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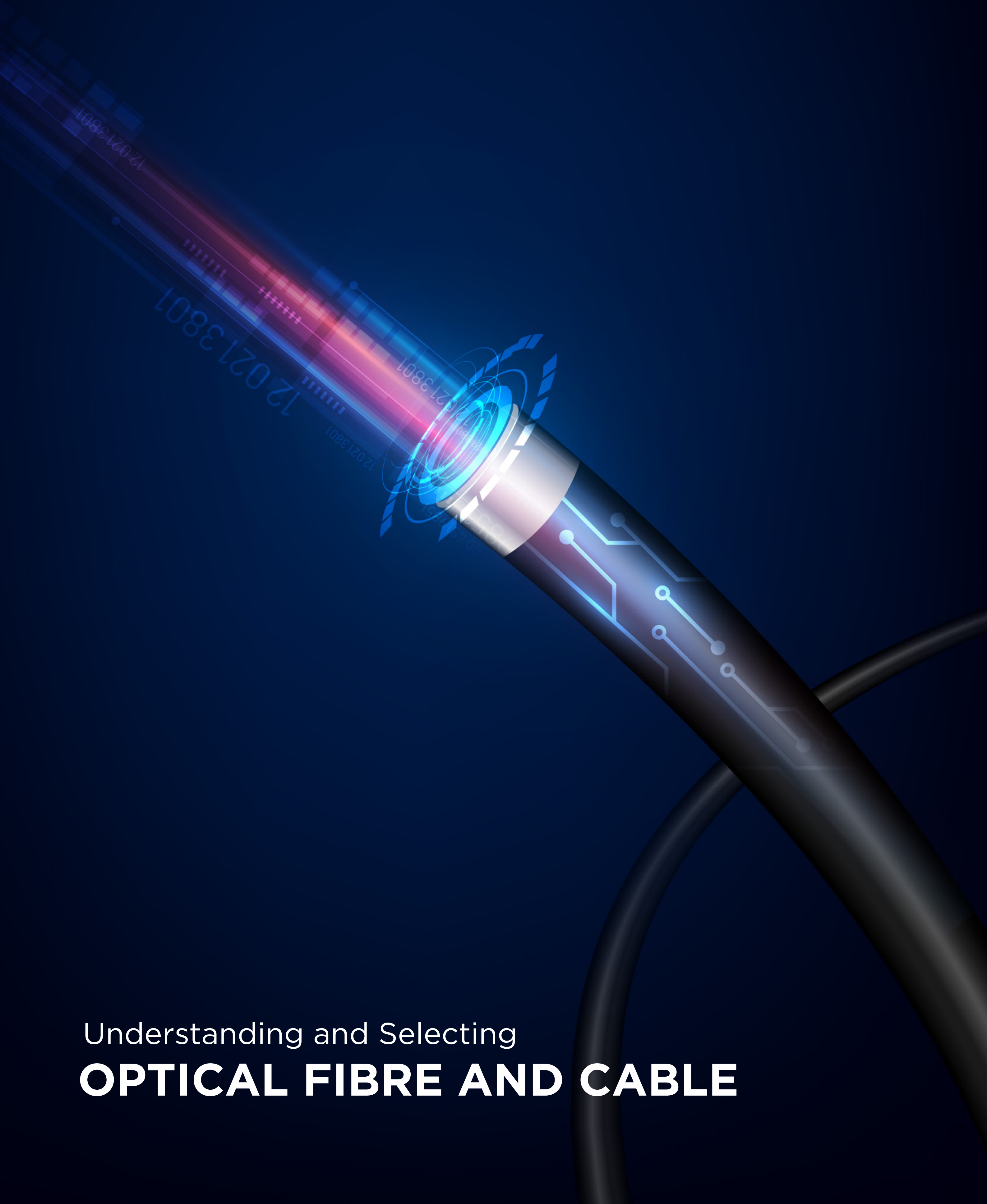


Understanding and Selecting

OPTICAL FIBRE AND CABLE

This document will provide an understanding of optical fibre, optical fibre cable (OFC), application standards, and key considerations that one should make before selecting optical fibre products.

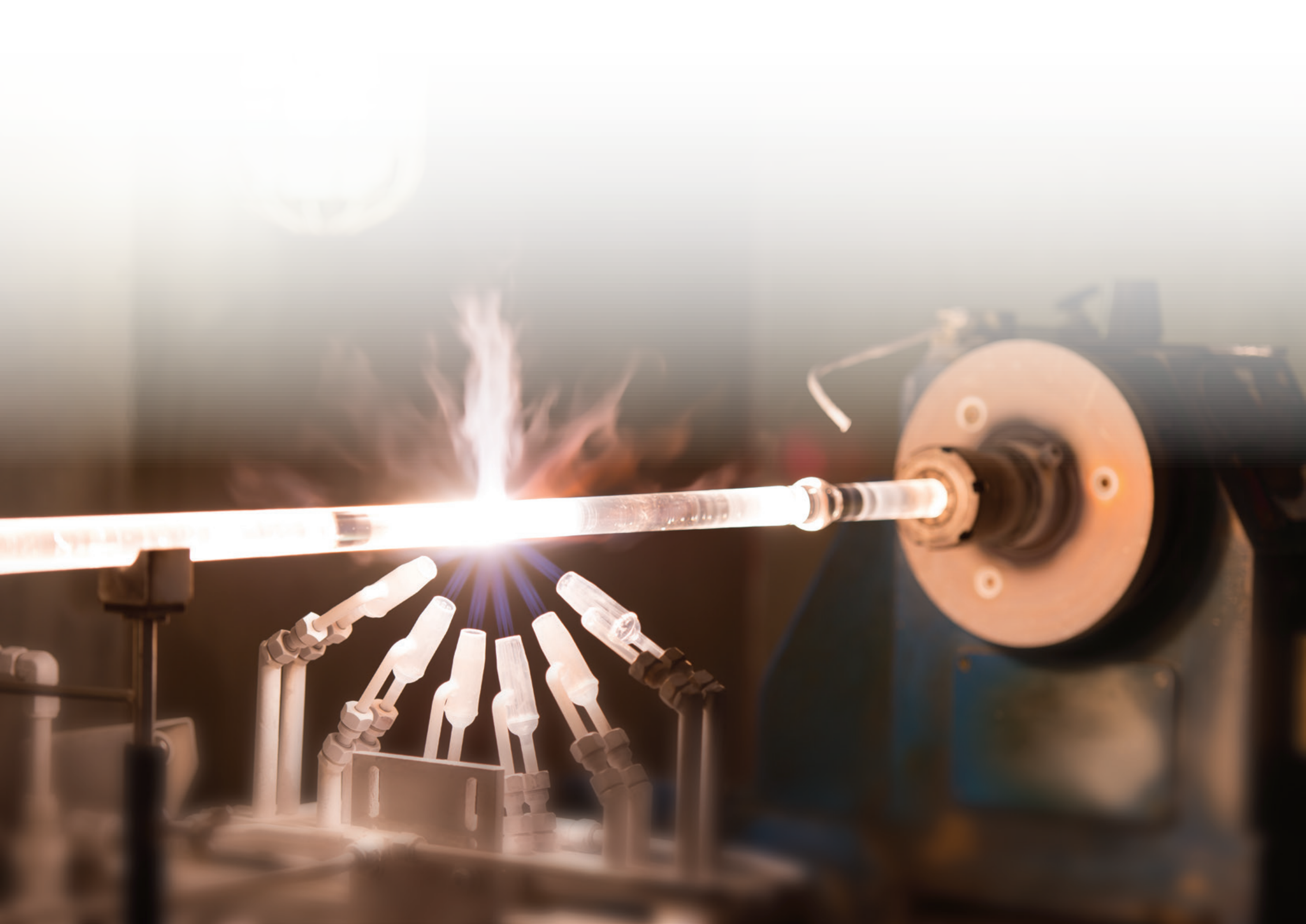
Typically, the first document shared with a user (Purchasing Manager, Technical Manager, and Installation Manager) is a technical datasheet. When several optical fibre cables are to be compared, as per the requirements of a project, a short list could be created based on the datasheets. However, all datasheets are not equivalent even if they look similar. One should know what the minimum relevant data are, how to find them, and how to compare them.

Before reading or comparing the technical datasheet, it is important to know the applications of optical fibre cables and the installation requirements for the project. The application and installation of optical fibre cables are dependent on each other. They impact the cable features and the relevant content of a datasheet. During the selection process, one can look at the datasheet to check for a product fit.

A proper understanding of the cables' characteristics and descriptions is also dependent on the standardisation documents referenced in the datasheet. Indeed, a technical value means nothing if it is not given with a clear test method and a clear acceptance criterion. Moreover, using standards allows a relevant and fair comparison between various datasheets **if acceptance criteria and test parameters are equivalent, which is often not the case.**

In this document, the relationship between the cable features, followed standards, test parameters, and acceptance criteria are explained with examples for a better understanding of an optical fibre cable datasheet.

This document highlights that the values given in an OFC datasheet are dependent on test parameters and acceptance criteria, which need to be clearly understood for a fair comparison and relevance to the application and installation.



OPTICAL FIBRE – SINGLE MODE

Fibre optics or optical fibre refers to the technology that transmits data as light pulses along a glass fibre. These products are extensively used for high-performance and long-distance data transmission, and networking. A majority of video, data, and voice signals also travel over optic fibre networks. 5G and FTTH deployments also use optical fibre.

At present, networks are struggling to keep pace as data demand grows exponentially. Thus, there is a need to grow the optical fibre network to address challenges driven by the exponential growth of data.

There are several types of optical fibre. Each is distinguished from the others through design, characteristics, and ability to operate with optical transceivers. The differences determine the application that is most appropriate for the given fibre cable. Network designers and operators must understand the different fibre types and technologies to make an informed selection for current and future application needs.

Before going into the details of the individual fibre types, one should understand their critical parameters and importance:

• Core
It is the part of the fibre that guides the light. The core is made from the purest form of glass.

• Cladding
The function of the cladding is to provide a lower refractive index at the core interface, causing reflection, which enables light waves to be transmitted through the fibre.

• Coating
It is a polymer layer that (mechanically) protects the fibre. Single mode fibre comes with 250 & 200 micron coating diameter options.

• Mode Field Diameter (MFD)
The mode field diameter represents a measure of the transverse extent of the electromagnetic field intensity of the mode in a fibre cross-section. To put it simply, it is an effective core diameter for propagating light.

• Dispersion
The spreading of the light pulse in optical fibre.

• Attenuation
Losses encountered during the propagation of the signal.

• Macro-Bending Loss
The loss values under different bend radii, and the number of coils. It increases with an increase in the wavelength of the light.

• Splice Loss
Splice loss refers to the part of the optical power that is not transmitted through the splice and is radiated out of the fibre.

OPTICAL FIBRE OPTIONS

There are two main categories of optical fibre

- **Multi-Mode Fibre**
- **Single Mode Fibre**

Multi Mode fibre is mainly used in premises networks. In multi-mode, 62.5/125 µm fibre is no longer preferred. It's the fibres with 50/125 µm like OM2, OM3, OM4, and OM5, which are used based on system requirements like attenuation, bandwidth, reach, etc.

Single Mode fibre is the most preferred fibre type for almost all applications. The following fibre types are mainly used in telecom networks:

- **ITU-T G.657**
  Bend Insensitive Optical Fibre.
  It is further subcategorised as G.657.A1, G.657.A2, G.657.B2 and G.657.B3. These fibres are fully compliant with ITU-G.652.D fibre. As the name suggests, loss due to sharp bends in this is almost negligible as compared to G.652.D fibre.

- **ITU-T G.652.D**
  It is also called dispersion unshifted single mode fibre with reduced water peak. It is the most popular fibre type deployed in long-haul applications.

- **ITU-T G.655**
  Non-Zero Dispersion Shifted Optical Fibre.
  It is the second most common fibre type used in terrestrial networks. This fibre has been widely deployed in the long-haul network and DWDM transmission systems. The key value proposition for this fibre type is low dispersion including Chromatic Dispersion at the 1550 nm band (C-band).

There are also other types of SM fibre like ITU-T G.653, ITU-T G.654 and ITU-T G.656 but their uses are limited to specific applications. These only account for about 3-5% of the total fibre deployed.

In the last few years with advancements in fibre manufacturing, a 200-micron fibre has come into the application, especially in ITU-T G.657 categories. In the case of 200-micron fibre, the core and cladding of the fibre are the same as those of traditional 250-micron fibre which makes it backward compatible (i.e splice loss and other optical properties). The 200-micron fibre solution has enabled OFC manufacturers to accommodate more fibre in a high fibre count cable. It has helped to reduce the size and weight of the cables, which has made them easier to install.

Now the following question arises for the user, network planner or purchaser:

- What/How to select when a wide range of fibres are available?
- How to compare the specification of different suppliers?
- What parameters need to be checked if the fibre is being deployed in the existing network?

The answer to the first question depends on the kind of transport technology that is being used. If DWDM technologies are being used, the preference should be the G.655 fibre though recent technological development enabled us to use G.652.D fibre as well.

Since there are multiple standardisation bodies, different manufacturers follow different standards and test methods, which may lead to confusion when comparing the multiple datasheets. To avoid these kinds of problems, the user should follow the IEC and ITU-T standards, which are used all over the world.

If we are replacing/upgrading the fibre in the existing network, key parameters like fibre type, mode field diameters, and optical budget of the network are to be checked for a reliable network.

Suppose a user, who wants to roll out a new network link, is facing challenges in its existing network that include an increased optical loss at fibre turns and macro-bend scenarios as shown in figure 1, particularly at higher wavelengths used in the technologies like L-band WDM, NGPON, 10G-PON, and 40G-PON.

Figure. 1 Tight fibre bends in a splice tray

After that, the user can switch to bend insensitive ITU-T G.657 fibre. Even the enhanced macro bend performance of G.657.A2 fibre can only be considered as a practical advantage, as it is backward compatible with the traditional G.652.D fibre. As shown the figure 2, the macro bend loss of G.657.A2 fibre doesn't increase with an increase in the wavelength, when compared to G.652.D and G.657.A1 fibres.

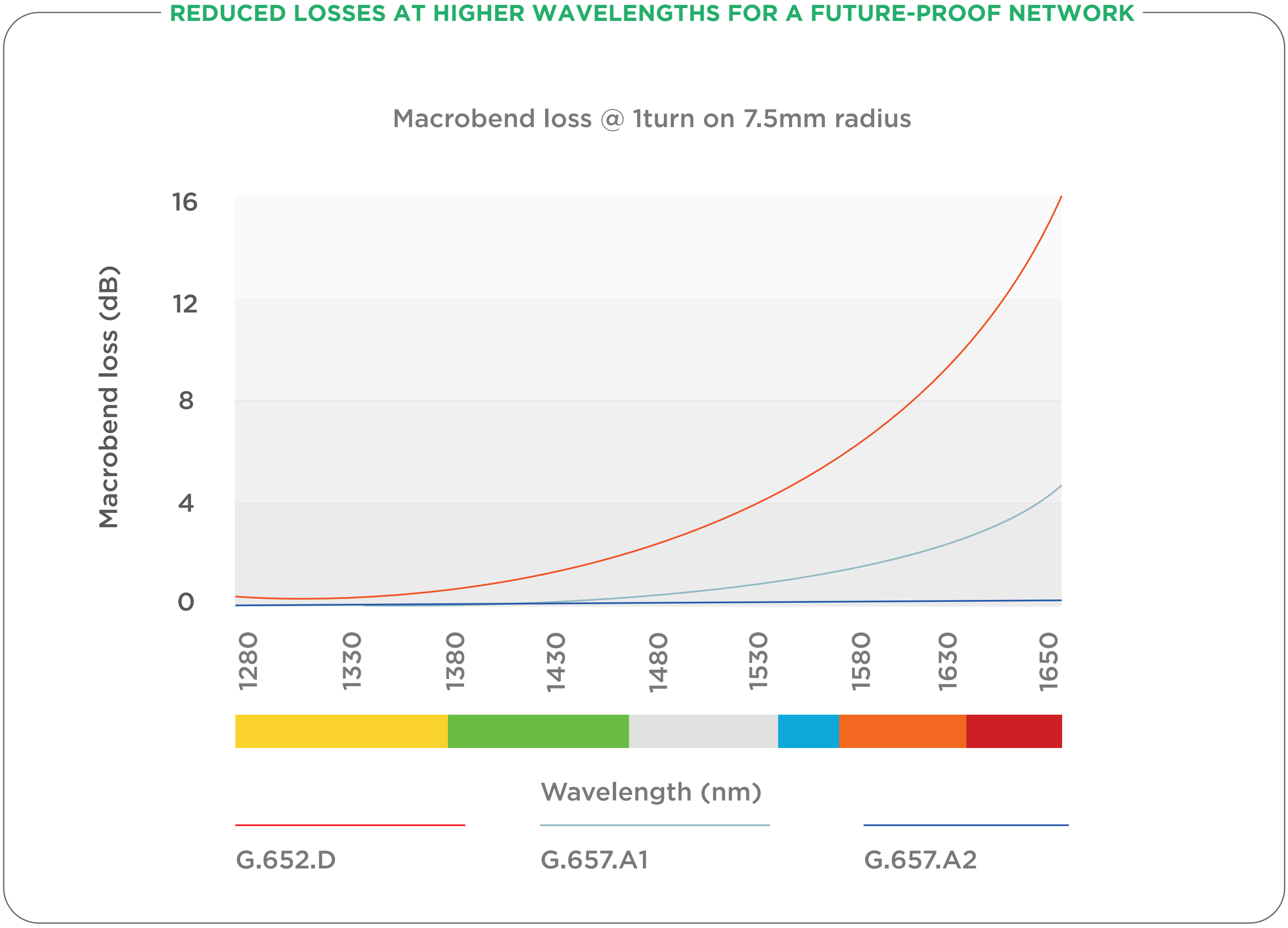


Figure. 2 Macrobend Loss vs Wavelength

Since the manufacturer has fibre with different MFD like 8.6, 8.8, and 9.1 microns, users may choose the right MFD type as per their requirements. G.657.A2 fibre with higher MFD (e.g. 9.1 microns) which is fully compatible and compliant with legacy G.652.D fibre, is the best choice to upgrade the existing optical fibre network and for the new deployment as well.

Now, let's understand the Optical Fibre Cable

CABLE APPLICATION AND INSTALLATION

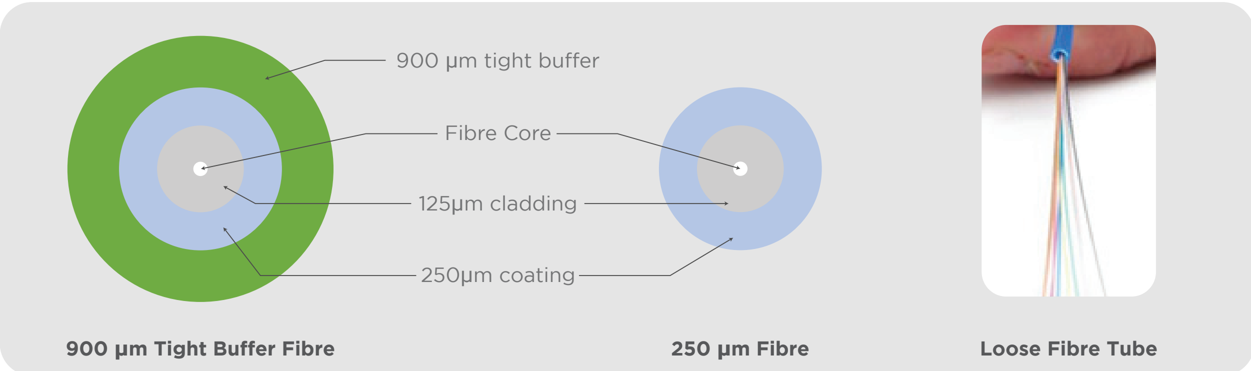
Before comparing the different datasheets of the OFC, the user should have a good understanding of the different types of optical fibre cable, their installation, and application requirements. These aspects directly help the user identify and finalise the optical/mechanical properties of the cable and its design.

1- Optical Fibre Cable Type

Optical Fibre Cables can be segmented, as detailed below:

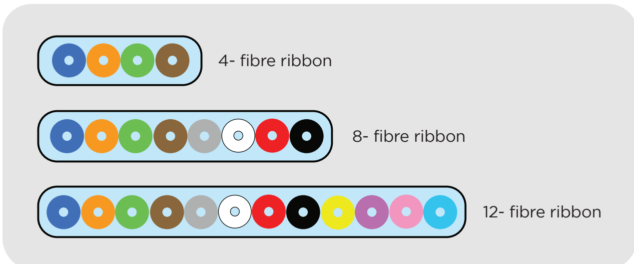
OFC Type based on fibre packing

Tight Buffer Cable: It is a ruggedised individual fibre unit with a compact polymer coating directly put over fibre. It is preferred in FTTH/Premises applications wherein an individual fibre unit is directly terminated on end-user equipment(s), as it provides certain strength to fibre for safe handling.

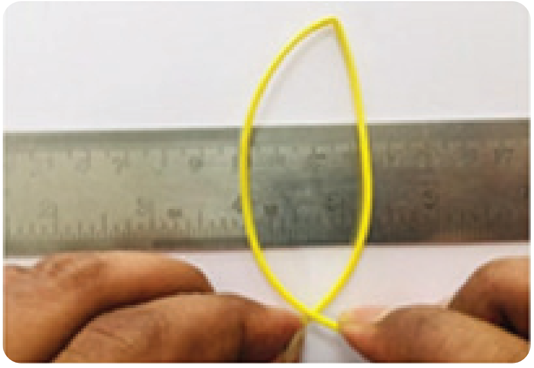


Loose Fibre Tube Cable: It is the most used type of fibre packaging wherein the user requires a high fibre count OFC. Usually, fibre is loosely packed in bundles of 1-12 inside a polymer tube. It is sometimes filled with water-blocking material like jelly or yarns to prevent water ingress inside the tube.

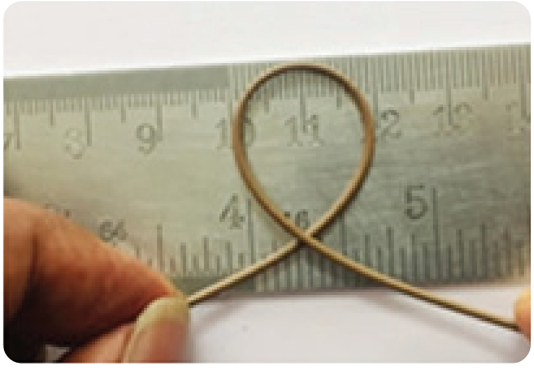
Ribbon Cable: When two or more fibres are arranged in a flat bonded pattern, it forms a ribbon. Ribbon cables help in mass fusion splicing leading to significantly lower splicing time and Mean Time To Repair (MTTR). Generally, lower fibre count can also be used on the basis of network configuration.



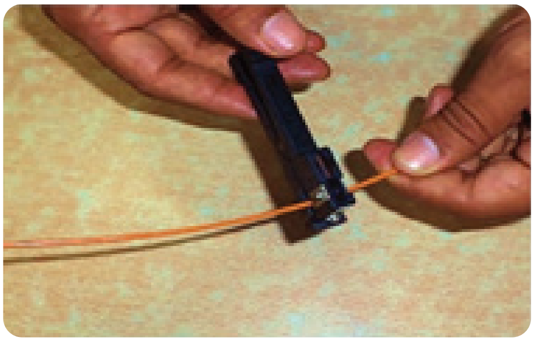
Micromodule Cable: The micromodule unit consist of groups of fibres protected by an easily strippable and flexible thermoplastic material. It is filled with water ingress resistant material. The unit exhibits kink-free bending, tool-free stripping and flexible properties.



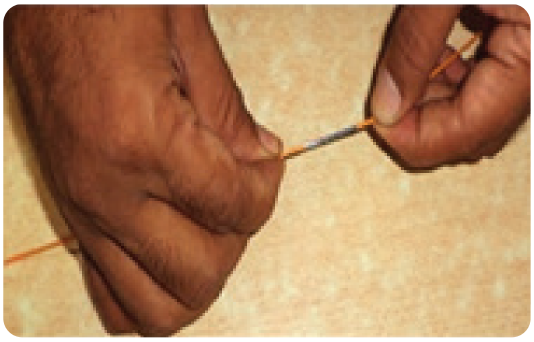
Legacy Optical Fibre Lose Tube



Micromodule



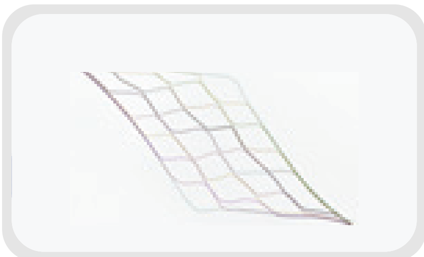
Traditional Fibre Cable
Tube Stripped by Tool



YogaLite™ Micromodule
Module Stripped by Finger Tips

Intermittently Bonded Ribbon (IBR) Cable: This is a relatively new technology that combines the benefits of both loose fibre and ribbon. As the name suggests individual fibres in a ribbon are bonded in sequence at an interval that enables the configuration to roll over as a bundle.

Looks like typical ribbon



Transform into LT single fibres

Rolls in highest density

IBR technology enables to utilize the properties of loose fibre to achieve higher density fibre cable and at the same time, enables to utilizese it as benefits of ribbon structure properties like mass fusion splicing. IBR cable combines robust performance for duct installations with the productivity of high-count mass fusion splicing. The innovative ribbon bond design results in dense fibre packing and smaller cable diameter. This cable offers an outstanding solution for demanding high-growth, high-bandwidth communications applications like data centres, equipment connections within cabinets and outside plant applications.

OFC Type based on Construction:

- **Unitube:** Cables containing single tubes with/without embedded strength members. It is generally preferred in lower fibre count cables for use cases like last-mile connectivity.
- **Multitube:** Cables containing multiple tubes with central strength members are referred to as Multitube cables. These are used in general cable construction across the network segment.
- **Armoured:** The cable core or tube is surrounded by steel or aluminium tape/wire or non-metallic elements that is further covered with a jacket to protect it from moisture and abrasion. It is generally preferred as a rodent-resistant cable solution. The use of a metallic armored OFC also allows the user to track the underground route.
- **Unarmoured:** Unarmoured cables are also known as dielectric armored cables. These cables do not contain any metal and can be either in the form of uni-tubes or multi-tubes. Rodent properties can also be attained with this design by using a protective layer of glass yarn.

OFC Type based on deployment environment:

- **Indoor Cable/ISP cable:** In this type of application, OFC generally contains a tight buffer as a fibre unit though it is not limited to that. Human and equipment safety are ensured because these cables are to be installed inside the building or premises. These cables are recommended for their anti-fire properties like fire propagation, smoke density, etc.

- **Outdoor Cable/OSP Cable:** OSP stands for Outside Plant. These OFCs are further deployed in two ways - underground and aerial. When the cable is deployed in an outside environment, it bears properties like UV protection, water protection, temperature resistance, rodent resistance, high tensile strength, crush and impact. Properties like track resistance are considered if OFC is aerially installed along the power line alignment. For outdoor cable, strength members mainly serve to limit tensile strain, but may also serve to limit compressive strain like temperature changes. The strength members may be located at the centre of the cable (known as central strength member or CSM) or in the outer sheath layers, or both. For outdoor aerial lashing applications, it is recommended that the overhead suspension steel wires be used as an additional component for the "figure-of-eight" cable type. Alternatively, the cable may be supported by attaching it to a supporting strand. Information on span, sag, wind velocity, and ice loads, as well as the permitted ground clearances, are necessary for designing cables for use in aerial applications.

- **Indoor-Outdoor Cable:** Since this cable connects the OSP with the ISP cable, these cables should have properties of both indoor and outdoor cables.

2- Cable installations and key performances

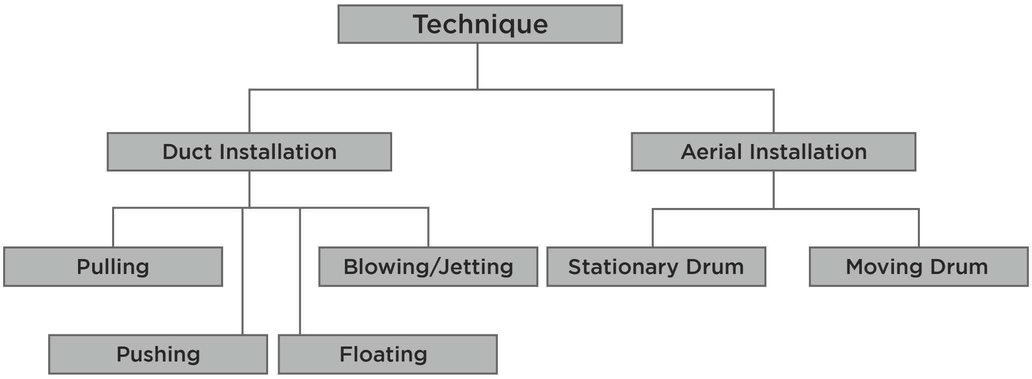
The major properties of any OFC can be defined by how the network planner has planned its installation. Accordingly, the performance parameter must consider ensuring the long-term reliability of the fibre.

OSP Installation Methods

There are mainly two types of OSP deployment scenarios: Underground and Aerial. Underground includes Direct Buried & Duct whereas aerial deployment includes ADSS, & Lashing methods.

- **Direct Buried:** Buried cable is placed directly under ground, without being encased in a conduit system. It is commonly placed with several feet of soil cover over the cable with the depth of cover depending upon the type of soil, surface loads, and applicable regulations.
- **Ducting:** OFC is placed inside the duct/conduit that provides mechanical protection to the cable and also eases cable movement during the O&M, especially during cable cuts.
- **ADSS:** ADSS stands for All Dielectric Self Supporting. As the name suggests, OFC installed on aerial poles can handle the mechanical & environmental stress without adding any support wire.
- **Lashing:** In this type of aerial deployment, the cable is hinged at frequent interval with a support wire so that it can sustain the mechanical & environmental stress.

The most common types of installation methods are:



In duct installation, there are various techniques used to place the OFC inside a installed duct.

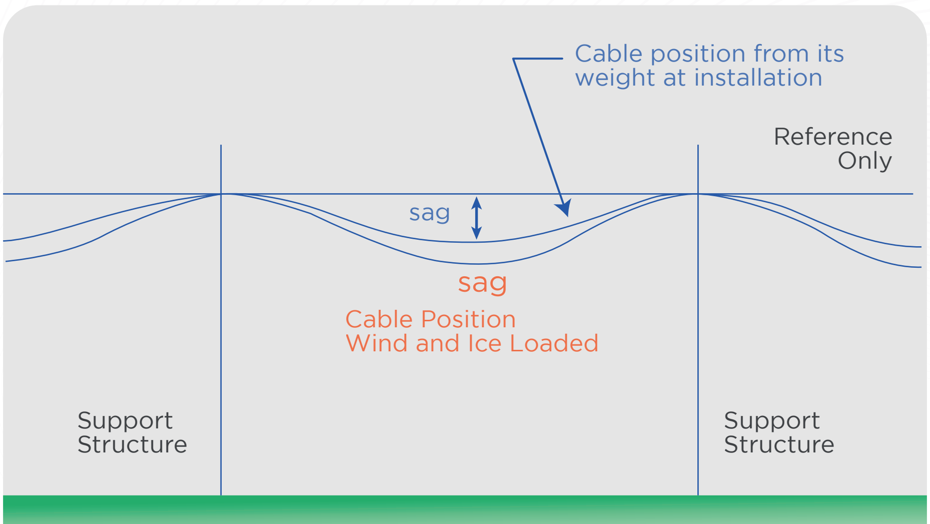
- **Pulling:** In this method, OFC is pulled through the duct with the help of pre-installed rope. It is preferred only if OFC is to be deployed over a short distance.
- **Pushing:** In this method OFC is pushed in through the duct.
- **Blowing/Jetting:** In this installation method, OFC is pushed in through the duct with the help of the air pressure/jetting technique. It is a highly efficient technique as a few kilometres of cable can be deployed in 2-3 hours whereas the manual technique requires lots of time.
- **Floating:** This technique is adopted where size of the OFC and the duct is big and blowing/jetting technique is relatively inefficient. In this technique, OFC is pushed in with the help of high-pressure water.

For Aerial installation, two techniques are used to place the cable:

- **Stationary Drum**
- **Moving Drum**

In the moving reel method, the cable is paid on the top of the cable reel which is carried by a moving vehicle as it drives along the pole line. It increases productivity as it is not as labour-intensive as the stationary reel method, in that it is not necessary to handle large numbers of cable blocks or sheaves and setup and cleanup time is shorter. Heavy tree conditions or right of- way access problems, however, could slow progress with this method. Also, the moving reel requires that alignment of the reel and the cable chute be maintained. This alignment must be continuously monitored to prevent excessive bending in the cable.

Typically, an aerial self-supporting cable is designed after considering various factors like road clearance, sag allowance, and span length of the cable that defines the tensile strength. Crush and impact resistance are important factors to consider for direct buried cable.



Sag Drawing of Aerial Plant Catenary Cable Deflection

The installation method influences the cable design in various ways. Usually, a cable installed by pulling is very different from a cable installed by air blowing. The pulled cable must have a high tensile resistance (typically 1.3 times of cable weight) whereas a blown cable is less focused on its tensile performance but must have a small diameter, lighter, and optimised stiffness to prevent undulation of cable inside the duct. For example, if a blown cable is installed by pulling, there is a high risk of fibre damage during the installation process. Trying to install a pulled cable by blowing is possible but less efficient with a dedicated blown cable, as it increases installation time.

ISP Installation Methods

- Riser Cable: It is an optical fibre cable developed for vertical installation inside the ducts or conduits that passes from one floor to another and serves the entire building. Its performance is based on its load-bearing capacity. Accordingly, its tensile strength is defined. Since one or more units of fibre are to be dropped on each floor, cable design should facilitate the midspan and easy access of the unit.
- Plenum cables: Plenum cables are installed in spaces intended for air circulation such as heating, ventilation, or air conditioning (HVAC). These cabling solutions are typically installed between a false and a structural ceiling or, in some cases, between a structural floor and a raised floor. Because of their exposition to air circulation and to prevent the risk of fire propagation, plenum cables have a higher fire safety rating than riser cables.

3- Standardisation and criteria

The main aim of standardisation is to give common attributes and qualification methods to products to ensure they are fit for specific applications. A clearly defined standard creates the possibility to compare various products and their suitability to meet the application requirements. If the user is comparing the different datasheets/product specification sheets, it is important to refer to the same standards and qualification/testing criteria for fair and easy analysis. For example, if various optical fibre cables for a micro-duct blowing application are considered, it should be done with the same IEC Standards which give a unique frame of comparison like blowing performance on an IEC track, etc.

As a basic requirement, a datasheet shall give cable performances and IEC generic standards covering optical fibre cables such as:

- **IEC 60794-1-21**
Generic specification – Basic optical cable test procedures – Mechanical test methods.
- **IEC 60794-1-22**
Generic specification – Basic optical cable test procedures – Environmental test methods.

These generic documents deal only with the test procedures and do not state a requirement regarding the acceptance criteria like test parameters, and pass/fail criteria. The users have to understand that even if two cables are tested with the same test procedure, the given performance in the datasheet may vary a lot if the test parameters are not aligned (eg. maximum allowed optical attenuation, maximum fibre elongation, etc).

Why acceptance criteria are important?

An acceptance criterion states the limit that simplifies the interpretation of the cable performance for a specific application. For example, during a mechanical test, attenuation should stay below a limit while the integrity of the cable remains intact without damage. This pair of criteria is a must to have. The cable quality can be evaluated more thoroughly as more criteria are used.

The following examples of criteria can be used to compare the datasheets to make sure they are reliable in the long run:

Optical criteria:

- **Attenuation reversibility:** This states if the attenuation increase observed during the testis returning to 0 dB with a tolerance (typically 0.05dB). To have reliable performance, it is important that after tests the fibre must return to a zero-stress state.
- **Maximum attenuation during the test:** When attenuation is measured, a maximum value of attenuation is set to monitor the stress on the fibre. If it does not reach (the set requirements) during the test, it means that the fibres are well protected against the tested specification.

For the main performances of an optical fibre cable, both reversibility and maximum attenuation are typically considered.

Mechanical criteria:

- **Outer sheath damage:** Mechanical integrity of the cable outer sheath is an important safety aspect. Sheath damage exposes the cable's inner elements to the outside environment and reduces the cable's lifetime.
- **Inner elements damage:** To ensure a high level of cable reliability, all internal cable elements remain intact after the test. The strength members must be fully operational to ensure the cable is safe during installation and operation, throughout its lifetime.
- **Fibre elongation during the test:** During tensile testing, fibre elongation is monitored to understand how much load is experienced by the fibre. The load on the fibre must be well below the fibre-proof-test load, which is 1% for most of the applications. This is key for the long-term mechanical reliability of the fibre.

For Underground applications:

Long-term load, T_L: Long-term load is referred to as tensile strength during operation.
Typical fibre elongation: Generally, it is recommended to have a value of 0.1% to 0.3%. TEC recommends 0.25% of fibre strain.
Typical attenuation variation: Maximum 0.1 dB and reversible
Short-term load, T_S: Short-term load is typically the tensile strength of the cable during installation. It is the highest load a cable can bear while installation without any permanent damage.
Typical fibre elongation: Maximum 0.5%
Typical attenuation variation: Maximum 0.1 dB and reversible

For self-supporting aerial applications:

Maximum allowable tension (MAT): It is the maximum tensile load that the cable can handle without compromising the performance requirements (e.g., attenuation, fibre reliability) due to fibre strain.
Typical fibre elongation: Maximum 0.35%
Typical attenuation variation: Maximum 0.05 dB and reversible

Breaking tension:

Tensile load that leads to physical rupture of the cable or fibre encounters strain exceeding the proof test value. At this level of elongation, the performance of the cable cannot be guaranteed. This tensile value is very important to know for the safety purpose of the installation team.

The main mechanical & environmental performances are usually:

- Tensile resistance
- Crush resistance
- Impact resistance
- Minimum bending radius
- Water tightness
- Temperature performance range

Other performances can be found but these are important parameters that the project requires.

As said before, a value shall be read with a test method and one or more criteria to be relevant. Here is an example of tensile strength.

	Maximum Tensile	Test Method	Attenuation Criteria	Remarks
OFC 1	1500 N	IEC 60794-1-21	Reversible	
OFC 2	1200 N	IEC 60794-1-21	Max 0.05 dB @ 1550 nm during the test and reversible	Max fibre elongation <0.25%

In this example, OFC 1 seems to have a better performance using the same test method. But if the user carefully observes the attenuation criteria, remarks for OFC 1 are not specified. There is a chance that OFC 1 is qualified with more relaxed attenuation criteria (for example Max 0.1 dB) and higher fibre elongation (for example <0.3 %). So, there is a possibility of a lower tensile value of OFC1 if the attenuation criteria and fibre elongation value of OFC 2 are considered. A detailed understanding of qualification criteria and test parameters is required to correctly compare two cable datasheets.

Mechanical and Optical criteria ensure the reliability of the cable and the fibre. The relevance of the features specified in a cable datasheet strongly depends on these criteria. A fair comparison requires comparing the values with a clear knowledge of these criteria.

Apart from these tests, there are some specific tests based on the operating condition of the OFC like:

- Rodent & Termite Resistance
- UV protection
- Fire Resistance

These are the special tests that are based on the user and application requirements, and for which manufacturers ensure properties in their OFC offering. For Rodent resistance, there are ways like OFC can be made with metallic armoured or glass yarn coverage or rodent/termite resistance chemical additives in the outer sheath. These are the various methods, and they offer varying degrees of protection against rodents or bio-attacks.

Let's Understand a real-world scenario – a prestigious and ongoing project like the Bharat Net.
Some of the key challenges faced in the network where this is deployed are:

1. Frequent cable cuts leading to the replacement of the cable every 5-7 years
2. Bends across the sections of the network
3. Cable reliability and maintenance

The cable solutions, mentioned below, are credible alternatives to overcome the challenges.

1. Dry-Dry Ribbon Cable with G.657.A2 for Zone, Mandals & GPs Connectivity

Ribbon with Dry-Dry Technologies will enable faster maintenance (MTTR) using the advantages of mass fusion splicing. Frequent cable cuts lead to an increase in optical loss (due to new splice point and bending in the tray) of the network route leading to lossy cable. With the use of ITU-T G.657.A2 fibre, the network life can be increased by 5-7 years. At the same time, the bend-insensitive behaviour of the G.657.A2 fibre will reduce the loss arising due to bends across the network.

2. Micromodule Optical Fibre Cable for Last Mile Connectivity

A project like Bharat net requires huge skilled manpower for fibre deployment, which is a challenge in a country like India. Traditional loose tube optical fibre cables require a skilled workforce and high-end tools for stripping the loose tube sheathing, cleaning the messy loose tube filling jelly, and dressing uncut tubes inside the closure. This process is time-consuming and more prone to damaging the fibre. Also, the loose tube is prone to kink easily and is not a viable solution for last-mile connectivity. It is better to have micromodule cable construction for the last mile.

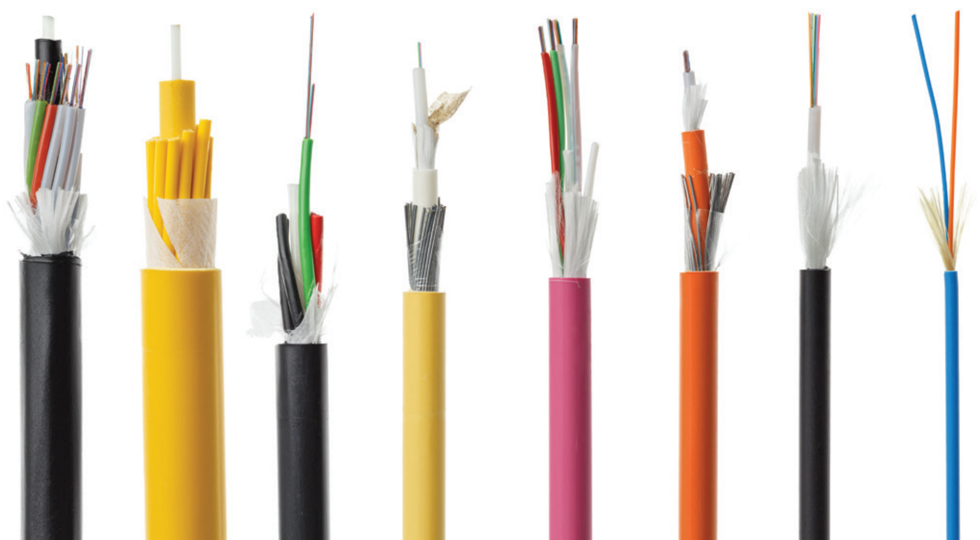
3. ITU-T G.657.A2 fibre for all sections of the network: Since G.652.D based network

Since G.652.D based network is not free of macro-bends, upgrading a PON network to a 10G-PON/40G-PON technology cannot be sustained without changing the fibre type to G.657.A2. On the other hand, any network deployed with bend-insensitive fibre on Day 0 can be upgraded without any additional CapEx on the passive components. This makes G.657.A2-based network infrastructure extremely relevant to any broadband service provider.

Bend Insensitive Fibre or G.657.A2 grade fibre has a considerable impact on all aspects of the network build, scale, cost and monetization potential. It allows network operators to cost-effectively extend the reach of the network even as they are able to provide reliable services over a longer period of time. Realizing these vast benefits, several leading network creators and operators have already started moving fibre specifications closer to G.657.A2.

The use of G.657.A2 bend insensitive fibre:

- ensures an optical lifetime over 25 years even in high cable cut scenario.
- make the network future-proof with next-generation technologies like L-band WDM, GPON, NGPON, and XGXPON, eliminating the need to deploy a new OFC network during upgradation.
- increase the network reach by up to 60% and thus help in connecting wider geographies from a central office.



About STL - Sterlite Technologies Ltd:

STL is one of the industry's leading integrators of digital networks providing All-in 5G solutions. Our capabilities across optical networking, services, software, and wireless connectivity place us amongst the top optical players in the world. These capabilities are built on converged architectures helping telecom service providers, cloud companies, citizen networks, and large enterprises deliver next-gen experiences to their customers. STL partners with service providers globally in achieving a green and sustainable digital future in alignment with UN SDG goals.

STL has a strong global presence in India, Italy, the UK, the US, China, and Brazil.

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