CHAPTER 2

GENERAL CHARACTERISTICS OF OPTICAL CABLES

Introduction

This Chapter is devoted to the description of the general characteristics of the optical cables. The basic purpose of optical fibre cable construction is to keep transmission and mechanical strength properties of the optical fibres stable in the course of the cable manufacturing, installation, and operation process.

The aim of clause 1 is to outline the external factors impacting optical cables. Clause 2 deals with the mechanical and environmental effects that the external factors can have on the optical fibres contained in a cable. In clause 3 a description is given of the general structure of the optical cables, while clause 4 describes the structure of the optical cables for specific applications.

The dimensional and transmission characteristics of the optical fibres put in the optical cables used for telecommunication should be in accordance with Recommendations 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 and ITU-T G.657, which are described in Chapter 1.

1 External factors impacting optical cables

Optical cables are installed in various environments (aerial, buried, duct, tunnel, underwater, etc.) and are therefore exposed to different environmental conditions. The range of environmental conditions must be considered with great care in order to determine the cable construction that will continuously maintain the desired characteristics. The external factors relating to the various environmental conditions can be divided into two categories:

i) natural external factors (temperature, wind, water, earthquakes, etc.), which are listed in Table 2-1;

ii) man-made factors (smoke, air pollution, fire, etc.), which are listed in Table 2-2.

For both categories of factors the tables show the *effects on the optical cables* laid in different environments.

Table 2-1 – External factors related to environmental conditions – Natural external factors

Natural external factors		**External cables**					**Internal cables**	
		Trunk, junction and distribution					**Customer premises**	**Central office**
		Aerial	**Buried**	**Duct**	**Tunnel**	**Underwater**	**Building**	
Temperature change	B	Cable sheath contraction with core thrusting out					–	–
	A	Increase of optical loss due to high and low temperature						
Very low temperature	B	Embrittlement of cable sheath under low temperature			–	–	–	–
	A	Crushing due to ice formation						
Wind	A	Excess strain due to wind pressure	–	–	–	–	–	–
	B	Periodical excess strain due to cable dancing	–	–	–	–	–	–
Salt water	B	Corrosion of metal catenary	Corrosion of armour	–	–	Corrosion of armour	–	–
Rain and hot spring	B	Corrosion of metal catenary	Corrosion due to hot springs		–	–	–	–
Snow and ice	A	Sheath degradation, crushing and excess strain due to snow and ice	–	–	–	Sheath degradation and crushing due to ice	–	–
Water and moisture	A	Increase in optical loss due to water penetration. Decrease of strength of fibre					–	–
Sunshine	B	Degradation of sheath by UV rays	–	–	–	–	–	–
Lightning	B	Crushing damage due to lightning and hazards to personnel			–	–	–	–
Earthquakes and slip, ground subsidence and falling stones	B	Sheath degradation and impulsive excess strain due to falling stones	Cutting of cables due to ground movements		–	–	–	–
Condition of soil	B	–	Corrosion of armour	–	–	–	–	–
Rodents, birds and insects	B	Sheath damage due to birds, rodents and insects		–	–	–	–	–
Hydrogen	A	Increase in optical loss due to hydrogen					–	–
Water flow	B	–	–	–	–	Cable damage	–	–
Mould growth	B	–	–	Sheath damage	–	–	Sheath damage	–

A. Particular consideration for optical fibre cables.
B. Intrinsic consideration for outside plant.

Table 2-2 – External factors related to environmental conditions – Man-made factors

Man-made factors		External cables					Internal cables	
		Trunk, junction and distribution					Customer premises	Central office
		Aerial	Buried	Duct	Tunnel	Underwater	Building	
Factory smoke and air pollution	B	Corrosion of metal	–	–	–	–	–	–
	B	Chemical attack on sheath	–	–	–	–	–	–
Traffic (cars, trucks)	B	–	Damage to cable sheath and joints due to creep. Transient optical loss due to vibration of fibres		–	–	–	–
Induced voltage (AC traction systems, power lines)	B	Damage to cable and hazards to personnel			–	–	–	–
DC current	B	–	Electrolytic corrosion	–	–	–	–	–
Petroleum gas leakage	B	–	Sheath degradation due to chemical attack	–	–	–	–	–
Fire	B	Sheath (and cable core) burning	–	–	Sheath (and cable core) burning	–	Sheath (and cable core) burning	
Nuclear radiation	B	Under consideration					–	–
Hydrogen	A	Increase in optical loss due to hydrogen					–	–
Installation practices	B	Cutting or breaking of the cables						
	A/B	B – Strain due pulling-in for installation			A - Strain due pulling-in for installation		–	–
	A/B	B – Bending at pulley for installation	B – Bending and squeezing due to burying machine		A – Bending at pulley for installation			
					A – Bending at curve in duct	–	–	–

A. Particular consideration for optical fibre cables.

B. Intrinsic consideration for outside plant.

2 Mechanical and environmental effects on the optical fibres

As shown in Table 2-3, the external factors have a direct impact also on the performance of the optical fibres contained in a cable.

The main objective in the design of an optical cable is to ensure that the protection technique used will maintain the good properties of the optical fibres, under all the kinds of conditions to which the cables may be exposed during manufacture, installation, and operation.

This clause lists the main mechanical and environmental effects on the optical fibres contained in a cable, giving the cause, the effect and the constructional measures to be taken to counteract these effects.

2.1 Residual fibre strain

2.1.1 Causes

Residual fibre strain may be caused by tension, torsion and bending occurring in connection with cable manufacture, installation and operational environment.

2.1.2 Effects

Residual fibre strain may shorten the lifetime of the fibre due to increased crack growth in the presence of environmental contaminants. Also, the level of residual strain will affect the level of dynamic strain which the fibre can withstand before breaking.

2.1.3 Constructional considerations

Optical fibres differ mechanically from copper and steel wires, mainly as regards elastic properties and failure mechanisms. Glass used for optical fibre behaves elastically up to a few percent and then it fails in brittle tension. The strength of fibres is mainly governed by the size of flaws, which are always present, under the influence of stress which causes the glass fibre to weaken. This weakening is accelerated if the stress is combined with moisture. When designing optical fibre cable, it is important to know the minimum strength of the fibres. For this reason, optical fibres are proof-tested to a certain stress level during manufacture. Studies of flaw growth mechanisms and accelerated aging experiments have shown that in order to achieve fibre lifetime of 20-40 years, the residual fibre stresses should not exceed 20-30% of the proof-test stress. In special circumstances where the cable is to be used in a high moisture environment or for aerial cable applications taking into account large thermal changes and strong winds, it should be noted that a larger proof-test strain may be necessary or the installation must compensate for the conditions. For example, a heavier support strand may be used for aerial applications to limit strains.

A good cable design will limit the long-term strain to the safe levels above to prevent the growth of surface flaws, which could eventually lead to fracture of the fibres. The proof-test strain may therefore be specified by the permissible strain and the required life time. Usually the fibre is proof-tested with a load applied to the fibre. The value of the load is specified for each type of fibre in the ITU-T G.65 x-series of Recommendations. The long term strain level is a small fraction of the maximum proof-test. When a whole cable structure is subject to residual longitudinal tensile strain, some strain may remain in the optical fibres of the cable.

2.2 Impulsive fibre strain

2.2.1 Causes

Impulsive fibre strains may be imposed by impact and snatch during installation and the operational life of the cable.

Table 2-3 – Relationship between external factors to be considered for optical fibre cables and mechanical / environmental effects on optical fibres

External factors			Mechanical and environmental effects on optical cables							
			Residual fibre strain	Impulsive fibre strain	Fibre macro-bending	Fibre micro-bending	Physical or chemical reaction			
							Water and moisture	Hydrogen	Lightning	Nuclear radiation
Natural factors	Temperature	High and low	–	–	–	Loss increase	–	–	–	–
		Ice formation	Strength degradation	–	–	Loss increase	–	–	–	–
	Wind	Pressure	Strength degradation	Fibre breakage	Loss increase	Loss increase	–	–	–	–
	Snow and ice	Ice loading	Strength degradation	–	–	–	–	–	–	–
	Water and moisture	Penetration	Strength degradation	–	Loss increase, strength degradation				–	–
	Water flow		Strength degradation	Fibre breakage	–	–	–	–	–	–
	Lightning		Strength degradation	Fibre breakage	–	–	–	–	Loss increase	–
Man-made factors	Hydrogen gas	Diffusion	–	–	–	–	–	Loss increase	–	–
	Nuclear radiation		–	–	–	–	–	–	–	Loss increase
	Impact		–	Fibre breakage	–	–	–	–	–	–
	Installation practices		Strength degradation	Fibre breakage	Loss increase	Loss increase	–	–	–	–
Manufacture			Strength degradation	Fibre breakage	Loss increase	Loss increase	–	–	–	–

2.2.2 Effects

When the impulsive strain exceeds a certain limit, breakage of the optical fibre will occur. The number and magnitude of these strains can allow a crack to reach a critical size, causing breakage of the optical fibre.

2.2.3 Constructional considerations

For the protection of optical fibres from the lateral force caused by impact, a buffer coating layer may be used. Further protective layers in stranding and sheath construction may also be considered. Armouring is considered to be one of them.

Under dynamic stress conditions encountered during installation, the fibre is subjected to strain from both cable tension and bending. The strength elements in the cable and the cable bending radius must be selected to limit this combined dynamic strain.

2.3 Fibre macrobending

2.3.1 Causes

Macrobending of an optical fibre may be caused through bending of the fibre by the stranding of optical fibres in cable manufacture as well as bending the cable into its final installed position.

2.3.2 Effects

The fibre may be bent to such a small radius to cause an increase in optical loss. In single-mode optical fibres, the further the operational wavelength is from the cut-off wavelength, the less well-guided the mode will be, resulting in greater loss for the same fibre bend radius.

2.3.3 Constructional considerations

The cable construction and the bends set into the installed cable must be selected to ensure that the fibre is not subjected to a bend radius that could cause an increase in optical loss due to macrobending.

2.4 Fibre microbending

2.4.1 Causes

Microbending of the fibre is caused by localized lateral forces along its length. These may be caused by manufacturing and installation strains, as well as dimensional variations in the cable materials due to temperature changes. Sensitivity to microbending is a function of the difference of refractive index of the core and the cladding, as well as of the diameters of the core and cladding.

2.4.2 Effects

The effect of microbending is increased optical loss.

2.4.3 Constructional considerations

To reduce microbending losses the cable structure must protect the optical fibres from lateral forces. The cable construction should be selected to prevent buckling of the fibre during temperature changes leading to microbending loss.

Cable components such as the cable sheath and the strength member are important because they also help to reduce the microbending caused by the external mechanical forces on the cable and by temperature changes.

Microbending losses may also be introduced in aerial cables subjected to excessive elongation (e.g. heavy ice loading).

2.5 Water and moisture

2.5.1 Causes

Moisture may permeate into optical fibre cables through diffusion and, in the case of inadequate cable construction or sheath damage, water may penetrate longitudinally within the cable core or between sheath layers.

2.5.2 Effects

The tensile strength of fibres in the presence of water or moisture is reduced and the time to static fatigue failure is also reduced. Optical loss may increase with some cable constructions incorporating metallic elements due to the generation of hydrogen when water is present in the cable structure.

2.5.3 Constructional considerations

Optical fibres should be isolated from water and moisture particularly in the presence of excessive fibre strain.

a) Moisture permeation

   Because filling compounds and plastic sheaths are not impervious to moisture, in time the moisture content in the cable may rise. Permeation is minimized by longitudinal overlapped and bonded metallic foil and the use of water-blocking material. Alternatively, a seamless metallic barrier can be completely effective in preventing permeation, but this barrier is recommended only for unfilled cables due to problems associated with trapped hydrogen.

b) Water penetration

   In order to prevent or minimize longitudinal penetration of water in an optical cable core, either water-blocking materials (continuous, as filling compound or discrete water-blocking) or dry-air pressurization may be used.

   When dry-air pressurized cable maintenance method are used for optical fibre cables, the cables do not need any water-blocking materials but require low pneumatic resistance.

2.6 Hydrogen

2.6.1 Causes

Hydrogen gas concentrations may build up within a cable from:

i) hydrogen released from the cable components;

ii) electrolytic effects between two different metallic elements in the presence of moisture;

iii) hydrogen contained in pressurized air pumped into the cable;

iv) corrosive reaction of the metallic elements in presence of moisture.

2.6.2 Effects

Hydrogen in the fibre core will increase the optical loss at wavelengths of 1.24 µm or 1.38 µm or both. Part of the loss is a reversible interstitial effect as a function of the relative pressure of hydrogen due to molecular hydrogen, and the rest is a permanent chemical change caused by the formation of OH bonds in the glass and a wavelength dependent loss.

2.6.3 Constructional considerations

Materials to be used in the cable construction should be selected so that the concentration of hydrogen within the cable is low enough to ensure that the long-term increase of optical loss is acceptable. Alternatively, hydrogen absorbing materials or dynamic gas pressurization can be used to eliminate or reduce the added loss due to hydrogen within the cable core. In the event of an external concentration of hydrogen greater than that within the cable core, a reduced influence on optical loss can be obtained by the use of hermetically coated fibres or by the use of a hermetic sheath around the cable core mainly.

The concentration of hydrogen within the cable core could be estimated from knowledge of the hydrogen released from the components of the cable. Some test methods are described in Recommendation ITU-T L.27.

2.7 Lightning

2.7.1 Causes

Optical fibre cables containing metallic elements have a greater susceptibility to be struck by lightning than cables without metallic elements.

2.7.2 Effects

When buried or aerial (and sometimes duct) optical cables contain metallic elements, such as conventional copper pairs, a metallic sheath, or a metallic strength member, and are struck by lightning, a current will flow in the cables. The mechanical impact and energy dissipated from the lightning strike may damage the sheath and the fibres in the cables.

2.7.3 Constructional considerations

To prevent or minimize lightning damage, consideration may be given to the use of non-metallic cables, high current carrying sheath layers or, alternatively, methods proposed in Recommendation ITU-T K.25.

When a non-metallic cable is used, it should be protected against mechanical damage.

2.8 Nuclear radiation

2.8.1 Causes

Optical fibre cables may be exposed to nuclear radiation.

2.8.2 Effects

Under exposure to nuclear radiation, the optical loss may increase to an unacceptable level.

2.8.3 Constructional considerations

Under study.

2.9 Induced voltage

2.9.1 Causes

Under fault conditions of electricity lines, optical fibre cables containing metallic elements are susceptible to induced voltages.

2.9.2 Effects

Induced voltages on the metallic elements of cables can reach magnitudes which may cause damage to the cable and/or be a safety hazard to personnel in contact with the cable.

2.9.3 Constructional considerations

To prevent or minimize the effects due to induced voltages the ITU-T *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines* shall be taken into account.

2.10 Biological attack

(For further information, see Recommendation ITU-T L.46.)

The outside cables can be damaged from biological attack which can be caused by:

i) mammals, squirrels, mice, rats, moles, gophers and other rodents;

ii) birds like woodpeckers and cockatoos;

iii) insects such as termites, ants, beetles, wasps and caterpillars;

iv) microorganisms like bacteria, fungus and/or moulds.

Where it is not possible to re-site the plant, one possible action could be to eliminate the pests, such as insects and rodents, using chemicals or poisons. However, it should be noted that, while some chemicals and poisons are useful as a countermeasure for biological attacks, they sometimes can also be a danger to humans and cause environmental pollution.

Some chemicals are useful as a deterrent. These chemicals do not work as poisons but they repel the attacker. For example, some chemicals are sprayed on the cable surface and leave a special smell as a deterrent.

Another option for protection of the plant is to shield it by the use of protective materials around the plant in order to prevent access. Cables with sheaths of lead, polyethylene, polyvinylchloride, neoprene and other polymers are all susceptible to attacks. Cables with steel armouring, dielectrical armouring such as fibreglass, or both do not suffer any damage of this type as long as the armour is intact.

3 General structure of optical fibre cables

The external factors (natural and man-made) listed in § 2 as well as the type of installation of the cable in the telecommunication network are the basic requirements for determining the structure, the dimensions and the materials of an optical fibre cable.

From a general point of view, the main components of an optical cable may be divided into the following five groups:

i) optical fibre coatings;

ii) cable core;

iii) strength members;

iv) water-blocking materials (if necessary);

v) sheath materials (with armour if necessary).

The relation between the mechanical and environmental factors and the main components of an optical cable is given in Table 2-4.

Table 2-4 – Mechanical and environmental factors affecting the choice of cable components

Mechanical and environmental factors	Coated optical fibres	Cable core	Strength member	Water-blocking materials	Sheath materials
Residual fibre strain	A	A	A	–	B
Impulsive fibre strain	A	A	–	–	A
Fibre macrobending	A	A	B	–	A
Fibre microbending	A	A	B	B	B
Water	A	A	–	A	A
Moisture	B	–	–	–	A
Hydrogen	B	B	B	B	B
Lightning	–	–	A	B	A
Nuclear radiation	under consideration				
A. Primary factor to be considered. B. Secondary factor to be considered.					

The cable core should be covered with a sheath suitable for the relevant environmental and mechanical conditions associated with installation and operation. The sheath may be of a composite construction and may include strength members of protective armour to meet particular environmental conditions.

The general structure of the optical fibre cables is described in this clause, while the specific characteristics of the structure related to some types of installation are described in § 4.

3.1 Coated optical fibres

Silica fibre has an intrinsically high strength but in actual practice its strength may be reduced by surface flaws. To protect the fibre surface a composite primary coating is applied at the fibre drawing stage. The term “primary coating” means the primary protection of a fibre. A secondary protection of primary coated fibres may be also applied by using several protection methods.

3.1.1 Primary coating of fibres

The primary coating of a fibre must withstand handling of the fibre during cable manufacture and installation. In addition, the primary coated fibre should be proof-tested, in order to be able to predict the fibre life for the installation and the expected environmental conditions.

The primary coating materials must be selected to ensure stability over the range of temperature to be considered and in the presence of moisture.

The primary coating should consist of an inert material that can be readily removed for splicing purposes without damage to the fibre. It is desirable that the material should have a slightly higher refractive index than the fibre cladding and an absorption loss to prevent the propagation of undesirable modes. Acrylate or silicon rubber is typically used for the primary coating.

If the primary coating needs to be coloured to aid fibre identification, the colouring should be stable in the presence of other materials and compatible with them during the lifetime of the cable, and the application technique should not affect any transmission characteristic. The colouring may be in the coating or applied to the surface of the coating.

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

3.1.2 Secondary protection of fibres

The primary coated fibre may be protected by:

- i) loose packaging within a tube or groove;
- ii) micromodule construction;
- iii) tight polymer coating;
- iv) ribbon construction.

The protection method should be selected, taking into account the optical fibre unit structure.

3.1.2.1 Loose packaging within a tube

Several methods for loose packaging of primary coated fibres within a tube are used. One typical method is shown in Figure 2-1.

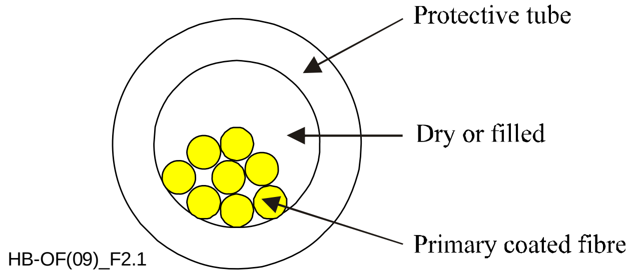


Figure 2-1 – Example of primary coated fibres protected by loose packaging within a tube

The protective tube may be reinforced with a composite wall. Special filling compounds are used within the protective tube to prevent longitudinal migration of water. They should be chosen so that the fibres are free to move throughout the filling compound when the cable is strained at any temperature within the operational range of the cable.

3.1.2.2 Loose packaging within a grooved cylindrical unit

The cabling element consists of a V-grooved core, in which one or more fibres are laid in each groove without tension and with a slight excess length. The slots are helical, or reverse-lay, and a central strength member reinforces the cylindrical rod (Figure 2-2). This provides the unit with enhanced mechanical and thermal qualities. The optical unit can be laid up with other elements as required.

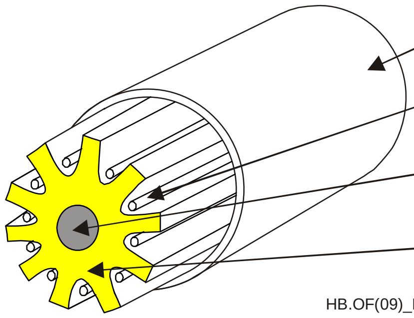


Figure 2-2 – Example of primary coated fibres protected by loose packaging within grooves

3.1.2.3 Micromodule construction

A micromodule is made with thin wall tubing, filled with a suitable compound, housing a bundle of optical fibres. In modified "micromodule cable" designs, replacing the central strength member with radial strength members (see examples in Figures 2-3 and 2-4), the compression of the micromodules against the central strength member is eliminated and easy access is enabled to both the micromodule tubes and the fibres. Such a cable design results in one of the smallest cable cross sections in the industry, offering increased protecting during sheath entry, and is resistant to crush and impact forces.

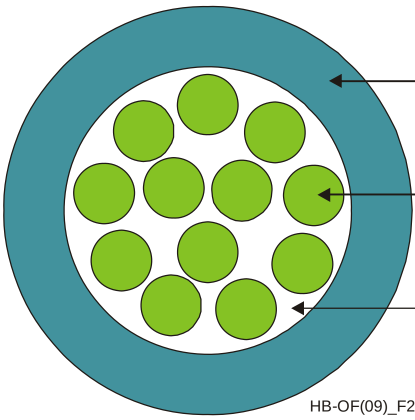


Figure 2-3 – Example of primary coated fibres protected by a micromodule

The small diameter micromodule is made of a very soft and flexible material which is easily strippable without dedicated tool. Furthermore this leads to easy micromodules storage in splicing boxes and trays.

Suitable for various applications, micromodule cables offer significant improvement in installation and deployment time over other cable type. Thanks to its attributes, "micromodule cables" is a suitable design for FTTH applications (see Chapter 9 dealing with the optical access network).

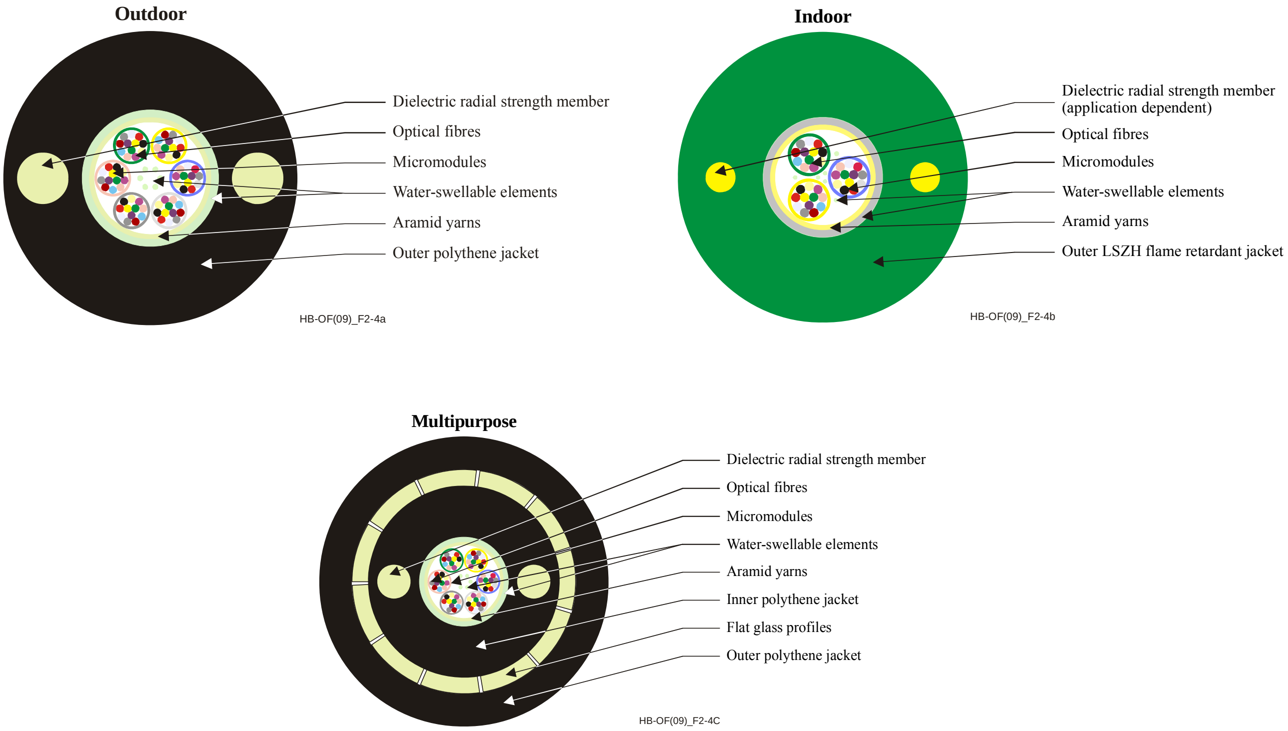


Figure 2-4 – Example of cable construction made with micromodule (outdoor, indoor or multipurpose application)

3.1.2.4 Tight secondary coating

A multiple layer tight coating consists of a composite primary layer, an optional buffer layer, and a polymer secondary coating. A buffer layer improves the stability of the optical loss when the fibre is subjected to radial pressure (Figure 2-5). A secondary coating of polymer improves the compressive load characteristic of the fibre. It improves the handling properties of the fibre and makes it particularly suitable as an equipment tail cable when it is encapsulated in a sheath reinforced with aramid yarn strength members.

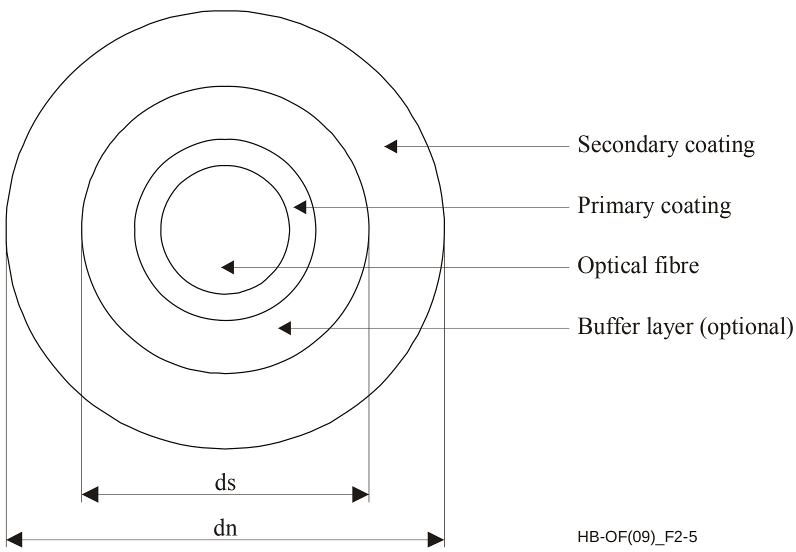


Figure 2-5 – Example of multilayer tight coated fibre

The dimensions of the multiple layers are determined from radial pressure and low temperature characteristic considerations. Example dimensions are shown in Table 2-5.

Table 2-5 – Example of dimensions on multilayer tight-coated fibre

Layer	Diameter (mm)
Primary coating	0.25
Buffer layer, ds	0.25-0.4
Secondary coating, dn	0.7-1.0

To improve the stability of optical loss during dimensional changes associated with temperature variations, a layer of secondary coated optical fibres is tightly stranded around a central steel wire to form an optical fibre unit (Figure 2-6). The laid up fibres are cushioned using a buffer layer which is held in position by an overall application of tape.

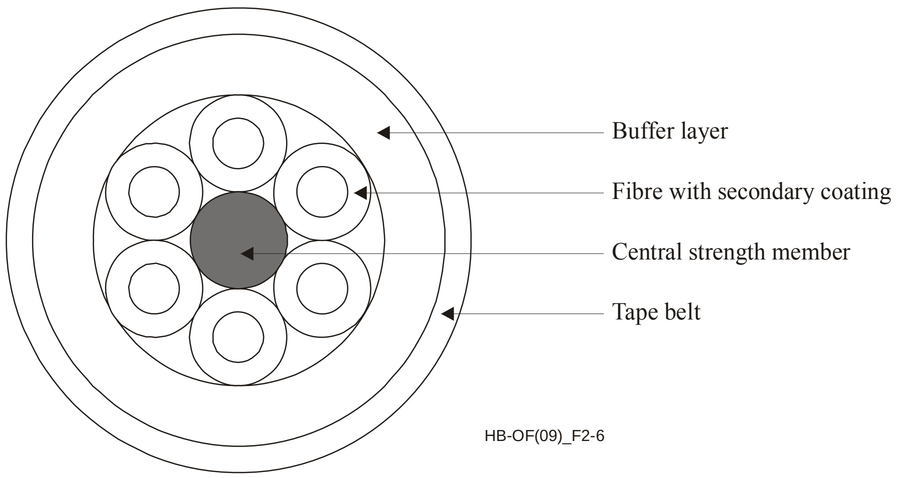


Figure 2-6 – Example of secondary coated fibre stranded around a central strength member

3.1.2.5 Ribbon construction

A ribbon construction is a linear array of fibres which may be assembled in a number of ways, examples of which are shown in Figure 2-7. A ribbon construction is advantageous for splicing multiple fibres, and allows greater fibre density within a cable.

Optical fibre ribbons consist of optical fibres aligned in a row. Optical fibre ribbons are divided into two types, based on the method used to bind optical fibres. One is the edge-bonded type; the other is the encapsulated type, shown in Figures 2-7(a) and 2-7(b) respectively. In case of the edge-bonded type, optical fibres are bound by adhesive material located between optical fibres. When the encapsulated type is adopted, optical fibres are bound by coating material. In ribbons, optical fibres shall remain parallel, and do not cross. Each ribbon in a cable is identified by a printed legend or unique colour.

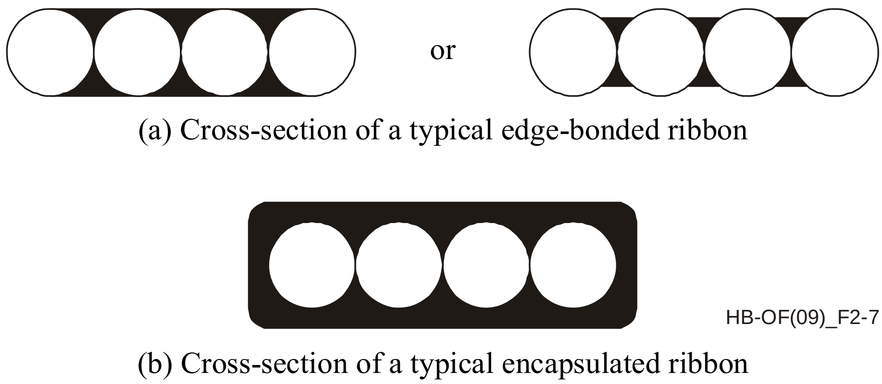


Figure 2-7 – Examples of ribbon construction

3.1.3 Fibre identification

Fibre should be easily identified by colour or position within the cable core. If a colouring method is used, the colours should be clearly distinguishable and the colouring should be stable in the presence of other materials used in cable construction during the lifetime of the cable. If the primary coating is coloured, it may be required that the coloured coating should also be compatible with local light injection into the fibre core and detection from it during core alignment when jointing the fibre.

3.1.4 Optical fibre unit

An optical fibre unit is defined as the basic unit for constituting the core of an optical fibre cable. The structure of an optical fibre unit usually depends on the type of the secondary protection of the primary coated fibres.

For ribbon construction, the optical fibre unit is usually formed by laying fibre ribbons with other elements, as required. In one of the optical fibre unit structures, multiple fibre ribbons are tightly stranded around a slotted rod which has several slots. In another structure, multiple fibre ribbons are stacked and helically twisted within a single tube.

A general relationship between types of secondary protection and structures of the optical fibre units is shown in Table 2-6. A combination of the types of the secondary protection may be assembled together to form an optical fibre unit. The unit so formed can be laid up with other elements as required.

3.2 Optical cable core structures

The core of optical fibre cable is usually formed by using one or more optical fibre units. The required number of fibres in the cable and the type of application of the cable will determine what kind of optical fibre unit structure is selected. In order to determine the cable core structure or to select the optical fibre unit structure, it is also important to take the cable installation and the fibre jointing into consideration.

In this section, the cable construction of optical fibre cables will be classified into the following two types:

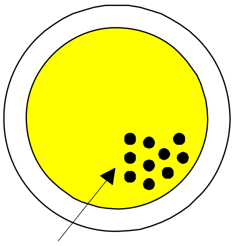
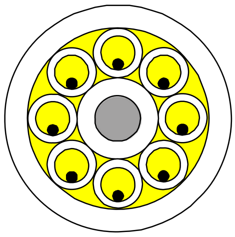
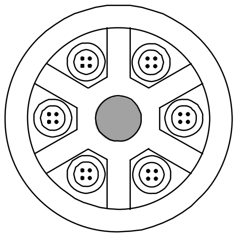
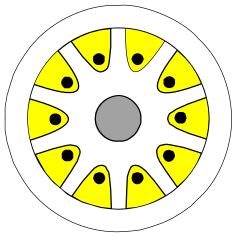
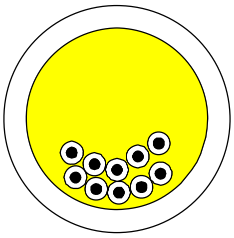
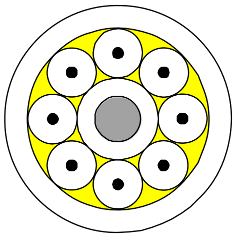
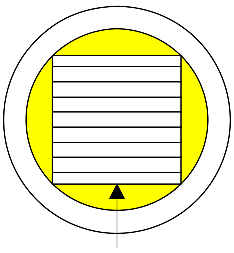
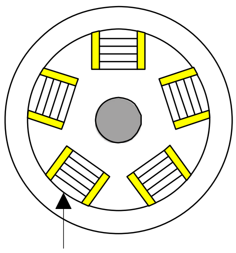
i) single unit cables, which consist of a single optical fibre unit;

ii) multiple unit cables, which consist of multiple optical fibre units.

3.2.1 Single unit cables

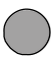
Cable core constructions of single unit cables correspond to the optical fibre units shown in Table 2-6.

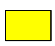
Table 2-6 – Examples of optical fibre unit structure

Protection		Structures of optical fibre units		
		Single tube structure	**Layer structure**	**Slotted rod structure**
Loose packaging	Within a tube	 Fibre brundle		
Loose packaging	Within a groove			
Tight secondary coating				
Ribbon construction		 Fibre ribbon		 Fibre ribbon

 : Primary coated fibre(s) [one or more]

 : Tight secondary protected fibre

 : Strength member

 : Water-blocking material

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Examples of medium to high fibre count cable constructions among various single unit cables are given in Figure 2-8.

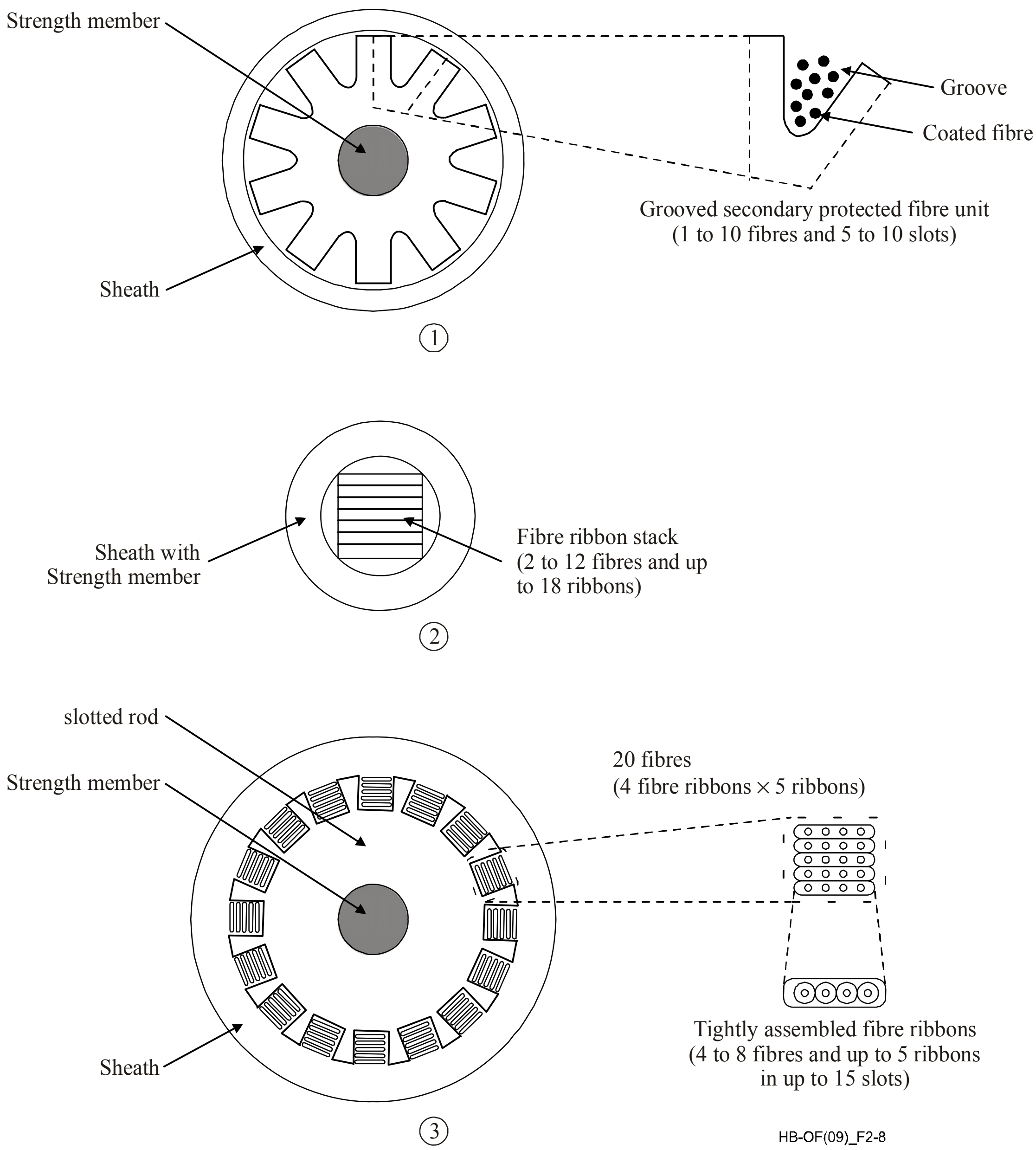

Figure 2-8 – Examples of single unit cable construction

Laying up small diameter optical fibre units can result in high pneumatic resistance from the small interstitial gaps within the cable core. In such cases, if gas pressurization is required, special low pneumatic resistance fillers must be introduced. As an alternative to gas pressurization, water-blocking materials may be introduced.

3.2.2 Multiple unit cables

Multiple unit cables are constructed by:

i) stranding multiple optical fibre units together around a central strength member;

ii) placing multiple, bound, optical fibre units loosely into a single tube within a sheath containing strength members.

If the size of the central strength member, to accommodate a single layer of the desired number of optical units does not provide sufficient design strength, then additional strength members may be stranded over the cable core. The stranding should be preferably in two directions to prevent torque when the cable is loaded.

Examples of multiple unit cable constructions are given in Figures 2-9a, 2-9b and 2-9c.

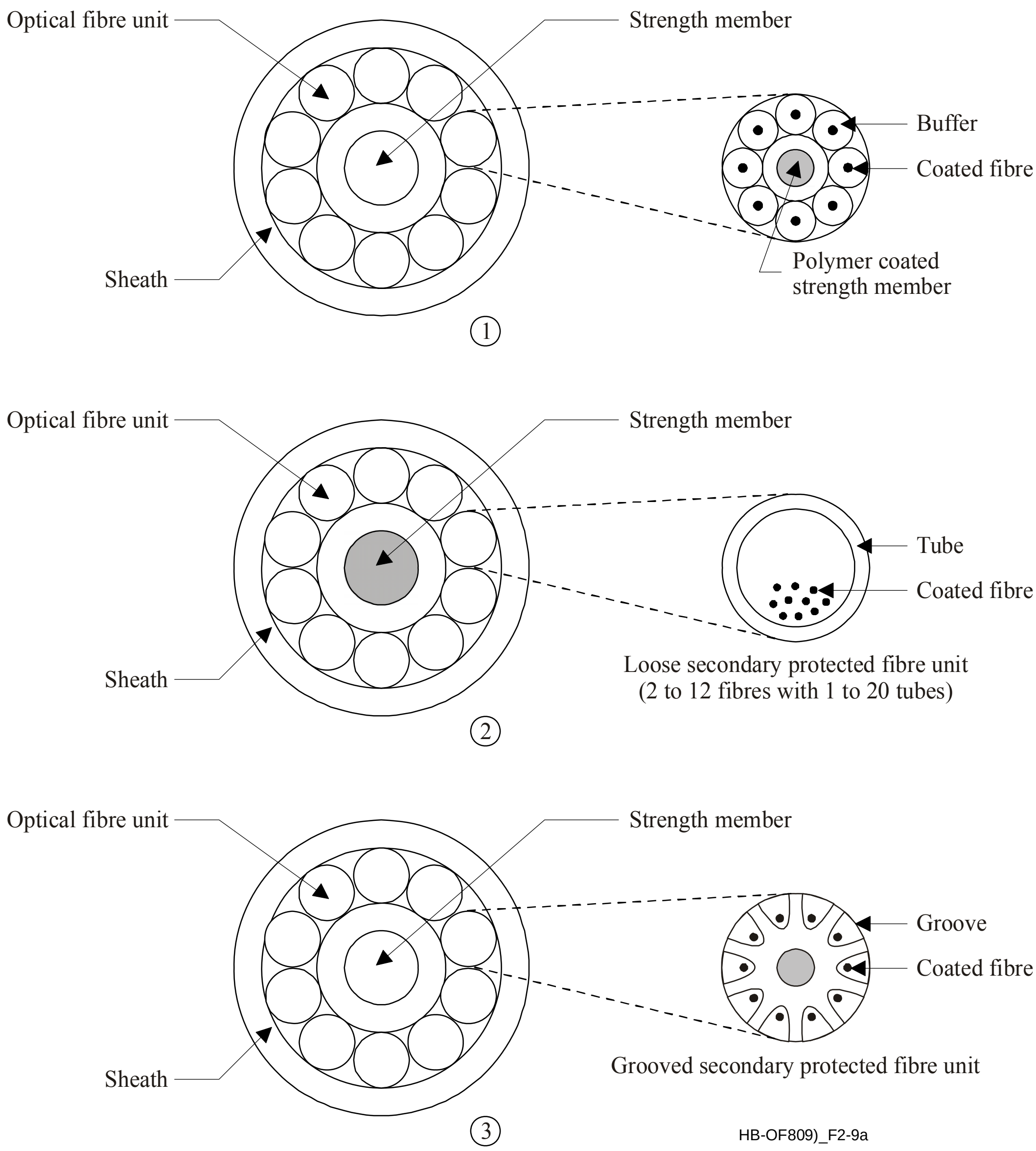

Figure 2-9a – Examples of multiple unit cable construction

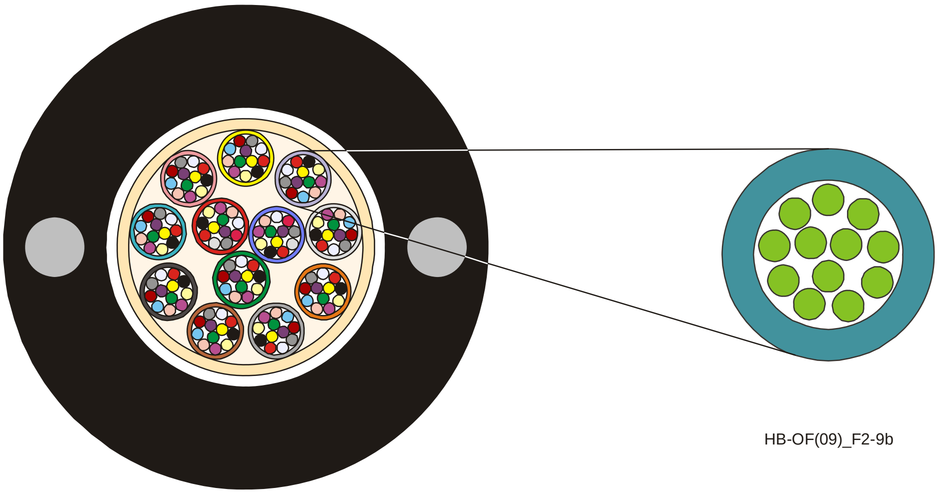

Figure 2-9b – Example of multiple unit cable construction

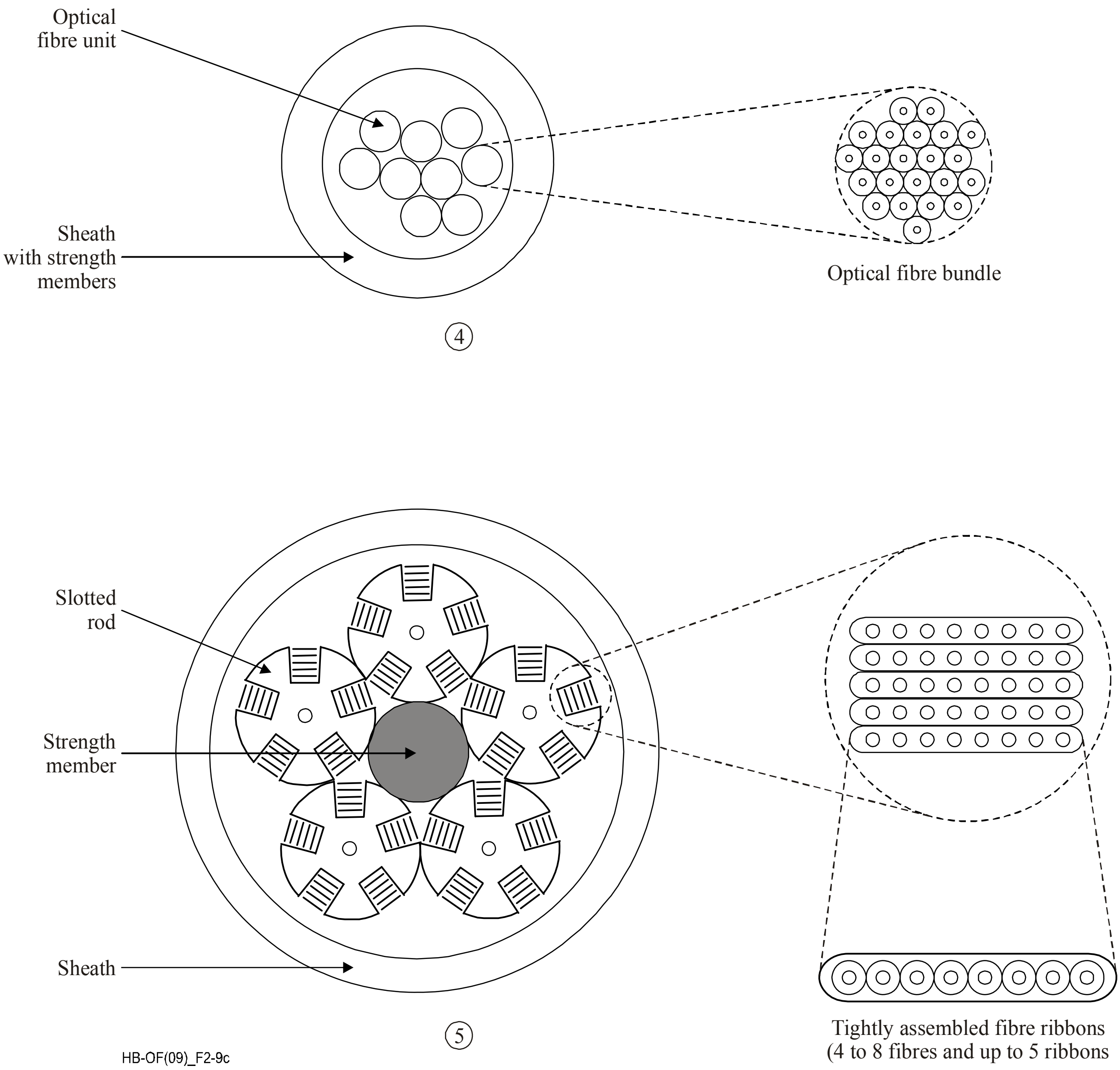

Figure 2-9c – Examples of multiple unit cable construction

3.2.3 Protection against moisture

The cable core is protected against water ingress by the cable sheath. Cable installed in the ground, ducts, or underwater environment should be particularly designed so that the cable core is protected against the ingress of water or moisture in the longitudinal direction if the sheath is perforated. The protection method should be selected from the following two methods when determining the cable core make-up:

i) protecting a cable with water-blocking material;

ii) pressurization.

3.2.3.1 Water-blocking materials

Water-blocking material is one means of protecting the fibres from the ingress of water or moisture. A filling compound, swelling tape, swelling powder or a combination of materials may be used. The filling compound or swelling powder is distributed into interstices of the optical fibre unit (Table 2-6) and the cable core. The filling compound can be also used as a filler of a tube or groove. Swelling tape is usually wrapped around the optical fibre units or the cable core.

The following points are important for the filling compound, swelling tape or power in optical fibre cables:

i) fibre movement should not be constrained by stickiness;

ii) compatibility with primary coating or colouring materials;

iii) no change in the optical performance with activation of the water-blocking material;

iv) no change in optical performance with temperature variations;

v) easy removal of water-blocking materials for splicing.

When longitudinal water tightness of the optical fibre cable including the cable joints is required, the following options are commonly used:

i) continuous blocking,

ii) discrete blocking.

In cable designs with a central strength member and filling compound, the filling material must be selected to minimize the slip between the strength member and the sheath. It should be noted that precaution needs to be taken for potential water migration within stranded elements should these be used as strength members.

In the case of discrete blocking it is desirable that water detectors be included within the cable (network) construction.

Hydrogen absorbing chemicals may be introduced into the filling compound applied to the interstices of the cable core should unacceptably high concentrations of hydrogen be predicted within the cable during its lifetime. Alternatively, the cable construction can be such as to minimize generation of hydrogen.

3.2.3.2 Pressurization

When dry-air pressurization is used for cable maintenance the optical fibre unit structure is selected taking into account the pneumatic resistance and the cable diameter which will satisfy the installation environment.

Such small diameter cables as single unit cables or multiple unit cables laying up small diameter optical fibre units may have high pneumatic resistance from the small interstitial gaps within the cable core. In such cases, if gas pressurization is required, special low pneumatic resistance fillers may be introduced.

3.3 Strength members

In order to select the strength members the required tensile load should first be estimated taking into account the cable weight, the cable design, the range of environmental temperatures and the conditions of installation (whether the cable is installed in ducts, is buried, is subject to bends, etc). The strength members must provide sufficient strength to the cable to ensure the fibres are not strained beyond their permissible limit taking into account the dynamic strain introduced during handling of the cable. Under maximum loading the strength members should remain elastic to ensure that when the cable is relaxed the fibres are maintained below their permissible long term residual strain.

Certain installation requirements may dictate where the strength members are located within the cable, for example:

i) cable preparation and fibre splicing;

ii) sheath jointing;

iii) cable pulling devices;

iv) cable size.

Any type of strength member can be employed as long as the fibre strain is held within permissible values. As the rigidity of a solid wire is proportional to the 4th power of its diameter, stranded wires should be used for the larger diameters. Non-metallic strength members, for example glass fibre reinforced plastic, fibre glass yarns, oriented polymers, or aramid yarn, may be used for strength elements.

When armour wires are used as the strength members, care should be taken to ensure that the torque introduced under maximum loading does not stress the fibres beyond their permissible long term strain limit.

3.4 Cable sheath and armour

The cable sheath protects the cable core from mechanical and environmental damage. The following characteristics should be considered when choosing a sheath:

i) hydrogen generation;

ii) climatic performance;

iii) air tightness;

iv) moisture penetration resistance;

v) mechanical stability (bending, torsion, radial pressure, tension, abrasion, etc.);

vi) chemical resistance;

vii) diameter;

viii) weight;

ix) fire resistance;

x) rodent resistance.

3.4.1 Cable sheath types

Various kinds of cable sheath have been introduced for optical fibre cables applied to both external and internal installations. These are classified into the following five types:

i) metal/plastic sheath with metallic tapes or metallic layer;

ii) plastic sheath only;

iii) plastic sheath with strength members;

iv) plastic sheath with embedded strength members with a metallic tape;

v) cable sheath with armour.

Typical application of them in various environmental conditions is shown in Table 2-7.

Table 2-7 – Typical application of cable sheath types in various environmental conditions

Cable sheath types	External cables					Internal cables
	Aerial	Buried	Duct	Tunnel	Underwater	Building
Metal/plastic sheath with metallic tapes or metallic layer	A	A	A	A	B	B
Plastic sheath only	A	B	A	A	B	A
Plastic sheath with strength members	A	A	A	A	B	A
Plastic sheath with embedded strength members with metallic tape	A	A	A	A	B	B
Cable sheath with armour	A	A	B	B	A	B

A. Typically applied type.
B. Rarely applied type.

3.4.2 Metal/plastic sheath with metallic tapes or metallic layer

This type of cable sheath has a metallic moisture barrier tape and, in some of these constructions, an impervious barrier is achieved. The metallic tape may be corrugated to improve the flexibility and crushing strength of the cable.

3.4.2.1 Metal/plastic bonded sheath with coated aluminium tape

This type of sheath incorporates a tape of aluminium which is usually coated on one side with a thin film of polyolefin or copolymer. The coated aluminium tape is laid longitudinally over the cable core with the coated side outwards so as to form a tube with an overlap. A polyolefin sheath is then extruded over the tape and the coating fuses to the extruded sheath to provide a firm bond between it and the aluminium tape. Aluminium tape coated on both sides may be used when it is necessary to seal the overlap to improve the moisture barrier or to avoid sheath circulating current.

3.4.2.2 Metal/plastic bonded sheath with coated steel tape

This type of sheath incorporates a tape of steel coated on both sides with a thin film of copolymer. This tape is corrugated and laid longitudinally over the cable core as to form a tube with an overlap, along which the copolymer is fused to ensure a firm bond. A plastic sheath such as polyethylene is then extruded over the tape.

3.4.2.3 Metal/plastic sheath with aluminium tape and soldered tinned-steel tape

This type of sheath includes a longitudinally applied aluminium tape formed into a tube over which is a similar tube of tinned-steel in contact with it. The edges of the tinned-steel tape are overlapped and soldered. For large cables both tapes are corrugated to improve flexibility. A layer of compound is applied over the tinned-steel tube before a plastic sheath is extruded over it for corrosion protection. This sheath forms an impervious moisture barrier.

3.4.2.4 Metal/plastic sheath with a welded-steel tape

This type of sheath includes a longitudinally applied steel tape formed into a tube with its edges continuously welded together. The tube is then corrugated down onto the cable core. A layer of compound is applied over the steel before a plastic sheath is extruded over it for corrosion protection. This sheath forms an impervious moisture barrier.

3.4.2.5 Metal/plastic sheath with an extruded lead sheath

This type of sheath includes as the impervious layer an extruded lead sheath. To protect the cable core from the lead extrusion temperature, a suitable heat barrier layer between core and lead sheath is necessary.

3.4.3 Plastic sheath only

This type of sheath is extruded from plastic material (PE or PVC etc.) and is not moisture resistant.

3.4.4 Plastic sheath with strength members

This sheath design contains longitudinal or cross-ply strength members which may be metallic or non-metallic.

3.4.4.1 Plastic sheath with cross-ply strength members

This type of sheath has helically wound strength members in two torsionally balanced layers in opposite directions, with a plastic sheath extruded over them. The strength members can be made of either steel of fibreglass reinforced plastic (FRP).

3.4.4.2 Plastic sheath with bonded strength members

This type of sheath has generally aramid strength members and may also include glass fibre strength members bonded to the cable sheath. With aramid strength members in the sheath construction it may be necessary to introduce an antibuckling central strength member. The sheath may contain a moisture barrier.

3.4.5 Plastic sheath with embedded strength members with a metallic tape

This type of cable sheath has two parallel, steel strength members embedded in the plastic sheath, which is extruded over a corrugated steel tape. The steel tape is placed over the core and provides a moisture barrier.

3.4.6 Cable sheath with armour

A number of armour oversheaths are used for added protection to the optical cable to meet particular environmental conditions. An example of where additional protection is applied to the cable sheath is for lake and river crossings to resist water current and snagging. One or more helically applied layers of zinc coated steel or stainless steel wires may be applied to the sheath and protected with layers of compound, twine bedding and wrapping, or layers of compound and an extruded plastic sheath. Generation of hydrogen due to corrosion must be considered when selecting the armour wires. A copper tape may be applied as anti-teredo protection.

A lead oversheath may be applied over the plastic sheath in areas of severe or extensive exposure to petrochemicals.

As a protection against rodents, a metal/plastic bonded sheath with a corrugated steel, or stainless steel, tape that is coated on both sides may be applied over the sheath.

3.4.7 Sheath with identification

If visual identification is required to distinguish an optical fibre cable from a metallic cable, this can be done by visibly marking the sheath of the optical fibre cable. For identifying cables, embossing, sintering, imprinting, hot foil and surface printing can be used by agreement between user and manufacturer.

4 Structure of optical fibre cables for specific installations

The general structure of the optical fibre cables described in § 3 well applies to optical cables to be installed in ducts, tunnels and bridges, as described in Recommendation ITU-T Rec. L.10, or to be directly buried in the ground, as discussed in Recommendation ITU-T Rec. L.43. On the contrary other types of installation (aerial, marinized, submarine and sewer duct) need specific structures, even if always based on the general ones described in § 3. These specific structures are described in this clause.

4.1 Optical fibre cables for aerial applications

(For further information, see Recommendation ITU-T L.26.)

4.1.1 Environmental conditions

In aerial applications *water* in the cable may be frozen under some conditions and can cause fibre crushing with a resultant increase in optical loss and possible fibre breakage.

Overhead cable *vibrations* are produced either by laminar wind streams, causing curls at the lee side of the cable (aeolian vibration) or by variations in wind direction relative to the cable axis (galloping effect). A well-established surveillance routine will identify the activity in order to make a careful choice of the route and to decide upon the installation techniques, or the use of vibration control devices, or both to minimize this type of problem. In these situations, cables should be designed and installed to provide stability of the transmission characteristics and mechanical performance. To reduce any fibre strain induced by wind pressure, the strength member should be selected to limit this strain to safe levels, and the cable construction may mechanically decouple the fibre from the sheath to minimize the strain. Alternatively, to reduce fibre strain, the cable may be lashed to a high-strength support strand.

Generally, aerial cables are more exposed to significant *temperature* variation than underground cables. Therefore, this issue is very important. Expansion of the cable due to a variation in temperature to a high level may cause a significant reduction of the safe clearance to ground. Shrinkage of the cable due to a variation in temperature to a low level may cause the maximum working tension to be reached. Under these conditions, the variation of attenuation of the fibres shall be reversible and shall not exceed the specified limits.

Fibre strain may be caused by tension occurring in connection with *snow loading* and/or *ice* formation around the cable. Induced fibre strain may cause excess optical loss and may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded. Dynamic strain in the fibre may be induced by vibration caused by the action of snow or ice falling from the cable. This may cause fibre breakage. Under the load of snow or ice, excessive fibre strain may easily be induced by wind pressure. To suppress the fibre strain by snow loading or ice formation or both, the strength member should be selected to limit this strain to safe levels, and the cable profile may be selected to minimize snow loading. Alternatively, to suppress fibre strain, the cable may be lashed to a high-strength support strand. Cable should be designed and installed to provide stability of the transmission characteristics, cable sag/tension, fatigue of the strength member and tower/pole loading.

Metal-free aerial cables installed in the high-voltage environment of power lines are susceptible to the influence of the *electric field* of these power lines, which may lead to phenomena such as corona, arcing and tracking of the cable sheath. To prevent damage, the cable should be installed on the power transmission lines in a position of minimum field strength, or special cable sheath materials may be used, or both approaches may be followed depending on the level of the electric field. Also, the effect of sheath marking should not cause any deterioration of the sheath in these circumstances.

4.1.2 Cable construction

For aerial application, the following special cable structures may be adopted:

– *All-Dielectric Self-Supporting* (ADSS): the tensile element is provided by a non-metallic reinforcement (e.g. aramid yarns, glass-fibre-reinforced materials or equivalent dielectric strength members) placed under or within the plastic sheath; the outer shape is circular (Figure 2-10a);

– *Self-Supporting (SS) cable*: the sheath includes a metallic or non-metallic bearing element, to form a figure "8" (Figure 2-10b);

– *Lashed cable*: non-metallic cables installed on a separate suspension catenary and held in position with a binder cord or special preformed spiral clips.

A knowledge of span, sag, wind and ice-loading is necessary to design a cable for use in aerial applications.

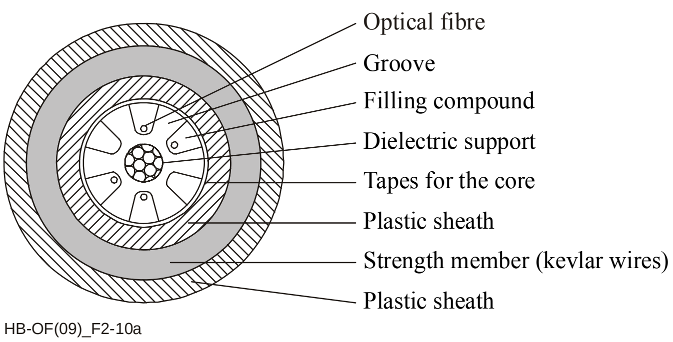

Figure 2-10a –
All-dielectric self-supporting cable

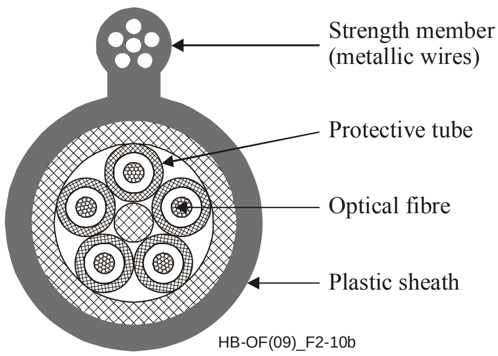

Figure 2-10b –
Self-supporting cable (figure 8 cable)

4.2 Marinized terrestrial cables

(For further information, see ITU-T Handbook, *Marinized Terrestrial Cables*.)

A marinized terrestrial cable (TMC) is an underwater optical fibre cable construction based on a *conventional multiple fibre terrestrial cable core*, protected to withstand the marine environment. MTC is designed for unrepeatered applications, hence without the need to carry electrical power and is tested for use in non-aggressive shallow waters. The main applications are for crossing rivers, lakes, fjords, etc.

4.2.1 Mechanical and environmental characteristics

Marinized terrestrial cables must be able to withstand during their life time the water pressures that act upon them, in accordance with the depth of the water (up to about 100 m) in which they are used.

Depending on the marine installation and maintenance operation adopted, the cable can be subjected to lateral pressure from the sheaves of a cable-laying vessel. Similarly, lateral pressure can be created on a laying vessel using a drum engine or a powered reel. All these lateral pressures increase with increased cable tension and depth of water. Moreover, the storage of cables in layers of coils produces lateral pressure proportional to the height of the accumulated layers in the cable span. The cable should be designed with sufficient strength to withstand the pressures it is intended to encounter.

The minimum bending radius should be as small as possible in order to minimize the space necessary for transportation and to maximize the cable length available for installation in one trip. Small vessels, unless specially designed for cable laying operations, may have relatively small size sheaves.

Laying and recovery operations induce also longitudinal tensile forces on marinized terrestrial cables, such as:

i) static tension which is related to the unit weight of the cable in water and the depth of the water;

ii) dynamic tension which is caused by the pitching of the cable laying vessel.

In recovery operations, the cable forms a catenary and is acted upon by static tension in accordance with the amount of slack in it and by the resistance of the water. In the case of buried cables, a further tensile force is involved in the earth moving operation of dragging the cable out of the sea beds.

4.2.2 Cable structure

The typical cable design is made by a terrestrial cable core, contained in an impervious sheath protected with armour to withstand local seabed environment.

The cable core should be preferably the same as the terrestrial cable to which it is to be joined. It should have preferably the same number of fibres as the terrestrial cable.

An impervious sheath of copper, lead or steel may be applied over the cable core. This may be protected with an extruded plastic sheath or a layer of servings to provide bedding for armour.

Usually the armouring consists of a single or double layer of steel wires. The wires may be individually coated with plastic. A layer of servings[1] may be applied between two layers of armour wires to act as bedding.

An outer covering of serving or a plastic sheath is usually applied as protection against wear and corrosion. Servings made of polypropylene, nylon or jute yarns usually include an application of bituminous compound.

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1 "Serving" is a traditional nautical term that refers to a tight **wind**ing of **spun yarn**, or the like, **around** a **rope** or **cable**, so as to **protect** it **from chafing** or **from** the **weather**.

A marinized terrestrial cable core may consist of a single optical unit or multiple optical units, which are similar to those used for terrestrial cables. As for the outer structures, which are specifically designed for this type of application, two alternatives generally are adopted (Figure 2-11):

i) Reinforced core structures, which is based on the winding of armours around a reinforced cable core. The reinforced cable core consists of a central optical unit protected by strength members (metallic or non-metallic), a metallic sheath and a polyethylene sheath. The strength members provide tensile strength and limit cable an fibre elongation. The metallic sheath is typically a continuous welded copper pipe. The welded copper pipe forms a seal against hydrogen diffusion.

ii) Standard core structure, which is specifically designed for shallow water applications. The cable usually consists of a central optical unit packed by a plastic sheath and armour winding. The armour is steel wire which can serve as both protection for the cable against abrasion and as a strength member.

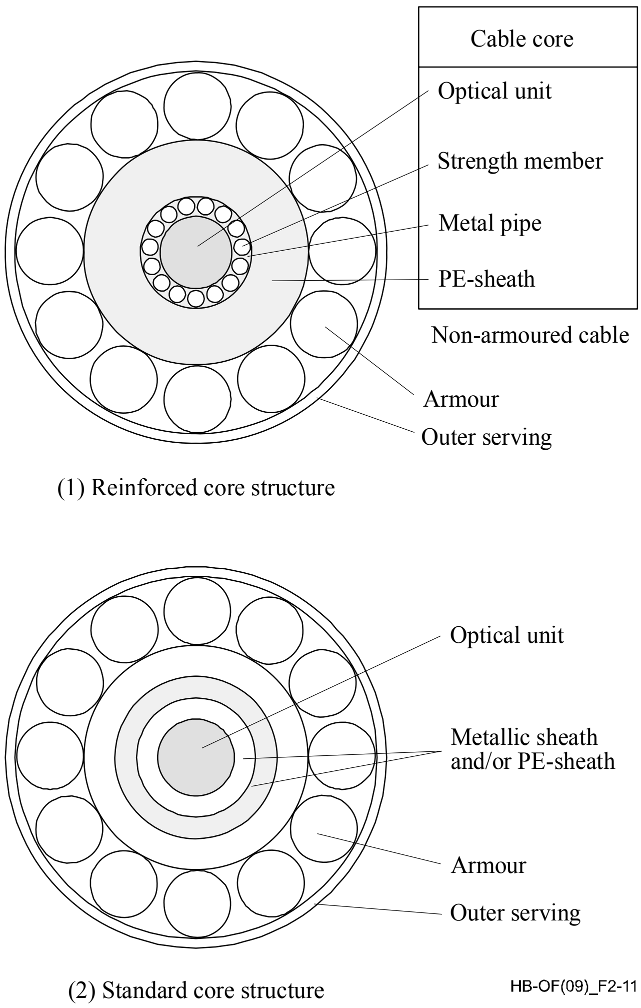


Figure 2-11 – Typical armour structures of marinized terrestrial cables

4.3 Submarine cables

(For further information, see Recommendation ITU-T G.978.)

The optical submarine cable is an underwater optical fibre cable designed to be suitable for shallow and deep water use, which is required to ensure protection of optical fibres against water pressure, longitudinal water propagation, chemical aggression and the effect of hydrogen contamination throughout the cable design life. The submarine cable is extensively tested to show it can be installed and repaired *in situ*, even in worst weather conditions, without any impairment of optical, electrical or mechanical performance or reliability. This means that the submarine cable is conceptually different from a marinized terrestrial cable defined in § 4.2.

Based on application, the optical fibre submarine cable can be a repeatered submarine cable or a repeaterless submarine cable. A repeatered submarine cable must contain a low resistance electrical conductor to provide power to the optical repeaters. A repeaterless submarine cable doesn't need to have the electrical conductor for repeaters. In general, while the typical maximum number of fibres within repeatered submarine cable is fewer than 16, repeaterless submarine cable contains much larger quantity of fibres (up to several hundreds of fibres).

4.3.1 Mechanical and environmental characteristics

The cable, with the cable jointing boxes, the cable couplers, and the cable transitions, should be handled with safety by cable ships during laying and repair operation (depth up to about 8 000 m); it should withstand multiple passages over the bow of a cable ship.

The cable should be repairable and the time to make a cable joint on board during a repair in good working conditions should be reasonably short.

Should the cable be hooked by a grapnel, an anchor or a fishing tool, it usually breaks for a load approximately equal to a fraction (depending on the cable type and the grapnel characteristics) of the breaking load in straight line conditions; there is then a risk of reduction of the fibre and cable lifetime and reliability in the vicinity of the breaking point, due in particular to the stress applied to the fibre or to water penetration. The damaged portion of cable should be replaced and its length should stay within a specified value.

Should a cable break on the sea bottom, water should not propagate in the cable for a given cable length (around 1 km).

Several parameters are defined in Recommendation ITU-T G.972 to characterize the cable mechanical characteristics and the ability of the cable to be installed, recovered and repaired; these can be used as guidance for cable handling:

i) the cable breaking load (CBL), measured during qualification test;

ii) the nominal transient tensile strength (NTTS), which could be accidentally encountered, particularly during recovery operations;

iii) the nominal operating tensile strength (NOTS), which could be encountered during repairs;

iv) the nominal permanent tensile strength (NPTS), which characterizes the status of the cable after laying;

v) the minimum cable bending radius, which is a guidance for cable handling.

4.3.2 Cable structure

The submarine cable should be designed so as to guarantee the system design life, taking into account the cumulative effect of load applied to the cable during laying, recovery and repair, as well as any permanent load or residual elongation applied to the installed cable. Two generic types of fibre containment structure are commonly used to protect the optical fibres:

i) the tight cable structure, where the fibres are strongly maintained in the cable, so that the fibre elongation is essentially equal to that of the cable;

ii) the loose cable structure, where the fibres are free to move inside the cable, so that the fibre elongation is lower than that of the cable, staying zero until the cable elongation reaches a given values.

The central optical unit is usually reinforced by closely packed high strength wires to withstand the weight of the cable during deployment and hydrostatic pressure of the sea bottom. They are formed into a locked vault structure around the central optical unit and wrapped by an external, welded copper tube. The copper tube provides strength, a powering path and hydrogen resistance (Figure 2-12).

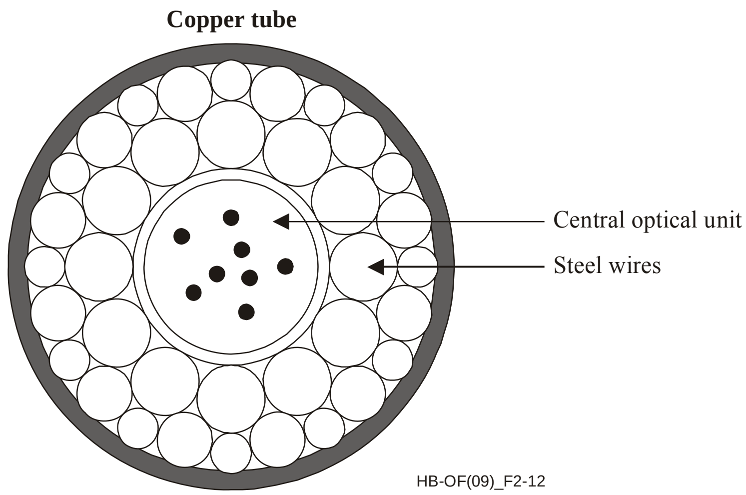


Figure 2-12 – Typical wire vault structure of submarine cables

The optical fibre submarine cable should also provide protection against the environmental hazards at its depth of utilization (up to ~8 000 m): protection against marine life, fish-bite and abrasion, and armours against aggression and ship activities. Different types of protected cable are defined in Recommendation ITU-T G.972, in particular:

i) the lightweight cable (LW cable) which is suitable for laying, recovery and operation, where no special protection is required;

ii) the lightweight protected cable (LWP cable) which is suitable for laying, recovery and operation, where special protection is required (Figure 2-13a);

iii) the single armoured cable (SA cable) which is suitable for laying, burial, recovery and operation and is suitably protected for specific area in shallow water;

iv) the double armoured cable (DA cable) which is suitable for laying, burial, recovery and operation and is suitably protected for specific area in shallow water (Figure 2-13b);

v) the rock armoured cable (RA cable) which is suitable for laying, recovery and operation and is suitably protected for specific area in shallow water.

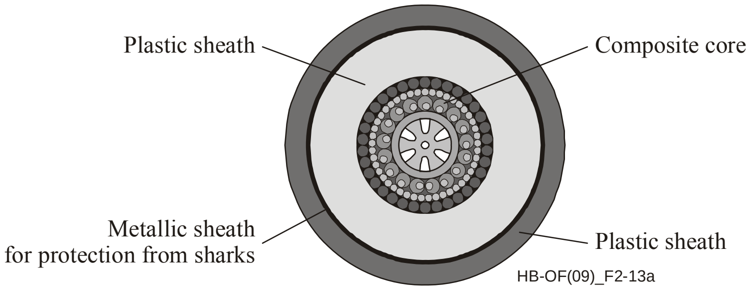


Figure 2-13a – Lightweight-protected cable

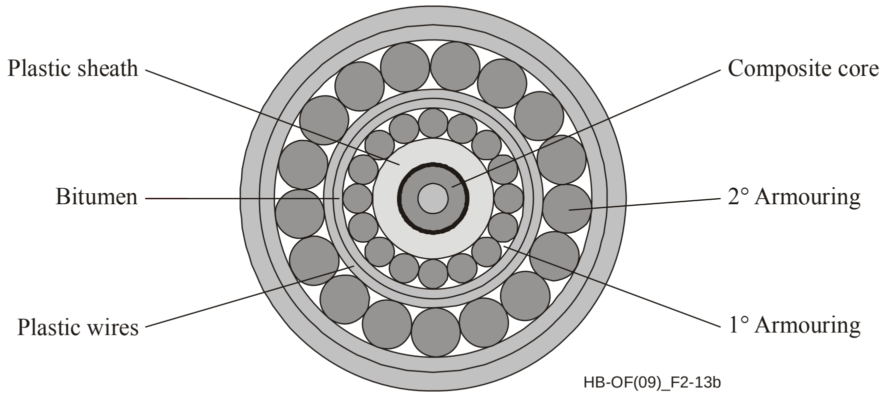


Figure 2-13b – Double-armoured cable

Table 2-8 indicates the typical application depth of each cable.

Table 2-8 – Typical application depth of optical fibre submarine cables

	LW/LWP cable	**SA cable**	**DA cable**	**RA cable**
Depth (m)	> 1 000	> 20 –1 500	0 – 20	0 – 20

Optical fibre land cable should protect the system and personnel against electrical discharges, industrial interference and lightning. Two types of protected land cable are commonly used:

i) armoured land cable, with an armour to be maintained at earth potential, and which is suitable to be buried directly;

ii) duct shielded cable, with a circumferential safety shield (which may be the fish-bite protection shield), and which is suitable to be pulled into ducts.

4.4 Optical fibre cables for sewer duct applications

(For further information, see Recommendation ITU-T L.78.)

4.4.1 Environmental conditions

The environmental conditions in a sewer pipe may be harsh compared with those experienced by conventional underground cables.

Temperature variation strongly depends on climatic conditions and the temperature of liquid passing through a sewer pipe. Therefore, it is important to examine the expected temperature range during their operational lifetime. It is recommended that the optical fibre cable structure be designed so that no increase in fibre attenuation exceeds the specified limits under those conditions.

Rodents may be found in sewer pipes. Where those rodents cannot be excluded, a suitable and effective protection should be provided. Further information is in Recommendation ITU-T L.46. Effective protection can be provided by metallic (steel tape or wire armouring) or non-metallic (e.g. fibreglass rods, glass yarns/tapes) barriers.

Although it is undesirable, there is a possibility that certain kinds of chemical agent will flow through a sewer pipe. After installation, contact with several chemical material agents may degrade the cable sheath characteristics, leading to the weakening of the cable core protection. To avoid this problem, cable sheath materials should be selected carefully, based on their robustness with regard to chemical agents. First of all, it is important to assess what kind of chemical agents may exist in the area where the cable is to be laid. Then, sheath material durability with respect to these chemical agents should be examined.

A highly humid environment may result in moisture permeation depending on the cable sheath structure. When moisture permeates the cable sheath and is present in the cable core, the tensile strength of the fibre deteriorates and the time-to-static failure will be reduced. To ensure a satisfactory cable lifetime, the long-term strain level of the fibre must be limited. Various materials can be used as barriers to reduce the rate of moisture permeation. Alternatively, filled metal-free cable construction can be used.

When an optical fibre cable is soaked in water, moisture permeation and water penetration may be caused depending on the cable structure. When there is a crack in the cable sheath, water may soak into the cable core. Water causes fibre strength degradation more rapidly than high humidity. If there is a possibility that the cable will be soaked in water, it is recommended that water-blocking materials be used to prevent the cable core from being immersed in water.

4.4.2 Cable structure

For sewer application, the following special cable structures may be adopted:

i) Single-armoured cable (SA cable), which is suitable for laying, recovery and operation and is suitably protected for specific area in sewer pipe (Figure 2-14a);

ii) Self-supporting (SS) cable, which is suitable for hungering, recovery and operation and is suitably protected for the specific conditions in sewer pipe. If using this type of a cable, knowledge of span and sag is necessary to design a cable (Figure 2-14b).

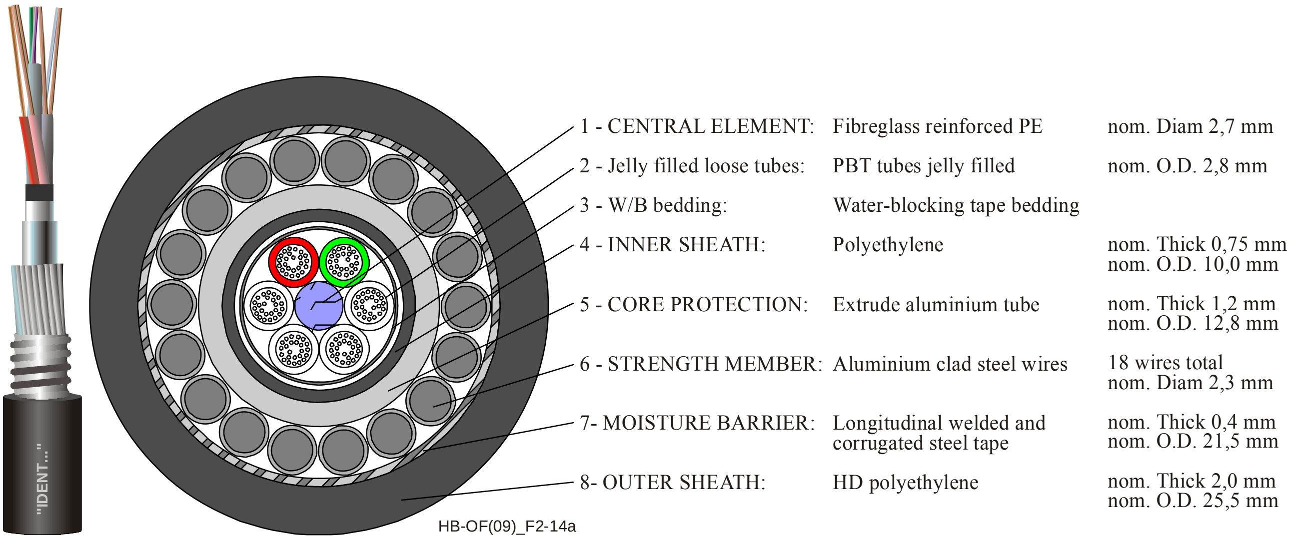
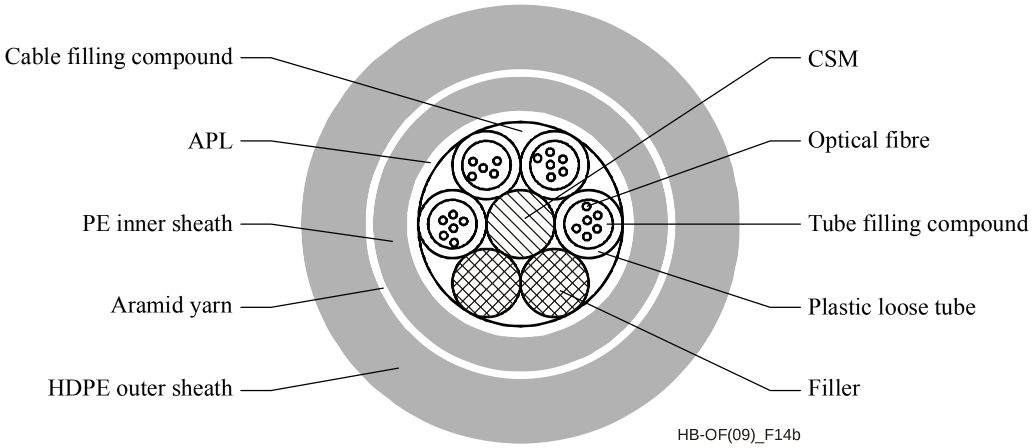


Figure 2-14a – Single-armoured cable with stranded plastic loose tube structure for sewer application



APL =	Aluminium polyethylene laminated	HDPE =	High-density PE
PE =	PolyEthylene	CSM =	Central support member

Figure 2-14b – Self-supporting cable with stranded plastic loose tube structure for sewer application

4.5 Optical fibre cables for multidwelling FTTH indoor applications: riser cable

4.5.1 Environmental conditions

Optical fibre communications networks have entered in a new phase with the ongoing demand for FTTH networks (fibre to the home). It is necessary to bring fibre(s) up to the customer premises following different scenarios (residential, aerial, multidwelling units, etc.). For more information on this issue, see Chapter 9 dealing with the optical access networks.

Indoor cables can be used from the building entry and may be for short runs within a house or long runs through a building. Since products are used in customer premises, they all offer some form of flame retardancy. This includes the use of a low smoke, zero halogen sheath, while the cable is constructed in such a way as to afford some degree of protection from flame propagation and smoke emission. The materials are characterized for halogen content and for corrosivity risks.

Focusing on multidwelling units, the vertical access to buildings with several floors requires a new types of cable, so-called "Riser".

For vertical cabling, a mid-span access allows one to extract a fibre or bundle of fibres on each floor, depending on the building configuration or on the number of customer to be connected.

There are two types of mid-span access:

i) full mid-span access: all fibres, or bundles of fibre, are extracted at each distribution point, by removing the entire riser sheath over few tens of centimetres;

ii) tapping access, or easy mid-span access: extraction of necessary fibre(s) or bundle(s) of fibre is made at the distribution point, creating windows into the cable sheath with a dedicated tool, in order to access the cable core content. The other fibre(s) or fibre bundle(s) remain in the cable core, without the need for dedicated management at the distribution point. This procedure is depicted in Figure 2-15. First, create two windows, one at the distribution point, and another somewhere further along its length. Cut the designated fibre(s) or fibre bundle(s) on the upper part and extract it (them) at the lower distribution point.

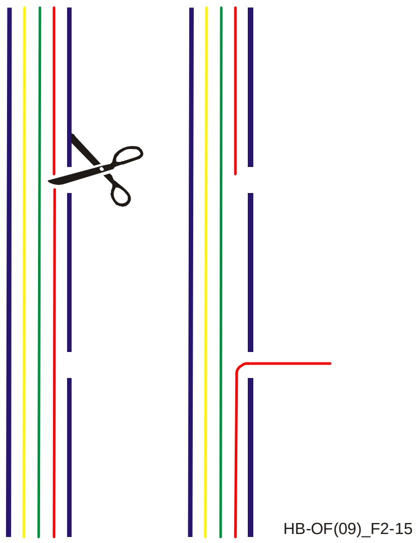


Figure 2-15 – Example of a tapping, mid-span access

4.5.2 Cable structure

Several riser cable designs have been developed and installed worldwide.

Strength members, such as glass fibre reinforced plastic material in the sheath or peripheral strength elements aramid yarns, can be used to provide the enough tensile strength to the cable, since the cable will be installed inside the buildings, sometimes in fully occupied ducts.

Below are described some of the designs available:

i) micromodule riser cable design, based on micromodules containing optical fibres (Figure 2-16);

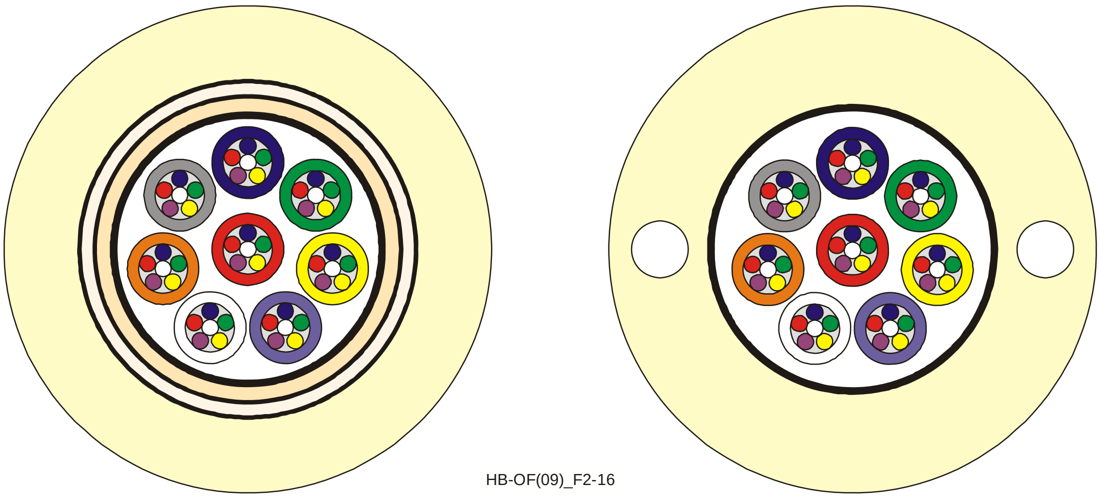


Figure 2-16 – Example of micromodule riser cable

ii) individual fibre protected by buffer, based on ITU-T G.657B optical fibres also complaint to ITU-T G.652D individually protected with a buffer, stranded to form the optical core (Figure 2-17).

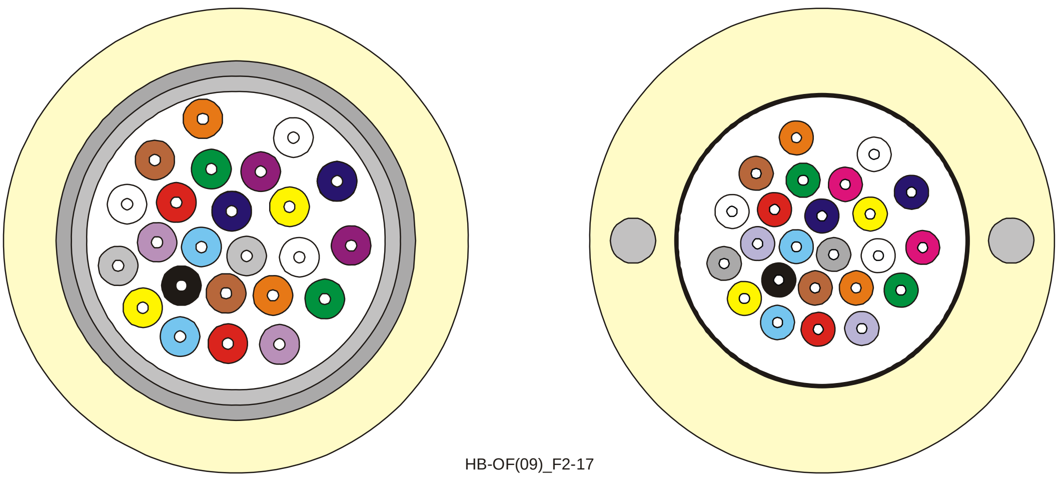


Figure 2-17 – Example of individual fibre buffer riser cable

5 Cable tests

The description of the cable tests is outside the scope of this Handbook. Information on cable tests can be found in Supplement 40 to the ITU-T G-series Recommendations and in the relevant ITU-T L-series Recommendations.