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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 indoor applications

Recommendation ITU-T L.103

ITU-T

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ITU-T L-SERIES RECOMMENDATIONS

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	**L.100–L.124**
Cable evaluation	L.125–L.149
Guidance and installation technique	L.150–L.199
OPTICAL INFRASTRUCTURES	
Infrastructure including node element (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.103

Optical fibre cables for indoor applications

Summary

Recommendation ITU-T L.103 (formerly, L.59) describes characteristics, construction and test methods for optical fibre cables for indoor applications. In order for an optical fibre to perform appropriately, characteristics that a cable should have are described. Also, the method of determining whether the cable has the required characteristics is described. 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 where a cable is to be used.

History

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Keywords

Cable structure, cable testing, indoor cabling, optical fibre cable.

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FOREWORD

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

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Table of Contents

Page

Recommendation ITU-T L.103

Optical fibre cables for indoor applications

1 Scope

This Recommendation:

– Applies to multimode and single-mode optical fibre cables to be used for telecommunication networks within buildings;

– Specifies the mechanical and environmental characteristics of the optical fibre cables concerned. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with one or more of [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], [ITU-T G.657] and [IEC 60793-2-10];

– Specifies the fundamental considerations related to optical fibre cable from mechanical and environmental aspects;

NOTE – Other types of fibre may be used to meet the intent of cables according to this Recommendation. Specific attributes may differ, and require agreement between the manufacturer and user.

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 (2015), *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*.

[ITU-T G.650.3] Recommendation ITU-T G.650.3 (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 (2009), *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 (2012), *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 dipersion-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 (2012), *Characteristics of a bending-loss insensitive single-mode optical fibre and cable for the access network*.

[ITU-T L.161/L.46] Recommendation ITU-T L.46 (2000), *Protection of telecommunication cables and plant from biological attack*.

[IEC 60331-25] IEC 60331-25 (1999), *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements - Optical fibre cables.*

[IEC 60332-1-1] IEC 60332-1-1 (2004) + AMD1 (2015), *Tests on electric and optical fibre cables under fire conditions – Part 1-1: Test for vertical flame propogation for a single insulated wire or cable – Apparatus*.

[IEC 60332-1-2] IEC 60332-1-2 (2004), *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame.*

[IEC 60332-3-24] IEC 60332-3-24 (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*.

[IEC 60332-3-25] IEC 60332-3-25 (2000) + AMD1 (2008), *Tests on electric cables under fire conditions – Part 3-25: Test for vertical flame spread of vertically-mounted bunched wires or cables – Category D.*

[IEC 60754-1] IEC 60754-1 (2011), *Test on gases evolved during combustion of materials from cables – Part 1: Determination of the halogen acid gas content*.

[IEC 60754-2] IEC 60754-2 (2011), *Test on gases evolved during combustion of materials from cables – Part 2: Determination of acidity (by pH measurement) and conductivity*.

[IEC 60793-1-1] IEC 60793-1-1 (2008), *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance.*

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

[IEC 60793-1-32] 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 (2015), *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 (2013), *Optical fibre cables – Part 1-2: Generic specification – Corss reference table for optical cable test procedures*.

[IEC 60794-1-20] IEC 60794-1-20 (2014), *Optical fibre cables – Part 1-20: Generic specification – Basic optical cable test procedures – General and definitions.*

[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 (2012), *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 elements Test Methods.*
[IEC 60794-2]	IEC 60794-2 (2002), *Optical fibre cables – Part 2: Indoor cables – Sectional specification*.
[IEC 60794-2-10]	IEC 60794-2-10 (2011), *Optical fibre cables – Part 2-10: Indoor optical fibre cables – Family specification for simplex and duplex cables.*
[IEC 60794-2-11]	IEC 60794-2-11 (2012), *Optical fibre cables – Part 2-11: Indoor optical fibre cables – Detailed specification for simplex and duplex cables for use in premises cabling*.
[IEC 60794-2-20]	IEC 60794-2-20 (2013), *Optical fibre cables – Part 2-20: Indoor cables – Family specification for multi-fibre optical cables*.
[IEC 60794-2-21]	IEC 60794-2-21 (2012), *Optical fibre cables – Part 2-21: Indoor optical fibre cables – Detailed specification for multi-fibre optical distribution cables for use in premises cabling.*
[IEC 60794-2-30]	IEC 60794-2-30 (2008), *Optical fibre cables – Part 2-30: Indoor cables – Family specification for ribbon cables.*
[IEC 60794-2-31]	IEC 60794-2-31 (2012), *Optical fibre cables – Part 2-31: Indoor cables – Detailed specification for optical fibre ribbon cables for use in premises cabling*.
[IEC 60794-2-50]	IEC 60794-2-50 (2008), *Optical fibre cables – Part 2-50: Indoor cables – Family specification for simplex and duplex cables for use in terminated cable assemblies.*
[IEC 60794-3]	IEC 60794-3 (2014), *Optical fibre cables – Part 3: Outdoor cables – Sectional specification*.
[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.*
[IEC 61034-1]	IEC 61034-1 (2005) + AMD1 (2013), *Measurement of smoke density of cables burning under defined conditions – Part 1: Test apparatus.*
[IEC 61034-2]	IEC 61034-2 (2005) + AMD1 (2013), *Measurement of smoke density of cables burning under defined conditions – Part 2: Test procedure and requirements.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the terms defined in [ITU-T G.650.1], [ITU-T G.650.2], [ITU-T G.650.3], [ITU-T G.651.1] and [IEC 60794-1-20].

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

FTTH	Fibre To The Home
IDF	Intermediate Distribution Frame
MDF	Main Distribution Frame
MDU	Multi-Dwelling Unit
OLT	Optical Line Terminal
SP	Splitter module Part
SZ	reverse oscillating stranding

5 Conventions

None.

6 Characteristics of optical fibres and cables

6.1 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], [ITU-T G.657] or [IEC 60793-2-10], depending upon users' environmental conditions and technical requirements.

6.1.1 Transmission characteristics

The typical transmission characteristics are described in the appropriate Recommendations (for single-mode) and the appropriate IEC fibre specifications (for multimode) on optical fibres. Unless specified otherwise by the users of the Recommendations and specifications, those values apply to the corresponding cabled optical fibre as described in [IEC 60794-1-1].

6.1.2 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 in cabled fibres by manufacturing and installation strains, as well as dimensional variations of cable materials due to temperature changes during operation.

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

6.1.3 Fibre macrobending

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

Macrobending may cause an increase in optical loss. Optical loss increases if the bending radius is too small.

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

6.1.4 Fibre attenuation

Maximum allowable attenuations are described in each Recommendation (for single mode) and the IEC fibre specification (for multimode) of optical fibres. "No change" in both fibre attenuation and fibre strain is specified in [IEC 60794-1-1]. However, if there is a different agreement between the manufacturer and user, higher values can be allowed.

6.2 Mechanical characteristics

6.2.1 Tensile strength

Optical fibre cable is subject to short-term load during manufacture and installation, and may be affected by continuous static loading or cyclic load during operation (e.g., temperature variation). Changes in the tension of the cable due to the variety of factors encountered during the service life of the cable can cause differential movement of the cable components. This effect needs to be considered in the cable design. Excessive cable tensile loading may increase 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 the design of the strength member, should not be exceeded.

Therefore, when designing a tensile member, an agreement between the manufacturer and user on maximum tensile load during storage, installation and operation is required.

NOTE – Where a cable is subjected to permanent loading during its operational life, the fibre should not experience strain in excess of that specified.

6.2.2 Bending

Under the dynamic conditions encountered during installation, optical fibre is subject 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.

The bending test should be performed according to clause 8.2.2. After the test, there should be no fibre breakage.

6.2.3 Crush

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

The crush may increase optical loss (either permanently or for the duration of application of the stress) and excessive stress may lead to fibre fracture.

Allowable crush load depends strongly upon the cable structure. Therefore, crush load for this test should be according to [IEC 60794-2] or as agreed between the manufacturer and user.

The crush test should be performed according to clause 8.2.4. During and after the test, the fibre attenuation coefficient should not change under permanent load. After the test, there should be no damage to the fibre or the cable elements.

6.2.4 Bending under tension (flexing)

Under dynamic conditions encountered during installation and operation, the cable may be subject to bending under tension (flexing). The bending under tension test should be performed according to clause 8.2.3. After the test, there should be no fibre breakage.

6.2.5 Torsion

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

The torsion test should be performed according to clause 8.2.5. There should be no fibre breakage after the test.

6.2.6 Impact

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

The impact may increase optical loss (either permanently or for the duration of application of the stress) and excessive stress may lead to fibre fracture.

The impact test should be performed according to clause 8.2.6. There should be no fibre breakage and no damage to the cable elements.

6.2.7 Kink

The cable may be subject to kink during installation.

The kink test should be performed according to clause 8.2.7. There should be no damage to the cable elements after the test.

6.2.8 Repeated bending

The cable may be subject to repeated bending during installation.

The repeated bending test should be performed according to clause 8.2.8. There should be no fibre breakage after test.

6.3 Environmental conditions

Environmental conditions for indoor cables may not be as severe as those for outdoor cables. Environmental requirements are defined by [IEC 60794-2] for most cable types (see Table 1). However, if environmental conditions are not defined, it is recommended that the same requirements as those for outdoor cables apply.

6.3.1 Hydrogen gas

Hydrogen testing of indoor cables is not needed except in the rare case. See [b-IEC TR 62690] for guidance.

6.3.2 Temperature variations

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

The ranges of temperature variations are shown in Table 1 (those values are described in [IEC 60794-2-20] as codes A and C), unless there is a different agreement between the manufacturer and user.

Table 1 – Temperature variations of optical fibre cable

Grade code	Temperature range (°C)		Recommended deployment configuration
	Lower temperature (T_A)	Higher temperature (T_B)	
A	–20	+60	Vertical installation
C	0	+50	Horizontal installation and cabling between optical equipment

6.3.3 Biotic damage

The size and deployment of indoor optical fibre cable make it vulnerable to many rodent attacks. This topic is covered in [ITU-T L.161/L.46].

6.3.4 Vibration

In buildings, there are various kinds of vibrations caused by construction, generators, elevators, etc. Usually, cable elements are maintained in position by friction and vibration may cause reduction of friction. It may cause moving of cable elements, which affects the transmission or mechanical characteristics of cables. It may have a greater effect when optical fibre cables are installed in a vertical cable shaft. Cables must withstand these vibrations without failure or signal degradation. Care should be exercised in the choice of installation method.

6.4 Fire safety

In buildings and houses, fire safety presents two major issues. Firstly, cables and cable elements should be difficult to burn. In another words, cables and cable elements should have flame-retardant characteristics. Secondly, cables and cable elements should not generate toxic gases and smoke when burning. Requirements for fire performance may differ in each country. Optical cables for indoor applications should meet regulations on fire safety as adopted in each country, or by telecommunication operators. The following should be considered if no fire safety specifications are provided and selected according to the application: [IEC 60331-25], [IEC 60332-1-2], [IEC 60332-3-24], [IEC 60332-3-25], [IEC 60754-1], [IEC 60754-2], [IEC 61034-1] and [IEC 61034-2].

7 Cable construction

7.1 Fibre coatings

7.1.1 Primary coating

Silica fibre itself has 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. In order to guarantee long-term reliability under service conditions, the proof-test strain may be specified, taking into account the permissible strain and required lifetime.

In order 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 1 – The optical fibres should be proof tested with a strain equivalent to 1%. For certain applications, a larger proof-test strain may be necessary.

NOTE 2 – Further study is required to advise on suitable testing methods for local light-injection and detection.

7.1.2 Secondary or buffer coating

The tight secondary coating of the fibre, if used, should comply with the requirements given in [IEC 60794-2].

NOTE 1 – When a tight secondary coating 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. While quite low coupling may cause fibre movement during the installation process, high coupling may cause high fibre stress when the cable is bent.

7.1.3 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 performance properties, also in the presence of other materials, during the lifetime of the cable.

7.1.4 Removability of coating

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

7.2 Cable element

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.

7.2.1 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 optical fibres. One is the edge-bonded type, another is the encapsulated type, as shown in Figures 1 and 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 coating material.

If the flexibility of optical fibre ribbons for bending is required, 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 3 may be optionally adopted for both the edge-bonded and the encapsulated 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].

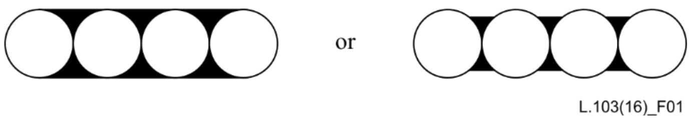

Figure 1 – Cross-section of a typical edge-bonded ribbon

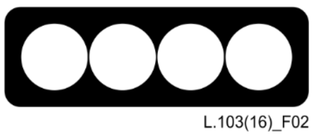

Figure 2 – Cross-section of a typical encapsulated ribbon

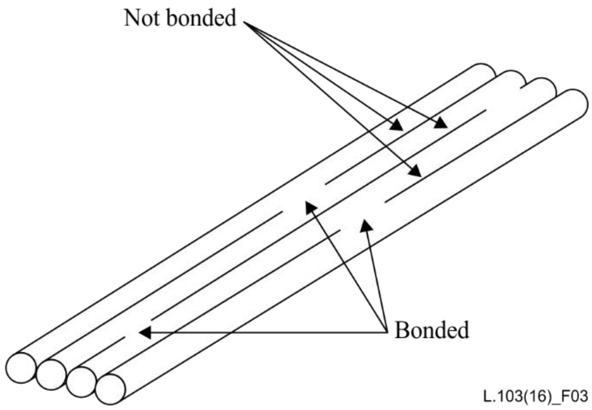

Figure 3 – Example of a typical partially bonded ribbon

7.2.2 Slotted core

In order to avoid direct pressure from the outside of the cable, optical fibres or ribbon fibres may be located in slots. Usually, slots are provided in a helical or reverse oscillation stranding (SZ) method configuration on a cylindrical rod. The slotted core usually contains a strength member (metallic or non-metallic). The 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.

7.2.3 Tube

A tube construction, commonly of polymeric materials, is frequently used to protect and gather optical fibres or fibre ribbons. Designs incorporating loose tubes are the most widely deployed cables, offering an optimized package for handling and robustness. They are typically stranded to minimize strain and enable easier mid-span access if the SZ method is utilized. Central tube designs may also be used. Filling material may be contained within the tube, if required.

7.2.4 Micro-module

A micro-module is a thin-walled tubing unit (typically smaller than the tube described in clause 7.2.3). These flexible modules have bending radii similar to those of unbundled fibre and are easy to strip without a tool for easy splice preparation and mid-span access. They have no shape memory and may be directly used in an enclosure up to the splicing tray. Water-blocking material may be contained in the micro-module, if required. See Figure 4.

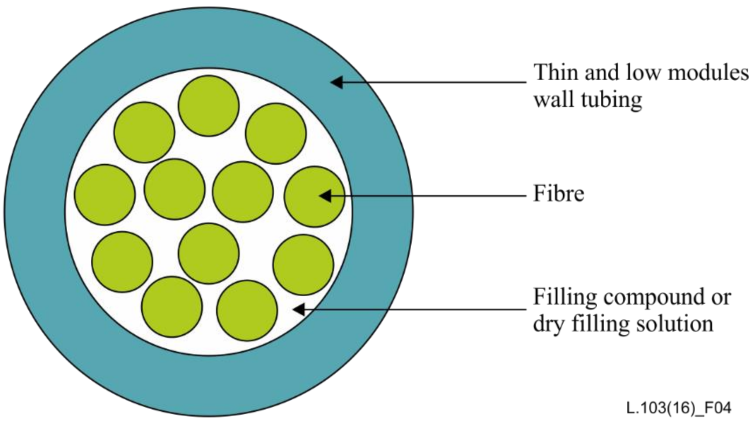

Figure 4 – Example of primary coated fibres protected by micro-module

7.2.5 Strength member

The cable should be designed with sufficient strength members to meet installation and service conditions so that fibres are not subject to strain levels in excess of those agreed between the user and manufacturer. The strength member(s) may be either metallic or non-metallic.

In case of the use of metallic strength members, care should be taken to avoid hydrogen generation effects (see clause 6.3.1).

If the cable is required to be installed by pushing into conduits, appropriately rigid strength members may be optionally adopted that are suitable for long distance installation with the resistance to buckling and flexibility for passing through conduit bends.

7.3 Sheath

The cable core should 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. The selection of the sheath material to optimize the friction forces between the cable sheath and duct should also 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 6.3.1).

Selection of sheath material is one of many important issues to be considered in order to satisfy fire safety requirements. Polyethylene is widely used as cable sheath material; however, it may not be suitable for indoor cables from the viewpoint of fire safety.

If the cable is required to be installed by pushing into conduits, a low friction sheath may optionally be adopted, which has both a low coefficient of friction between cables and conduits or other cables and appropriate cable performance, e.g. with regard to fire safety and ageing.

7.4 Identification of cable

It is recommended that a visual identification of optical fibre cables be provided: this can be done by visibly marking the outer sheath. For identifying cables, embossing, sintering or imprinting, or hot foil, ink-jet or laser printing can be used by agreement between the user and manufacturer.

8 Test methods

It is not intended that all tests be carried out; the frequency of testing and the relevant severe conditions to which fibre and cable are subject should be agreed between the user and manufacturer. Testing of cabled fibre and cables requires consideration of the general and guidance documents, [IEC 60793-1-1], [IEC 60794-1-1], [IEC 60794-1-2] and [IEC 60794-1-20].

8.1 Test methods for cable element

8.1.1 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], [ITU-T G.651.1] and the IEC 60793-1-xx series.

8.1.1.1 Dimensions

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

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

8.1.1.2 Coating strippability

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

8.1.1.3 Compatibility with filling material

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

The stability of 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 the user and manufacturer.

8.1.2 Tests applicable to tubes

8.1.2.1 Tube kink

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

8.1.3 Tests applicable to ribbons

8.1.3.1 Dimensions

For measuring ribbon dimensions, three test methods should be used properly. The first one, called a type test, is used to assess and verify 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. Those test methods are described in [IEC 60794-1-23] method G3, aperture gauge, and [IEC 60794-1-23] method G4, dial gauge. For inspection purposes, a visual measurement method can also be used.

8.1.3.2 Separability of individual fibres from a ribbon

A separability requirement can be given to a fibre ribbon if the user and manufacturer agree. When separability is required, the following should be avoided in order to ensure an extended reliability of the fibres:

1) damage to mechanical characteristics of fibres;
2) removal of colour coding of each fibre.

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

8.2 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 should be made to appropriate IEC 60794-2-xx series standards.

8.2.1 Tensile strength

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

Measurements are made to examine the behaviour of the fibre attenuation and strain 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.

8.2.2 Bending

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

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

This test should be carried out in accordance with [IEC 60794-1-21] method E11.

8.2.3 Bending under tension

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

The purpose of this test is to determine the ability of an optical fibre cable to withstand bending around rollers or bows during installation, when a specified load is applied.

This test should be carried out in accordance with [IEC 60794-1-21] method E8.

8.2.4 Crush

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

The appropriate test method is the plate-plate crush method.

This test should be carried out in accordance with [IEC 60794-1-21] method E3.

8.2.5 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 [IEC 60794-1-21] method E7.

8.2.6 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 [IEC 60794-1-21] method E4.

8.2.7 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 [IEC 60794-1-21] method E10.

8.2.8 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 [IEC 60794-1-21] method E6.

8.2.9 Coefficient of friction

[b-IEC TR 62470] may be used to assess friction coefficient of friction.

8.3 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 should be made to appropriate IEC 60794-2-xxseries standards.

8.3.1 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 that may occur during operation.

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

8.3.2 Vibration

This subject is for further study. For additional information refer to clause 6.3.4.

8.3.3 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 [IEC 60794-1-22] method F9.

8.4 Test methods for fire safety

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

8.4.1 Flame retardant characteristics

This test should be carried out in accordance with [IEC 60332-1-1], [IEC 60332-3-24] or [IEC 60332-3-25] unless there is a different agreement between the manufacturer and user.

8.4.2 Toxic gases characteristics

This test should be carried out in accordance with [IEC 60754-1] or [IEC 60754-2] unless there is a different agreement between the manufacturer and user.

8.4.3 Smoke characteristics

This test should be carried out in accordance with [IEC 61034-1] or [IEC 61034-2] unless there is a different agreement between the manufacturer and user.

Appendix I

Overview of IEC specifications for indoor optical fibre cable

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

This appendix is intended to provide an overview of the specifications of indoor optical fibre cables defined in the IEC system. The complete IEC optical fibre cable specification structure is also described in [b-ITU-T G-Sup.40].

The IEC optical fibre cable structure specification is hierarchical, with the different levels being identified with numeric suffixes of different levels of detail. These are:

– Generic: The general framework.
– Sectional: Attributes for a broad category of applications, e.g., indoor or outdoor.
– Family: Attributes and values or ranges of values for different constructions, e.g., simplex/duplex or ribbon.
– Product: Detailed requirements specific to particular applications, e.g., specific cable attenuation coefficients or multimode fibre bandwidth or temperature ranges.

In addition to the generic specification, [IEC 60794-1-1], and test methods, [IEC 60794-1-2x series], the relevant specifications for indoor cables are:

– IEC 60794-2 (2002), *Optical fibre cables – Part 2: Indoor cables – Sectional specification.*
– IEC 60794-2-10 (2011), *Optical fibre cables – Part 2-10: Indoor optical fibre cables – Family specification for simplex and duplex cables.*
– IEC 60794-2-20 (2013), *Optical fibre cables – Part 2-20: Indoor cables – Family specification for multi-fibre optical cables.*
– IEC 60794-2-30 (2008), *Optical fibre cables – Part 2-30: Indoor cables – Family specification for ribbon cables.*
– IEC 60794-2-50 (2008), *Optical fibre cables – Part 2-50: Indoor cables – Family specification for simplex and duplex cables for use in terminated cable assemblies.*

The family specifications call out the attribute and values for the different main types of constructions. For some attributes, a number of value ranges may be listed, taking into account that not all of the specific applications or different regions may need the same values. The product specification level of the hierarchy is intended to provide specific values for specific applications.

The following product specifications are intended to define the product requirements specific to [b-ISO/IEC 11801]. Cables according to these IEC product specifications may be used for guidance for indoor cables for general application.

– IEC 60794-2-11 (2012), *Optical fibre cables – Part 2-11: Indoor optical fibre cables – Detailed specification for simplex and duplex cables for use in premises cabling.*
– IEC 60794-2-21 (2012), *Optical fibre cables – Part 2-21: Indoor optical fibre cables – Detailed specification for multi-fibre optical distribution cables for use in premises cabling.*
– IEC 60794-2-31 (2012), *Optical fibre cables – Part 2-31: Indoor cables – Detailed specification for optical fibre ribbon cables for use in premises cabling.*
– These documents also refer to the following fibre specifications:
  • IEC 60793-2-10 (2015), *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*.
  • IEC 60793-2-50 (2015), *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*.

Appendix II

Indoor pathway systems for optical fibre cables (Japanese experience)

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

II.1 General

An optical fibre cable is normally led into a building through an underground conduit from a manhole or handhole. Pathway systems for optical fibre cables in a building consist of a vertical pathway in the height direction and a horizontal pathway along the floors. This appendix outlines the pathway systems for optical fibre cabling in a building and important points to be kept in mind when selecting from among them.

II.2 Vertical cable pathway systems

An optical fibre cable led into a building is terminated at the building distributor and then routed vertically to provide cabling to appropriate floors or to each floor distributor.

Table II.1 shows three types of vertical cable pathway systems, namely, the ladder cable tray system, the metal duct system and the conduit tube system (see clause II.4 for further information).

Table II.1 – Comparison of vertical cable pathway systems

Pathway systems	Ladder cable tray system	Metal duct system	Conduit tube system
Outline	Cabling performed on ladder cable tray installed in the cable shaft area	Cabling performed in metal wiring duct fixed on the building wall, etc.	Cabling performed in conduit tube installed in the building wall, etc.
Cabling capability	Large	Medium	Small
Flexibility for cabling modification	High	Higher than conduit tube	Low because of cable removal needed
Security	Ensured with lock and key for the cable shaft	Slightly low because duct cover can be opened easily	Slightly low when installed in a tenanted area, although tube protection itself good
Fireproof performance	Secured by making a cable shaft to fireproof run	Slightly low because fire protection only performed by the metal cover, although no flames reach the cables	Slightly low because fire protection only performed by the metal conduit tube, although no flames reach the cables
Space requirement	Large space needed due to large cable shaft requirement	Moderately large space needed because medium-size metal wiring duct required	Small space needed because conduit tube usually installed with an exposure
Cost	Advantageous for a large number of cables	Advantageous for a large number of cables	Advantageous for a small number of cables

The vertical cable pathway system requires high flexibility for subsequent extension of optical fibre cabling, capacity to house distributors and network equipment and security for the network system. It is, therefore, recommended that a dedicated cable shaft be provided as an architectural space in the building and that ladder cable trays be installed in it up to the appropriate floor for vertical cabling. Metal ducts or conduit tubes may be installed where the cable shaft includes power lines, low-voltage lines, etc., or where there is no cable shaft. However, these systems show less flexibility in cabling capacity and cabling modification than the ladder cable tray system, so their size and number should be selected with great care.

The cable shaft is, as a rule, located in the shared area of a building so that operators for equipment maintenance or cabling system extension can work outside the tenant-occupied area. To ensure security against human interference (intentional and unintentional), the entrance and exit doors should be kept under lock and key, and the entrances and exits should be located away from the flow lines of occupants, visitors and others. In a tenanted building, a cable shaft dedicated to each tenant should be provided if necessary. A cable shaft, which could present a danger of providing a spreading route for fire, should form vertical runs and horizontal runs with fireproof floors and walls in agreement with an architectural plan.

The parts where the ladder cable tray or optical fibre cable pass through the fire-resistant floor or wall should be given fireproofing treatment as specified in building standards law. The same requirements should be applied to metal ducts and conduit tubes as well. Where certain equipment is located, a cable shaft, which forms a closed space, should be provided with an appropriate ventilation system or air-conditioning system in order to maintain the temperature at 0°C to 40°C and the humidity at 80% or below.

II.3 Horizontal cable pathway systems

A horizontal cable pathway system is installed on the floor slabs, in the floor slabs or in the ceilings. It should be selected from the under-carpet cabling system, simplified access floor system (Figure II.3), raised access floor system, under-floor duct system, cellular raceway system, conduit tube system, ladder cable tray system and metal duct system (see clause II.4 for further information).

Table II.2 shows the advantages, disadvantages and application of these systems. In selection, careful attention should be paid to the construction of the floor (thickness of floor slabs, reinforcement bar arrangement, floor finish, etc.), cabling capacity, expected movement and increase or decrease of terminal equipment, arrangement of furniture and fixtures, cost considerations, etc.

The simplified access floor system is very advantageous because the whole space under the floor can be used for cabling; such selection can be made using a wide variety of products and the cabling procedure can be simply carried out by removing the floor panels. Use of this system is therefore recommended in ordinary office buildings. The following points should be taken into consideration in selecting this system.

When re-cabling is done after desks and equipment are placed in the completed office, cables may be laid obliquely to save the trouble of moving the equipment and unnecessary cables may be left in place. As a result, the cabling space will become full quickly and the existing cables may suffer damage easily. It is therefore necessary to manage the cabling system with care. This is particularly important when the low floor-mounted type with minimum cabling space is employed from the viewpoint of economy, and as much space as possible is needed above the floor within a limited storey height.

Table II.2 – Comparison of horizontal cable pathway systems

Place	Systems	Outline	Advantages	Disadvantages	Application
On the floor slab	Under-carpet wiring system	A flat cable installed under the carpet	– Not influenced by storey height – Cable extraction from anywhere	– High cost – Small cabling capacity	Small wiring quantity, and when simplified access floor system is not available
	Simplified access floor system	– Two types – Panel-leg monoblocks and panel-leg separate type (Height: 50-150 mm)	– Easy cabling modification – Free cable extraction position – Applicable to existing buildings	Moderately high cost	Fairly large wiring quantity, frequent cabling modification, and when space from 50 mm to 150 mm can be ensured
	Raised access floor system	Panels with legs placed on the floor slab (Height: 200-500 mm)	– Extremely large cabling capacity – Free cable extraction position	– High cost – Difficult cabling modification with time – High storey height needed	Extremely large wiring quantity (for computer room or dealing room, for example)
In the floor slab	Floor duct system	Steel ducts cast in floor slabs and cable access hatches installed at intervals	Well-arranged cabling	– Relatively small capacity – Fixed cable extraction point	– Infrequent cabling modification – Available together with under-carpet wiring system
	Cellular raceway system	Cabling raceway where cover plates enclose gaps in corrugated deck plates	– Large cabling capacity – Well-arranged cabling	– Capacity depends on header duct – Troublesome cabling modification	Large wiring quantity, and when cabling route is fixed
	Conduit tube system	Conduit tubes buried in floor slabs	Low cost	– Small capacity – Fixed cable extraction point – Repairing becomes difficult due to pipe corrosion	Small wiring quantity, and when cabling fixed (for a meeting room, for example)
In the ceiling	Ladder cable tray system	Ladder cable tray installed in the ceiling	– Large capacity – Easy cabling maintenance	– Troublesome cable protection and fireproofing – Aesthetically unpleasing due to exposed cabling	Large wiring quantity, and when simplified double-floor system is not available
	Metal duct system	Ducts placed in the ceiling and cables installed in it	Easy maintenance	Smaller cabling capacity than that of ladder cable tray system	Small wiring quantity and when exposed cabling is prohibited

II.4 Pathway systems facilities

II.4.1 Ladder cable tray

Ladder cable trays are used to install a large number of cables for power supply, telecommunications, etc. Recently, they have been used more widely because of their greater receptivity to installation and extension of cable systems than rigid metal conduits and metal ducts.

Tray materials are metals and plastics. The metal trays include steel trays (including zinc-coated ones) and aluminium trays, which are selected according to the place of use. In selecting ladder cable trays, careful consideration should also be paid to their load capacities.

Figure II.1 illustrates an example of a ladder cable tray system. The supporting interval is generally 2.0 m or less for steel ladder cable trays or 1.5 m or less for aluminium ladder cable trays. Aseismic design metal fittings should also be attached below the main beams, wall surfaces and posts to protect the trays against earthquakes. Ladder cable trays may have widths of 200 mm, 300 mm, 400 mm, 500 mm and 600 mm. Cables should, in principle, be installed on the trays in single-level arrays. Ladder cable trays of proper dimensions should be selected by taking into consideration the cable dimensions, the required cable separation from each other, and the margins at each end of the trays.

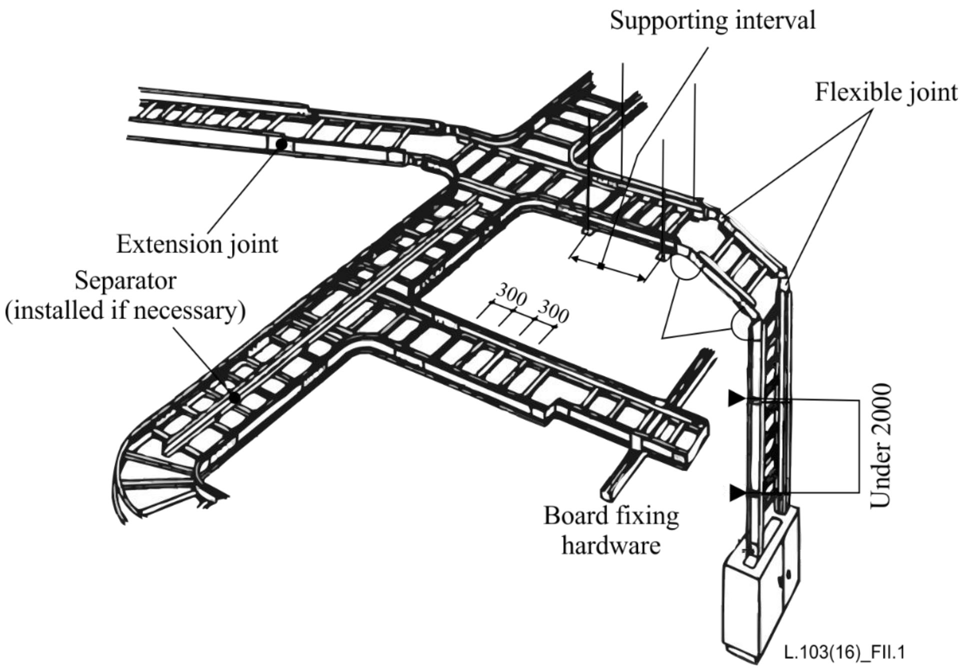

Figure II.1 – Example of ladder cable tray system

II.4.2 Metal duct

Metal ducts, which have structures like the one shown in Figure II.2, are used to install a large number of electric wires or cables. The technical standard for electrical installations, according to electric appliance and material control law, states that metal ducts should have steel, or other metallic material of equal or superior strength, sheets with a width of 50 mm or more and a thickness of 1.2 mm or more. They should be supported securely at intervals of 3 m or less on the ceiling, or the equivalent (6 m or less where the metal duct is installed vertically in a place to which no-one except authorized personnel have access). The total cross-sectional area of electric wires and cables (including insulation) installed in a metal duct should be 20% or less of the cross-sectional area of the duct (it can be 50% or less for the wires for control circuits or in-out annunciators). Also, it is desirable that the number of wires is less than 30.

Careful consideration should be paid to the use of a metal duct since it contains a large number of electric wires or cables and the fireproofing procedure is difficult at the point where it penetrates the firewall within the building.

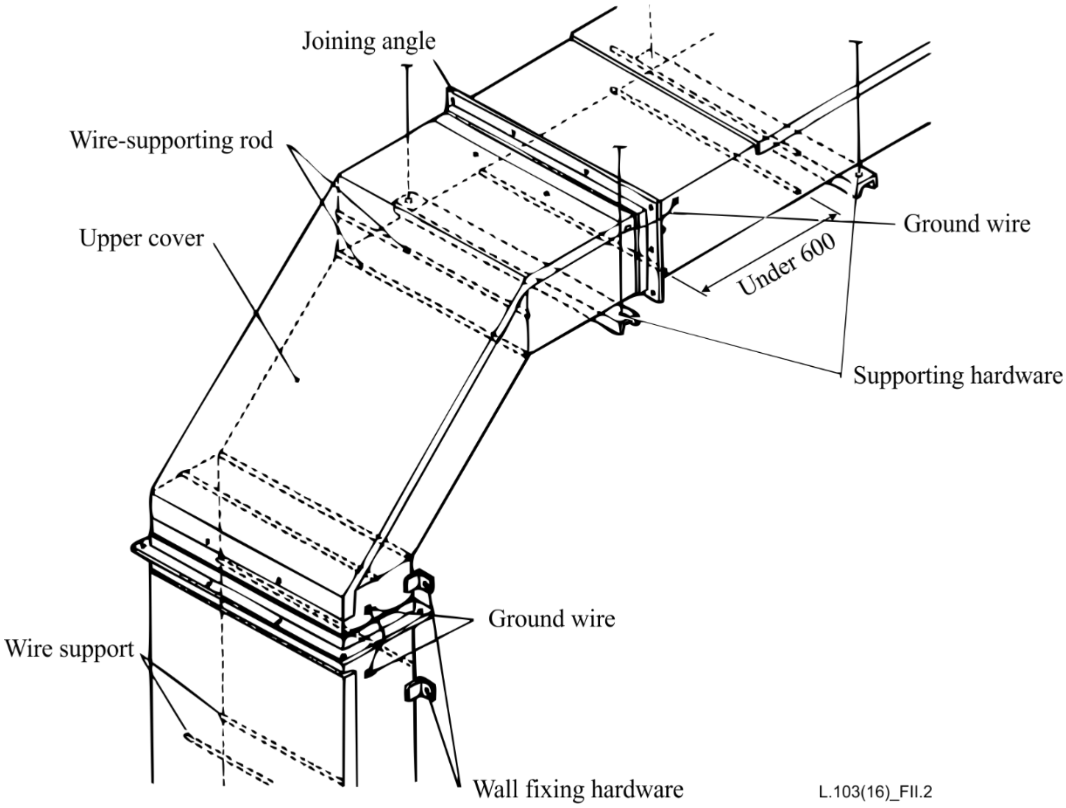

Figure II.2 – Metal duct system

II.4.3 Conduit tube

Conduit tubes, which are used to protect electric wires or cables, are chosen from metal tubes (steel conduit tubes) and plastic tubes. There are three types of metal tubes, namely, thin wall steel conduit, thick wall rigid steel conduit and plain conduit. See Table II.3.

Table II.3 – Characteristics of conduit tubes

Type	Name	Outer diameter (mm)	Thickness (mm)	Inner diameter (mm)
Thin wall steel conduit	C19	19.1	1.6	15.9
	C25	25.4	1.6	22.2
	C31	31.8	1.6	28.6
	C39	38.1	1.6	34.9
	C51	50.8	1.6	47.6
	C63	63.5	2.0	59.5
	C75	76.2	2.0	72.2
Thick wall rigid steel conduit	G16	21.0	2.3	16.4
	G22	26.5	2.3	21.9
	G28	33.3	2.5	28.3
	G36	41.9	2.5	36.9
	G42	47.8	2.5	42.8
	G54	59.6	2.8	54.0
	G70	75.2	2.8	69.6
	G82	87.9	2.8	82.3
	G92	100.7	3.5	93.7
	G104	113.4	3.5	106.4
Plain conduit	E19	19.1	1.2	16.7
	E25	25.4	1.2	23
	E31	31.8	1.4	29
	E39	38.1	1.4	35.3
	E51	50.8	1.4	48.0
	E63	63.5	1.6	60.3
	E75	76.2	1.8	72.6

II.4.4 Raised access floor (including simplified access floor)

A great variety of raised access floors are available on the market today. Raised access floors, which are made up of floor panels, constituting part of the residential space, and legs to support the floor panels above floor slabs are classified into the types described in clauses II.4.4.1 to II.4.4.3.

II.4.4.1 Panel-leg separate type

Method: Removable panels are placed on legs fixed to floor slabs.

Placement: Legs are fixed to floor slabs with adhesive or rivets and panels are secured on top of the legs.

Level adjustment: ±10 mm adjustable by floor-level adjusting nuts on legs.

Cabling space: Largest, with wide selectability of floor height.

Material: Panel: steel, aluminium, ceramic, composite steel.
Leg: steel, aluminium.

II.4.4.2 Panel-leg combined type

Method: Panel has legs at four corners. Panel and legs cannot be separated.

Placement: Panel-leg monoblocks are placed on structural floor.

Level adjustment: ±10 mm adjustable by screw elements on legs.

Cabling space: Relatively large.

Material: Panel: steel, aluminium, ceramic, composite steel.
Leg: steel, aluminium.

II.4.4.3 Floor-mounted type

Method:	Panel and legs are unified. Panel and legs cannot be separated.
Placement:	Panel-leg monoblocks are placed on floor slabs.
Level adjustment:	Level difference between panels is prevented by choice of small dimensions of panel. Level difference due to installation error of floor slabs cannot be absorbed.
Cabling space:	Small.
Material:	Plastic, ceramic, aluminium, composite steel.

Raised access floor panels (elements) on the market are made of metallic panels (steel mouldings, aluminium castings), ceramic panels (fibre-reinforced calcium silicate plates, fibre-reinforced concrete plates, etc.), organic panels (plywood-resin mouldings) and composite panels (wood core and steel, mortar core and steel, etc.). Panels with metal legs (steel welded structure, aluminium castings) or organic legs (resin mouldings) are also commercially available.

Figures II.3 and II.4 illustrate an example of a simplified access floor system and an example of a floor-mounted type simplified access floor system, respectively, which are both widely used in ordinary offices.

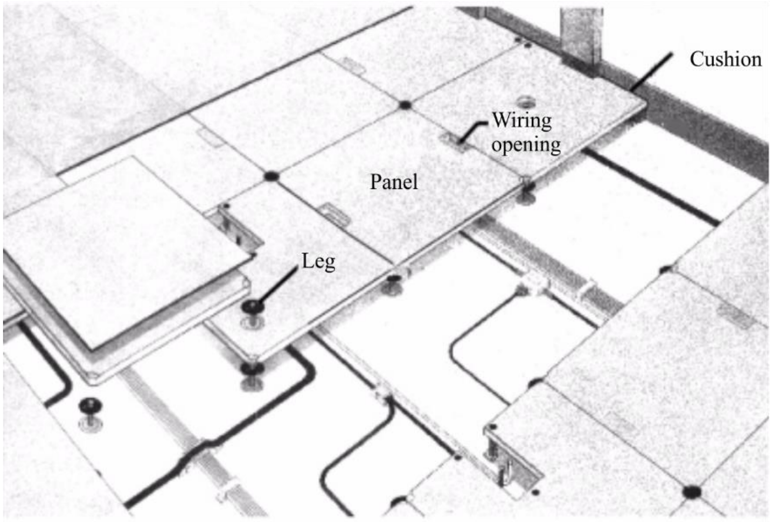

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Figure II.3 – Example of simplified access floor system (panel-leg separate type)

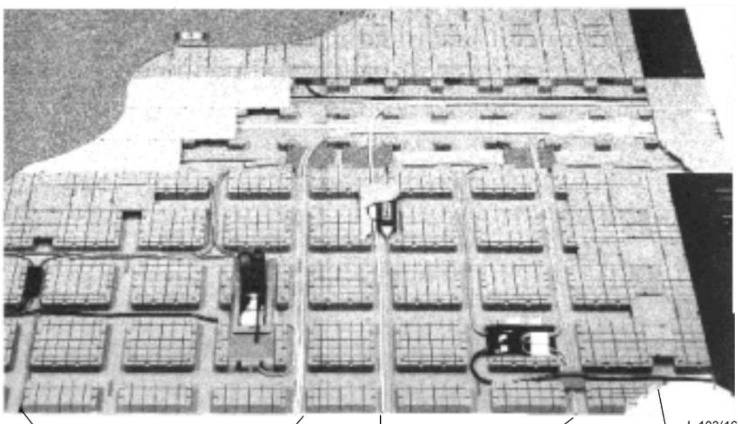

Figure II.4 – Example of simplified access floor system (floor-mounted type)

II.4.5 Under-floor duct

The structure of under-floor ducts is shown in Figure II.5. Steel ducts buried in concrete floor slabs are used for power cabling, plug sockets, etc., as well as telecommunication and information cabling for telephones, office automation equipment, etc. Figure II.6 gives an example of installation.

Wires and cables in the buried floor ducts are led out from the insert studs provided at 600 mm intervals.

Piping to cabinets and distribution panels inside a cable shaft should be so arranged that pipes do not cross each other or converge on the same point, in order not to weaken the strength of floor slabs around the cable shaft.

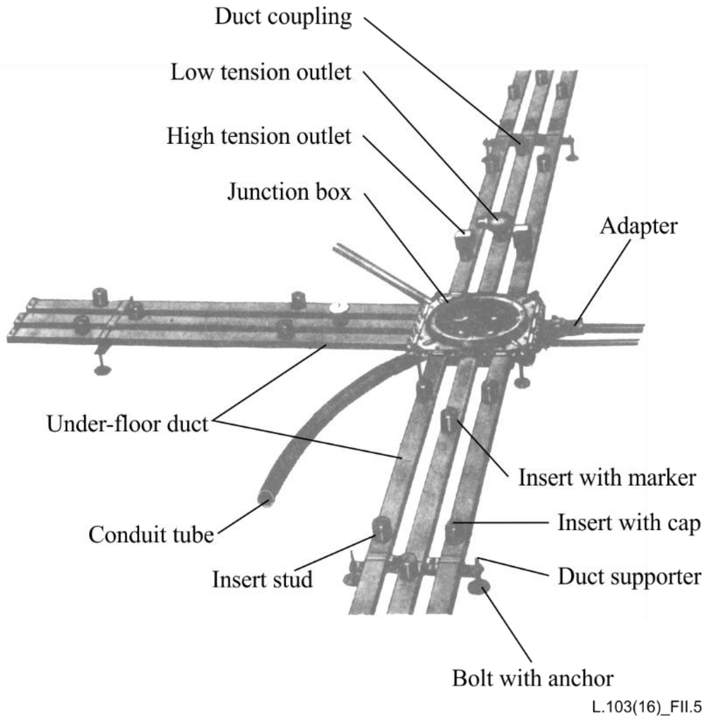

Figure II.5 – Outline of under-floor duct system

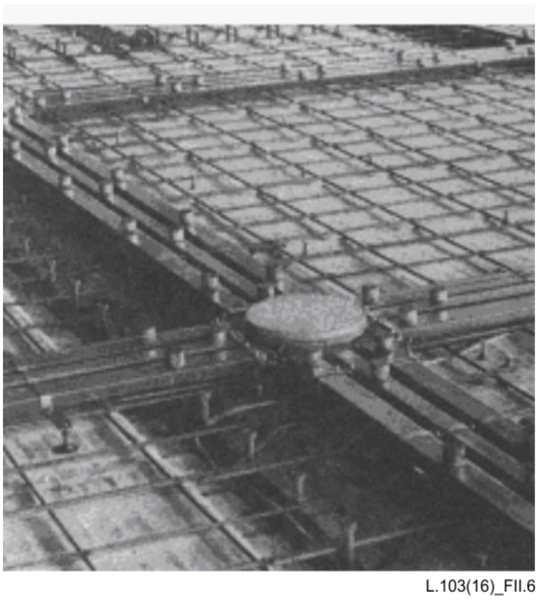

Figure II.6 – Example of under-floor duct installation

II.4.6 Cellular raceway

Cellular raceways are cabling ducts formed by enclosing with cover plates the gaps in corrugated deck plates used as floor formworks in a building.

With larger cross-sectional areas than under-floor ducts, cellular raceways can hold more wires and cables. Also, cabling is easier because of the larger diameter studs for outgoing cables. Some fireproofing procedures should be followed for the cellular raceways buried in the floor, which may reduce the cross-section of the floor. Also, consideration should be given to cracks in the concrete.

As shown in Figure II.7, cellular raceways are normally used in combination with under-floor ducts. Figure II.8 gives an installation example of a cellular raceway for reference.

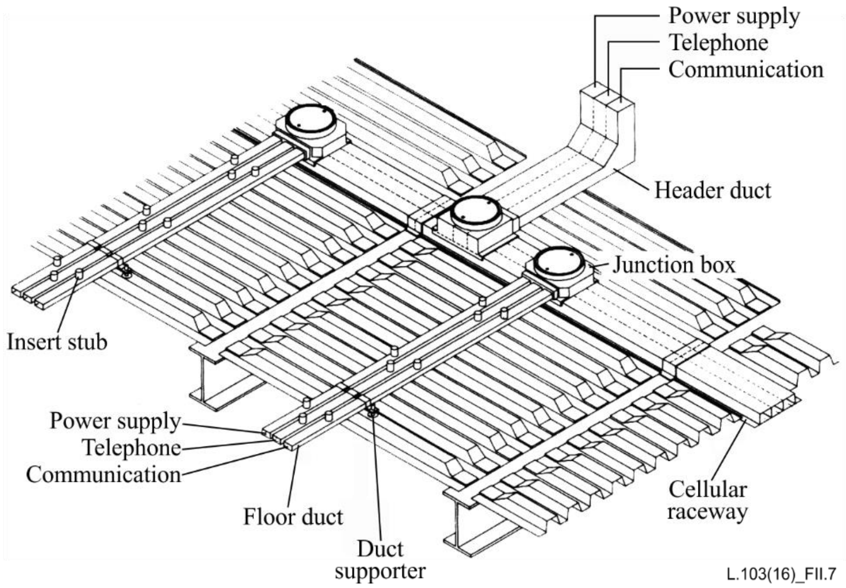

Figure II.7 – Outline of cellular raceway system

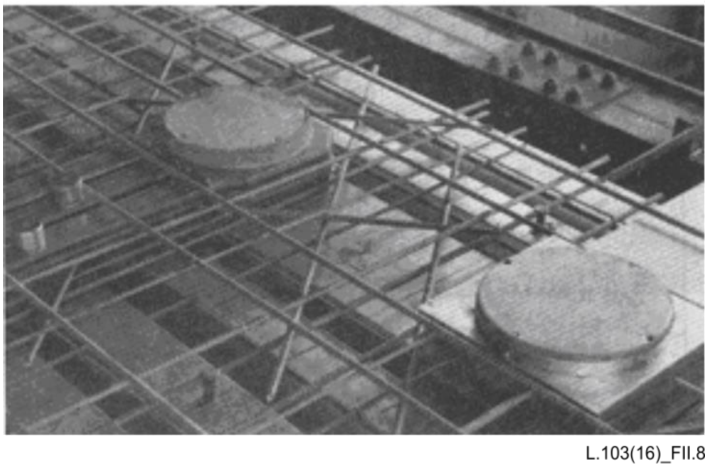

Figure II.8 – Example of cellular raceway installation

Appendix III

Indoor cable specification (Chinese experience)

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

In order to match with indoor facilities in each country, required test conditions and allowable results can be changed on agreement between the manufacturer and user. This appendix shows the Chinese experience with indoor cables.

III.1 Fibre attenuation

The maximum attenuation coefficient of fibres in cable should meet Table III.1.

Table III.1 – Maximum attenuation coefficient of fibres in cable

Type of fibre	Wavelength (nm)	Tight buffer fibre (dB/km)	Loose tube fibre (dB/km)	
ITU-T G.652	1 310/1 550	0.8/0.6	0.45/0.3	0.5/0.4
ITU-T G.655	1 310/1 550	–/0.6	–/0.3	–/0.4
50/125 and 62.5/125	850/1 300	3.5/1.5	3.0/1.0	

III.2 Mechanical characteristics

III.2.1 Bending tensile strength

Allowed tensile strength of optical fibre cable should be in accordance with Table III.2. Unless otherwise required by the user, fibre strain should not exceed 0.2%, and the fibre-added attenuation coefficient should not change under permanent load. Under installation load, fibre strain should not exceed 0.4%. There should be no remaining attenuation, and there should be no damage to the cable elements.

Table III.2 – Allowed minimum tensile strength and minimum crush resistance

	Tensile strength (N)	Crush (N/10 cm)	Recommended deployment configuration
Installation load	≤12 cores: 660 >12 cores: 1 320	1 000	Vertical installation
	≤12 cores: 440 >12 cores: 660	1 000	Horizontal installation
	≤4 cores: 220	350	Cabling between optical equipment
Permanent load	≤12 cores: 200 >12 cores: 400	300	Vertical installation
	≤12 cores: 130 >12 cores: 200	200	Horizontal installation
	≤4 cores: 70	200	Cabling between optical equipment

III.2.2 Crush

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

The crush and impact may increase optical loss (either permanently or for the duration of application of the stress) and excessive stress may lead to fibre fracture.

The crush test should be performed according to clause 7.2.3. After the test, the fibre-added attenuation coefficient should not change under permanent load. Under installation load, there should be no damage to the fibre or cable elements. For allowed minimum crush load, see Table III.2.

III.3 Environmental conditions

III.3.1 Temperature variations

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

The range of temperature variations and the limit of added attenuation are shown in Table III.3.

Table III.3 – Temperature variations of optical fibre cable

<table>
<tr><th rowspan="2">Grade code</th><th colspan="2">Temperature ranges (°C)</th><th colspan="4">Added fibre attenuation limits (dB/km)</th><th rowspan="2">Recommended deployment configuration</th></tr>
<tr><th>Lower temperature (T_A)</th><th>Higher temperature (T_B)</th><th>ITU-T G.652.A and ITU-T G.652.B</th><th>ITU-T G.652.C and ITU-T G.652.D</th><th>ITU-T G.655</th><th>50/125 and 62.5/125</th></tr>
<tr><td>A</td><td>–20</td><td>+60</td><td colspan="3" rowspan="2">≤ 0.40</td><td rowspan="2">≤ 0.60</td><td>Vertical installation</td></tr>
<tr><td>C</td><td>0</td><td>+50</td><td>Horizontal installation and cabling between optical equipment</td></tr>
<tr><td colspan="8">NOTE – The temperature-added attenuation of optical fibre cable is the dispersion relative to 20°C.</td></tr>
</table>

III.4 Test methods for mechanical characteristics of the cable

III.4.1 Tensile strength

Test method: IEC 60794-1-2 E1.

Diameter of chuck drums: Not lower than 30 times the diameter of the cable (30*D*) or 30 times the height of the cable (30*H*), but not larger than 560 mm.

Hold time: 5 min.

Velocity of transfer device: Either 100 mm/min or force gradually applied at a rate of 100 N/min.

Load: According to Table III.2.

Length of sample: Not less than 50 m.

III.4.2 Crush

Test method: IEC 60794-1-2 E3.

Force: According to Table III.2.

Hold time: 1 min under permanent load and installation load.

III.5 Test methods for environmental characteristics

III.5.1 Temperature cycling

Test method: IEC 60794-1-2 F1.

Length of sample: Sufficient to achieve the desired measurement accuracy of attenuation and should not be lower than 2 km.

Scope of temperature: The low temperature (T_A) and the high temperature (T_B) should be according to Table III.3.

Duration: Not shorter than 8 h.

Number of cycles: 2.

Attenuation measurement: The change of attenuation of fibres should be measured at a wavelength of 1 550 nm for single mode fibre and at a wavelength of 1 300 nm for multimode fibre.

Appendix IV

Low friction indoor cable and wiring (Japanese experience)

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

IV.1 Introduction

Low friction indoor cable is widely used for multi-dwelling unit (MDU) wiring in Japan. Clauses IV.2 to IV.5 describe the fibre to the home (FTTH) configuration for MDUs, problems of conventional wiring and their solutions in Japan.

IV.2 Configuration of fibre to the home for multi-dwelling units

The basic configuration of optical access network in Japan is shown in Figure IV.1. Two types of topology are employed according to the type of user, namely passive double star or single star topology. First, for home users, a 4-branch optical splitter module part (SP) is installed in the central office and an 8-branch SP is installed on the user side. Second, by contrast, a 32-branch SP (or a combination of one 4-branch SP and four 8-branch SPs) is installed in MDUs, such as apartment houses, condominiums and office buildings. As a result, 32 users share an optical line terminal (OLT) and 32 users share a fibre. A configuration consisting of the single star topology with a media converter is widely used to provide MDUs with FTTH services. For a medium-sized MDU, SPs are installed in a main distribution frame (MDF) and effective wiring approaches involve using a star configuration from an SP installed in an MDF to each unit according to demand as shown in Figure IV.2. This approach makes it easy to manage such operations as a change of service.

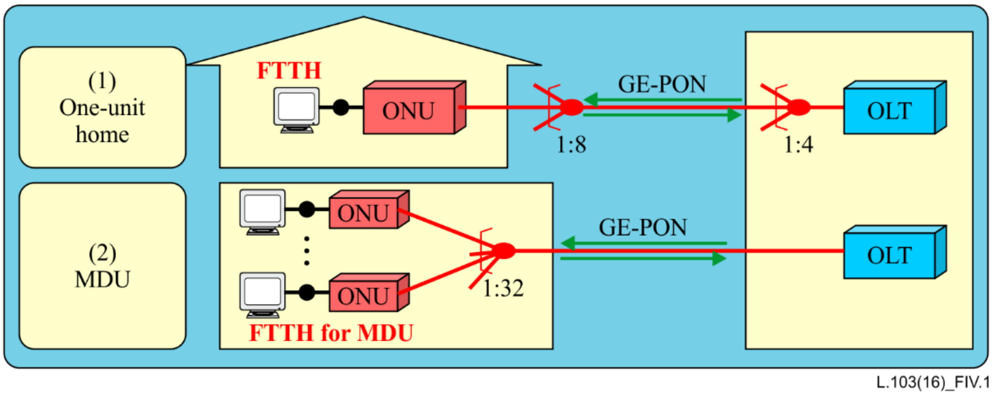

Figure IV.1 – Configuration of optical network

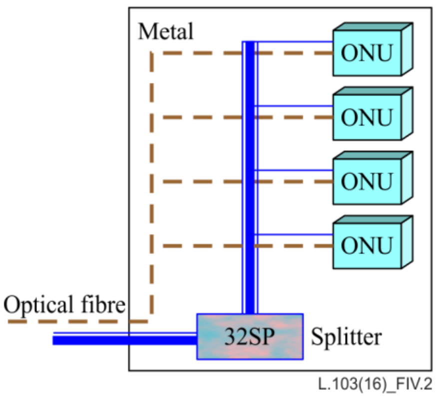

Figure IV.2 – Topology of wiring inside a multi-dwelling unit

IV.3 Problems of conventional wiring

Figure IV.3 shows main distribution frame/intermediate distribution frame (MDF/IDF) boxes and conduits in an existing MDU. Copper facilities have already been installed and the space available for optical fibre wiring is very limited. Moreover, conduits have a small diameter and there are no free conduits.

Existing copper cable with a diameter of more than 10 mm is usually installed in conduits. However, cable installation is difficult when a conduit is curved because the cable diameter is large. If optical indoor cable for each unit is required, additional conduits and cabinet boxes would have to be installed due to the lack of space, and this would be both time consuming and costly. To expand FTTH to existing MDUs, it was necessary to develop effective wiring techniques for using the free space in existing conduits and the confined space of an MDF.

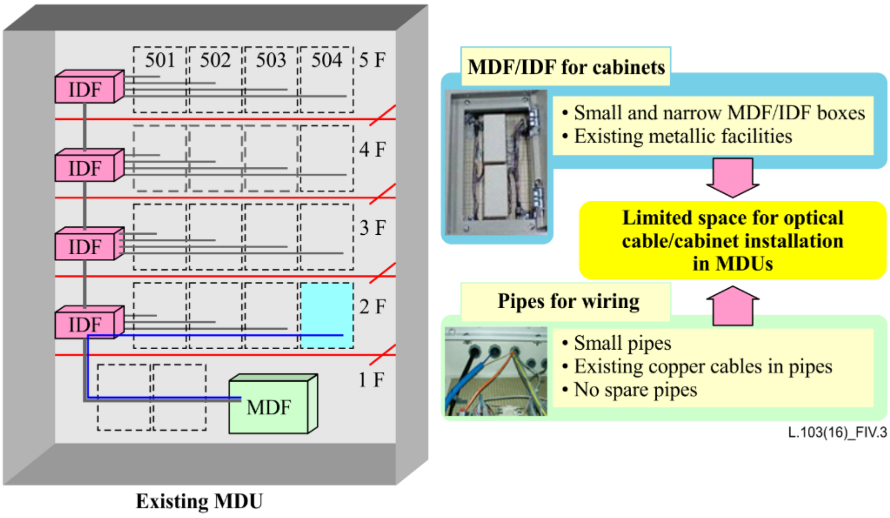

Figure IV.3 – Indoor cable wiring problems with existing MDUs

IV.4 Conventional indoor cable

The most widely used way of installation of a conventional indoor cable (hereinafter, "conventional cable"), as shown in Figure IV.4, in Japan is described below:

1) Insert a lead wire into a conduit and connect a cable to its head.

2) Pull the lead wire to install the cable and then disconnect it.

If a conventional cable is installed with existing copper cables, strong traction-tension is needed to pull it, because of the friction drag imposed by the cable surface. When there are several conventional cables, the traction-tension limit means that installation is impracticable. Volatility is high even though a lubricant is painted on the surface of the cable to reduce friction to facilitate cable construction. Moreover, existing cables may be dragged along during installation. In fact, careful attention must be paid to cable installation and removal from a conduit when troubleshooting.

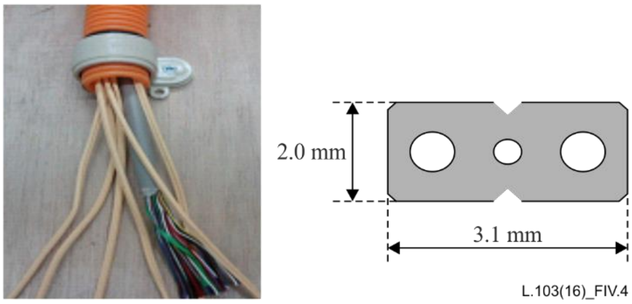

Figure IV.4 – Image of conventional cable

IV.5 Low friction indoor cable

IV.5.1 Functions expected with new cable

To make it possible to wire all units, three main technical problems have to be overcome.

1) Reducing cable size
   – Installing cables for all units into existing conduit.
2) Achieving low cable friction
   – Reducing the traction-tension.
3) Adjusting appropriate cable bending rigidity
   – Resistance to buckling when pushing and flexibility for passing through bent parts of the conduit.

IV.5.2 Design

Figure IV.5 shows the small size, low friction and appropriately rigid indoor cable (hereinafter, "low friction cable") and Figure IV.6 shows an example of the test method setup for the measurement of coefficient of friction. The size of its cross-section is about one-half of that of the conventional cable. The coefficient of friction is less than 0.25, which is about one-fifth of that of a conventional cable, and the bending rigidity is about double of that of the conventional cable. The coefficient of friction of low friction cable is much less than that of the conventional cable painted with lubricant. Furthermore, the coefficient of friction of the low friction cable is maintained over time. In addition, the required cable characteristics, which are the same as those of the conventional cable, are realized.

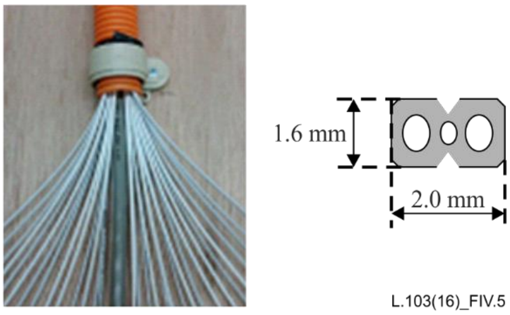

Figure IV.5 – Image of low friction cable

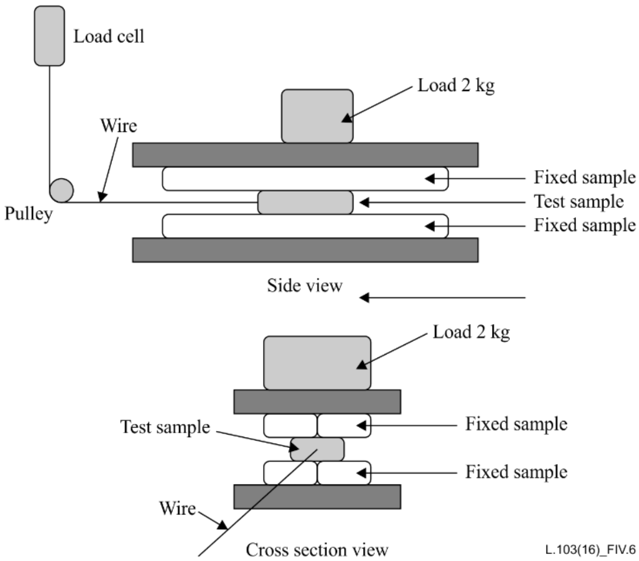

Figure IV.6 – Test method setup for the measurement of coefficient of friction

IV.5.3 Effect of low friction indoor cable

The difference in the numbers of the conventional and the low fiction cable that can be installed is shown in Table IV.1. Three times as many low friction cables can be installed in the space of conventional cables. A total of 30 low friction cables can be installed in an existing 22-mm conduit with an 8.6-mm copper cable as shown in Figure IV.5.

Table IV.1 – Numbers of installed conventional vs. low friction cables

	Diameter of conduit		
	16 mm	**22 mm**	**28 mm**
Conventional cable	4	8	15
Low friction cable	12	30	over 35
* Copper cable, diameter of 8.6 mm, is already installed. * Conventional cable: installed without lubricant			

The low friction reduces the pulling tension and shortens the installation time. Figure IV.7 presents a comparison of pulling tension and installation time of the low friction cables vs. conventional cables. It is possible to pull the cable with about 1/10 of the usual tension, and also the installation time becomes about 1/5 of the conventional installation time. Additionally, it is possible to remove the low friction cables without disturbing the existing cables because the low friction characteristics remain.

A new installation method is also established that involves pushing the cable into a conduit rather than using a pulling wire. Figure IV.7 shows that the installation time is reduced by about one-third compared with the conventional method when the conduit condition is good. This is because the conventional method requires two steps whereas the new insertion method requires only one.

In addition, the pushing method may make it possible to insert a cable into a conduit that is damaged, such as a dented portion that is preventing the insertion of a new cable. There are cases where it is impossible to insert a new cable into an existing conduit with the conventional method. However, it is possible with the new method.

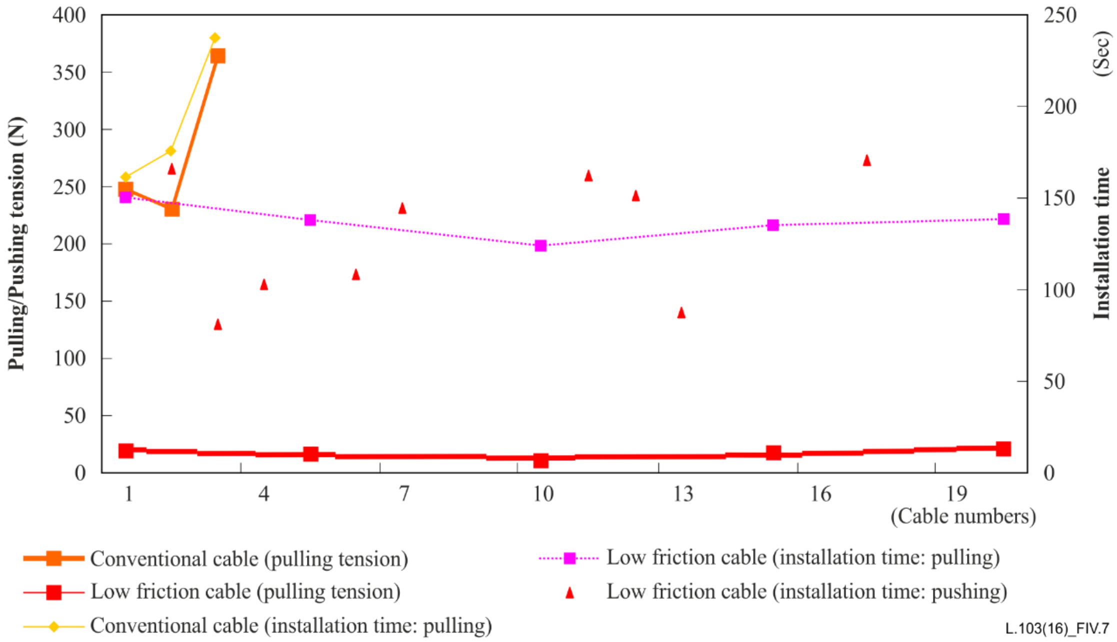

Figure IV.7 – Installation results examples of conventional cable and low friction cable in a 22-mm conduit

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