# CORE STRUCTURE OF OPTICAL CABLES

In common optical cable designs, one or more optical fiber conductors are combined in a given ıstructure and form the heart of the cable, called the cable core.

There are various possibilities how to build up a cable core and, indeed, the optical cables are mainly distinguished by the type of their core.

## Central Loose Tube Design

The most simple version of an optical cable is the central tube design. Here, only one loose tube is placed in the center of the cable thus forming a very simple cable core.

Although the general layout of the central tube cable is straightforward, the performance of such a cable requires some consideration.

For a loose tube with no intrinsic fiber excess length lying straight in a cable, every elongation of the cable would automatically lead to elongation of the fibers. To avoid this, the fibers have to be introduced into the loose tube already with a certain extra length. However, the introduction of a great number of fibers with much extra length into a tube generates high conductor dimensions which present disadvantages for several cable applications, since the permissible minimum cable bending radii would be relatively large.

Moreover, the transversal stability of a central buffer tube costruction is predominantly implemented when fiber counts are low.

The most simple central tube cable desing is a loose tube covered with glass yarns and enclosed by a single plastic sheath (see figure). The glass yarns do not only provide the required tensile performance but also a certain compression resistance.

A cable like this is well suited for in-house cabling purposes and for duct applications provided the temperature range is limited.

For outdoor applications with stricter requirements, additional strength elements must be included in the cable jacket to reduce the low-temperature induced contraction.

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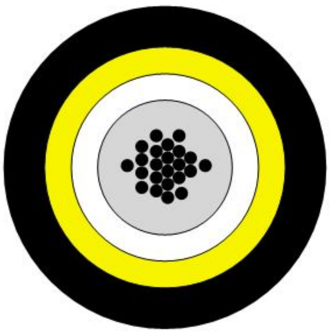


Typical cable with a central loose tube

## Stranded Loose Tube Design

Cables with stranded loose tubes represent the fiber optic cable design which is most frequently used all over the world and can certainly be referred to as the Standard cable type. Beyond the mechanical properties stemming from stranding, such as flexibility, it also provides the optical fibers with the clearance necessary to protect them from external loads.

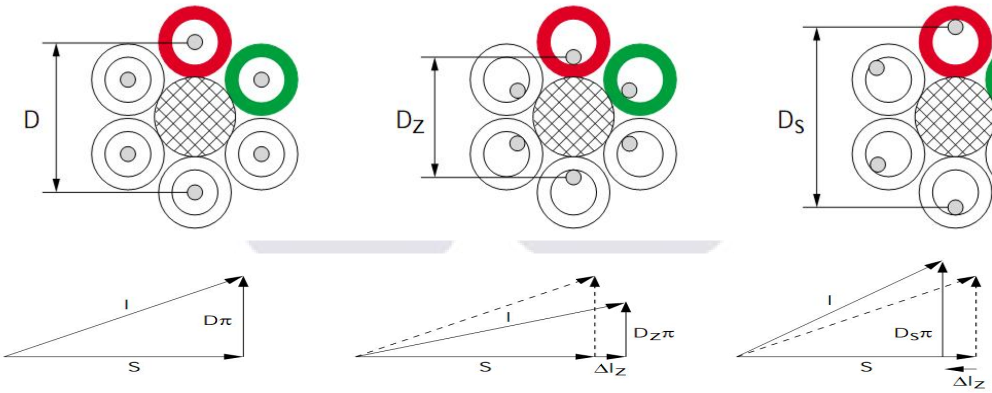
Usually, the tubes of optical fiber cables are stranded in concentric layers around a central strength element, also referred to as central strength member (CSM). The elements can either be stranded helically into one direction around the cable axis or, as practiced today, into alternating twisting directions (SZstranding). Such cables can be built in several layers to reach high fiber counts. This design achieves that the tubes with the fibers lay in a helix around the cable axis, like the fibers within the buffer tubes.

Consequently, the length of the fibers is larger than the linear length of the cable. In other words, the stranding produces some fiber **excess length** which is of great use, as described below.

In case the buffer tubes do not contain extra fiber length and when no tensile load or strain applies to the cable, the fibers position themselves in the center of the tubes.

If required, the fibers inside the tube can move radially. Thus, the fibers move towards the cable axis when longitudinal tensile loads elongate the cable. In contrary, the fibers move to the outside in case of cable contraction – as, e.g., initiated by low temperatures.

When the cable elongation exceeds the extension margin stemming from excess lengths, the fibers themselves are elongated with ongoing tensile stress. If such tensile overload occurs only for a short period of time, as for instance during cable pulling into protection ducts, a fiber elongation of up to some ‰ is not critical, provided the cable relaxes after having been pulled into the conduct.




Cable Unloaded | Cable Elongated | Cable Contracted

**Demonstration of the lateral motion margin of the fibers due to the stranding**

In the relaxed cable core, the fibers are located in the loose tubes. In case the cable is elongated, the fibers move towards the center of the cable core until they reach the inner surface of the tubes. Contrary, if the cable contracts, the fibers move outwards.

For cables under permanent tensile load, such as aerial cables, fiber elongation should be avoided since they would generate a reduction of the fiber's life time. To compensate for this effect, such aerial cables are often manufactured with an additional elongation margin achieved by introducing the fibers with some 2 ‰ extra length into the buffer tubes.

However, this will reduce the compression margin proportionally which is the reason why aerial cables are usually not suitable for underground installation.

If the contraction of the cable exceeds the value determined by the compression margin, fibers can be squeezed together inside the tube, creating a fiber extra length in the tube in addition to the compression margin stemming from stranding.

As this happens in a disordered manner, the bending radii of the fibers become rapidly so small that additional attenuation occurs.

Since neither the fibers themselves nor the protective coatings and wrappings are able to absorb high extension and compression loads, virtually all optical fiber cables have to contain – depending on their application – special elements providing relief from strain and contraction.

Cable engineering has to include the specification of the correct stranding parameters which depend on buffer tube dimensions and on the material choices for the whole cable in order to fulfill the specified properties, such as maximum tensile load, temperature ratings, etc.

Since the fiber's extension coefficient is negligibly small compared to that of the plastics contained in the cable, a temperature-induced modification of the cable length has a direct influence on the fiber excess length. To compensate the thermal modification of the cable length, strain and compression relief elements made of materials combining higher strength and the lowest possible temperature coefficient for extension are introduced into the cables.

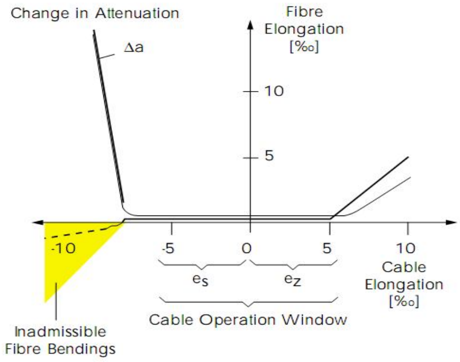
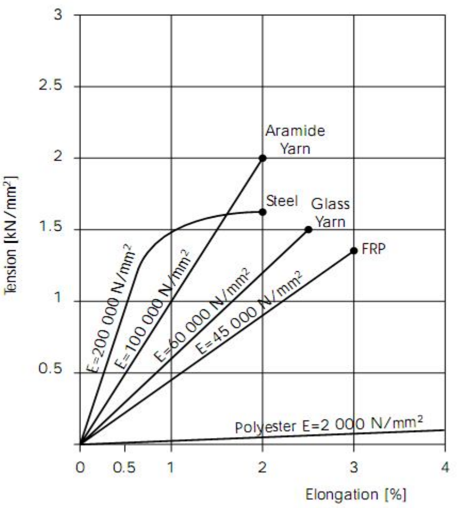



Illustration of the cable performance under elongation and contraction

In a certain range of elongation and contraction, the fibers are nor elongated or crushed and there is no change of attenuation. If the cable is elongated or contracted beyond the given limits, attenuation rises strongly.

The central strength element ensures the compensation of the thermal length shrink for a specified temperature range. Besides steel, which can be used as central strength element in cables which do not have to be metal-free, glass fiber reinforced plastic (FRP) is a material frequently employed in metal-free (dielectric) cables or in cables requiring a dielectric core. If the central element's strength in load direction is not sufficient, further strain relief elements (mostly glass or aramid yarns) can be arranged especially under or in the outer sheath. These yarn arrays, however, cannot compensate longitudinal compressions.




If required, the cable core, i.e. the interstices left between the stranding elements, can be filled with a filling material preventing the longitudinal penetration of water into the cable. In general, greases are used for this purpose.

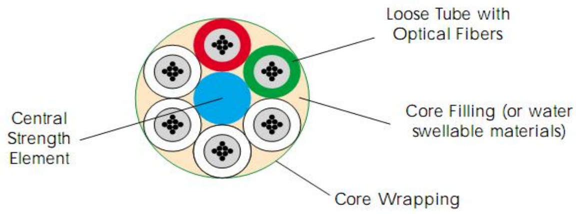
A major requirement for filling compounds is their perfect compatibility with the other cable components together with a high drop point, preventing the dripping of the filling mass at the highest operating temperature.

This is achieved in particular by compressible filling compounds.

Apart from filling the core, longitudinal watertightness can also be achieved by application of water swellable materials in or around the cable core. In this case, the water blocking effect becomes operational after penetration of water under the cable sheath.

| Material | Density [Kg/dm³] | E-Modulus [N/mm²] | Temperature elongation coefficient [K⁻¹] |
|---|---|---|---|
| Quartz | 2,2 | 72.500 | $0,5 \cdot 10^{-6}$ |
| Glass yarn | 2,5 | 60.000 | $5 \cdot 10^{-6}$ |
| FRP | 2,1 | 45.000 | $7 \cdot 10^{-6}$ |
| Aramide yarn | 1,45 | 100.000 | $-3,5 \cdot 10^{-6}$ |
| Stell wire | 7,85 | 200.000 | $12 \cdot 10^{-6}$ |
| PBT (Buffer Material) | 1,31 | 2.200 | $130 \cdot 10^{-6}$ |
| Polyamide | 1,04 | 1.800 | $110 \cdot 10^{-6}$ |
| LDPE | 0,93 | 200 | $200 \cdot 10^{-6}$ |
| MDPE | 0,95 | 700 | $150 \cdot 10^{-6}$ |
| HDPE | 0,96 | 1.100 | $150 \cdot 10^{-6}$ |
| PVC (Soft-PVC) | ~1,5 | 30…70*) | $70 \cdot 10^{-6}$ |
| HFFR | ~1,5 | ~5*) | $150 \cdot 10^{-6}$ |

*) at 5% Elongation




Typical Stranded Multi Loose Tube Cable core structure

## The Stranding Process

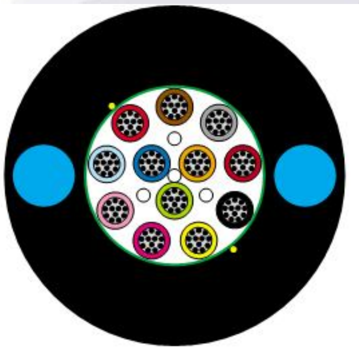
The cable core can eventually be covered by a wrapping of paper or plastic tape, plus eventual strain relief elements which may be coated with a hot-melt for improved load transmission to the next layer sheath.

In stranded loose tube designs, the tubes are stranded around the central strength element either helically or according to the SZ-method.

The latter is the most common stranding method for loose tube cables, as it offers high-speed stranding and the jacketed cables are best suited for mid-span access.

In SZ stranding machines, the required number of loose tubes and eventually filler rods are guided through the stranding plate while the central element is guided in the center. By rotating the stranding plate by several turns clock- and counterclockwise and pulling all elements through the assembly at a constant speed, the result is a rope-like structure with a certain pitch length. At the stranding point following the stranding plate, the loose tubes are fixed to the central element by binders.

## Stranded Flex / Micro Tube Design



FlexTube™ cable with 144 fibers

12 FlexTubes™ containing 12 optical fibers each are stranded and protected by a jacket with two embedded FRP rods. Watertightness is achieved by water swellable materials.

Presently, the Standard for fiber optic cables used in long-distance or Access Networks is set by the well known and proven loose tube design. When attempting to reduce the diameter of fiber optic cables or to increase the fiber count at a given cable size, new designs, like, ribbon or central tube cables could be employed.

Nevertheless, to achieve miniaturization and simultaneously keep the advantages of the loose tube cables regarding easy identification and handling of the different sub-units as well as usage of Standard splicing equipment, many producersl developed a new cable design based on very small semi-tight buffered tubes.

Moreover, this new designs overcomes the disadvantages of the Standard loose tube cables which are the poor strippability and stiffness of the tubes as well as their "long-term memory" due to the stranding pitch.

These cables are based on very small and flexible semi-tight buffered tubes (FlexTubes™) containing up to 12 optical fibers. Their small dimensions allow to implement high fiber capacity in tight spaces while the installation time (for, e.g., cable Access and splicing) and therefore the installation cost can be significantly reduced.

Since the tubes are covered with a comparatively soft buffer material, the combination of a central strength element to which the tubes are fixed by binders does not apply. Thus, the cable core is stranded without a central strength element loosely confined by a jacket which contains the compression resistive elements.

The figure shows the cross section of such a cable containing 144 optical fibers. The tubes inside the cable core may be either stranded SZ or helically.

The cables according to this design are preferably dry core cables in which the longitudinal watertightness is achieved by the application of water swellable elements.

The two radial strength members which are embedded in the cable jacket serve for both the compression resistance and the tensile strength of the cable. If higher tensile strengths are required, additional strain bearing elements (e.g. aramide yarns) may be applied over the cable core. Depending on the application of the cable, a proper balance can be selected to provide a certain tensile strength and keep the diameter of the cable small at the same time.

Generally, the design of the newly developed cables combines the advantages of the loose-tube cables (fibers protected in tubes which are easily identified) and the central tube cables (the absence of a central strength member simplifying, e.g. midspan access).

The most critical issue for the new cable design using semi-tight buffered tubes as described above is the performance at low temperatures. Since the fibers do not have space inside the tubes to compensate longitudinal contraction of the cable like in conventional loose tube designs, the temperature performance must be achieved by different measures.

Firstly, the dimension of the compression resistive elements in the cable jacket must be properly selected to keep the jacket contraction at a minimum.

Secondly, the gap between the cable core and the inner surface of the jacket has to be carefully adjusted in order to allow some core movement caused by temperature changes. Moreover, the process parameters of the jacketing operation must ensure the core being relaxed after the initial shrinkage of the jacket.

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