IEC 61034-1] IEC 61034-1 (2005), *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus.*
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/034053?opendocument>

[IEC 61034-2] IEC 61034-2 (2005), *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements*.
<http://webstore.iec.ch/webstore/webstore.nsf/artnum/034054?opendocument>

[EIA/TIA-598] EIA/TIA-598 (2000), *Color Coding of Fiber Optic Cables*.
<http://global.ihs.com/search_res.cfm?RID=TIA&INPUT_DOC_NUMBER=EIA%2FTIA%2D598>

3 Definitions

For the purpose of this Recommendation, the definitions given in [ITU-T G.650.1] and [ITU-T G.651.1] apply.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

APL Aluminium Polyethylene Laminate

CSM Central Strength Member

PBT Polyethylene Terephthalate

5 Characteristics of the optical fibres and cables

5.1 Optical fibres

The optical fibres described in [IEC 60793-2-10] and [ITU-T G.652], [ITU-T G.653], [ITU-T G.654], [ITU-T G.655], [ITU-T G.656] and [ITU-T G.657] should be used.

5.2 Mechanical characteristics

If mechanical forces (e.g., expanding, 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.

5.2.1 Bending

Cable bending during installation and operation may impose strain on fibres, and this may affect fibre strength. 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.

5.2.2 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 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.

5.2.3 Crushing 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.

5.2.4 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.

5.3 Environmental conditions

The environmental conditions in a sewer pipe may be harsh compared with those experienced by conventional underground cables. This clause describes expected environmental conditions that require consideration when designing optical fibre cables for sewer applications.

5.3.1 Temperature variation

Temperature variation strongly depends on climatic conditions and the temperature of liquid passing through a sewer pipe. Therefore, it is important to examine the expected temperature range during a cable's 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.

5.3.2 Rodent attack

Rodents may be found in sewer pipes. Where those rodents cannot be excluded, a suitable and effective protection should be provided. Further information is described in [ITU-T L.46].

Effective protection can be provided by metallic (steel tape or wire armouring) or non-metallic (e.g., fibreglass rods, glass yarns/tapes) barriers.

5.3.3 Chemical attack

Although it is undesirable, there is a possibility that certain kinds of chemical agent will flow through a sewer pipe. After installation, contact with several chemical material agents may degrade the cable sheath characteristics, leading to the weakening of the cable core protection.

To avoid this problem, cable sheath materials should be selected carefully, based on their robustness with regard to chemical agents. First of all, it is important to assess what kind of chemical agents may exist in the area where the cable is to be laid. Then, sheath material durability with respect to these chemical agents should be examined.

5.3.4 High humidity

A highly humid environment may result in moisture permeation, depending on the cable sheath structure. When moisture permeates the cable sheath and is present in the cable core, the tensile strength of the fibre deteriorates and the time-to-static failure will be reduced. To ensure a satisfactory cable lifetime, the long-term strain level of the fibre must be limited.

Various materials can be used as barriers to reduce the rate of moisture permeation. Alternatively, filled metal-free cable construction can be used.

NOTE – If required, minimum permeation is achieved by using a longitudinal overlapped metallic foil. A continuous metallic barrier is effective in preventing moisture permeation.

5.3.5 Water immersion

When an optical fibre cable is soaked in water, moisture permeation and water penetration may be caused depending on the cable structure. With respect to the moisture permeation issue, see clause 5.3.4. When there is a crack in the cable sheath, water may soak into the cable core. Water immersion 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 being immersed in water.

5.4 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 indoor applications should comply with the fire safety regulations of each country or telecommunication carrier.

6 Cable construction

6.1 Fibre protection

6.1.1 Primary coated fibre

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

6.1.2 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 15 to 25 mm for fibre splicing.
– A semi-tight buffer should be easily removable over a length of 300 to 2000 mm for fibre splicing.
– With a tight buffer, the nominal diameter should be between 300 and 1000 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.

6.1.3 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.

6.2 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.

6.2.1 Tube

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

6.2.2 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 in excess of those agreed between manufacturers and customers. The strength member may be either metallic or non-metallic.

Cable for sewer 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 installation conditions is necessary to design a cable strength member for use in sewer applications.

6.3 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 maximum and minimum allowable overall diameter 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 indoor cables from the viewpoint of fire safety.

6.4 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 armour is provided.

Armouring for metal-free cable may consist of Aramid yarns, fibre-glass reinforced strands or strapping tape, etc.

6.5 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. Any material used should not be harmful to human beings. The materials in the cable should be compatible with each other, and in particular should not adversely affect the fibre. These materials should not hinder splicing and/or connection.

6.6 Cable identification

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

7 Test methods

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

7.1 Test methods for cable elements

7.1.1 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 [ITU-T G.651.1] and the IEC 60793-1-series.

7.1.1.1 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.

7.1.1.2 Coating strippability

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

7.1.1.3 Compatibility with filling material

When fibres contact a filling material, the stability of the fibre coating and the filling material should be examined by tests after accelerated aging.

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

Dimension stability and coating transmissivity should be examined by using a test method agreed upon by the user and supplier.

7.1.2 Tests applicable to tubes

7.1.2.1 Tube kink

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

7.2 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 IEC 60794-1-series.

7.2.1 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 IEC 60794-1-2 E1A.

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 identical to those of [IEC 60794-2-10].

7.2.2 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 IEC 60794-1-2 E11A.

The test conditions shall be identical to those of [IEC 60794-2-10].

7.2.3 Flexing

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

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

The test conditions should be identical to those of [IEC 60794-2-10].

7.2.4 Crushing

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

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

The test conditions shall be identical to those of [IEC 60794-2-10].

7.2.5 Torsion

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

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

The test conditions should be identical to those of [IEC 60794-2-10].

7.2.6 Impact

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

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

The test conditions shall be identical to those of [IEC 60794-2-10].

7.2.7 Kink

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

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

The test conditions should be identical to those of [IEC 60794-2-10].

7.2.8 Vibration (optional)

For further study.

7.2.9 Repeated bending

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

The test conditions shall be identical to those of [IEC 60794-2-10].

7.2.10 Repeated bending at low temperature (optional)

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

The test conditions should be identical to those of [IEC 60794-2-10].

7.3 Test methods for environmental characteristics

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

7.3.1 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 IEC 60794-1-2 F1.

7.3.2 Vibration

For further study.

7.4 Test methods for fire safety

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

7.4.1 Flame retardant characteristics

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

7.4.2 Toxic gases characteristics (optional)

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

7.4.3 Smoke characteristics (optional)

This test shall be carried out in accordance with the method described in [IEC 61304-1] or [IEC 61304-2], unless there is an agreement between the manufacturer and user.

Appendix I

Chinese experience
Construction of self-supporting optical fibre cables for sewer applications

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

I.1 Cable design

In order to ensure the moisture-proof, anti-corrosion and mechanical performance of the cable, two cable structures have been recommended, as shown in Figures I.1 and I.2. Figure I.1 shows a stranded plastic loose tube structure. The outstanding characteristic of the cable is that Aramid yarn is adopted for the strength member to enhance the tensile strength of the cable, so that the cable can be directly suspended in the drainpipes. Meanwhile, the cable possesses an inner sheath and an outer sheath. The material of the outer sheath is High Density Polyethylene (HDPE), which can guarantee the anti-corrosion performance of the cable; PE-coated aluminium tape is affixed to the inner sheath of the cable as a chemical and moisture barrier. Figure I.2 displays a central metallic loose tube structure. If necessary, a PE inner sheath can be extruded on the tube over which several small diameter stainless steel wires are stranded. These steel wires are covered with an outer sheath made of HDPE. In this structure, the metallic loose tube can act as a good moisture barrier and the steel wires can ensure that the cable has sufficient tensile strength for cable installation.

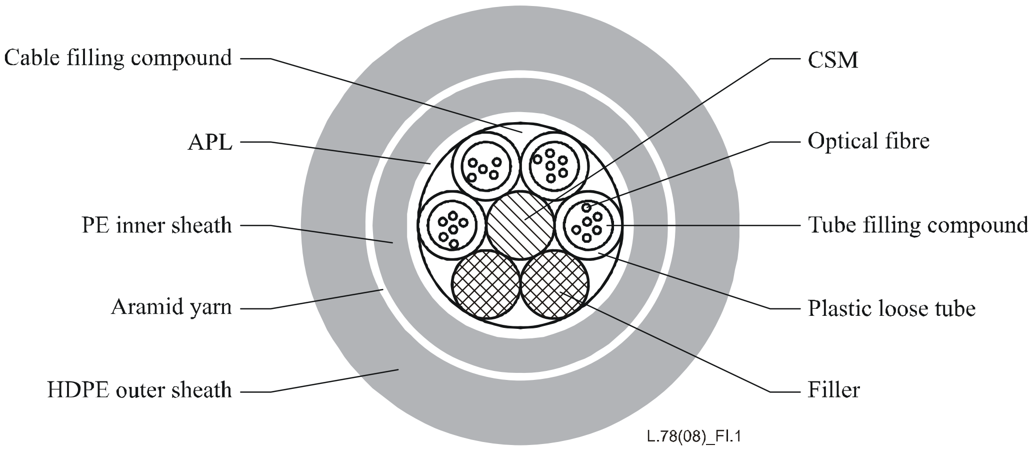

Figure I.1 – Self-supporting cable with stranded plastic loose tube structure deployed in drainpipes

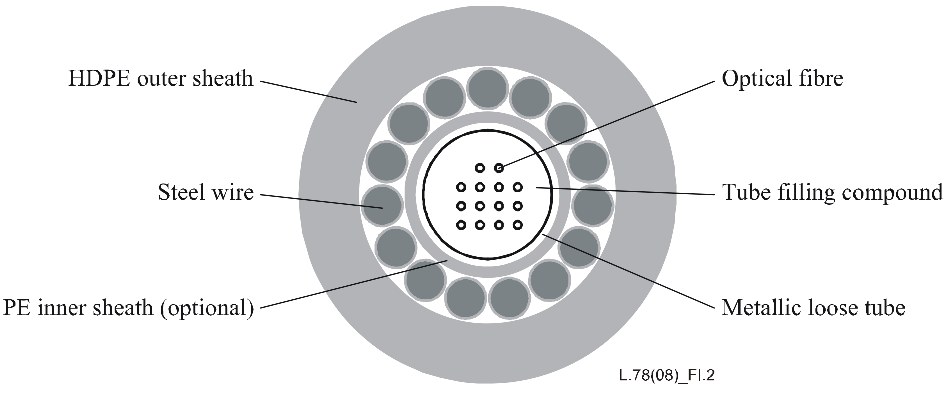

Figure I.2 – Self-supporting cable with central metallic loose tube structure deployed in drainpipes

The above two cable designs adopt self-supporting structures so that the cables can be directly suspended at the top part of the drainpipes. Compared with cable deployment with robots or other installation methods such as placing the cable in HDPE pipes suspended by stranded steel wires in advance, the deployment of these self-supporting cables is simple and cost-effective. Both cable structures have already been successfully deployed in China.

I.2 Fibre identification

The optical fibres in the loose tube should be identified by 12 different colours according to international standards. If the number of fibres in one tube does not exceed 12, the fibre colour should be selected according to the priority shown in Table I.1. Generally, the natural colour of the fibre can replace white in the Table as long as it does not affect fibre identification. If the number of fibres in one tube is more than 12, the fibres can be bundled by using yarn and identified by the colour of the yarn, or they can be identified by the coloured ring markings applied along the fibres. The colour of the yarn or the ring marking should also be selected according to the priority shown in Table I.1.

Table I.1 – Colour code for fibre identification

Priority	**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

I.3 Mechanical performance of the cable

The mechanical performance of the cable includes the following items: tensile strength, crush resistance, impact, repeated bending, torsion, coiling, flexing and sheath abrasion. Tensile strength is a very important index for self-supporting cables installed in drainpipes. According to chinese experience in cable design and installation, the maximum sag of the cable after installation should not exceed 3% of the cable suspension span (i.e., the span of two adjacent manholes). In addition, there should be no significant fibre strain during the long-term operation of the cable.

The minimum allowable bending radius of the cable will be stated as the cable outer diameter D multiplied by a number, which is described as follows:

a) Minimum allowable bending radius (during installation): 20D

b) Minimum allowable bending radius (after installation): 10D

The main items reflecting the mechanical performance of the cable are shown in Table I.2.

Table I.2 – Mechanical performance of the cable

Item			Technical requirements	
			Short-term	Long-term
Tensile strength	Allowable tensile strength (N)		≥2.5 G	
	Fibre strain (%)	Core network	No significant fibre strain	
		Other networks	≤0.05	
	Attenuation change (dB)		No significant attenuation change	
Crush resistance	Allowable crush (N/100 mm)		2200	1000
	Attenuation change (dB)		No significant attenuation change	
Impact			Load: 1000 g, 1 m high, 5 points at intervals of 0.5 m, 5 times at each point	
Repeated bending			Load: 250 N, 30 cycles	
Torsion			Axial load: 250 N, 1 m long, ±90°, 10 cycles	
Coiling			10 coils each cycle, more than 5 cycles	
Flexing			Outer diameter of pulley: 250 mm, Load: 150 N, 10 cycles	
Sheath abrasion			Load: 65 N Diameter of steel needle: 1 mm	
NOTE – The maximum sag of the cable should not exceed 3% of the cable suspension span. Assuming that the safety coefficient is 1.2, the tensile strength of the cable should be no less than 2.5 G (G is the cable weight per kilometre, unit: N)				

I.4 Environmental characteristics of the cable

The environmental characteristics of the cable include the following items: attenuation change under certain temperatures, dripping performance, sheath integrity, water-blocking performance, bending performance at low temperature, and impact resistance at low temperature.

I.4.1 Attenuation change under certain temperatures

The environment in which the cable can be used is divided into three categories according to the extreme temperatures on each occasion (categories A, B and C). The attenuation change in each category can be also classified into three grades, as illustrated in Table I.3.

Table I.3 – Attenuation change under certain temperatures

Category	Temperature range [°C]		Allowable attenuation change of single-mode fibre (dB/km)		
	Extreme low temperature	Extreme high temperature	Grade I	Grade II	Grade III
A	–40	+60	No remarkable attenuation change	≤0.05	≤0.10
B	–30	+60			
C	–20	+60			
NOTE – The attenuation change refers to the difference between the fibre attenuation at 20°C and that at a certain temperature.					

I.4.2 Dripping performance

No filling compound or coating compound should drip from the cable after it has been kept at 70°C for 24 hours.

I.4.3 Sheath integrity

The sheath of the cable should be continuous and intact; and its integrity must be verifiable by electrical methods.

If the electric spark test is adopted to verify the sheath integrity, the sheath should not break down under the test voltage described in Table I.4.

Table I.4 – Voltage in electric spark test

Voltage type	DC (kV)	AC (kV)
Test voltage (minimum value)	9t, maximum 25	6t, maximum 15
NOTE 1 – t is the nominal wall thickness of the sheath, unit: mm. NOTE 2 – AC test voltage is the virtual value.		

If the water-soaking test is adopted to verify the sheath integrity, the electrical characteristics of the cable after it has been soaked in water for 24 hours should conform to the following:

1) The insulation resistance must be no less than 2000 MΩ.km when tested under a DC voltage of 500 V.

2) No breakdown is observed as regards the sheath under a DC voltage of 15 kV for at least 2 minutes.

I.4.4 Water-blocking performance

No water permeation at the other end of the cable is allowed when a one-metre-high water head has been imposed on one end of three-metre-long cable samples for 24 hours (this does not apply to the steel wire armour of the cable).

I.4.5 Bending performance at low temperature

The cable should have the ability to withstand U-shaped bending at –20°C with a bending radius 15 times the cable diameter.

I.4.6 Impact resistance at low temperature

The cable should be resistant to impact down to –20°C.

Appendix II

Italian experience
Construction of optical fibre cables for sewer applications

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

II.1 General design of the cable

The cable is designed to ensure the transmission of proper light-wave information and to protect the optical fibres against water pressure, chemical corrosion/aggression, moisture/water penetration and the effect of hydrogen contamination throughout the designed life of the cable.

Moreover, the fibres are protected from any external stress, either axial or radial, by being loosely contained in a structure that has been designed to guarantee a suitable degree of fibre movement and also by means of an external aluminium tube.

II.2 Description of cable structure

– Dielectric central element: fibreglass reinforced with a polyethylene (PE) sheath.
– Optical core: 6 loose tubes, stranded over the central element, containing up to 24 fibres, each filled with a non-hygroscopic jelly compound.
– Protection of optical core: water-blocking tapes, an outside polyethylene sheath and an aluminium tube.
– Mechanical protection: a peripheral strength member consisting of a single layer of aluminium clad steel (ACS) wires, is stranded over the aluminium tube.
– Protection of ACS: a longitudinally welded corrugated stainless steel tube is used to cover the ACS wires.
– Other protection materials: a plastic tape may be inserted under the corrugated tube to lower the friction coefficient between the ACS wires and steel tube and to make it easy to remove the outer tube from the inside part of the cable.
– External protection: an outer sheath completes the cable construction. The material of the outer sheath is high-density polyethylene (HDPE).

II.3 Main performance characteristics of the cable

Very high mechanical protection – high resistance to pulling load and transversal stresses.

High chemical resistance to corrosive agents.

The cable can be installed using conventional techniques, e.g., by pulling, so there is no need for robotized installation.

The cable is laid directly at the bottom of the sewer.

The optical core is sheathed so it can be used as a conventional all-dielectric cable (e.g., from the sewer and the splicing box which, for technical reasons, can be located far from the sewer itself).

Radial penetration of water or moisture is prevented by two metallic barriers (an extruded aluminium tube and a corrugated steel tube).

Longitudinal penetration of water is avoided by using water blocking tape bedding and/or jelly compound filling or some other kind of water blocking material.

II.4 Other characteristics of the cable

There is no need to fix the cable along the sewer because it is heavy enough to remain in place on the ground.

If necessary, the cable can be removed directly by means of outside operations.

If needed, the mechanical protection can be easily removed to allow access to the optical core.

Ten-metre cable lengths are easily allowable.

There is no need to clean or to dry the sewer conduit.

Fibre types

Fibres are in accordance with ITU-T Recommendations and with customer specifications.

The cable can be equipped with G.652, G.655 or any type of telecommunication fibre including such combinations as single mode reduced (SMR) + non-zero dispersion (NZD) fibres (G.652 + G.655 fibres).

Fibre count: from 12 to 144 fibres

In low-count cable, each tube has 12 fibres. In high-count cable (e.g., 144-fibre cable) each tube contains 24 fibres.

Fibre identification

a) 12-fibre tube: fibres are identified by using 12 different colours according to the reference standard.

b) 24-fibre tube: fibres are identified by colours and ring marking applied at a distance of 25 or 50 mm along the fibre (see Table II.2).

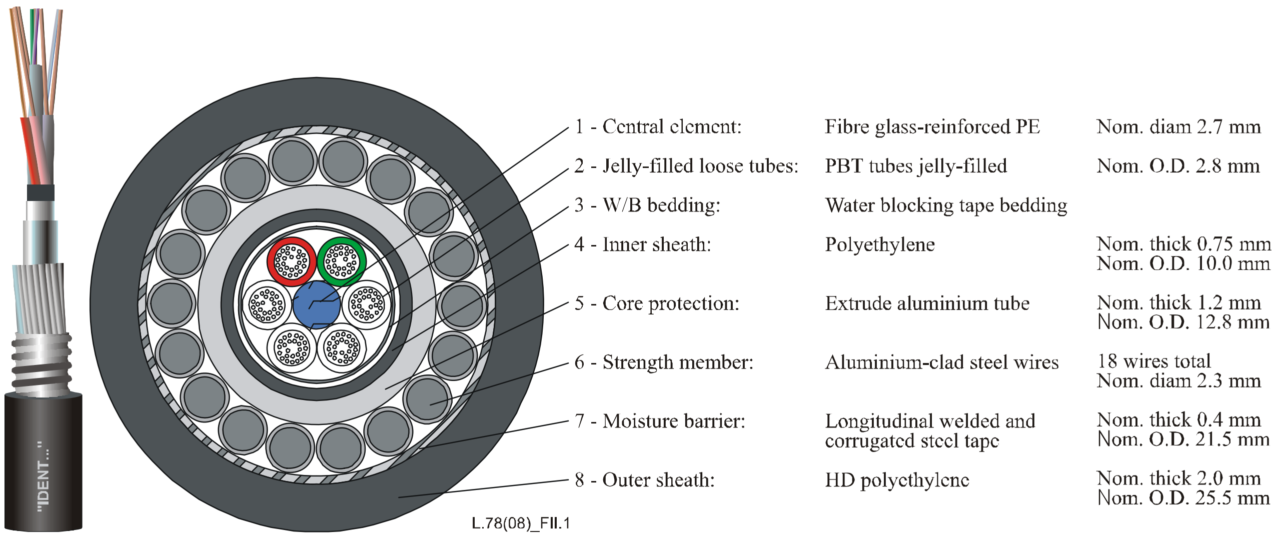

Figure II.1 – Example construction parameters for optical fibre cables used in water conduits or sewers with 144 fibres

Table II.1 – Example colour code of identification (based on [EIA/TIA-598])

No. Fibres	Colour	No. Fibres	Colour
1	Blue	13	Blue with black tracer
2	Orange	14	Orange with black tracer
3	Green	15	Green with black tracer
4	Brown	16	Brown with black tracer
5	Slate	17	Slate with black tracer
6	White	18	White with black tracer
7	Red	19	Red with black tracer
8	Black	20	Black with black tracer
9	Yellow	21	Yellow with black tracer
10	Violet	22	Violet with black tracer
11	Rose	23	Rose with black tracer
12	Aqua	24	Aqua with black tracer

Table II.2 – Example formations

Number of fibres	Number of fibres per tube	Number of filler
12	1 × 12	5
24	2 × 12	4
48	4 × 12	2
96	4 × 24	2
144	6 × 24	–

Table II.3 – Mechanical characteristics of the cable

Test	Reference standard	Nominal values
Nominal outer diameter (mm)	**–**	**25.5**
Estimated weight (kg/m)	–	1.450
Minimum bending radius Only optical core (up to inner PE sheath) repeated bending (100 cycles) Bending under tension	IEC 60794-1-2, E11A or B IEC 60794-1-2, E18 A	10 × diameter – 100 cycles 20 × diameter – 100 cycles 30 × diameter – at 500 N
Tensile performance (N) Permanent Short time	IEC 60794-1-2, E1	30 100
Crush (N/cm)	IEC 60794-1-2, E3	3
Impact (N.m)	IEC 60794-1-2, E4	50
Temperature cycling	IEC 60794-1-2, F1	–30 to 70°C
Water penetration 3 m cable/1 m water × 24 core	IEC 60794-1-2, F5	No failure

Bibliography

[b-ITU-T plant] ITU-T Handbook (1991), *Outside plant: Outside plant technologies for public networks, ITU, Geneva*.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2009