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Technical newsletter
Optical fibre cables to close the gap between network access point and the building

July 2023

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We encourage recipients to read all of them and to pay particular attention to the Newsletter “Optical Reliability of optical infrastructure” and “Understanding an optical fibre datasheet”

1. Introduction

A FTTH network (see figure 1) typically consists of 2 types of cables: the distribution cables which contain many fibres (e.g. 96f and more) and low fibre count cables, so called drop cables with a minimum of 1 fibre. The drop cables close the gap between distribution cables (starting at the Network Access Point (NAP)) and the single user´s home, Multi Dwelling Units (MDUs), or other premises. Since the distances are normally short, up to approx. 500 m, the cable designs are optimized for this specific application.

Drop cables are deployed between poles, in ducts, directly buried, or attached on facades. Installation in sewer-/gas-/drinking water pipes are technically feasible however have only minor importance because of its complexity and legal aspects (e.g. installation of cables in drinking water pipes is not allowed everywhere). In the following examples, suitable cable designs are presented which can be used for the different application spaces.

Drop cables end either outside the building in a wall box or inside the building in a distribution frame or when the cable also fulfils the appropriate fire performance requirements it can be routed directly to the end-user without splicing in between. Therefore often so called indoor/outdoor or double sheath cables are needed to provide the appropriate fire performance.

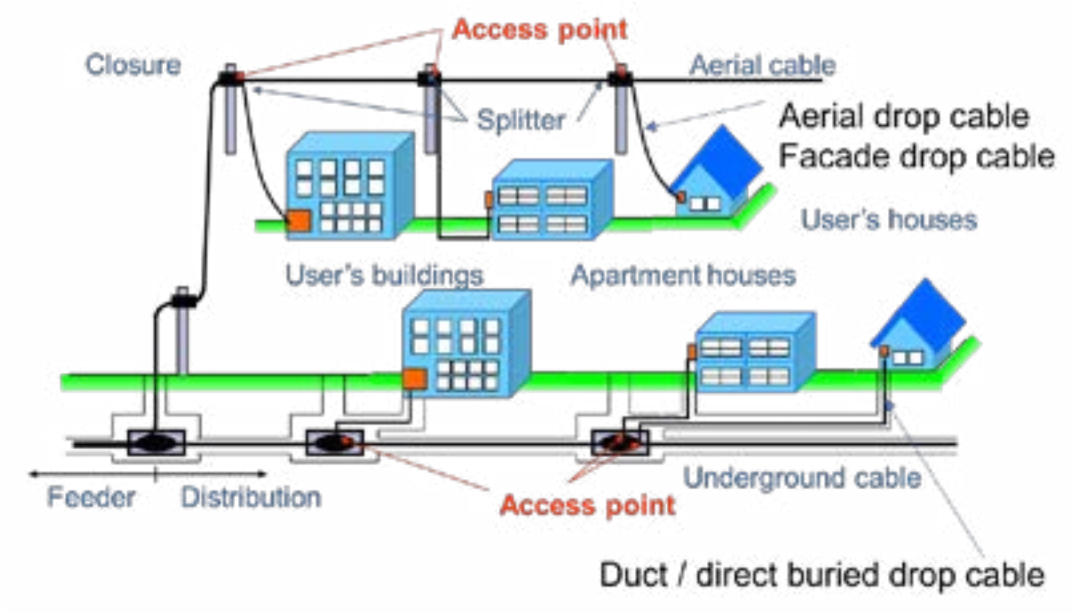

Figure 1 – Configuration of a typical FTTH network.

2. Application spaces and appropriate cable designs

The following paragraphs describe most of the different ways commonly used to connect the end user to the distribution cable. This paragraph contains examples of cable designs which are commercially available currently and used as drop cables. This selection does not represent all constructions available on the market. However it highlights some design criteria which make the cable suitable for a specific application. All design examples shown below are specific designs. All dimensions can vary without affecting the general design concept.

2.1. Installation between poles

2.1.1. General

In some countries, the installation of fibre optic aerial drop cable is the most preferred option because of the relatively low effort compared to other methods like installation in ducts, direct burying etc.. Especially when the distribution cable has been installed between poles it is common practice to also use an aerial installation for the last few metres from the NAP to the building. The connection to the NAP can either be done by splicing individual fibres to the NAP, or using field-installable connectors, or pre-connectorized cables when the NAP is designed to access the branched fibres via already installed connectors. Normally, only lower fibre counts (e.g. 1 to 8 optical fibres) are required. The distances are short (typically between 20 m and 100 m sometimes up to 500 m), thus the span lengths between the poles are also short (15 m to 50 m). Depending on the specific requirements, optical fibre cables can be installed as self-supporting cables, lashed cables or suspended cables.
Even though the span length is short, ice and wind loads have to be taken into account

especially when stringent sag requirements are to be fulfilled. Detailed information about calculations of tension, sag, wind and ice load can be found in the Newsletter "Aerial cables in FTTH roll out" [6].
Typically, cables with a black sheath are used for that purpose. The black colour is the result of the addition of "carbon black". A concentration of approx. 2.5% ensures the long term stability against UV radiation. When other sheath colours are used (e.g. for a better appearance) UV stabilizers have to be added. The functionality of those stabilizers has to be demonstrated by appropriate test procedures.

2.1.2. Design of self-supporting cables

Central tube

Figure 2 shows a typical cross section of an all dielectric self-supporting aerial cable based on a central tube design. For the application as an Aerial Drop Cable only low diameter tubes (e.g. 3 mm) are required because of the low fibre count (e.g. 1-8f). Depending on the specific installation conditions (e.g. span between 15 m and 50 m, allowed sag approx. 0,5 m) only a small amount of tensile elements (normally aramid yarns) is required (e.g. 9600 dtex). Thus, the overall diameter can be as small as 6 mm. Also stranded designs could be used. However these designs result in much larger diameters and are not cost efficient especially for low fibre counts.

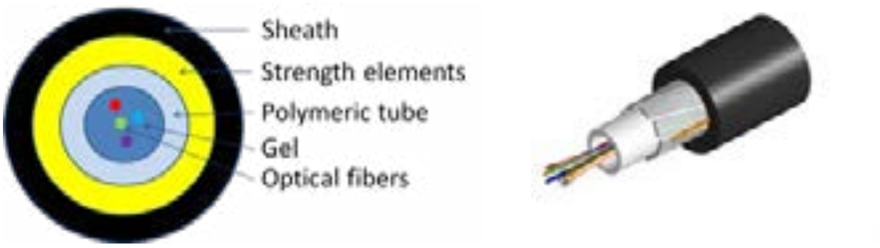

Figure 2 – Self-supporting dielectric aerial cable as aerial drop cable.
Profile:
Cross section aramid: 5,4 mm2, Outer diameter: 9,6 mm, Central tube diameter: 4,2 mm, Jacket thickness: 2 mm, Water blocking: gel, # of fibres: up to 12
Features: no preferential bend

An alternative round cable design is based on 2 strength elements oppositely arranged and embedded in the cable jacket (see figure 3). The strength elements could be dielectric and thus made of GRP (glass fibre reinforced plastic) or metallic wires to provide higher strength.

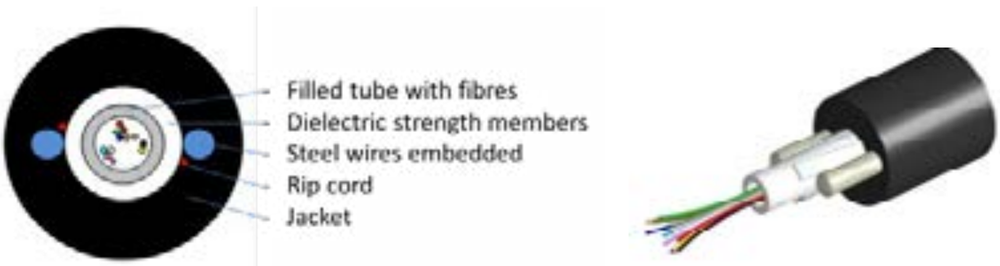

Figure 3 – Self-supporting drop cable with strength elements embedded in the cable jacket. Instead of steel wires GRP can be used and offer of more secure use due to their dielectric property

Profile:
Outer diameter: 8 mm, Wire diameter: 1,2 mm, Central tube diameter: 3 mm, Jacket thickness: 2 mm, Water blocking: gel, # of fibres: up to 12

The typical diameter of such a design, using loose tube, is always slightly bigger than the design which uses yarns as a strength element since the round GRP elements are relatively thick and need to be surrounded completely by the jacket material. Due to the preferred bending requirements, handling of the cable is more difficult.

Flat cables:

A very robust drop cable design is shown in figure 4. A polymeric tube which contains the fibre elements (bare fibres or tight buffered fibres) is placed in the centre. Two rigid strength elements are located on both sides. The dimensions of such a cable are approx. 8 mm x 4.5 mm. The fibres are very well protected: even under high lateral load the fibres won´t be affected since the strength elements will limit the deformation.

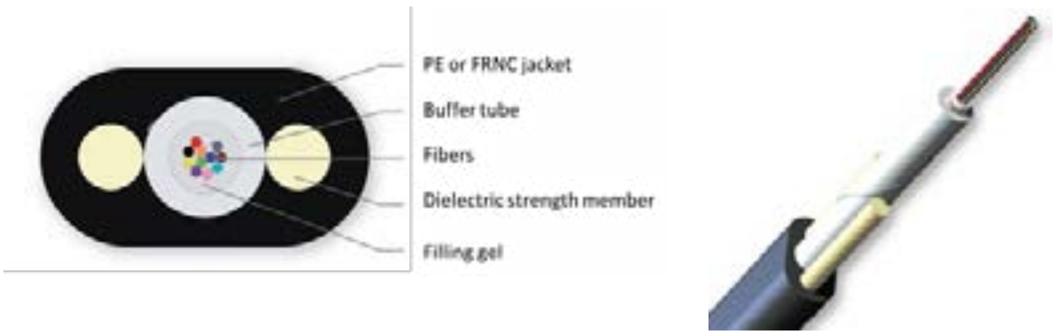

Figure 4 – "Flat" self-supporting aerial cable with strength members (GRP or metal wires) on both sides.
Profile:
Dimensions: 8,1x4,5 mm2, GRP or steel wire diameter: 1,5 mm or 1,2 mm, Central tube diameter: 3 mm, Water blocking: gel, # of fibres: up to 12
Features: preferential bend, reduced flexibility, if steel wires are used: not dielectric, grounding has to be considered, easy installation with P-clamps (see figure 7)

So called figure-8 cables are also used as aerial drop cables (figure 6). The striking feature of the design is a cross section which looks like an "8". The cable element containing the optical elements is separated from the messenger (made of a metallic element or GRP). Both elements are surrounded by a thermoplastic resin (Polyethylene or Polypropylene). A small lobe connects both elements. Both elements can be easily separated just by tearing them apart. This simplifies the installation significantly. The messenger wire can easily be clamped and fixed to a tensioning device. The "optical" part can be guided to a splice box for further distribution. Typical fibre counts go up to 24f. Other common designs are shown in figure 10 which also can be used.

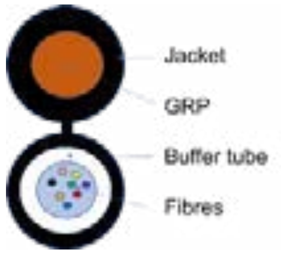

Figure 5 – Aerial drop cable in “Figure 8” cable – design.
Profile:
Dimensions: 5x12 mm2, GRP or steel wire diameter: Approx. 2,5 mm, Buffer tube diameter: 3 mm, Water blocking: gel, # of fibres: up to 24
Features: preferential bend, reduced flexibility, if steel wires are used: not dielectric, grounding has to be considered, easy installation with clamps

The designs shown so far are terminated either in a wall box outside the building or are inserted through the wall to be terminated immediately (approx. 2m, see [1] chapter 4.1.8.2) after they have entered the building.

Double sheath cables:

Examples of drop cables design which can overcome this limitation are shown in in figure 6a and 6b. The outer sheath of that cable design consists of black Polyethylene which has excellent UV resistance. The outer sheath can be easily removed. The inner subunit is suitable to be deployed in house because its sheath consists of FRNC (flame retardant non corrosive) and thus can be rated according to the Construction Product Regulation (CPR see CLC EN 50575). The example in figure 7a shows a variation with just one tight buffered fibre. However also bare fibres or micromodules filled with fibres can be accommodated (see figure 6b).

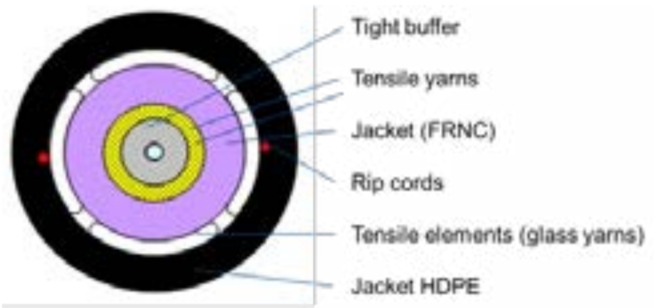

Figure 6a – Indoor / outdoor aerial drop cable with removable sheath. Alternate design with micromodule instead of Tight buffer are widely use.

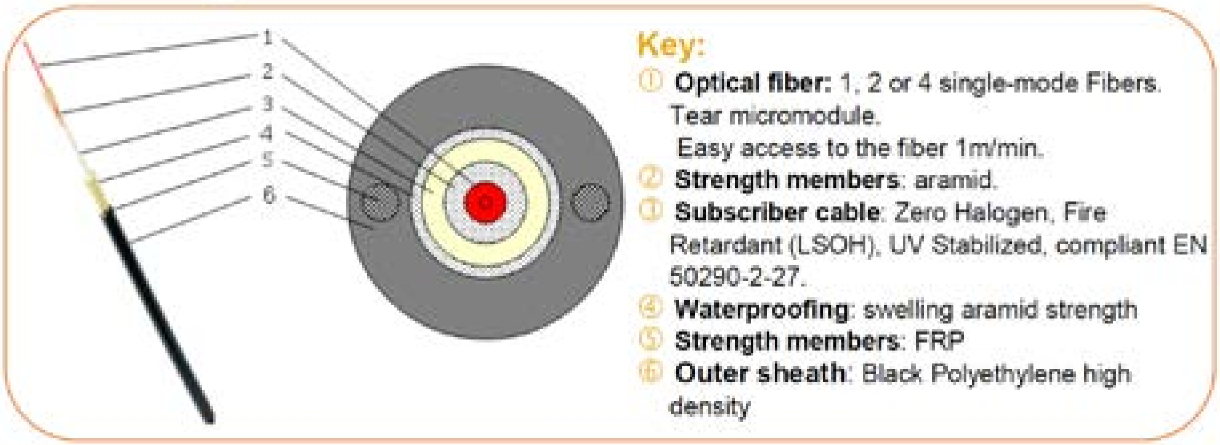

Figure 6b – Indoor / outdoor aerial drop cable with removable sheath.
Profile:
Outer diameter: 6,1 mm, Subunit diameter: 2,65 mm, Water blocking: WB yarns, # of fibres: 1 to 4
Features: UV resistant, low weight, low diameter, high crush resistance, easy installation with clamps, subunit suitable for indoor installation.

2.1.3. Installation of aerial drop cables

Aerial drop cables are usually self-supporting cables which means that all tensile elements are included in the cable design (see figures 2 to 6). Depending on the specific design appropriate technology has to be used to fix the cables to the poles. Commonly clamps of different design are used (see figures 7 a, b, c, d). For more detailed information on installation practices please refer to the Newsletter "Aerial cables in FTTH roll out".

a) b) c) d)

Figure 7 – a) P – clamp: cable is inserted straight b) MCC clamp, left: "open", right "closed" c) round drop wedge clamp, d) mandrel clamp for soft drop cable

2.2. Installations in ducts

Cable installation in ducts is the most reliable installation method. Traditionally the installation was done by either pulling, jetting or blowing [4]. Nowadays the preferred method for fibre optical cable installations in FTTH networks is very much country dependent. In Germany for example, blowing is preferred because the tensile force on the cable during installation is very low and thus it is seen as less risky than other methods). In France, installation by pulling is dominant because it does not need additional installation equipment (see chapter 2.2.3) and cables are designed to be compliant with this method and do not need further protection than cables designed for blowing.
In the blowing case, there may be several subducts (typically 7 ducts with a diameter of 10 mm) blown into a protective polymeric duct with a diameter of up to approx.

100 mm. The duct can be considered as an additional protection of the fibre optic cable. As a consequence, the strength of a cable (e.g. lateral crush resistance) can be smaller than the one for directly buried cables. In any case, no UV protection is needed when the cable is installed in ducts. Each of the subducts can accommodate a fibre optical cable, designed for blowing or pulling.
Care has to be taken that the ducts are not deformed at any point along its length. Before cables will be installed (e.g. by blowing, jetting or pulling) the diameter of the duct has to be checked by means of an appropriate test method along its length. Typically, when using the blowing method, a metallic sphere of a diameter slightly smaller than the inner duct diameter is blown through the duct. When it arrives at the duct end, then the route is considered free of obstacles [3].
In case of pulling, the rope pulled before pulling the cable or the fact that an existing rope is not blocked gives evidence that the pulling will be possible (see 2.2.3).

2.2.1. Cable designs to be installed by blowing into ducts

When a subduct system was preinstalled in the network the most popular method of cable installation is blowing the cables into the duct by compressed air. This method requires a minimal level of cable strength since the driving force for the blowing process, the drag force, acts uniformly along the cable length. Thus the cable only needs a minimal level of tensile strength just enough to be pulled safely from the cable drum. The duct size which will be used to access buildings depends on the overall concept of the network. Typically, ducts with an outer diameter (OD) of 10 mm and an inner diameter (ID) of 8 mm are in use. Alternatively, ducts with dimensions OD/ID of 7 mm/4 mm are also installed. Depending of the inner diameter of the duct the cable diameter has to be selected. As a rule of thumb the free space between duct inner surface and cable outside should be in the order of 0.7 mm to also accommodate for some diameter variations due to undulations of the duct which never can be avoided. This leads to a cable diameter of approx. 2.6 mm for a 4 mm inner duct diameter. Cable weight, coefficient of friction, bend stiffness, ODca/IDduct will strongly impact the blowing performance. The cable weight and the coefficient of friction should be as small as possible to reduce the frictional force which reduces the blowing distance. The duct route should have only few bends preferably with large bend diameter thus the friction force due to bends is minimized [2].
Appropriate cable designs are shown in figures 8 and 9. A central tube of only 2.0 mm diameter is surrounded by a number of aramid yarns to provide the required tensile strength of roughly 80 N which is mainly determined by the pay-off tension from the delivery reel during installation. The jacket is made of Polyethylene with a low coefficient of friction (COF, typically 0.07).

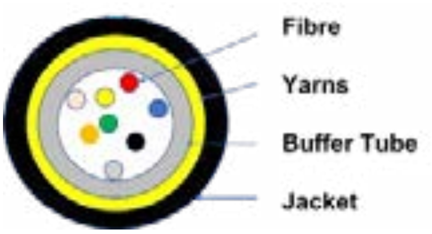

Figure 8 – Central tube cable
Profile:
Outer diameter: 2,5 mm, # of fibres: 4 to 12, Min. bend radius: 20 mm, Crush: 1000 N
Features: low friction, low weight, low diameter, optimized for blowing into 7/4 mm ducts.

2.2.2. Cable designs to be installed by pushing into ducts

Since the distances from the NAP to the building are typically only between 50 m and 100 m alternate methods e.g. "pushing" can be applied. This method only requires a minimum amount of equipment. The cable will be pushed from one end through the duct until it reaches the end of the duct. The pushing force has to be high enough to overcome the friction caused by the weight of the cable and the friction caused by bends of the route.

Therefore cables with a higher stiffness can be installed in longer length since buckling is avoided.

The maximum applicable push force can be estimated according to the formula:

$$F \leq \frac{2 \cdot B}{(DD_{in} - DC_{out}) \cdot R_b}$$

(eq. 1)

B = cable stiffness / Nm2
DD_{in}, DC_{out} = duct inner diameter, cable outer diameter / m
R_b = min. specified bend radius of the cable / m

The factors which are valid for optimized blowing are also relevant for pushing: the coefficient of friction between the cable and duct should be as low as possible, bends in the duct should be avoided.

Ruggedized designs which are suitable for pushing are shown in figures 9a, 9b. Both designs include strength members made of GRP (glass fibre reinforced plastic) which provide a high stiffness which avoids buckling of the cable during insertion of the cable into the duct.

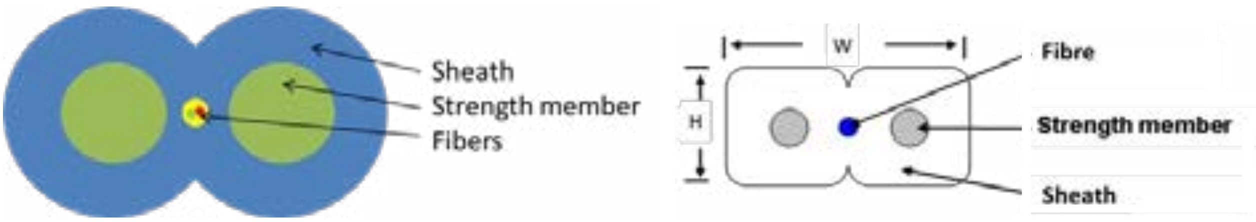

Figure 9 – Cable with high stiffness. Dimensions are a) 3x5,4 mm², b) 2x3 mm² . Thus they are suitable for duct with inner diameter of 8 mm and 4 mm respectively.
Profile:
Dimensions: a) 3x5,4 mm2, b) 2x3,0 mm2 # of fibres: 1 up to 4
Tensile load (short term): a) 1,35 kN, b) 0,15 kN Cable weight: a) 1,5 kg/100 m,
b) 1kg/100 m Min. bend radius: a) 63 mm, b) 30 mm, Bend stiffness: a) 0,024 Nm2
Features: low friction, low weight, low diameter, preferential bend, direct connectorisation more difficult because of the shape, high bend stiffness, can be pushed into ducts, also suitable for the installation between poles. The maximum push force for the design a) is approx. 290 N using the formula eq.1 and the data given in the profile above.
When the distances are less than 50 m, the cable can be pushed "by hand" into the duct. Motor driven handheld devices are available to ease the pushing process.
A round version of a push type cable design is shown in figure 11. The embedded strength elements in the outer jacket provide the appropriate stiffness and the cable can therefore easily be pushed into a duct.

Figure 10 - Pushable round cable. Embedded strength elements in the jacket provide appropriate stiffness for pushing.
Profile:
Outer diameter: 8,6 mm, Optical elements: micro modules; Water blocking: dry with yarns, # of fibres: up to 12), Tensile load (short term): 1,0 kN (Fibre elongation ≤ 0.5 %), Cable weight: 7,0 kg/100 m, Min. bend radius: 60 mm, Crush: 2000 N/100 mm
Features: LS0H jacket can provide flame retardancy in agreement with CLC EN 50575 (CPR)

2.2.3. Cable designs to be installed by pulling into ducts

As stated in 2. installation by pulling can also be used. In some countries, it is the preferred method because the installers do not need specialized equipment e.g. blowing equipment which is costly and not available for every installer. The pulling process will be done in 3 steps. A pulling rope has to be inserted into the duct and pushed through until its end reached the duct end (1), then the cable has to be attached (2) and finally the cable will be pulled through the duct. Sometimes the pulling rope is already present in the preinstalled ducts and step 1 is obsolete [4]. Since the cable is pulled, care has to be taken to not exceed the maximum allowed tensile force for the specific cable design. The shorter the total length of the duct and the less bends are present the lower is the tensile force required for pulling (see Europacable newsletter “pulling and blowing a cable in a duct”). The cables shown in chapter 2.1 “Installation between poles” can also be used for pulling because they are designed to withstand higher tensile forces (see e.g. fig. 2 and fig. 3, fig 11).

Figure 11: Multifibre cable to be used for pulling into ducts. High fibre count to be used for e.g. the connection of Multi Dwelling Units (MDU).
Profile:
Outer diameter: 6.1 mm, Optical elements: micro modules, tight buffers; Water blocking: dry with yarns, # of fibres: up to 72f), Tensile load (short term): 0,8 kN, Cable weight: 31,0 kg/1000 m, Min. bend radius: 60 mm, Crush: 2000 N/100 mm
Features: designed to be used for pulling, high fibre count to address connections of MDU

2.3. Installation as direct buried cables

2.3.1. General remarks

Direct buried cables are cables which are deployed in the soil without any additional protection. They are laid in pre-dug trenches or ploughed in when the trench is dug. They have to withstand higher mechanical forces as well as chemical loads compared to cables installed in ducts. Therefore these cables need more protection i.e. the design needs to be more ruggedized to be better protected against e.g. crush and/or impact but also attacks from rodents and chemical impact.

2.3.2. Cable designs to be installed direct buried

Cables to be used as drop cables to be buried directly can be armored with metallic tapes and surrounded with a thick layer (1 mm to 3 mm) of thermoplastic jacket made of e.g. Polyethylene or Polypropylene. Figure 13 shows a traditional distribution cable according to the standard IEC 60794-3-10 as described before.

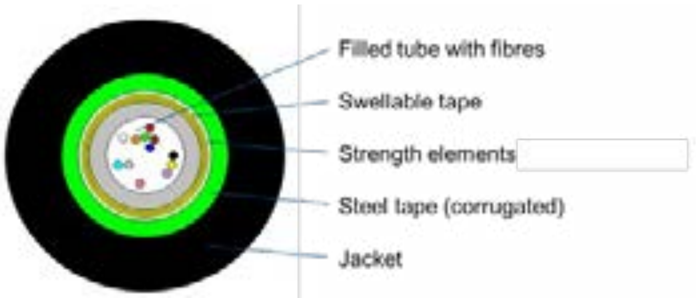

Figure 12 – Robust tape armored drop cable to be directly buried into the soil.
Profile:
Outer diameter: 7,5 mm, Buffer tube diameter: 3,0 mm, Jacket thickness: approx. 1.5 mm, Jacket material: PE or LSZH, Water blocking: gel or powder, # of fibres: up to 12
Tensile load (short term): 1,0 kN, Cable weight: 7,6 kg/100 m, Min. bend radius: 110 mm, Crush: 2000 N/100 mm,
Features: robust design, suitable to be direct buried

The armouring with a corrugated steel tape provides the most efficient protection against rodents.

2.4. Installation on facades

2.4.1. General remarks

Historically, when FTTH deployment became more popular, more and more fibre optical cables were installed directly at the house walls to access the individual apartments from the outside by drilling a hole through the wall and guiding the cable through it to the interior of the home. When reaching the building, a closure can be installed to connect the incoming cable (many fibres) to the different cables (e.g. 1-12 or 24 fibres) needed to access the end user´s apartment. The main driver for the installation on facades is the relatively low deployment effort (schematic façade installation is shown in fig. 14). Because of varying regulations in different countries not all installation methods can be applied everywhere. The following methods are seen as examples in use and do not reflect other possibilities which are not covered in this newsletter:

1. Tensioning the cable using clamps between anchors
2. Attaching the cable using crimps on the wall

3. Attaching a duct on the wall (e.g. fixed by crimps) and pushing the cable through the duct

For a “point to point” connection (see fig. 14 vertical cable installation at the left) the cable can easily be installed vertically just by tensioning it between anchors fixed to the wall (method 1). When the cables are manually tensioned by the installers, the maximum tension is around 250 N. At the maximum specified tensile load, the fibre strain should not exceed 0.3% (higher values have to be agreed between customer and supplier). To simplify the installation procedure, clamps as shown in Figure 8 [6] are often used. These clamps require cables which are very flexible: bend radii of ≤ 15 mm are typical. However care has to be taken to avoid sheath damage caused by vibration. Wind induced vibration can cause the cable to swing and successively scratch across the rough outer surface of the house wall. The resistance of the cable against this kind of load needs to be tested (see 60794-1-21 E2b the “felt” needs to be replaced by a rough surface similar to a façade surface). Test parameters (force, mass and number of cycles need to be determined). Since the drop cables deployed outdoors with method 1 & 2, the jacket needs to be stabilized against UV radiation. Typically cables with a black sheath are used for that purpose. The black colour is the result of the addition of “carbon black”. A concentration of approx. 2.5% ensures the long term stability against UV radiation. When other sheath colours are used (e.g. for a better appearance) UV stabilizers have to be added. The functionality of those stabilizers has to be demonstrated by appropriate test procedures.

When multifibre cables are installed to provide access for numerous users (see vertical and horizontal cable in fig. 14) cables with a mid-span access feature (see fig.16a) would enable a quick connection to the individual apartments.

When method 3 is used considerations given in 2.2.2 apply.

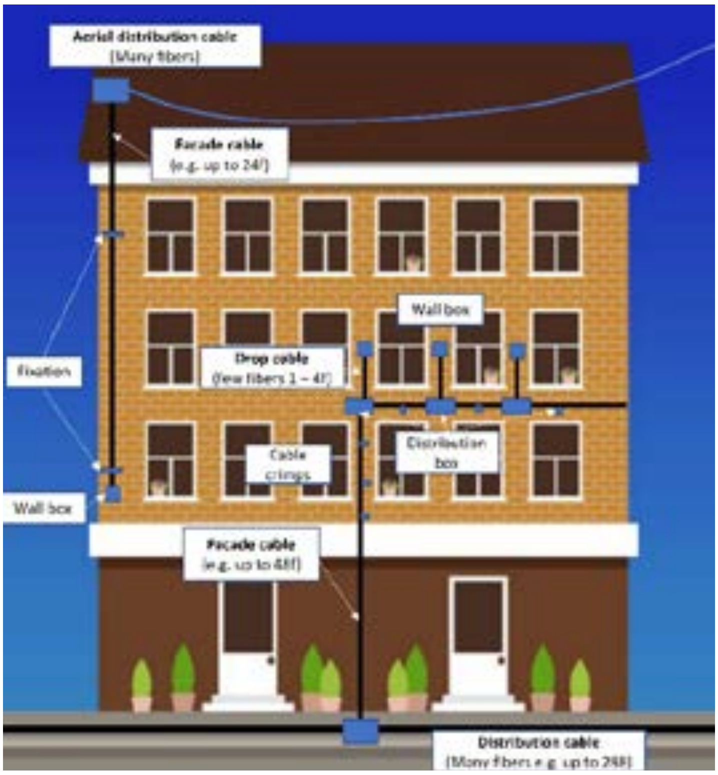

Figure 13: Schematic of façade installation

2.4.2. Design of cables to be installed on facades

The design shown below (see figure 15a) can be used for the installation on facades for point to point connection. It provides enough strength (depending on the amount of tensile elements, e.g. aramid/glass yarns) to be tensioned between fixations e.g. using clamps (see figure 8, 9, 10). Or just being guided through “guiding rings“ or fixed by crimps (see figure 16). Where an FRNC jacket (Flame retardant non corrosive) is applied the cable can be guided directly through the house wall into the building and further deployed inside without the need of an additional splice. The low diameter of the cable in combination with the ruggedized protection of the tight buffered fibre (TB) by the buffer tube enables the use of clamps without significant attenuation increase after installation. Designs with multiple fibres are also available (see figure 14b). The double sheath cable designs are also very relevant in this case (see figures 6a and 6b).

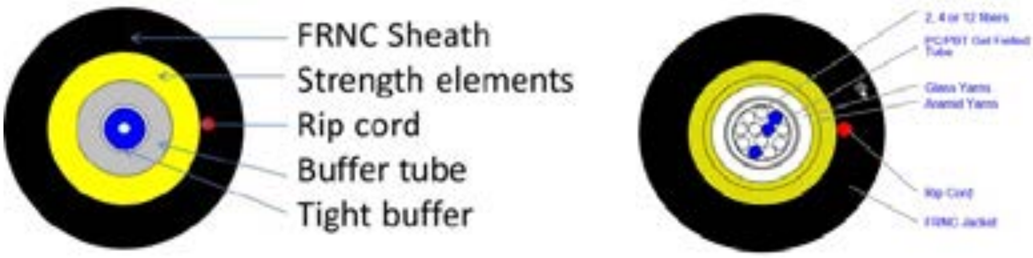

Figure 14 – Facade cable suitable for the installation between fixations using clamps. a) With 1 tight buffered fibre, b) with multiple fibres
Profile:
Outer diameter: 4,8 mm, Buffer tube diameter: a) 2,0 mm b) 1.4 mm, Jacket thickness: approx. 0.9 mm, Jacket material: PE, LSZH Water blocking: gel or powder, # of fibres: a) 1 tight buffered b) up to 12
Tensile load (short term): a) 1,0 kN, b) 1,25 kN, Tensile Load (long term):
a) 0.35 kN, b) 0,45 kN Cable weight: a) 3 kg/100 m, Min. bend radius: a) 15 mm, Crush: 800 N/100 mm
Features: flexible, can be used with MCC clamps (see figure 9)

More rigid designs are jacketed with an HDPE jacket to provide better abrasion resistance. Abrasion is caused by the fact that the cable will vibrate due to the wind flow when it is fixed on the façade e.g. by tensioning between two fixation clamps (e.g. see figure 7b, [6]) several meters apart. Depending on the applied tension and distance from the wall surface (typically around 2 cm), the cable can frequently scratch across the rough surface of the wall. Flame retardant jacket materials are “softer” than HDPE (High Density Polyethylene) and thus more affected by mechanical load. Since a cable with a PE jacket cannot be deployed inside the building (does not meet the CPR requirements) the cable has to be terminated either in a wall box at the outside of the building or terminated immediately after it has entered the building (maximum of 2m, [1]). To overcome this drawback, designs with a removable outer jacket can be used as shown in figures 6a and 6b. The inner cable is certified according to the CPR and thus can be deployed inside the building.

Figure 15 – Cable crimps for installations according to method 2.

Facade installation solutions are based on multifibre cables (see figure 17 a) and b)) which are attached e.g. by crimps on the wall and distributed e.g. horizontally (see fig. 16, method 2). To provide access to the individual apartments / flats, a wall box needs to be installed which protects either the fibre splice to a suitable drop cable or the branching point when retractable fibre elements are used (fig 1 a). When the drop cable is an indoor/outdoor or a double sheath drop cable which fulfills the required fire performance (for indoor cables) no additional wall box is needed to enter the flat/ apartment.

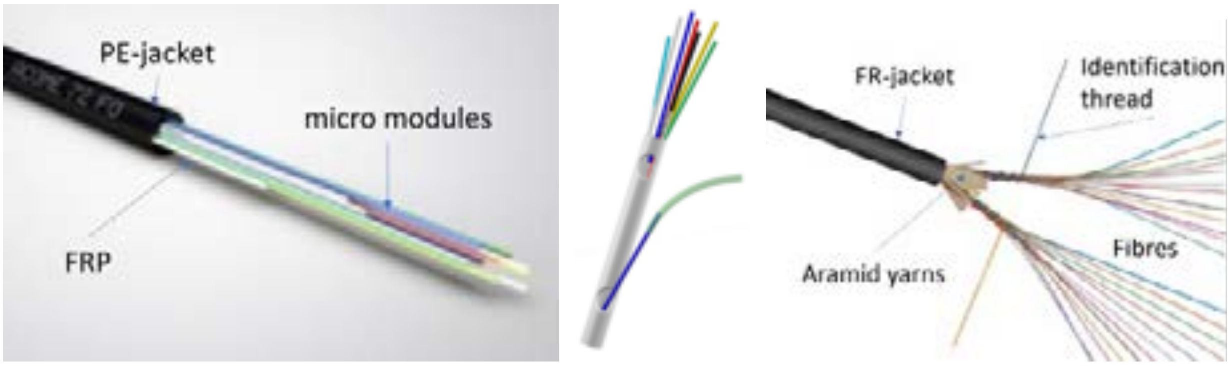

Figure 16 – Facade cable suitable for installation with crimps. a) mid span access, with retractable fiber elements, b) with up to 24 single fibers.
Profile:
Outer diameter: a) 8,6 mm, b) 3.8 mm, Jacket material: a) PE or FR material, b) FR-material, Water blocking: gel, powder or swellable yarns, # of fibres: a) up to 48f, e.g. grouped in micromodules b) up to 24 single fibres grouped by yarns in 12f bundles.
Features: a) easy access b) no preferential bend

3. Conclusion

The question which cable type is the right cable for the last few metres is not easy to answer. It strongly depends on the specific circumstances. The examples given above should only be seen as examples of designs which are currently available on the market and which might be suitable for specific application spaces. Most cable designs are designed in a way so they can be used for different application spaces. The Europacable newsletter "Fibre to the home – indoor optical fibre cables", gives complementary information to this newsletter.

4.Bibliography

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