International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.110

(08/2017)

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 direct surface application

Recommendation ITU-T L.110

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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.110

Optical fibre cables for direct surface application

Summary

Recommendation ITU-T L.110 describes characteristics, construction and test methods of optical fibre cables for direct surface application. First, in order that an optical fibre demonstrates sufficient performance, characteristics that a cable should have are described. Then, the method of examining whether the cable has the required characteristic is described.

History

Edition	Recommendation	Approval	Study Group	Unique ID[*]
1.0	ITU-T L.110	2017-08-13	15	11.1002/1000/13295

Keywords

Direct surface application, natural disaster, optical fibre cable, rapid network installation, rural and remote areas.

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[*] To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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Optical fibre cables for direct surface application

1 Scope

This Recommendation describes an optical fibre cable for direct surface application, which has a simple protection structure and easy operability needed for some applications, particularly when it is difficult to prepare conventional installation infrastructures, such as duct, pipe and pole. This Recommendation provides requirements for optical, mechanical and structural characteristics, and test methods for optical fibre cables for direct surface application. Optical fibre cables for direct surface application enable the rapid and/or temporary construction of an optical network. Potential applications include, but are not limited to, network recovery against natural disaster or rapid network installation into rural or remote areas with insufficient infrastructures.

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.650.2]	Recommendation ITU-T G.650.2 (2007), *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 (2008), *Test methods for installed single-mode optical fibre cable links*.
[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 (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 (2016), *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.100] Recommendation ITU-T L.100/L.10 (2015), *Optical fibre cables for duct and tunnel application*.

[ITU-T L.101] Recommendation ITU-T L.101/L.43 (2015), *Optical fibre cables for buried application*.

[ITU-T L.102] Recommendation ITU-T L.102/L.26 (2015), *Optical fibre cables for aerial 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*.

[ITU-T L.430] Recommendation ITU-T L.430/L.28 (2002) *External additional protection for marinized terrestrial cables*.

[ITU-T L.1700] Recommendation ITU-T L.1700 (2016), *Requirement and framework for low-cost sustainable telecommunications infrastructure for rural communications in developing countries*.

[IEC 60793-1-1] IEC 60793-1-1 (2017), *Optical fibres – Part 1-1: Measurement methods and test procedures – General guidance*.

[IEC 60793-1-21] IEC 60793-1-21 (2001), *Optical fibres – Part 1-21: Measurement methods and test procedures – Coating geometry*.

[IEC 60793-1-22] IEC 60793-1-22 (2001), *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*.

[IEC 60793-1-30] IEC 60793-1-30 (2010), *Optical fibres – Part 1-30: Measurement methods and test procedures – Fibre proof test*.

[IEC 60793-1-32] IEC 60793-1-32 (2010), *Optical fibres – Part 1-32: Measurement methods and test procedures – Coating strippability*.

[IEC 60793-2-10] IEC 60793-2-10 (2017), *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*.

[IEC 60793-2-50] IEC 60793-2-50 (2015), *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*.

[IEC 60794-1-1] IEC 60794-1-1 (2015), *Optical fibre cables – Part 1-1: Generic specification – General*.

[IEC 60794-1-2] IEC 60794-1-2 (2017), *Optical fibre cables – Part 1-2: Generic specification – Basic optical cable test procedures – General guidance*.

[IEC 60794-1-21] IEC 60794-1-21 (2015), *Optical fibre cables – Part 1-21: Generic specification – Basic optical cable test procedures – Mechanical tests methods*.

[IEC 60794-1-22] IEC 60794-1-22 (2017), *Optical fibre cables – Part 1-22: Generic specification – Basic optical cable test procedures – Environmental test methods*.

[IEC 60794-1-23] IEC 60794-1-23 (2012), *Optical fibre cables – Part 1-23: Generic specification – Basic optical cable test procedures -Cable element test methods.*

[IEC 60794-3] IEC 60794-3 (2014), *Optical fibre cables – Part 3: Outdoor cables – Sectional specification*.

[IEC 60794-3-10] IEC 60794-3-10 (2015), *Optical fibre cables – Part 3-10: Outdoor cables – Family specification for duct, directly buried and lashed aerial optical telecommunication cables*.

[IEC 60794-3-30] IEC 60794-3-30 (2008), *Optical fibre cables – Part 3-30: Outdoor cables – Family specification for optical telecommunication cables for lakes, river crossings and coastal application*.

[IEC 60794-4] IEC 60794-4 (2003), *Optical fibre cables – Part 4: Sectional specification – Aerial optical cables along electrical power lines*.

[IEC 60811-202] IEC 60811-202 (2012), *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*.

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], [ITU-T G.651.1] and [ITU-T L.102] apply.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 direct surface application: Cable deployment directly on the ground.

3.2.2 maximum allowable tension: The maximum tensile load that may be applied to the cable without detriment to the tensile performance requirement (optical performance, fibre strain).

3.2.3 rated tensile strength: Summation of the product of nominal cross-sectional area, minimum tensile strength and stranding factor for each load-bearing material in the cable construction.

3.2.4 strain margin: The amount of strain the cable can sustain without strain on the fibres due to cable elongation.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DA	Double wire Armouring
DSA	Direct Surface Application
RA	Rocky Armour
SA	Single wire Armouring
SZ	Reverse oscillating stranding
WiMAX	Worldwide interoperability for Microwave Access

5 Conventions

None.

6 Concept/image of optical fibre cables for direct surface application

[ITU-T L.1700] identifies affordability with best-effort reliability as the priority requirements for rural and remote area communication networks in developing countries. Sustainability requires environmental consciousness and reliability/recoverability.

A cable is installed directly on the surface of the ground when it is difficult to prepare conventional infrastructures, such as trench, duct, pipe or pole installations.

The cable should be designed for easy handling and should be robust enough to be installed using affordable installation techniques. If such a cable requires manual installation including shallow burying, submerging or short-length aerial wiring, installation should be by using simple tools such as handy picks, with no heavy machinery.

Since a length of cable exposed on the ground surface could later be covered by the soil, sand, snow or flood water, and may exceptionally need to be suspended in the air to cross a river, valley or road, it should withstand shallow burying, submerging, or short-length aerial wiring.

The cable must, therefore, be robust against disturbances such as crush, biotic attacks, floods, high/low temperatures, strong winds and even wildfires. However, long-term trouble-free operation of the cable under various landforms and changing environmental conditions cannot always be guaranteed. Cables could be exposed simultaneously to the above-mentioned disturbances. The cables could also be used for rapid network recovery following a disaster or for deployment of a network for temporal use. Thus, specific tests or specific conditions, in addition to usual tests, should be agreed upon by users and suppliers as necessary. Specific tests for cable installation methods and processes may also be agreed upon by users, suppliers and local communities.

7 Characteristics of the optical fibres and cables

7.1 Optical fibre characteristics

Optical fibres should be used as described in [ITU-T G.651.1], [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].

7.1.1 Transmission characteristics

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

7.1.2 Fibre microbending

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 is called microbending. This may be caused by manufacturing and installation strains, and also by dimensional variations of cable materials due to temperature changes during operation. Microbending can cause an increase in optical loss. To reduce microbending loss, stress randomly applied to a fibre along its axis should be eliminated during the incorporation of the fibres into the cable, as well as during and after cable installation.

7.1.3 Fibre macrobending

Macrobending is the resulting curvature of an optical fibre after cable manufacture and installation.

Macrobending can cause an increase in optical loss, which increases if the bending radius is too small.

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

7.2 Mechanical characteristics

7.2.1 Bending

Under 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 radius must be selected to limit this combined dynamic strain. Any fibre bend radius remaining after cable installation should be large enough to limit the macrobending loss or long-term strain limiting the lifetime of the fibre.

7.2.2 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).

Fibre strain may be caused by tension, torsion, bending and creep occurring in connection with cable weight, cable installation and/or the type of exceptional aerial installation for a short length and/or environmental conditions such as a wind, ice, temperature and physical movement of the cable on the ground.

Changes in the tension of the cable, due to a variety of factors encountered during the service life of the cable, can cause a differential movement of cable components. This effect needs to 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. To avoid this, the maximum tensile strength determined by the cable construction, especially by the design of the strength member, should not be exceeded.

To design tensile characteristics, maximum allowable tension, rated tensile strength and strain margin should be considered.

7.2.3 Crush and impact

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

Crush and impact may increase optical loss (permanently, or for the period of time during the application of the stress) and excessive stress may lead to fibre fracture.

For cables for direct surface application (DSA), in particular, higher crush and impact requirements may be appropriate.

7.2.4 Torsion

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

7.2.5 Residual fibre strains

The maximum residual fibre strains expected, caused by torsion, tension and bending, should be used to specify the long-term strain limit of the fibre.

7.3 Environmental conditions

7.3.1 Hydrogen gas

In the presence of moisture and metallic elements, hydrogen gas may be generated. Hydrogen gas may diffuse into silica glass and increase optical loss. It is recommended that the hydrogen concentration in the cable, as a result of its component parts, should be low enough to ensure that the long-term effects on the increase of optical loss are acceptable. The method for estimating the concentration of hydrogen in optical cables is given by [ITU-T L.126].

Only in rare cases will hydrogen generation be a problem for terrestrial cables. In cases where hydrogen may be a hazard, the use of dynamic gas pressurization and hydrogen-absorbing materials, and by careful material selection and construction (moisture barrier sheath) or elimination of metallic components, the increase in optical loss can be maintained within acceptable limits.

Further information can be found in [b-IEC TR 62690].

7.3.2 Moisture permeation

When moisture permeates the cable sheath and is present in the cable core, the tensile strength of the fibre diminishes, and the time-to-static failure will be reduced. To ensure a satisfactory lifetime of the cable, the long-term strain level of the fibre must be limited.

Various materials can be used as barriers to prevent or reduce the rate of moisture permeation. A continuous metallic barrier is effective to prevent moisture permeation; a minimum permeation is achieved by employing a sealed longitudinal overlapped metallic foil (glued, thermo-welded or welded). In metal-free cables, filling compounds are effective in preventing longitudinal water propagation, but do not significantly hinder radial moisture permeation through plastic sheaths.

7.3.3 Water penetration

In the event of damage to the cable sheath or to a splice closure, longitudinal penetration of water in a cable core or between sheaths can occur. The penetration of water causes an effect similar to that of moisture. The longitudinal penetration of water should be minimized or, if possible, prevented.

In order to prevent longitudinal water penetration within the cable, techniques such as filling the cable core with a compound or with discrete water blocks or swellable components (e.g., tapes, roving) are used. In the case of unfilled cables, dry-gas pressurization can be used. Water in the cable may be frozen and, under some conditions, can cause fibre crushing with a resultant increase in optical loss and possible fibre breakage.

7.3.4 Lightning

Fibre cables containing metallic elements, such as conventional copper pairs or a metallic sheath are susceptible to lightning strikes.

To prevent or minimize lightning damage, consideration should be given to [ITU-T K.29] and [ITU-T K.47].

7.3.5 Biotic damage

The size and deployment of an optical fibre cable makes it vulnerable to many biological attacks. This topic is covered in [ITU-T L.161], where "type of damage experienced" includes that from mammals (e.g., squirrels, rats, gophers), insects, birds and micro-organisms. Although a DSA cable may experience severe attacks from large mammals (e.g., monkeys) or birds (e.g., woodpeckers), a simple protection structure and easy operability are desired.

Although [ITU-T L.161] states that optimum protection is generally obtained by the use of metallic tapes, it reports that 0.1 mm aluminium tape is easily penetrated by rodents. Corrugated steel tapes (0.15 mm and thicker) and some aluminium tapes (0.25 mm and thicker of particular alloys) have been proven to successfully deter attacks by some rodents. Such cables using a central metal tube construction are quite robust. Designs which accommodate optical fibres within a continuous metallic barrier, welded stainless steel tube, for example, with sufficient wall thickness are exceptionally robust. Resistance to attack by gnawing insects has been demonstrated by using over-jackets of materials such as nylon.

7.3.6 Vibration

DSA cables may be subject to vibrations from traffic, railways, pile-driving and blasting operations. These cables should withstand vibrations generated by these activities without degradation. Cables designed for normal outdoor use have demonstrated sufficient resistance to such routine vibrations.

A short length of DSA cable may need to cross a valley, river, lake, road or railway, or a length of the cable may need to be suspended in the air with/without using an independent suspension wire. Overhead cable vibrations are produced either by laminar wind stream causing curls at the lee side of the cable (aeolian vibration) or by variations in wind direction relative to the cable axis (galloping effect). For cases where the length of cable in the air is long enough to cause concern or where the location is known to be windy, the DSA cable may be lashed, tied, or otherwise connected to a suspension member (messenger), or a self-supporting cable can be used. See [ITU-T L.102].

It is important to make a careful choice of the cable route and to select installation techniques and/or the use of vibration control devices to minimize this type of problem.

7.3.7 Temperature variations

The cables will be subject to temperature variations during their lifetime. Generally, cables installed on ground surfaces or in the air are more exposed to more significant temperature variation than those installed underground. Shrinkage of a cable due to a lowering in temperature may cause the maximum working tension to be reached. Expansion of a suspended cable due to an increase in temperature may cause a significant reduction in the safe clearance to ground and an increase of fibre strain.

It is therefore necessary to investigate the temperature variations in the location where DSA cables are to be installed, and to select the type of DSA cable installation suitable for that environment. For example, when a length of DSA cable needs to cross a large, slow-running river, aerial suspension or submergence may be chosen.

Thermal variation causes different dimensional changes in each element of the cable, since they have different thermal expansion coefficients, with a large difference between the smallest and the greatest value. This difference in behaviour can cause attenuation increase of the optical fibres due to microbending or macrobending effects.

Under all such conditions, the variation of attenuation of the fibres should be reversible and should not exceed the specified limits.

7.3.8 Chemical attack

After cable installation, contact with several chemical agents may degrade the cable's sheath characteristics, leading to the weakening of the cable core protection.

To avoid this problem, cable sheath materials should be selected carefully based on its robustness against chemical agents that they may be in contact with.

Although jacketing polyethylene has been shown to offer effective protection against a wide range of environmental chemicals, it is important to assess what kind of chemical agents may exist in the area where the cable is located. Then, sheath material durability for such chemical agents should be examined. A combination of suitable materials (metallic and non-metallic) can be selected to prevent chemical attacks based on the specific environmental criteria.

7.3.9 Mechanical aggression

It is difficult to estimate the level of mechanical aggression that a cable may undergo during its handling, installation and maintenance. However, it is clear that DSA cables are less protected than cables which are properly buried or in ducts and underground pipes. Therefore, internationally recognized requirements such as impact, alternated flexions, torsion, compression and bending tests should be adhered to. Specific tests or specific conditions for usual tests should be agreed upon by users and suppliers.

7.3.10 Wind

Since a length of DSA cable may need to cross a valley, river, lake, road or railway, a short length of the cable may need to be suspended in air with/without using an independent suspension wire. Under such conditions, the cable needs to withstand the effects of wind.

Fibre strain may be caused by tension, torsion and vibration occurring in connection with wind pressure, which may result in fibre breakage or attenuation increases. See [ITU-T L.102] for guidance on limiting fibre strain to safe levels.

In windy situations, cables should be designed and/or installed to provide stability of the transmission characteristics and mechanical performance. Cable installations should be designed to minimize the influence of wind.

7.3.11 Snow and ice

DSA cables will be directly exposed to snow and ice in climates where such weather events occur. Exposure to snow and ice for cables on the ground is generally not a significant hazard. Snow and ice temperatures are within the performance range of outdoor cables. Surface ice freezing is generally within the crush capabilities of outdoor cables.

However, since a length of a DSA cable may need to cross a valley, river, lake, road or railway, a short-length of the cable may need to be suspended in air with/without using an independent suspension wire. Under such conditions, the cable needs to withstand the build-up of snow and ice on the cable structure.

Fibre strain may be caused by tension occurring in connection with snow loading and/or ice formation around the cable, snow or ice falling from the cable, and increased wind pressure due to ice build-up. See [ITU-T L.102] for guidance on the mechanisms of such loading and design consideration to avoid them.

To suppress fibre strain caused by snow loading and/or ice forming, the cable may be lashed to, or suspended by a high-strength support strand.

7.3.12 Ballistic protection

Damage to cables due to shotgun or other fire arms is an occasional occurrence. Due to the variations in this test, it is considered a specialty test for very specific applications.

Further discussion may be found in [IEC 60794-1-21] method E13.

7.3.13 Water pressure

Shallowly submerging a conventional outdoor cable under a lake, pond or shoreline has been shown to be effective for water depths up to 10 metres. To keep a cable submerged, burial or weights may be necessary as most conventional optical fibre cables are buoyant in water.

Shallowly submerged DSA cables with welded metallic core tube under the lake, pond or shore, may be placed for water depths up to 100 metres and may not be buoyant.

When cables are subjected to hazardous currents, tides, or water activities (e.g., boat traffic), additional external protections could be adopted, in addition to the various armour usually implemented for the cable construction. For example rocky armour (RA), steel wire armouring such as single wire armouring (SA) or double wire armouring (DA), can be used to protect cables if necessary. Such protections can be applied both approaching the coast in shallow water and onshore in the portion between the water edge and the beach joint, or along the cable route where external factors or seabed features could damage the cables. See [IEC 60794-3-30] for guidance for cables for lakes, river crossings and coastal applications.

For greater depths, the use of continuous metallic barriers within the cable accommodating the fibres protects optical fibres against water pressure: better durability is available with a thicker metallic barrier. Single or double wire armouring (SA or DA) may also be indicated.

For considerations regarding hydrogen protection and testing at greater depths, see [ITU-T L.126] and [b-IEC TR 62690].

7.3.14 Aerial suspension

A short length of a DSA cable could cross a river, valley or road via aerially suspension. Such lengths of cable should be limited such that the maximum allowable working tension of the cable and long-term strain on the fibre is not be exceeded. The length may be limited by the weight of the cable in the span, or more frequently by wind or ice loading unless independent tension wires to support cable weight or wind or ice loading are used.

In the case of longer aerial span lengths or strong winds or ice loading (see clauses 7.3.10 and 7.3.11), a DSA cable may be lashed, tied, or otherwise attached to a high-strength support strand (messenger). Or, a self-supporting cable may be used for that section. See [ITU-T L.102] for guidance in both cases.

7.4 Installation near high-voltage power lines

Generally, DSA cables should not be installed close to power lines, either on the ground or in the air. In rare cases where DSA cables are installed directly beside or very close to power lines, the following should be considered.

If a length of fibre optic cable is placed adjacent to high-voltage power lines, a special sheath material should be considered to avoid tracking effects. Depending on the conductivity of the soil, a voltage gradient may be generated by the electric field of the power line. Under the variation of conductivity, high-voltage difference may result on the optical fibre cable's jacket and lead to leakage currents and dry-band arcing which can damage the jacket over time. One typical solution is the use of a semi-conductive over-jacket. The function of the semi-conductive over-jacket is to reduce the high-voltage difference. Another solution is using a track-resistant jacket compound.

If the optical fibre cable has metallic components, currents may be induced in these members. Bonding and grounding for personnel safety must be considered. Further guidance may be found in [IEC 60794-4].

8 Cable construction

Since DSA cables are closely related to outdoor optical fibre cables, references to [ITU-T L.100], [ITU-T L.101], [ITU-T L.102], [ITU-T L.126], [ITU-T L.161], [ITU-T L.430] and [IEC 60794-3] are useful.

8.1 Fibre coatings

8.1.1 Primary coating

Silica fibre itself has an intrinsically high strength, but its strength is reduced by surface flaws. A primary coating must therefore be applied immediately after drawing the fibre to size. The optical fibre should be proof-tested. To guarantee long-term reliability under service conditions, the proof-test strain may be specified, taking into account the permissible strain and required lifetime. To prepare the fibre for splicing, it should be possible to remove the primary coating without damage to the fibre, and without the use of materials or methods considered to be hazardous or dangerous.

The composition of the primary coating, coloured if required, should be considered in relation to any requirements of local light-injection and detection equipment used in conjunction with fibre jointing methods. Primary-coated fibres should comply with relevant optical fibre specifications in [IEC 60793-2-10] and [IEC 60793-2-50].

NOTE – The optical fibres should be proof-tested with a strain equivalent to 1 per cent. For certain applications, a larger proof-test strain may be used.

8.1.2 Secondary or buffer coating

The tight or semi-tight secondary coating of the fibre (the buffer), if used, should comply with the requirements given in [IEC 60794-3]

NOTE 1 – When a tight or semi-tight buffer is used it may be difficult to use local light-injection and detection equipment associated with fibre jointing methods.

NOTE 2 – Mechanical coupling between fibre and cable should be carefully designed; a low coupling may cause fibre movement during installation process; a high coupling may cause high fibre stress when the cable is bent.

8.1.3 Fibre identification

Fibre should be easily identified by colour/tracer/marker or position within the cable core. If a colouring method is used, the colours should be clearly distinguishable and have good colour permanence properties, also in the presence of other materials, during the lifetime of the cable.

8.1.4 Removability of coating

The primary and secondary protections should be easy to remove and should not hinder the splicing, or the fitting of fibre to optical connectors.

8.2 Cable elements

The make-up of the cable core, in particular the number of fibres, their method of protection and identification, the location of strength members and metallic wires or pairs, if required, should be clearly defined.

8.2.1 Fibre ribbon

Optical fibre ribbons consist of optical fibres aligned in a row. Optical fibre ribbons are divided into types, based on the method used to bind the fibres. One type is the edge-bonded type, and another is the encapsulated, as shown in Figures 8-1 and 8-2, respectively. In the case of the edge-bonded type, optical fibres are bound by adhesive material located between the optical fibres. When the encapsulated type is adopted, optical fibres are bound by a coating material.

If flexibility of optical fibre ribbons is required for bending, in conjunction with, for example, a small cable diameter or ease of handling in closures, the partially bonded configuration in the longitudinal direction shown in Figure 8-3 may be optionally adopted for both the edge-bonded and the encapsulated ribbon types.

Optical fibre ribbons should be capable of mass splicing. The fibres of optical fibre ribbons in the as-manufactured configuration should be parallel and not cross. Each ribbon in a cable is identified by a printed legend or unique colour. Optical fibre ribbons are specified in [IEC 60794-3].

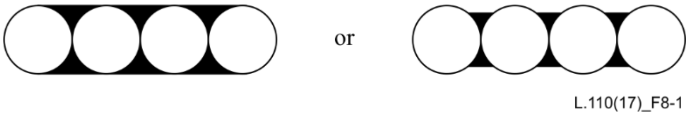

Figure 8-1 – Cross-section of a typical edge-bonded ribbon

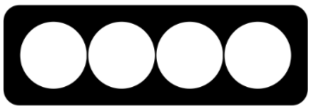

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Figure 8-2 – Cross-section of a typical encapsulated ribbon

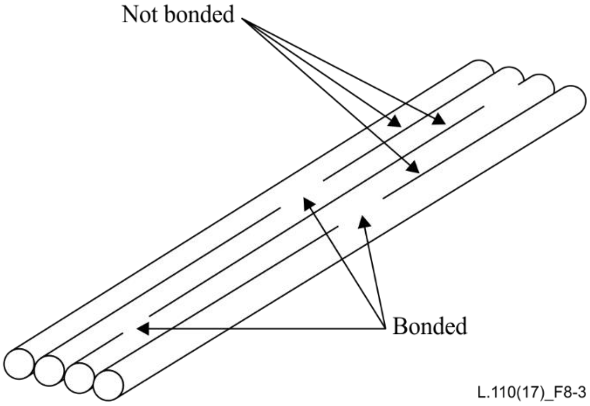

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Figure 8-3 – Example of a typical partially bonded ribbon

8.2.2 Slotted core

In order to avoid direct pressure from the outside of the cable on optical fibres, optical fibres and/or ribbon fibres can be located in slots. Slots are usually provided in a helical or reverse oscillating stranding (SZ) method configuration on a cylindrical rod. The slotted core usually contains a strength member. A strength member should adhere tightly to the slotted core in order to obtain temperature stability and avoid their separation when a pulling force is applied during installation. Water-blocking material may be contained in the slots.

8.2.3 Tube

A tube construction, commonly of polymer materials, is used for protecting and gathering optical fibres and/or ribbon fibres. A particularly rugged cable design may utilize a central metal tube construction with a welded seam. Cable designs incorporating loose tubes are typically stranded to minimise strain and enable easier mid-span access if the SZ method is utilised. Water-blocking material may be contained in the tube, if required.

8.2.4 Micro-module

This is a fibre bundle consisting of a multiplicity of fibres, encapsulated in a thin-walled sheath and optionally, containing water-blocking materials (see Figure 8-4). The micro-module construction is intended to minimize the size of the bundle to optimize handling and fibre management. The thin-walled sheath is manufactured from a soft material which allows its removal without the need for tools for easy splice preparation and mid-span access, hence reducing preparation time and the risk of fibre damage. It has the added benefit that the modules are flexible and have bending radii similar to that of the unbundled fibres, therefore reducing the necessary storage volume both within the overall cable and also within splicing units.

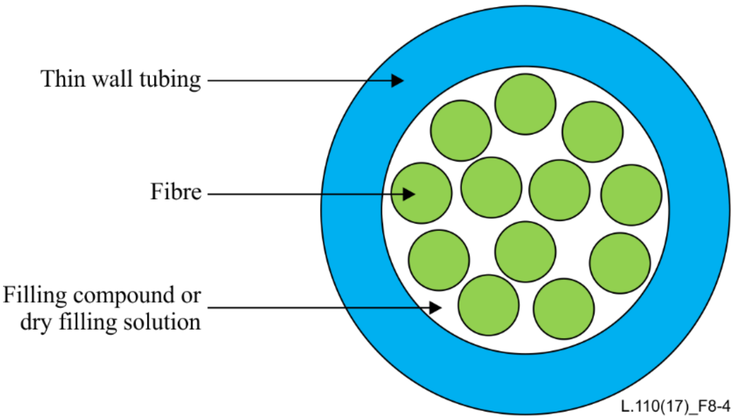

Figure 8-4 – Example of micro-module with primary coated fibres

8.2.5 Strength member

The cable should be designed with sufficient strength members to meet installation and service conditions so that the fibres themselves are not subjected to strain levels in excess of those specified (see [IEC 60794-3] for outdoor cables) or as agreed upon between customer and supplier. The strength member(s) may be either metallic or non-metallic. When metallic members are used, care should be taken to avoid hydrogen generation effects (see clause 7.3.1).

8.2.6 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 (yarns, tapes, filling compound, water-swelling powder or combination of materials) may be used. Any materials used should not be harmful to personnel. The materials in the cable should be compatible, one with the other, and in particular should not adversely affect the fibre. These materials should not hinder splicing and/or connection operations.

8.3 Sheath

The cable core should be covered with a jacket or sheath 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. The selection of the sheath material to optimize the friction forces encountered in installation should be considered. Sheath considerations for optical fibre cables are generally the same as for metallic conductor cables. Consideration should also be given to the amount of hydrogen generated from a metallic moisture barrier (see clause 7.3.1).

NOTE – One of the most commonly used sheath materials is polyethylene. There may, however, be some conditions where it is necessary to use other materials, for example, to limit fire hazards, to protect from rodents and/or termites, etc.

8.4 Armour

Where additional tensile strength or protection from external damage (e.g., crush, impact, rodents) is required armouring should be provided.

Armouring for metal-free cables may consist of aramid yarns, fibre-glass-reinforced strands or strapping tape, etc. The degree of rodent/gopher protection can vary significantly with all-dielectric designs. Mechanical protection can usually be achieved by adjusting the radial sheath thickness and/or the application of armouring which can be implemented as steel wire armour, galvanized steel tape armour or steel braid, or glass yarn/tape armour. Protection for DSA cables is generally obtained by using overlapped metal armour or welded metallic core tubes.

8.5 Identification of cable

It is recommended that visual identification of optical fibre cables is provided; this can be done by visibly marking the cable's sheath. For identifying cables, embossing, sintering, imprinting, hot foil or ink-jet or laser printing can be used when agreed upon between customer and supplier.

8.6 Cable sealing

It is recommended that an optical fibre cable should be provided with cable end-sealing and protection during cable delivery and storage. If splicing components have been factory installed, they should be adequately protected. Pulling devices can be fitted to the end of the cable, if required.

9 Test methods

It is not intended that all tests should be carried out; the frequency of testing and the relevant severities should be agreed upon between customer and supplier.

9.1 Test methods for cable element

9.1.1 Tests applicable to optical fibres

In this clause, optical fibre test methods related to splicing are described. Mechanical and optical characteristics test methods for optical fibres are described in [ITU-T G.650.1] and [IEC 60793-1-xx] series.

9.1.1.1 Dimensions

For measuring primary coating diameter, method [IEC 60793-1-21] should be used.

For measuring tube, slotted core and other ruggedized elements, methods [IEC 60811-202] and [IEC 60811-203] should be used.

9.1.1.2 Coating strippability

For measuring the strippability of primary or secondary fibre coatings, method [IEC 60793-1-32] should be used.

9.1.1.3 Compatibility with filling material

When fibres come into contact with a waterproofing filling material, stability of the fibre coating and of the filling material should be examined by tests after accelerated ageing.

The stability of the coating stripping force should be tested in accordance with [IEC 60794-1-21] method E5.

Dimensional stability and coating transmissivity should be examined by the test method agreed upon between by both the user and supplier.

9.1.2 Tests applicable to tubes

9.1.2.1 Tube kink

For measuring kink characteristics of tube, [IEC 60794-1-23] method G7 should be used.

9.1.3 Tests applicable to ribbons

9.1.3.1 Dimensions

For measuring ribbon dimensions, three test methods should be used. The first one, called a type test, is used to establish and verify the ribbon manufacturing process. The type test should be carried out in accordance with [IEC 60794-1-23] method G2, the visual measurement method. The two remaining methods are used only for product inspection after the manufacturing process has been carried out. These tests are described in [IEC 60794-1-23] method G3, aperture gauge, and [IEC 60794-1-23] method G4, dial gauge. For inspection purposes, the visual measurement method can be also used.

9.1.3.2 Separability of individual fibres from a ribbon

A separability requirement can be given to a fibre ribbon if agreed upon by user and supplier. When separability is required, the following should be avoided to ensure long-term reliability of fibres:

– damage to mechanical characteristics of fibres;

– removal of the colour coding from each fibre.

In reality, it is difficult to completely avoid such phenomena. However, if the user and supplier agree, [IEC 60794-1-23] method G5 should be used to examine fibre separability. Also, other special test methods can be used upon agreed upon between the user and supplier.

9.2 Test methods for mechanical characteristics of the cable

This clause recommends appropriate tests and test methods for verifying the mechanical characteristics of optical fibre cables. For test methods, reference should be made to [IEC 60794-1-21]. For specifications, reference is made to appropriate [IEC 60794-3] standards.

9.2.1 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 [IEC 60794-1-21] method E1.

The amount of mechanical decoupling of the fibre and cable can be determined by measuring the fibre strain, with optical phase-shift test equipment, together with the cable elongation. See [IEC 60794-1-21] method E1 for the application of [IEC 60793-1-22] to measure fibre strain in the cable. This method may be non-destructive if the tension applied is within operational values.

9.2.2 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 should be carried out in accordance with method [IEC 60794-1-21] method E11A or E11B.

9.2.3 Crush

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

The appropriate test method for most terrestrial cables is the plate-plate crush method.

This test should be carried out in accordance with method [IEC 60794-1-21] method E3A.

9.2.4 Abrasion

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

The purpose of this test is to evaluate the ability of the cable sheath to resist abrasion.

This test should be carried out in accordance with method [IEC 60794-1-21] method E2A.

9.2.5 Torsion

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

The purpose of this test is to evaluate the ability of optical fibre cables to accommodate torsion associated with normal installation and handling.

This test should be carried out in accordance with method [IEC 60794-1-21] method E7.

9.2.6 Impact

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

The purpose of this test is to evaluate the ability of optical fibre cables to survive impacts associated with normal installation and handling.

This test should be carried out in accordance with method [IEC 60794-1-21] method E4.

9.2.7 Kink

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

The purpose of this test is to evaluate the ability of optical fibre cables to undergo normal handling without kinking.

This test should be carried out in accordance with method [IEC 60794-1-21] method E10.

9.2.8 Repeated bending

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

The purpose of this test is to evaluate the ability of optical fibre cables to undergo repeated bending associated with normal handling and service.

This test should be carried out in accordance with method [IEC 60794-1-21] method E6.

9.3 Test methods for environmental characteristics

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

For test methods, reference should be made to [IEC 60794-1-22]. For specifications, reference is made to appropriate [IEC 60794-3] standards.

9.3.1 Temperature cycling

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

Testing is carried out by temperature cycling to determine the stability of the attenuation of a cable due to temperature changes, which may occur during operation.

This test should be carried out in accordance with method [IEC 60794-1-22] method F1.

9.3.2 Longitudinal water penetration

This test method applies to water-blocked outdoor cables installed under all environmental conditions.

The intention is to check that all the interstices of a cable are sufficiently filled with a compound or water-blocking material to prevent water penetration down the length of the cable.

This test should be carried out in accordance with [IEC 60794-1-22] method F5B or [IEC 60794-1-22] method F5C as appropriate to the design.

9.3.3 Moisture barrier

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

This test applies to cables supplied with a longitudinal overlapped metallic foil.

The moisture penetration can be tested according to the test method as described in Part I, Chapter III of the [b-ITU-T Handbook].

9.3.4 Freezing

This test method applies to optical fibre cables installed under environmental conditions in which freezing of the ground surrounding the cable may occur.

The purpose of the external freezing test is to simulate freezing of the medium surrounding a buried cable, as in wet earth or water. This external freezing test is not of use for evaluating outdoor cables, as such cables rarely fail this test. The aggregate of other requirements for outdoor cables results in a cable that is sufficiently robust to easily withstand this test. However, it may be useful for evaluating cables that are not normally intended for outdoor installation. Users are encouraged to refer to national standards in effect in applicable regions.

This test should be carried out in accordance with method [IEC 60794-1-22] method F15.

9.3.5 Hydrogen

In some unusual installation situations, such as being sealed within a metallic pipe or being under great water depths, hydrogen effects may occur.

See clause 7.3.1, [ITU-T L.27] and [b-IEC TR 62690] for guidance.

9.3.6 Nuclear radiation

This test method assesses the suitability of optical fibre cables to be exposed to nuclear radiation.

This test should be carried out in accordance with method [IEC 60794-1-22] method F7.

9.3.7 Vibration

There are no agreed upon tests for general vibration of cables lying upon the ground.

Clause 7.3.6 discusses vibration associated with DSA cables.

9.3.8 Ageing

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

The purpose of this test is to evaluate the reaction of cable components under simulated ageing by applying a high temperature to accelerate ageing.

This test should be carried out in accordance with method [IEC 60794-1-22] method F9.

9.3.9 Lightning

Optionally when a metallic material is used as a cable element, the lightning protection of the cable may undergo a test described in [ITU-T K.47], subject to agreement between the user and supplier.

Appendix I

Example cable for DSA

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

I.1 Products and experiences of Japan

I.1.1 Optical fibre cable with welded stainless steel tube

Figures I.1 shows the cross-sectional views and side view of the optical cable with a welded stainless steel tube, where perfect welding is electrically confirmed in the process. This cable has been commercially installed in lakes, slow rivers and temporarily installed on ground surfaces.

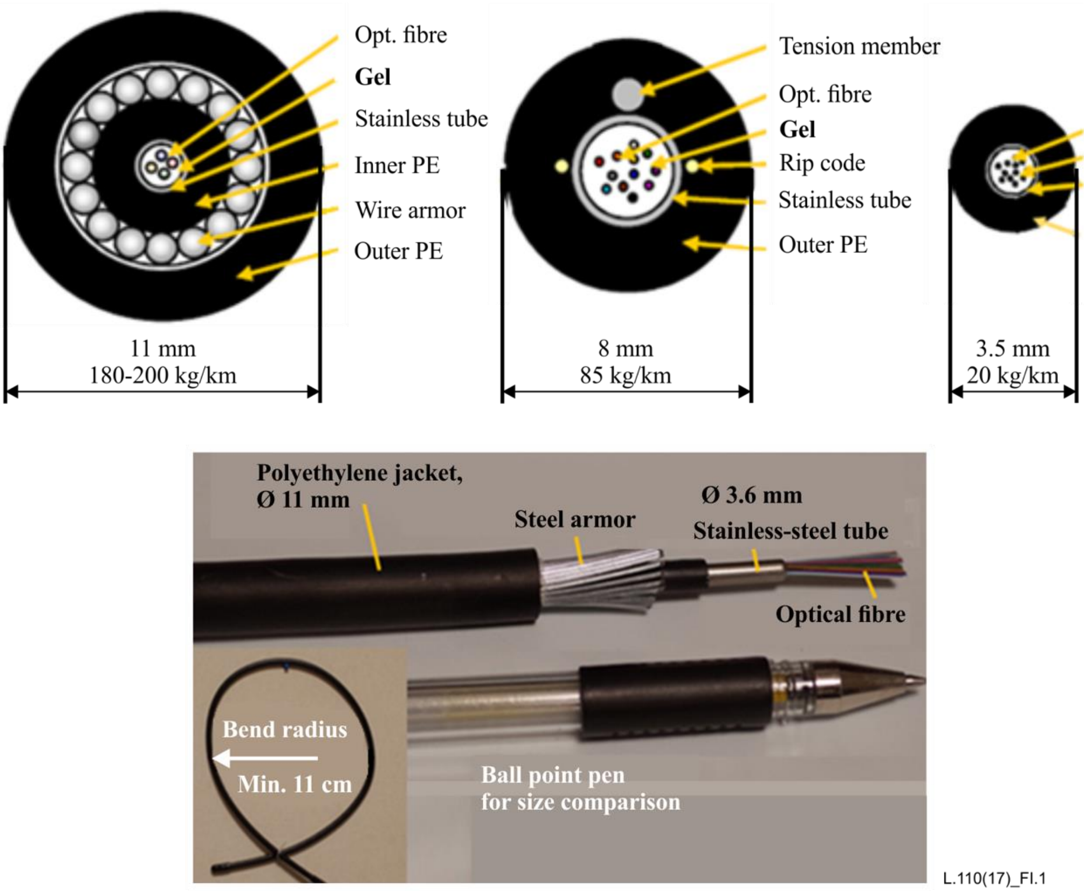

Figure I.1 – Examples of DSA cable: cross-sectional and side views

The same cable structure allows direct burial application, direct surface application and even aerial applications for a short- length of cable.

[b-ITU-T L-Suppl.22] describes a best-effort example of low-cost sustainable telecommunication systems for rural communications in developing countries using this type of DSA cable.

I.1.2 Field experience in Bhutan using cables with Japanese-made welded-steel tubes

Internet connectivity was provided, by the cable described above, for a local government office, a basic health facility and a public school in Shengana Gewog (village), Phunakha, Bhutan and was supported by an APT J3 grant led and coordinated by the Department of Information Technology and Telecom (DITT) of Ministry of Information and Communications (DITT/MoIC), Bhutan.

The project shown in Figure I.2 below, used a 1.2 km length of cable. It was not necessary to use different types of cable structures for different outdoor environments such as for direct burying, submerging, aerial wiring and exposed ground surface cables. This project did not demand a precise cable-route, pre-survey, cable-type selection, cable length adjustment or jointing of different cable types at the construction site.

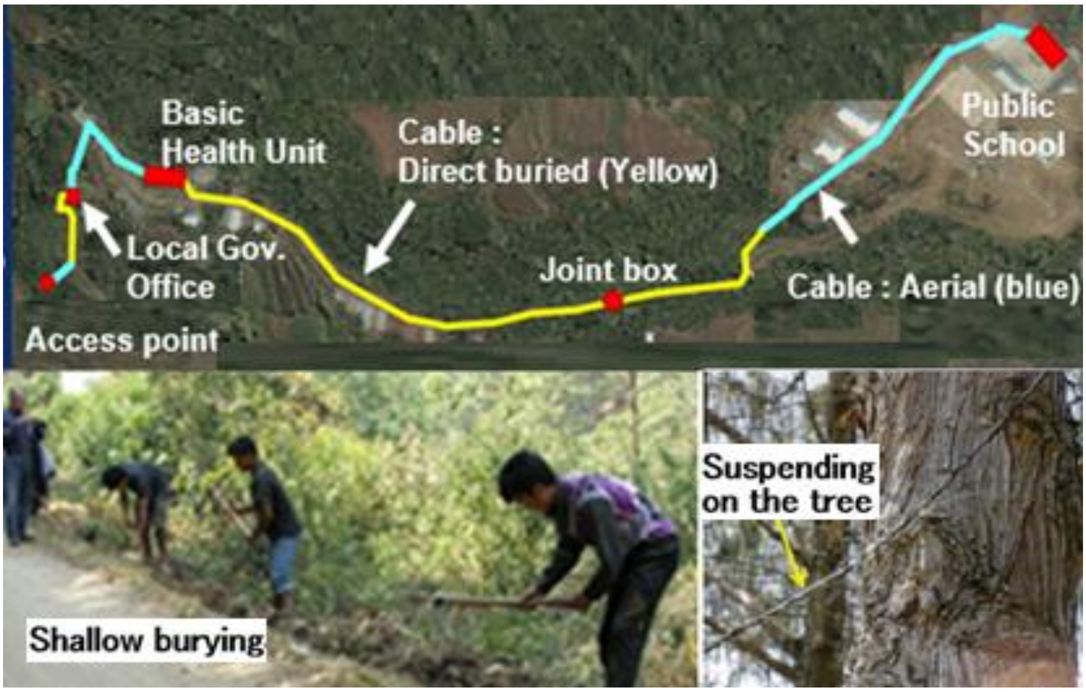

Figure I.2 – Implementation of the cable in Spring of 2012 in Bhutan

The cost of laying the cable was very low because it was implemented, in part, by non-skilled local labour in a "do-it-yourself" manner without the use of heavy machinery or specific infrastructure such as cable ducts, underground pipes, trenches or poles. Direct burial of the cable was accomplished using handy spades and pickaxes which secured the link. As of May 2017, no problems have been reported following the Spring 2012 installation. This project also implemented a worldwide interoperability for microwave access (WiMAX) wireless solution at a nearby location.

In early 2016, a preference was heard in Bhutan about the optical cable solution for its wide bandwidth, ease of equipment setting, simplicity, installation cost-effectiveness and cable robustness proven under the conditions tested. The signal throughput of the WiMAX(wireless) solution is inherently limited, and requires licensed and skilled engineers for the system setup and adjustment.

I.2 Products and experiences in Italy

The information in this clause is derived from Italian experience related to cable installation in sewage systems. Given the simplicity and immediacy of laying cable on the sewer bottom, this solution has been deployed in Italy since 2002, with over 450 km of cables installed. To date, there have been no problems reported with the optical cable.

The most significant feature that defines the suitability of an optical cable to be laid directly on the sewer bottom is its armour, which besides functioning to protect against rodent attacks, determines the strength of the cable and preserves its safety in case of unexpected events or interventions such as inspection, cleaning of the duct by high-pressure hydrodynamic probes, or flash floods with transport of materials. A further distinctive feature is the composition of the outer sheath that ensures resistance to chemically aggressive environments such as sewage sludge.

The main technical data and a schematic diagram of the cable are shown below.

TECHNICAL DATA

Cable diameter (mm)	20
Cable weight (kg/km)	1210
Cable drum length (m)	2000 ~ 6000
Permanent bending radius (mm)	400
Breaking load (kN)	227
Maximum laying load (kN)	163
Permanent crush resistance (N/cm)	2000
Operating temperature (°C)	−40 ~ + 60
Tubes with fibres (n)	3
Number of fibres (n)	96
Type of fibres	ITU-T G.652 ITU-T G.655
Standards	IEC 60794

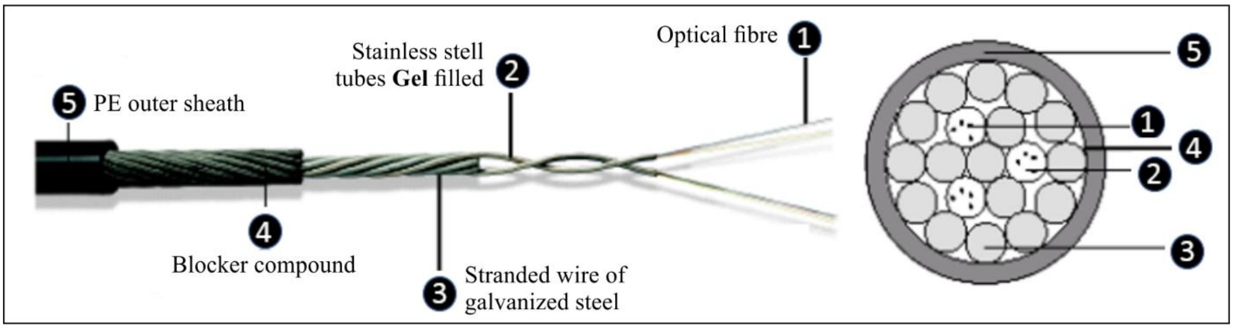

Figure I.3 – Optical fibre cable with stainless steel tubes and technical data

The advantages of robustness of this type of cable are offset by disadvantages the cables weight and a certain difficulty in splicing it. All of these features will be taken into account during the final cable design.

With the experience gained in Italy, cables designed to fit into sewer systems can be suitable for use by laying directly on the ground or are, at least, a good starting point for the final cable design.

I.3 Products and experiences in USA

Below a cable suitable for the DSA is described. It is a central core, linear strength member cable.

This cable described has been produced and in service since the 1980s in North America. This cable was not designed for DSA service, as this is not an application space used in North America. Instead, it was designed for general outdoor use in ducts, lashed aerial and buried plants. However, this cable has been used in "temporary DSA" service, but often for extended periods of time. And, while it was not designed for this application, it has been found to be sufficiently robust to be fully functional in DSA service.

Figure I.4 shows a summary sketch example of the cable. It is an armoured, metallic cable. However, this cable is also produced and used in an all-dielectric version.

Table I.1 shows characteristic data from normal cable tests. The data are for the armoured, metallic cable. Typical dimensions are shown and both the standard and robust versions are noted.

Figure I.5 is a photograph of non-standard testing done during the development of the example cable. In the photograph, a heavy line truck is shown driving over the cross-over point of a length of standard cable stored in a figure-eight configuration. The result was minimal visual deformation and no degradation of fibre or cable performance.

I.3.1 Description of the example cable for DSA

An overlapped armour layer of 0.15 mm corrugated electrolytic chrome-coated steel (ECCS) or stainless steel envelops the core tube and has a ripcord under it to ease its removal. The steel armour is coated to inhibit corrosion and to bond to the outer jacket. Two steel wire strength members run longitudinally along the armour, diametrical from each other. A ripcord is located next to each steel wire for ease of sheath removal. The sheath is completed with a black high-density polyethylene (HDPE) jacket. The central core may use any of the common constructions: fibre bundles, ribbon stacks, micromodules, etc.

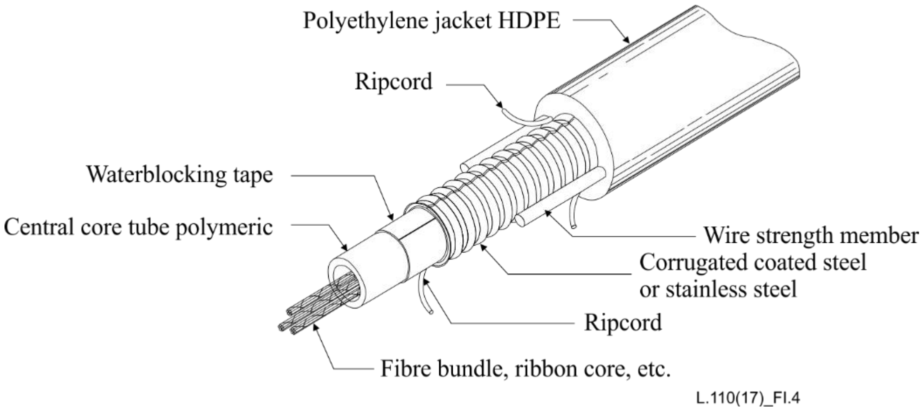

Figure I.4 – Central core, linear strength member, armoured sheath

Table I.1 – Example DSA cable test attributes

Fibre counts	12-48	60-144	156-216	264-432
Cable diameter, d (mm)	13.0	15.5	13.0	21.3
Cable weight (kg/km)	174	227	289	345
Bend diameter	40 × d			
Rated tensile load (N)	2700 standard, 5000 robust			
Crush load (N)	2200 standard, 6000 robust			
Operating temperature (°C)	−40 to +70			

Figure I.5 – Abusive testing of central core, linear strength member, armoured sheath

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[b-ITU-T L-Suppl.22]	ITU-T L-Series Recommendations, Supplement 22 (2016), *ITU-T L.1700 – Low-cost sustainable telecommunication for rural communications in developing countries using fibre optic cable*.
[b-IEC TR 62690]	IEC TR 62690 (2014), *Hydrogen effects in optical fibre cables – Guidelines*.

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Printed in Switzerland
Geneva, 2017