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TECHNICAL REPORT

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Optical fibre cables – Guide to the installation of optical fibre cables

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRE CABLES –

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FOREWORD

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IEC 62691, which is a technical report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86A/1415/DTR	86A/1426/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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A bilingual version of this publication may be issued at a later date.

OPTICAL FIBRE CABLES –

Guide to the installation of optical fibre cables

1 Scope

Optical fibre cabling provides a high performance communications pathway whose characteristics can be degraded by inadequate installation. This technical report provides guidance to assist the user and installer with regard to the general aspects of the installation of optical fibre cables covered by the IEC 60794 series of specifications, and the particular aspects of the 'blowing' technique.

Optical fibre cables are designed so that normal installation practices and equipment can be used wherever possible. They do, however, generally have a strain limit rather lower than metallic conductor cables and, in some circumstances, special care and arrangements may be needed to ensure successful installation.

It is important to pay particular attention to the cable manufacturer's recommendations and stated physical limitations and not exceed the given cable tensile load rating for a particular cable. Damage caused by overloading during installation may not be immediately apparent but can lead to failure later in its service life.

This guide does not supersede the additional relevant standards and requirements applicable to certain hazardous environments, e.g. electricity supply and railways.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60794-3 series, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 60794-3-40, *Optical fibre cables – Part 3-40: Outdoor cables – Family specification for sewer cables and conduits for installation by blowing and/or pulling in non-man accessible storm and sanitary sewers*

IEC 60794-3-50, *Optical fibre cables – Part 3-50: Outdoor cables – Family specification for gas pipe cables and subducts for installation by blowing and/or pulling/dragging in gas pipes*

IEC 60794-3-60, *Optical fibre cables – Part 3-60: Outdoor cables – Family specification for drinking water pipe cables and subducts for installation by blowing and/or pulling/dragging/floating in drinking water pipes*

IEC/TR 62362, *Selection of optical fibre cable specifications relative to mechanical, ingress, climatic or electromagnetic characteristics – Guidance*

IEC/TR 62470, *Guidance on techniques for the measurement of the Coefficient Of Friction (COF) between cables and ducts*

ISO/IEC 24702, *Information technology – Generic cabling – Industrial premises*

ISO/IEC TR 29106, *Information technology – Generic cabling – Introduction to the MICE environmental classification*

ITU-T Recommendation K.25, *Protection of optical fibre cables*

ITU-T Recommendation L.35, *Installation of optical fibre cables in the access network*

ITU-T Recommendation L.38, *Use of trenchless techniques for the construction of underground infrastructures for telecommunication cable installation*

ITU-T Recommendation L.57, *Air-assisted installation of optical fibre cables*

ITU-T Recommendation L.61, *Optical fibre cable installation by floating technique*

ITU-T Recommendation L.77, *Installation of optical fibre cables inside sewer ducts*

3 Installation planning

3.1 Installation specification

The successful installation of an optical fibre cable can be influenced significantly by careful planning and assisted by the preparation of an installation specification by the user. The installation specification should address the cabling infrastructure, cable routes, potential hazards and installation environment and provide a bill of materials and technical requirements for cables, connectors and closures.

The installation specification should also detail any civil works, route preparation (including drawpits, ductwork, traywork and trunking) and surveying that are necessary, together with a clear indication of responsibilities and contractual interfaces, especially if there are any site or access limitations.

Post installation requirements for reinstatement, spares, ancillary services and regulatory issues should also be addressed.

3.2 Route considerations

Whilst optical fibre cables are lighter and installed in longer lengths than conventional metallic cables, the same basic route considerations apply.

Route planning and cable handling methods must carefully take into account the specified minimum bending radius and maximum tensile loading of the particular optical fibre cable being installed so that fibre damage, giving rise to latent faults, can be avoided.

Some of the most difficult situations for the installation of optical fibre cables are in underground ducts and the condition and geometry of duct routes is of great importance. Where the infrastructure includes ducts in poor condition, excessive curvature, or ducts already containing cables or access points with abrupt changes of direction, the maximum pull distance will be reduced accordingly.

Provision of long cable lengths in underground duct or aerial situations may involve installation methods that require access to the cable at intermediate points for additional winching or blowing effort, or “figure 8” techniques, these sites should be chosen with care. Consideration should also be given to factors of time and disturbance. Installation equipment may be required to run for long periods of time and the time of day, noise levels, and vehicular traffic disruption should be taken into account.

Because the condition of underground ducts intended for optical fibre cable is of particular importance, care should always be taken to ensure that ducts are in sound condition and as clean and clear as possible. Consideration can also be given to the provision of a sub-duct system, either in single or multiple form, to provide a good environment for installation, segregation of cables, extra mechanical protection and improved maintenance procedures. Sub-ducts can be more difficult to rope and cable than normal size ducts, particularly over long lengths, and the diameter ratio between the cable and subduct should be considered. Note that in ducts or subducts, bundles of microducts can also be installed, e.g. by pulling or blowing.

For overhead route sections, a very important consideration is the need to minimise in-service cable movement. Movement of the cable produced by thermal changes, cable weight, ice loading, wind, etc. may have a detrimental effect. A stable pole route, with all poles set as rigidly as possible, is therefore an important element in reducing possible movement and consideration should be given to purpose-designed, optical fibre-compatible, pole top fittings and attachments.

Although optical fibre cables are generally light in weight, their addition to an existing suspension member can take the optical fibre beyond its recommended strain limit and the added dip and extension should be calculated before installation.

Where it is planned for long lengths of optical fibre cable to be directly buried or ploughed, those sections involving ploughing can, with advantage, be pre-prepared using specialised slitting or trenching equipment.

3.3 Cable installation tension considerations

The potential for providing very long lengths of optical fibre cable can lead to the need for confidence that a particular installation operation will be successfully achieved, particularly in underground ducts, and a good indication can be provided, in some cases, by calculating the maximum cable tension. This maximum tension can be compared with the stated mechanical performance of the cable and, where these values are close, consideration can be given to methods for providing a greater margin of safety such as an alternative cable design, shortening the route, changing the route or direction of cabling, provision of intermediate winches, or by taking special precautions at particular locations. Calculation considerations are indicated in the clauses which follow.

Cable tensions in overhead installations where the cable is lashed or clipped to a messenger strand or other supporting members are generally minimal. Rollers or similar types of hangers are used to support the cable at frequent intervals such that it does not sag during the installation process. Rollers, quadrant blocks, or other guides should be used when the cable line changes direction in order to minimize cable tensions and support the cable’s minimum bend radius. If cables are pulled from the end, many of the same considerations for pulling into ducts are present, though generally with lower tensions. Changes in elevation may increase the tension, and must be considered. Moving reel installation methods generally exhibit minimal cable tension, but jerking of the cable due to reel inertia and movements must be guarded against. See the further discussion in 4.5. Considerations for self-supporting cables (figure-8 or ADSS, for example) are addressed in 4.5.

Cable tensions in ploughing or trenching are generally minimal, much smaller than the rated tension of the cable. Momentary tensions and jerking due to cable reel inertia when paying off cables, which result in tensions in the immediate area being installed, should be considered. In ploughing, frictional tension through the plough chute must be considered, but is generally small. See also 3.6.

3.4 Cable tension predictions – duct installations

It should be noted that the tension calculations for duct installations are of necessity inexact since the actual geometry and characteristics of the ducts are seldom well known. The calculations, therefore, should be utilized with regard to experience and empirical data from similar installations.

Two sets of equation are presented below. The first, presented in 3.5.2, is used to calculate cable tension in pulling applications. The second, presented in 3.5.3, is used to calculate cable tension in cable pushing and blowing applications; it may also be used for pulling. Note that the first set, for pulling only, is much simpler and neglects cable weight in Equation 3. The second equation, for any of the duct installation methods, comprises very complex equations involving much more data, including amplitude and frequency of innerduct undulations. Much of this sort of data are generally not known and must be estimated from cable experiments and empirical data from similar installations.

3.5 Maximum cable tension

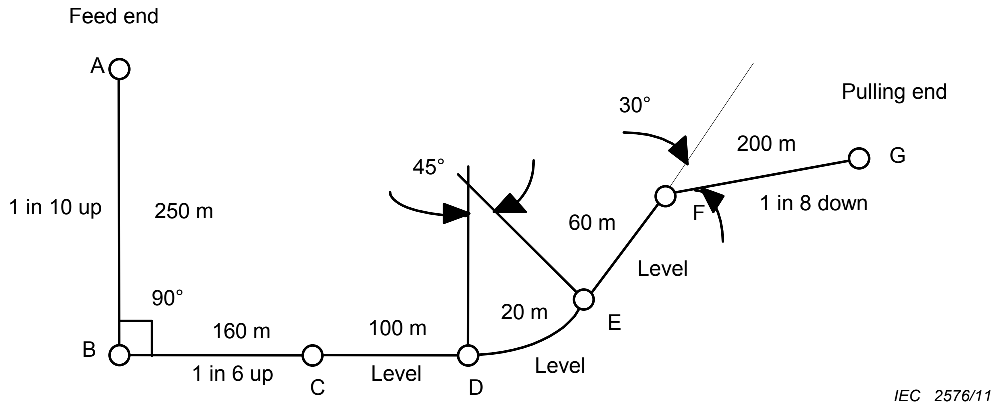
3.5.1 General

The following main contributory functions need to be considered when calculating cable tensions:

– the mass per unit length of cable;
– the diameter of the cable;
– the stiffness of the cable;
– the coefficient of friction between cable sheath and surfaces with which it will come in contact;
– the inner diameter of the duct;
– deviations (bends and undulations) and inclinations.

3.5.2 Total cable tension – pulling applications

Using the routes and common tension formulae in Figure 1 as an example:



T is the tension at end of section (N);

T_i is the tension at beginning of section (N);

μ is the coefficient of friction (between cable and duct or guide);

l is the length of section (m);

w is the cable specific mass (kg/m);

θ is the inclination (radians, + up, – down) or deviation (radians, horizontal plane);

g is the acceleration due to gravity (9,81 m/s²);

$T = Ti + \mu lwg$ *Equation 1 (for straight sections)*

$T = Ti + lwg\ (\mu \cos\theta + \sin\theta)$ *Equation 2 (for inclined sections)*

$T = Ti\ e\mu\theta$ *Equation 3 (for deviated* sections and bends)

Figure 1 – Cable tension calculations (equations. 1 through 3)

The resulting total tension calculations are shown in Table 1:

Table 1 – Calculation for total tension

Section	Length	Tension at beginning of section T_i	Inclination	Deviation	Equation	Tension at end of section (cumulative) T
	m	N	rad	rad		N
A	–	0	–	–	–	0
A – B	250	0	0,100	–	2	1 460
B	–	1 460	–	1,571	3	3 464
B – C	160	3 464	0,165	–	2	4 484
C	–	4 484	–	–	–	4 484
C – D	100	4 484	–	–	1	4 980
D	–	4 980	–	–	–	4 980
D – E	20	4 980		0,785	3	7 669
E	–	7 669	–	–	–	7 669
E – F	60	7 669	–	–	1	7 967
F	–	7 967		0,524	3	10 628
F – G	200	10 628	– 0,124	–	2	11 390

NOTE Where more than one cable per duct is installed, tension can be greatly raised and it is necessary to take account of this by applying a factor before the deviation calculation. Factors vary with the number of cables, sheath/cable materials, cable/duct sizes, cable flexibility, etc. Values can be in the order of 1,5 to 2 for two cables, 2 to 4 for three cables and 4 to 9 for four cables.

3.5.3 Total cable tension – pushing, blowing, or pulling applications

Total tension can be calculated on a cumulative basis working through each section from one end of the route to the other. Calculation is done using the common tension and blowing formulae listed below:

$$F = \frac{WP^2}{8\pi A}\sinh\left[\frac{8\pi Afl}{P^2} + \sinh^{-1}\left(\frac{8\pi A}{WP^2}F_i + \frac{3AB}{2W(P/4)^4}\right)\right] - \frac{48B}{\pi P^2}$$ Horizontal pulling, Equation 4

$$F = \left(F_i \pm \frac{WP^2}{8\pi fA} + \frac{48B}{\pi P^2}\right)e^{\frac{8\pi fA}{P^2}l} \mp \frac{WP^2}{8\pi fA} - \frac{48B}{\pi P^2}$$ (+ .. – for upwards) Vertical pulling, Equation 5

$$F = F_i e^{f\theta} + \frac{2Bf}{\sqrt{6(D_d - D_c)R_b^3}}$$ Deviations and bends, Equation 6

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2} + W\sin\alpha$$ Inclined pulling, Equation 7

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2 + \left(\frac{D_d - D_c}{\pi^2 B}F^2\right)^2} + W\sin\alpha$$ Inclined pushing, Equation 8

$$\frac{dF}{dx} = f\sqrt{(W\cos\alpha)^2 + \left[\frac{3AB}{2(P/4)^4} + \frac{8\pi A}{P^2}F\right]^2 + \left(\frac{D_d - D_c}{\pi^2 B}F^2\right)^2} + W\sin\alpha - \frac{\pi D_c D_d\left(p_i^2 - p^2\right)}{8l\sqrt{p_i^2 - \left(p_i^2 - p^2\right)\frac{x}{l}}}$$

Blowing (inclined), Equation 9

F = force at end of section (N)

F_i = force at beginning of section (N)

f = coefficient of friction, COF (between cable and duct or guide)

m = cable specific mass (kg/m)

l = length of duct (m)

W = cable specific weight = gm (N/m)

g = acceleration of gravity (9,81 m/s^2)

B = cable stiffness (Nm^2)

D_c = cable diameter (m)

D_d = duct inner diameter (m)

A = amplitude of duct-undulations (m)

P = period of duct-undulations (m)

R_b = bending radius of bend (m)

θ = deviation of bend (radians, horizontal plane)

α = inclination (radians, + up, – down)

p_i = air pressure (absolute) at beginning of section (N/m²)

p = air pressure (absolute) at end of section (N/m²)

x = position in the section (m)

Equations 4, 5 and 6 are analytical solutions, equations 7, 8 and 9 have to be solved numerically.

The example in Figure 2 is given as an illustration.

A cable with diameter of 18 mm, weight of 2 N/m and stiffness 5 Nm² is installed in a 40/33 mm duct of 2 000 m total length laid in the trajectory below (the red sections are vertical):

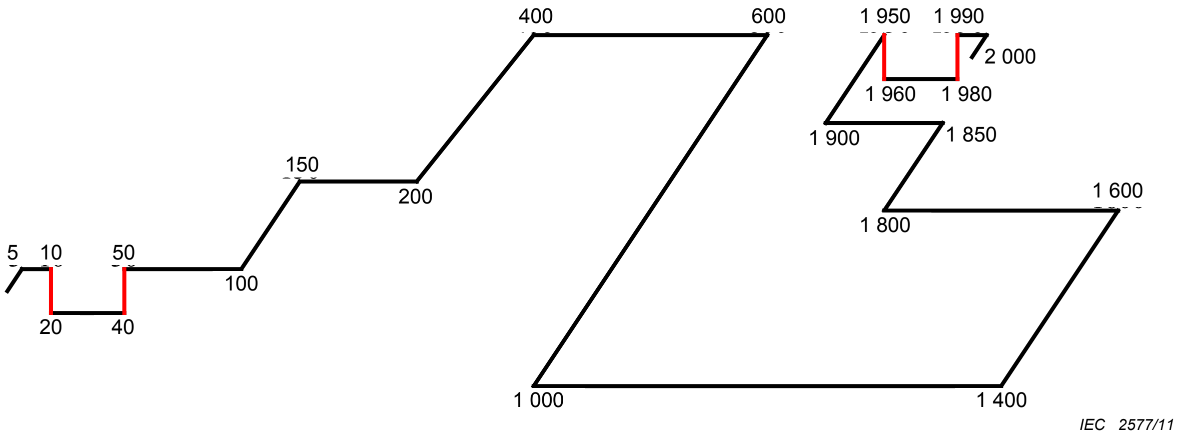


Figure 2 – Cable tension calculations (equations. 4 through 9)

The COF between cable and duct is 0,1, the (right-angled) bends in the trajectory are of radius of 1,2 m and the straight sections still make undulations with amplitude of 5 cm and period of 8 m.

IEC/TR 62470 describes techniques to measure the coefficient of friction (COF) between cables and ducts.

Pulling force:

The pulling force is calculated for the situation that the winch is placed at the beginning of the trajectory. The cable is placed somewhere in the field. First the pulling force is calculated for one location of the cable, at 1 100 m, with boundary condition that the cable enters the duct without any tension as shown in Table 2.

Table 2 – Calculation for pulling force in Figure 2

Position (m)	**Pulling force** (N)
1 100	0
1 000, before bend	20
1 000, after bend	26
600, before bend	127
600, after bend	151

Position (m)	Pulling force (N)
400, before bend	236
400, after bend	279
200, before bend	421
200, after bend	495
150, before bend	547
150, after bend	642
100, before bend	709
100, after bend	833
50, before bend	920
50, after bend	1 079
40, before bend	1 080
40, after bend	1 266
20, before bend	1 317
20, after bend	1 544
10, before bend	1 595
10, after bend	1 869
5, before bend	1 887
5, after bend	2 210
0	2 232

In Figure 3 the pulling force is also plotted for other lengths.

Pushing force:

The pushing force is calculated for the situation that the pushing device is placed at the beginning of the trajectory. The cable is placed at the same location. First the pushing force is calculated for one location of the cable, at 450 m, with boundary condition that the pushing force at the cable end is zero as shown in Table 3.

Table 3 – Calculation for pushing force in Figure 2

Position (m)	Pushing force (N)
450	0
400, before bend	10
400, after bend	14
200, before bend	59
200, after bend	72
150, before bend	86
150, after bend	103
100, before bend	131
100, after bend	156
50, before bend	202
50, after bend	239
40, before bend	282
40, after bend	333
20, before bend	415

Position (m)	Pushing force (N)
20, after bend	488
10, before bend	558
10, after bend	655
5, before bend	720
5, after bend	845
0	950

NOTE that the available software only gives the end-result of 950 N. In Figure 3 the pushing force is also plotted for other lengths.

Blowing force:

The blowing force is calculated for the situation that the blowing device is placed at the beginning of the trajectory. The cable is placed at the same location. The calculation is done for a pressure at the cable inlet of 12 bar relative to atmosphere (13 bar absolute) and the duct open at 2 000 m. Note that the calculation starts with the cable-end at the "critical point", the position where the pushing force reaches a maximum, at the bend at 1 000 m (beyond this position the airflow propelling forces become larger than the friction forces). The calculation does not take into account the effect of the filling of the duct with cable on the airflow (which shifts the critical point to a position further in the trajectory), which makes the calculation worst case. In this example the full 2 000 m can be bridged by blowing. This is illustrated in Table 4.

Table 4 – Calculation for blowing force in Figure 2

Position (m)	Pushing force (N)
1 000, before bend	0
1 000, after bend	2.5
600, before bend	5
600, after bend	8
400, before bend	13
400, after bend	18
200, before bend	26
200, after bend	34
150, before bend	38
150, after bend	47
100, before bend	52
100, after bend	64
50, before bend	70
50, after bend	85
40, before bend	108
40, after bend	130
20, before bend	136
20, after bend	161
10, before bend	142
10, after bend	169
5, before bend	171
5, after bend	204
0	208

In Figure 3 the pushing force is also plotted for other lengths. Note that calculation is still done with the duct open at the corresponding lengths. Also note that the plotted pushing force in Figure 3 is a little higher than the force in the table. The forces plotted in Figure 3 are obtained with software that also takes into account that the cable end needs a little higher pushing force when exactly in the bend than when passed. This is why a bend is picked as the critical point, while the airflow propelling forces were already a little higher than the friction forces.

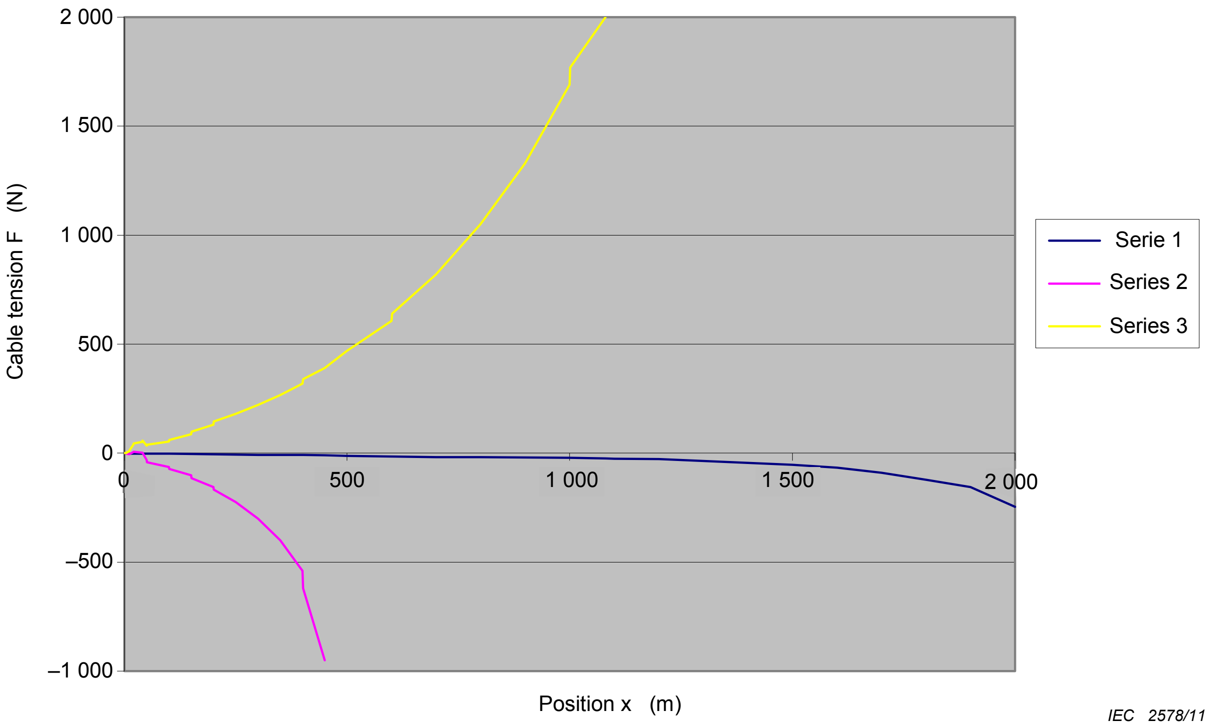


Figure 3 – Cable tension calculations; Series1 = blowing; Series2 = pushing; Series3 = pulling

3.6 Installation temperature

Installation temperature may affect installation procedures and it is good practice to install optical fibre cables, particularly in long lengths only when the temperature is within the limits set by the particular cable manufacturer.

The mechanical properties of optical cables are also dependent on the temperature and the materials used in their construction. Typically, cables containing PVC in their construction should not be installed when their temperature is below 0 °C whilst cables incorporating polyethylene can be installed when their temperature is down to – 15 °C. For most cables the upper installation temperature limit is + 50 °C. Unless special measures are taken, cables should not have been exposed to temperatures outside the specified installation temperature range for a period of 12 h prior to installation.

NOTE Polyethylene which is used as a common sheath material starts softening around 50 °C. Thus the coefficient of friction increases remarkably. This will impact installation performance (pulling, pushing, blowing) negatively.

3.7 Information and training

Methods and practices used in the handling of optical fibre cables during installation can, without producing any immediately obvious physical damage or transmission loss, affect their long-term transmission characteristics.

Technicians involved in installation procedures should be made fully aware of the correct methods to employ, the possible consequences of employing incorrect methods, and have sufficient information and training to enable cables to be installed without damage to fibres.

In particular, installation crews should be made aware of minimum bending criteria, and how easy it is to contravene these when installing by hand.

4 Cable installation methods

4.1 General considerations

Optical fibre cable can be installed using the same or similar general methods employed for metallic cables but with more attention required to certain aspects such as long lengths, cable bending and cable strain and it may be necessary to employ particular methods and equipment in some circumstances. Optical fibre must be protected from excessive strains, produced axially or in bending, during installation and various methods are available to do this. The aim of all optical fibre, cable-placing methods and systems should be to install the cable with the fibre in an as near as possible strain-free condition, ready for splicing.

Other general precautions:

– delivery of cable to site should be monitored to ensure that no mechanical damage occurs during off-loading from vehicles;
– storage conditions should be suitable, taking into account mechanical and environmental considerations;
– documentation should be checked to ensure that cable delivered is in accordance with the procurement specification;
– suitable protective caps should be fitted to the exposed ends of the optical cable. End caps should be handled carefully to avoid damage during installation, and any damaged caps should be repaired or replaced.

4.2 Safety in confined spaces

During the installation of optical fibre cables, it may be necessary to work in confined spaces such as manholes, underground passageways, tunnels and cable ways and areas where air circulation is poor or where entry and exit is difficult.

Where the possibility of working in confined spaces exists, it is necessary to consider any health and safety hazards that may be present, such as explosive, asphyxiating or toxic gases, lead, asbestos, etc. and ensure that any additional safety equipment and/or instruction is provided prior to the commencement of work.

4.3 Pre-installation procedures

Before installation commences, the installer should carry out the following checks:

– establish that the routes defined in the installation specification are accessible and available in accordance with the installation programme. The installer should advise the user of all proposed deviations;
– establish that the environmental conditions within the routes and the installation methods to be used are suitable for the design of optical cable to be installed;

– determine any measures necessary to prevent the optical fibre within the optical cable experiencing direct stress following installation. Where long vertical runs are proposed, optical cables may need to deviate from the vertical at intervals as recommended by the manufacturer (by the inclusion of short horizontal runs, loops or support arrangements);
– determine the proposed locations at which drums (or reels) shall be positioned during the installation programme and establish the accessibility and availability of those locations;
– identify proposed locations of service loops and establish their accessibility and availability in accordance with the installation programme;
– ensure that all necessary installation accessories are available;
– identify proposed locations of closures and establish their accessibility and availability in accordance with the installation programme.

The closures should be positioned so that subsequent repair, expansion or extension of the installed cabling may be undertaken with minimal disruption and in safety.

4.4 Installation of optical cables in underground ducts

4.4.1 Application

A typical underground duct installation is shown in Figure 4.

4.4.2 Installation using trenchless technique

Installation of ducts using trenchless techniques can reduce environmental damage and social costs and at the same time, provide an economic alternative to installing ducts by digging methods.

This technique is described in ITU-T, L.38.

4.4.3 Cable overload protection methods

Where all actions and precautions have been taken to protect the cable and its fibres from excessive load as far as suitability of route, guiding etc. is concerned, then there still remains the possibility, in the dynamics of an installation operation, for high loads to be applied to the cable and it may be advisable to provide a cable overload prevention mechanism. Two classes of device provide this protection: those situated at the primary or intermediate winch and those at the cable/rope interface. Those at the winch include (depending on winch type) mechanical clutches, stalling motors and hydraulic bypass valves which can be set to a predetermined load and the dynamometer/cable tension monitoring type systems to provide feedback for winch control. Those at the cable/rope interface include mechanical fuses (tensile or shear) and sensing devices to provide winch control information. All these systems have a common aim of limiting or stopping the winching operation when loads applied on the cable approach a damaging level.

4.4.4 Cable bending and guiding systems

To avoid subjecting cables and optical fibres to unacceptable bending stresses, the cable manufacturer's recommendations regarding bending diameters should be observed during pulling and installation. Guiding equipment should be used at bends in the cable route and at duct entrances so that the minimum bending diameter recommended for the particular cable type is observed.

Bending optical fibre cable under tension during installation should be undertaken with care. Guiding systems and equipment should be examined for their suitability for purpose and properly take into account cable manufacturer's stated bending criteria. In general, a minimum bending diameter of around 20 times the cable diameter is considered appropriate but when being installed under tension, it is suggested that this ratio may be doubled. Most guiding equipment can be used for both optical fibre and metallic cables but long length placing may require many guiding elements and they should all have the properties of lightness and low friction.

4.4.5 Winching equipment and ropes

Provided the need for overload protection is borne in mind, most normal, speed-controlled cable winching equipment and systems are suitable for installing optical fibre cables in ducts. These include end-pull winches, with various types of primary mover, intermediate winches for longer length schemes and, where necessary, powered cable feeding equipment. Where intermediate winches (capstan or caterpillar) and/or powered cable feeding equipment are used, a method of synchronization, to prevent excessive fibre strain, should be employed, and it should be borne in mind that some intermediate capstan type winches can introduce a twist into the cable. Ropes or lines of low specific weight and a high modulus of elasticity are necessary for optical fibre cabling. Placing long lines or ropes can be difficult but can usually be accomplished by successively using normal installation methods. Lines or ropes must be placed with care where there are already optical fibre cables in a duct and knots must be avoided.

Cable winches should be capable of providing varying rope speeds, particularly with regard to low starting speeds, and should be equipped with a calibrated winch-line dynamometer (or a tension sensor or mechanical fuse can be fitted at the beginning of the cable). The maximum installation force shall be limited to the safe working load of the cable as measured at the winch-line dynamometer or the tension sensor at the beginning of the cable. The winch shall be provided with a tripping device that automatically stops the winch if the installation force exceeds the pre-set tension limit. If a mechanical fuse is used, it shall be designed to break at the maximum safe working load of the cable.

If a capstan type intermediate puller is used, the diameter of the capstan should be greater than or equal to the minimum bending diameter of the cable.

To reduce twisting during installation, the pulling end of the cable can be connected to the end of the winch rope via a twist compensation device, for example a rotary shackle or a rope socket with a swivel. When pulling the cable with a winch, the pull should be started with a low rope speed. Pulling speed can be gradually increased up to the maximum speed of 75 m/min when there is no danger that the maximum permissible tensile loading for the cable will be exceeded.

Factory-fitted "pulling eyes" should be capable of pulling a cable at its rated tensile load without failure. If the cable is not already provided with a pulling eye, a cable sock-type grip shall be fitted to the pulling end of the cable, whose eye shall be fitted to the winch rope by means of a rotary shackle, and whose minimum safe working load is greater than the maximum allowable cable tension. The cable grip can be fitted directly onto the outer sheath when the latter is secured internally to the strength members. Strength members which are not sufficiently coupled to the outer sheath shall be provided with a connection for high tensile loading when such loading is anticipated.

Pulling eyes and cable grips should not pass around capstans or pulleys whilst the cable is under tensile load.

Factory-fitted pulling eyes and cable grips intended to protect pre-connectorized cable should not pass around capstans or pulleys whilst the cable is under tensile load. Sock-type grips installed on the cable sheath may be pulled around capstans and pulleys unless prohibited by local practices.

4.4.6 Cable friction and lubrication

Special attention should be paid to friction and lubrication when installing optical fibre cables. The friction forces which must be overcome are related to several factors, primarily the materials and finishes of the cable sheath, duct, cabling rope or line and guiding elements, and all can contribute significantly to the total installing force required. Lubrication can have beneficial effects in reducing the total installing force needed and attention should be paid to both the rope/duct and cable/duct interfaces and steps taken to ensure that the rope/cable attachment point presents a smooth profile. Any lubrication system employed shall have long-term compatibility with cable, rope and duct material and be safe from an occupational health point of view.

4.4.7 Cable handling methods to maximise installed lengths

Where it is not possible, because of load limitations, to install long length optical fibre cables using a single end-pull, it may be necessary to employ a method of dividing the load along the cable length and this can be done, depending on circumstances, by either static or dynamic methods.

The most common static method is known as “the figure 8” system. This procedure requires that the cable drum be placed at an intermediate point and the cable drawn in one direction of the route using normal end-pull techniques. The remaining cable is then removed from the drum and laid out on the ground in a figure-of-eight pattern. The figure-of-eight pile must be flipped over for access to the outside end.

For long pulls, an intermediate pulling and figure 8 operation may be performed using a capstan winch at intermediate points. As the cable is pulled off of the low-tension side of the capstan winch, it is laid out on the ground in a figure-of-eight pattern. At the end of the pull, the figure-of-eight must be flipped over to access the outside cable end. The winch is then moved to the next pulling point, and the operation repeated as many times as necessary. At the final section, the winch is moved to the other end of the section and the laid out cable is drawn in for the final time.

The winch is then moved to the other end of the section and the laid out cable is drawn in using the same end-pull method. This method requires appropriate space at the figure 8 point.

Dynamic load sharing is more complicated and requires more equipment and setting-up; however, it has the advantage of allowing installation in one direction straight from the drum. In this process, special cable winches or urgers are employed at intermediate points and the maximum load on the cable is related to the distance between these intermediate points. It should be borne in mind that with intermediate winching, all the installing forces are transmitted through the cable sheath and the design of a particular cable being placed by this method should take this into account. Intermediate or distributed winching systems require good co-ordination, synchronisation and communication between the intermediate points. Capstan-type intermediate winches may introduce additional cable twisting.

Hand-pulling methods can be employed at intermediate points on long length optical fibre cable installations but great care must be taken to ensure that specified bending and other mechanical criteria are not contravened.

4.4.8 Jointing length allowance

It is important, when installing optical fibre cable lengths in underground ducts, to make proper arrangements for an adequate extra length of cable at the access point for testing and jointing. This additional length, at each end of the cable, is normally greater than that allowed for metallic cables and should not include that part of the cable used for the rope attachment which is not suitable for jointing. The additional length may be established by the splice or closure manufacture or by the splicing procedure, especially if the splicing is carried out in an adjacent vehicle.

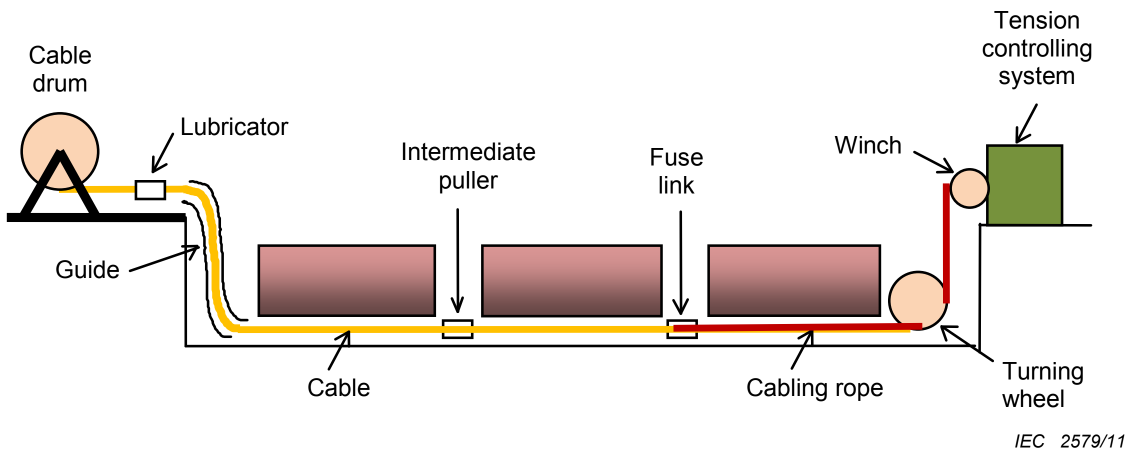


Figure 4 – Optical fibre cabling in an underground duct

4.4.9 Blowing techniques for the installation of fiber optic cables into ducts

Special care has to be taken when microcables with diameters lower than 6 mm will be installed. The equipment has to be adjusted not to damage the cable because of too high traction forces in the blowing equipment.

Additional recommendation for installation by blowing technique is given in ITU-T, L.57.

4.4.10 Optical fibre cable installation by floating technique

The floating technique is based on forcing cables along the cable route, by means of a pump, a suitable water flow.

Additional recommendation for installation by blowing technique is given in ITU-T, L.61.

4.5 Installation of aerial optical cables

4.5.1 Application

Cables for installation on overhead high voltage lines, such as composite overhead ground wires with optical fibres (commonly known as OPGW) are excluded from the scope of this guide.

Some examples of applications covered by the scope are shown in Figure 5.

4.5.2 Installation methods

In general, those methods used and considerations made in the installation of metallic aerial cables can and should be employed for optical fibre aerial cables. These include the normal practices of lashing or attaching hanger rings to a pre-provided tension strand, self-supporting systems, lashing to an existing aerial cable or, with a special design of cable and equipment, using the optical fibre cable itself as the lashing medium. The mechanical stresses and therefore strain experienced during aerial cabling are generally less than those induced during underground placing and in a mixed underground/overhead route underground cable may be used for overhead sections.

Where end-pull and/or intermediate pullers are used, care should be taken to ensure there are sufficient devices of adequate power available to pull the very long continuous sections, possible on aerial routes.

4.5.3 Cable protection methods

In general, where end-pull or distributed pull methods are used, the various methods as in underground duct installations (see 3.4) to protect the cable from excessive strain during installation may be employed for aerial cable and it is also good practice to ensure that cable back-tension is always carefully controlled.

Where lashing to pre-tensioned support wire or existing metallic cable is employed, the optical fibre aerial cable shall be constructed to withstand lashing. The lashing-wire tension shall be controlled. Care shall be exercised when handling cable in aerial route installations.

4.5.4 Winching and guiding systems

Provided the need to protect from overload and over-bending is borne in mind, most normal aerial cable installation, winching equipment including end-pull winches, controlled cable feeding devices, etc. can be used.. For long length installations where end-pull or distributed-pull systems are used, it is important that proper guiding equipment is provided at positions where sharp changes of direction occur, and every effort is made to ensure pulling-in at even speed.

4.5.5 Methods to maximise lengths

Where relatively unrestricted access to the route exists, it is feasible in many cases to install, using a variety of normal methods, very long lengths of aerial optical fibre cable, the only limitation being the capacity of the cable drum. However, where road or other crossings are involved and extra splices are not acceptable, a system of pulling through this section shall be devised. Also, where winching methods are used, cumulative friction effects limit the installation length and, as with underground systems, intermediate winching systems may be employed.

4.5.6 Jointing length allowance

It is important when installing aerial optical fibre cable lengths, to make proper arrangement for an adequate extra length of cable at a pole position for testing and jointing. This length at each end of the cable shall be sufficient to enable construction of joints and sheath closures at a convenient work position and it may be necessary to allow extra length for ground level operations.

4.5.7 In-service considerations

Care should be taken, during cable installation, to minimise fibre strain and, with aerial routes in particular, steps to ensure that strain levels remain within the manufacturer's recommendations during service are necessary. All types of movement, whether produced by cable weight, thermal changes, ice loading or wind, produce strain and shall be taken into account and minimised where possible. In particular, proper optical-fibre pole fittings to provide movement damping over a longer length than metallic types should be employed.

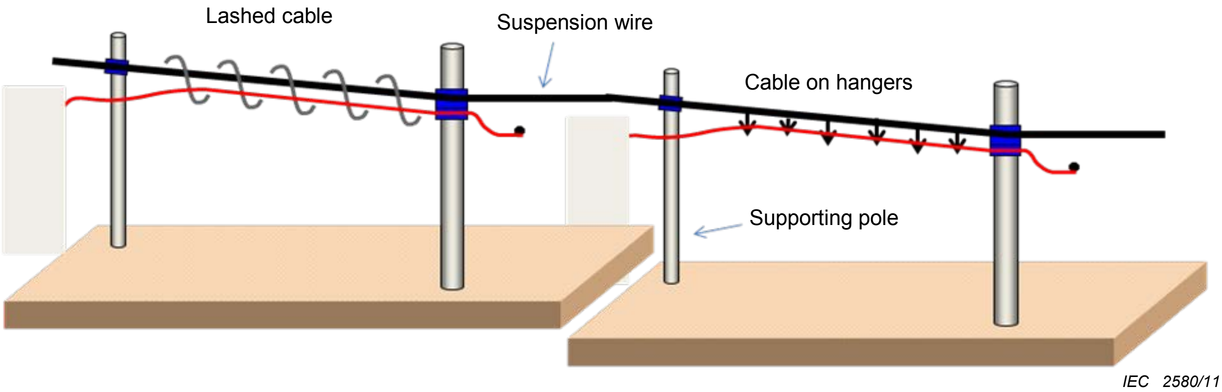


Figure 5 – Aerial cable installation

4.6 Installation of buried cable

4.6.1 Installation methods

Normal buried cable installation methods including ploughing (direct, vibratory or winched) and trenching can, in general, be used for direct burial of optical fibre cable, provided the cable is specifically designed for this type of application. The same depth of cover as for metallic cables is usually adequate but traffic capacity or other considerations of security may indicate a requirement for greater depth. Where a trench method is used, backfilling materials and practices may require particular consideration so that fibre strain limits are not reached during this operation.

4.6.2 Cables in trenches

When installing cables in trenches, the following precautions should be observed.

– The bottom of the cable trench shall offer a firm base, such as compacted soil and be free from stones. If stones are present, an approximately 15 cm high layer of sand or finely sieved granular soil should be added.

– Installation depths (to the foot of the trench) are shown in Table 5 and reflect the risk associated with the application and the cost of replacement.

– The direct burial of cables under roadways in the longitudinal direction is permitted only in exceptional cases. At the crossings of roadways or installations longitudinally under roads, cables shall be protected by cable duct. When cables run almost parallel to a road, the duct between trenches should cross the roadway at an angle of about 45 ° in order to reduce the pulling forces.

– When the cable trench is free of obstacles and where local conditions allow, the cables can be unrolled from the cable transport trailer driven along the trench and laid in the trench. The unrolling of the cable from the coil should correspond to the forward movement of the vehicle and a suitable braking device can ensure that not too much cable is unrolled. As it is unrolled, the cable should be moderately tensile loaded, in order to straighten it on the bottom of the trench.

– If, because of location conditions, the cable is laid on the ground prior to trenching, the cable should be laid out in sufficiently large curves, to ensure that no undue bends, twists, kinks, compression or abrasions occur.

– If the cable is drawn into a cable trench using a cable winch, the cable will graze the foot of the trench or trench walls in virtually all cases. Significant abrasion of the cable may occur. Therefore, this method is discouraged.

– Special measures shall be taken in areas where earth settling may occur. In those areas where cables enter buildings or ducts, there is the danger that cables could be kinked or sheared off in the building or duct if the soil surrounding the cable settles. Such damage can be prevented by precautionary measures such as making cable loops, padding, junction boxes or compacted backfill.

– Stone-free or slag-free filler (earth or sand) may be tipped onto the cable lying flat on the foot of the trench up to a depth of at least 15 cm above the cable, and lightly tamped and levelled.

Sand-encased cables in built-up areas or in areas of increased hazard can be protected against damage with cable protection covers or cable cover plates.

When the cable trench is filled, compacting machinery shall be employed only when coverage of the cable is at least 30 cm deep. For filling cable trenches within roadway zones, compliance with local regulations should be ensured.

A warning strip of corrosion-proof material e.g. soft PVC, should be placed at a distance of 30 cm to 40 cm above the cable.

Table 5 – Minimum installation depths

Application	Installation depth m
High data rate / heavy concentration (trunk)	0,8
Medium data rate / medium concentration (distribution)	0,6
Low data rate / low concentration (service / drop)	0,5

NOTE The installation depth may be shallower in certain locations, where particular obstacles or ground conditions cause considerable difficulties and where there are no justifiable objections. Where depths are less than as shown above, the cables shall be provided with special protection (e.g. by means of cable duct).

4.6.3 Installing cables by ploughing

When ploughing methods are used, the design of the guiding equipment between the cable reel and the cable laying guide shall take careful account of specified cable-bending criteria and have a low friction value to prevent fibre overstrain. Cable tensile overload protection systems are not normally necessary, but where a large ploughing machine is used and there are driven cable reels and guide wheels, a tension device can be incorporated. In-service mechanical protection at road or service crossings or in situations of high vulnerability may be felt to be necessary.

Generally a ripping pass or passes should be made to ensure that the path is clear and the required depth can be attained. The minimum cable depth is as shown in Table 5.

A warning strip of corrosion-proof material, e.g. soft PVC, should be laid simultaneously at a distance of 30 cm to 40 cm above the cable.

4.6.4 Methods to maximise lengths

Provided proper preparations are made, direct buried installation of optical fibre cable is normally only limited by obstructions and, to a lesser extent, the reel capacity. However, where some parts of a long length ploughed installation involve difficult ploughing through stony or rocky sections, preparation by trenching can be beneficial. A moving reel technique may also be used to maximise lengths installed.

4.6.5 Jointing length allowance

It is important, when installing directly buried optical fibre cables, to make proper arrangement for an adequate extra length of cable at both ends of a section for testing and jointing. This length shall be sufficient to enable construction of joints and sheath closures at a convenient work position.

4.7 Installation in special situations

4.7.1 Tunnel and building lead-in

Winching optical cable by end-pull or distributed methods in tunnel or building leads-ins can be considered a special case of cabling in duct and those methods and considerations indicated in 3.4 apply. However, where cable is laid out and manhandled onto trays or bearers, care shall be taken to ensure that support geometry and handling operations do not contravene specified bending criteria. Cleating and fixing systems shall be made-suitable for use with optical fibre cables.

4.7.2 Bridges

The normal considerations for placing metallic cable also apply to optical fibre cable but with additional care required to counter cable movement in steep approach sections or vertical sections. This type of movement, which can be produced by traffic vibrations, can lead to excessive fibre strain and suitable cable restraints should be used.

4.7.3 Underwater

Where it is necessary to place optical fibre cable underwater in river crossings or in lakes, the cable shall be constructed for this purpose. Often, standard outdoor cables can be suitable for immersion in less than 10 meters water depth if benign conditions exist and sufficient burial depths are employed. A continuous length should be provided where possible to avoid underwater joints. In addition, the gradient of the cable route down the river bed or lake shore should be as gentle as possible to avoid the fibre moving within the cable. Underwater cable can be subjected to large degrees of movement on all planes, producing fibre overstrain, and measures to restrict this movement by the use of trenching, sandbagging, ducts, etc., should be taken. Consideration of bottom erosion by currents, dragging anchors, bottom scouring, etc. should be part of the planning for route planning, burial depth, or special armouring.

4.7.4 Storm and sanitary sewers

Installation in sewers should have no adverse effects on the efficiency of the sewer system. Cables are generally placed manually in pre-installed trays or ducts by end-pulling or blowing. They may also be secured to the sewer wall by means of hooks, adhesive beds, sewer pipe liners, or the like, by manual, pre-engineered, or robotic means. Such methods may require intermittent tensioning in order to maintain the duct or cable out of the flow within the sewer. Application of cables into existing sewer systems requires detailed surveys and planning and frequently requires prior maintenance or rehabilitation of the sewers.

Cables for sewer installation are the subject of IEC 60794-3-40. Recommendations for such applications are described in ITU-T, L.77.

4.7.5 High pressure gas pipes

Placing optical fibre cables in high pressue gas pipes require especial consideration of safety issues regarding gas leaks where cables enter and exit the gas pipe. Due to the relatively small size of gas pipes, microcables or microducts are suitable for installation in gas pipes. The ducts or cables, as appropriate, must withstand degradation by or contamination of the gas within the gas pipes. See IEC 60794-3-50 for related information.

4.7.6 Drinking water pipes

Placing optical fibre cables in drinking water pipes presents few hazards to the cable, but the cable must not contaminate the water. Local codes and ordinances generally place specific restrictions on the chemicals which may be present in any components within the water pipes.

Cables and ducts must be designed for water immersion at elevated pressures and consideration should be given to water blocking. See IEC 60794-3-60 for related information.

4.7.7 Industrial environments

Industrial environments criteria for systems may be useful in establishing performance criteria for cable, and such cable ratings may be useful for evaluating cable applications. The criteria is collected in tables according to mechanical, ingress, climatic and electromagnetic MICE requirements. MICE criteria are most commonly used for industrial applications of optical fibre cable. MICE guidelines are included in IEC/TR 62362 and many IEC 60794-series family specifications. ISO/IEC 24702 and ISO/IEC/TR 29106 specifications may offer further guidance.

4.8 Installation of indoor cables

4.8.1 General considerations

Within buildings, various types of optical fibre cable construction can be used and it is important to ensure that the most appropriate type for each part of the indoor network is employed. To make indoor cable installation less sensitive to cable bending, cables containing bend insensitive fibres are strongly recommended. The use of preconnectorized cables will be advantageous to further reduce installation time.

4.8.2 Cable routing

Where cables are routed along the floor, a short straight route is preferable with cable passing through rather than around walls to avoid sharp bends. For within-floor installation, computer installation type flooring is normally satisfactory. Non-ruggedized cable is best run in trunking or trays, but care shall be taken to ensure that turning points are properly constructed so that cable bending criteria can be complied with. For duct installations, cables should be drawn in and not pushed in so as to avoid the risk of kinking. Vertical installations in the riser section are already addressed in 4.9.2.

Where cable is fitted directly to walls, care shall be taken to ensure proper cleats and straps are used and that they are not over-tightened. Much internal optical fibre cable placing is done manually and the attendant risks of fibre overstrain during this handling should be borne in mind.

Optical fibre cable must be secured using techniques to minimize added attenuation. Only cables stapling (rugged drop cable is a common example) should be fixed using this technique. Bend-insensitive fibres and special cable constructions rated for sharp bends may be required for some installations. Emerging documents in the FTTX and MDU space may be useful references.

Fire-ducts, gas seals, floor passages and building entry ducts installed or opened during the installation should be sealed in an approved manner in order to prevent ingress of gas, water or foreign material. The integrity of all barriers should be retained.

4.8.3 Confined spaces

Where the possibility of working in confined spaces exists, the precautions given in 4.2 should be observed.

4.9 Blown systems

4.9.1 General considerations

In blown systems, the network infrastructure is created by installing, by the most appropriate cabling method, one or a group of empty plastic tubes. Subsequently, as and when circuit provision is required, fibres or cable can be blown by compressed air into the tubes. Generally the fibres are specially packaged or buffered.

There are several types of blown systems but, in general, all require the correct combination of fibre or cable, tube and blowing method. The manufacturer's recommendations should be followed closely not only during the installation of the tube and fibre or cable, but also when planning the route, taking into account the maximum route length, the number of bends and the distance between bends.

Installation is usually carried out in two phases, first the installation of the tube infrastructure and second the installation of the fibre.

4.9.2 Installation of cables in the vertical riser area of buildings

Optical fiber cables can be installed vertically inside the building as well as outside the building.

Optical fibre cabling in the vertical risers of buildings can be accomplished using normal placing methods but care should be taken to ensure that fixing and cleating systems are designed specifically for this type of cable, are used frequently on long risers to avoid excessive cable strain, and do not transmit stress to the fibre. Blocking coils or other means to mitigate excessive fibre movement within the cable must be used for long risers.

The installation inside the building is usually referred to as installation in the “riser section”. However also vertical installations outside the building e.g. along the façade of the building is being performed. Optical fibre cabling in the vertical sections of buildings can be accomplished using placing methods e.g. pulling through ducts, laying in channels, attaching cables to the wall. But care should be taken to ensure that fixing and cleating systems are designed specifically for this type of cable and do not transmit stress to the fibre. Especially when installed in high buildings care has to be taken to avoid tensile stresses caused by the cable weight when the cable is installed vertically without any fixing. Therefore the placement of cable loops is recommended every 20 m.

When cables are being installed at the façade of the buildings the fixing has to prevent the cable from swinging and frequently touching the rough surface of the wall which could lead to abrasion of the cable sheath. Nowadays also preconnectorized cables are being installed in the riser sections. Care has to be taken, that the mechanical protection of the assembly is not damaged or has not been removed.

Cable weight in long risers can cause excessive cable strain, thus fibre strain, unless hangers are used frequently.

In cables with loose tubes, blocking coils are needed at frequent intervals to avoid the fibres slipping within the cable on long riser runs.

4.9.3 Tube installation

Indoor tubes and tubes for blown fibre systems are generally lightweight and the routes relatively short, so the installation does not require the use of pulling or winching equipment, and average lengths can be installed by hand.

Outdoor tubes may be more substantial, heavier or larger than indoor tubes and are installed in longer lengths. They can be installed using standard laying procedures.

Some tubes may require special handling procedures to preserve the integrity of the inner bore surface but, in general, the following precautions should be observed:

– do not stand on or otherwise crush tubes, which could cause problems at the fibre blowing phase;

– do not bend or cause the tube to bend at diameters less than those specified by the supplier;
– do not stretch the tube by attempting to install excessive lengths or by using faulty pay-off equipment;
– do not twist the tube, unreel by rotating the pay-off drum and not by feeding over the flange;
– do not allow tubes to be contaminated by water or dirt; seal tubes if necessary before installation;
– re-seal un-terminated tubes after installation;
– sidetracking of tubes on longer runs may need a larger area than with cables;
– when pulling in by rope, always use a swivel;
– identify and label tubes at both leading and trailing ends;
– cable ties should be tightened sufficiently well to secure the tube in position but not so tight that they deform the tubes.

4.9.4 Fibre and cable installation

Prior to the installation of fibre, it is advisable to ensure the integrity of the tube route. This can be achieved by conducting pneumatic tests in order to prove the integrity of the tube wall and the uniformity of the tube bore. When using compressed air, and particularly if bore diameter is checked by small spheres (indoor tubes) or larger shuttles (outdoor tube), the following precautions should be observed:

– the test site shall be adequately guarded and warning signs posted;
– safety glasses shall be worn;
– pressurised supply hoses shall be firmly secured;
– recommended pressures shall not be exceeded;
– a blown sphere or shuttle test should not be undertaken without first ensuring that provision has been made to capture the sphere or shuttle at the remote end and that the tube to be tested has been positively identified at each end.

The efficient installation of fibres or cables into the tube network often requires the use of specially designed fibres or cables and specially designed equipment such as air supply modules, insertion tools and pay-offs. The supplier normally provides instructions regarding compressor pressures and capacities, insertion techniques to prevent kinking and crushing and the use of lubricants.

When installing cables in long tube routes, it may be necessary to use a pulling shuttle attached to the leading end of the cable. Such shuttles should be short in length and attached in a manner that allows independent movement. Alternatively, if the use of shuttles is to be avoided, a cascade method of blowing may be used as shown in Figure 6, with short tube lengths between each blowing point.

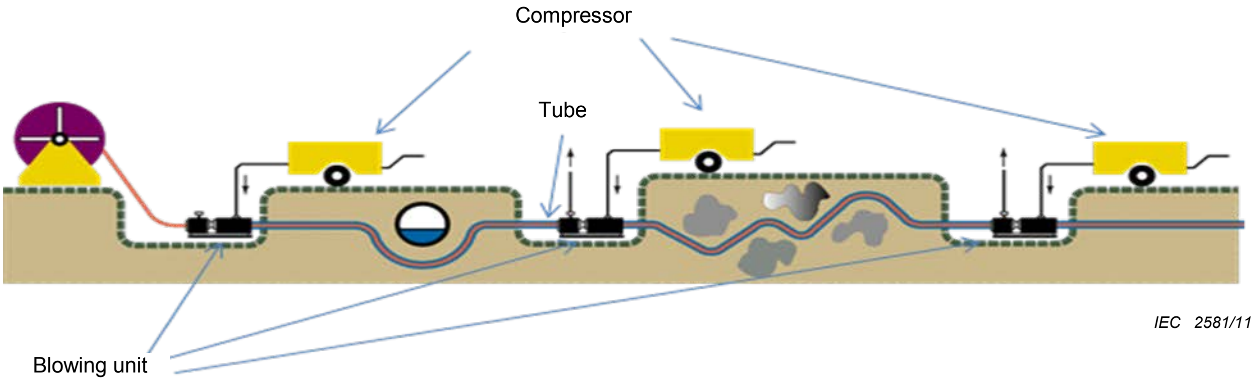


Figure 6 – Cable installation by cascade blowing

4.10 Cable location

Where optical fibre cables with little or no metallic content in their construction are directly buried, the question of location at a later date should be considered at the time of installation. It may be appropriate to use an over-ground post-marking system or to bury a locating wire with the cable, and use discrete buried markers at the splice points.

5 Lightning protection

Optical fibres are not susceptible to lightning surges but they are often incorporated in cables with a metallic content. Therefore, apart from the possibility of adopting non-metallic cable designs, the methods used to protect optical fibre cables are the same as those used for metallic cables adapted to suit the longer lengths. In this respect, ITU-T Recommendation K.25 should be observed.

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