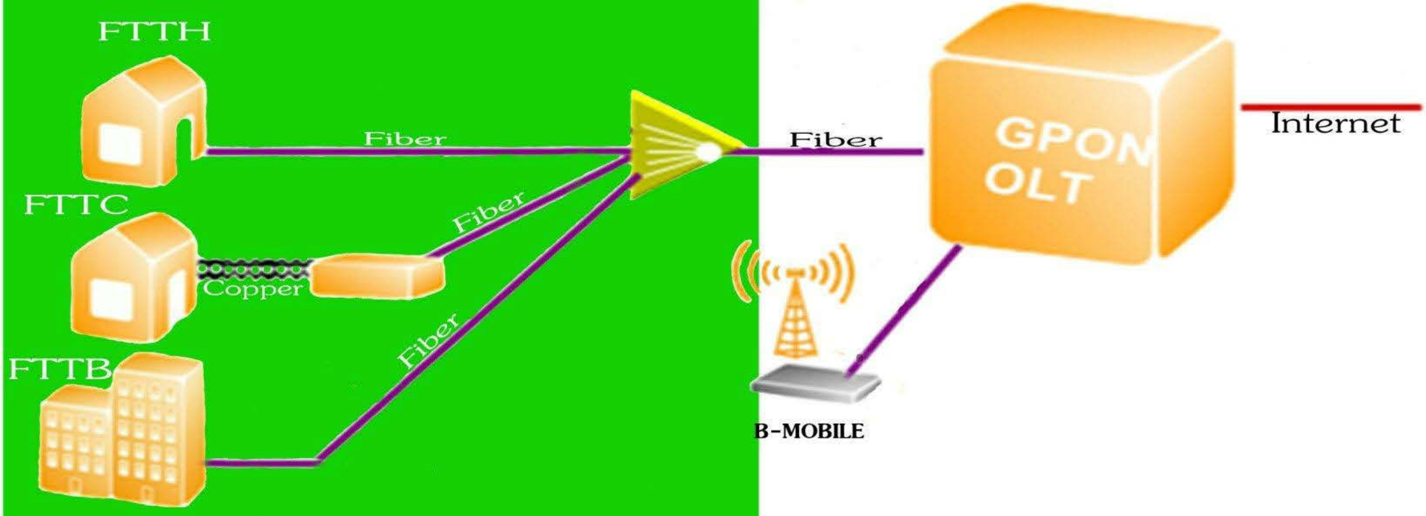
ANNEX 2-12

FTTx Manual

(Version 6)

November 2016

> Design
> Construction
> Safety
> Specification



Technical Cooperation Project for Optical Fiber Techniques in Telecommunication Engineering

Content Page No.

CHAPTER - I

FTTX DESIGNING & PLANNING

CONTENTS Page

1. INTRODUCTION

The optical fiber is the most advanced transmission medium and the only one capable of supporting next generation services. The main advantages of having a last mile of optical fiber are having unlimited bandwidth, longer distances accessible from the central to the subscriber, the more resistance to electromagnetic interference increased security, reduced signal degradation. Moreover, the fact of using PON technology assumes the elimination of repeaters and optical amplifiers and therefore reduces reducing the initial investment, lower power consumption, fewer failure points and occupies less space.

Progressing from the copper wire of a century ago to today's fiber optic cable, our increasing ability to transmit more information, more quickly and over longer distances has expanded the boundaries of our technological development in all areas.

1.1 The Fiber Optic Cable

The cable consists of one or more glass fibers, which act as waveguides for the optical signal (light). Fiber optic cable is similar to electrical cable in its construction, but provides special protection for the optical fiber within. For systems requiring transmission over distances of many kilometers, or where two or more fiber optic cables must be joined together, an optical splice is commonly used.

1.2 The Optical Transmitter

The transmitter converts an electrical analog or digital signal into a corresponding optical signal. The source of the optical signal can be either a light emitting diode, or a solid state laser diode. The most popular wave-lengths of operation for optical transmitters are 850, 1310, 1550 and 1625 nanometers. Most transmission equipment manufactured by Communications Specialties operates at wavelengths of 850 or 1310nm.

1.3 The Optical Receiver

The receiver converts the optical signal back into a replica of the original electrical signal. The detector of the optical signal is either a PIN-type photodiode or avalanche-type photodiode, receiving equipment use PIN-type photodiodes.

2. Fundamentals of Optical Fibers and Communication

Given the importance of the transmission channel for a good communication, throughout this chapter it will detail all general aspects which must have taken into account in a network of fiber optic transmission. The main element of study in this chapter is the optical fiber network design in BTL context, which it shall specify the other key elements in an optical communication network.

2.1. Introduction

Optical fiber is a transmission medium commonly used in data networks, like passive optical networks and others. It can be defined by a thin, transparent and flexible glass or plastic, by which light pulses are sent in order to represent data to be transmitted. The beam is completely contained and it spreads inside the fiber at an angle of reflection above the critical angle of total reflection, according to Snell's law.

Optical fibers are widely used in telecommunications, since they allow sending large amounts of data at a great distance and having higher bandwidths (data rates) than other forms of communication. They are the transmission medium par excellence to be immune to electromagnetic interference and because signals travel along them with less losses.

This transmission mode allows the transport of a multitude of information, used for applications such as broadband Internet, telephone and cable television, through more effective signals than copper wires.

Throughout the chapter, it will detail the generic characteristics of the optical fiber particularizing the most influential aspects of it on the passive optical fiber network

2.2.Basics of optical fibers

As mentioned above, optical fiber is a dielectric waveguide that operates at optical frequencies and transmits information in the light form along its axis.

In this section it will explain the principles and physical laws that obey any type of optical fiber and make possible their operation as optical waveguides.

2.2.1. Electromagnetic waves

An electromagnetic wave is the propagation of electromagnetic radiation through space and theoretical aspects are related to the waveform solution that supports Maxwell's equations. Unlike mechanical waves, electromagnetic waves do not require a material medium to propagate; i.e., they can move through the vacuum.

Light waves are electromagnetic waves whose frequency is within the range of visible light. Each pulse of light is a single electromagnetic field in propagation or "mode". Particularized solutions for

Maxwell's equations for the various pulses of light are those that determine the propagation of electromagnetic fields in waves through optical fiber.

In light waves, like all electromagnetic waves, there are electric and magnetic fields at each point of space, which fluctuate rapidly. As these fields also have a magnitude and a given direction, they are vector quantities.

Other important concept in relation to the waves is the number of oscillations per second at a point of the light wave, which it is known as frequency. Also important is the concept of wavelength, which is defined as the distance along the direction of propagation between two points in phase, i.e., points occupying equivalent positions in the wave.

Below is an example of wavelength in a sine wave:

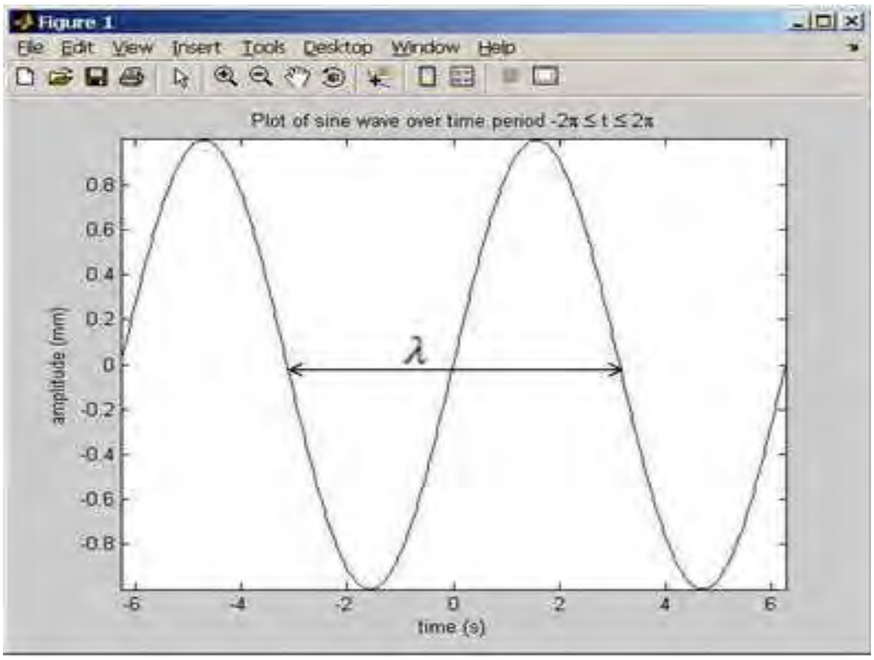


Figure 1-1: Representation of a sine wave of 2π period

In electromagnetic spectrum, the visible spectrum, different wavelengths are differentiated by colors. This way, the visible range is from 350 nm (violet) to 750 nm (red). White light is obtained from the mixture of all visible wavelengths.

The speed of a wave in a vacuum is always the same regardless of wavelength, and therefore, it is equal for all wavelengths. However, the speed of light in material substances is lower than in a vacuum and it varies for different wavelengths.

2.2.2. Refraction and reflection

When a ray of light propagates through a homogeneous medium and strikes the surface of a second homogeneous medium with different composition, part of the light is reflected and the other part penetrates as a refracted ray in the second medium, which may or may not be absorbed. Then, refraction produces a change in the direction of a ray or beam of light rays entering in the medium with different propagation speed.

The plane of incidence is defined as the physical plane formed by the incident ray and the normal (i.e., the vector perpendicular to the surface of the medium) in the point of incidence.

This way, we can say that the light beam incident on another medium with different composition or transmission speed of light is divided into two beams: one reflected in the first medium, and the other refracted crossing the edge.

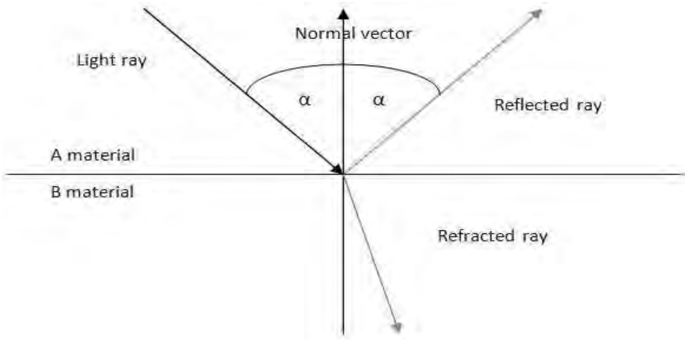


Figure 1-2: Law of Reflection and Refraction

From the above theory, in which a beam is subdivided into two beams of light traveling on different mediums, it can extract two fundamental laws of optical physics to quantify the two events: the Law of Reflection and the Law of Refraction, also known as Snell's Law.

The Law of Reflection says that when a light ray strikes on the boundary between two homogeneous and isotropic transparent mediums, part of the incident beam is reflected at the same angle and the other part is transmitted to other medium.

Other important law to understand the operation of the light guided within the fiber is the law of refraction (Snell's law). To understand this law, first it must define the index of refraction as the relationship between the speed of the light in the vacuum (c) and the speed of light in that medium(Vp).

$$n = \frac{c}{V_p}$$

Once this is understood, the law of refraction says that the relationship between the sine of the angle of incidence and the sine of the angle of refraction is equal to the ratio of the speed of the wave in the first medium and the speed of the wave the second medium, or better known by the following formula:

$$n_1 \cdot \sin \theta_1 = n_2 \cdot \sin \theta_2$$

Where: n1 = refractive index of the first medium,

Ø1 = Angle of Incidence,

n2=index of refraction of the second medium and Ø2 = angle of refraction.

Another important concept that it must take into account for the guiding of light within the fiber is the Total Internal Reflection, which is based on the Law of Reflection.

The Total Internal Reflection phenomenon occurs when, in the refraction, the angle of incidence is greater than the critical angle, and therefore all light is reflected.

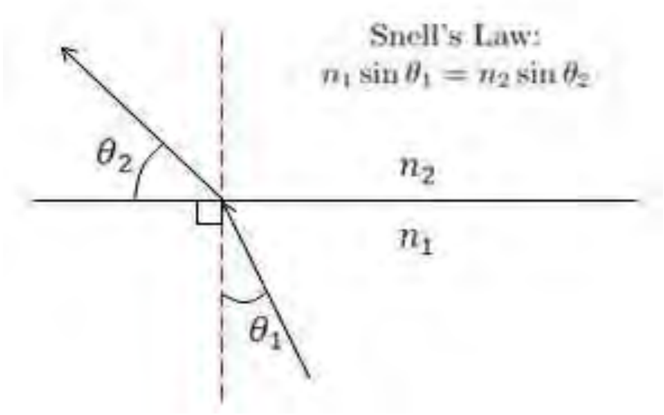


Figure 1-3: Snell's Law

In the area of interest to this project, it is not worthy that the optical fiber is a new practical application of total internal reflection. Thus, when light enters through an end of a solid tube of glass or plastic, it can be totally reflected on the outer surface of the tube, and after a series of successive total reflections, out the other end.

2.2.3. Operating principles of optical fibers

It is important to note that, to make possible transmission of information through optical fiber, it is necessary to inject light beams from a light source (usually LED or LASER) in the same fiber.

Incoming light pulses enter into the fiber core, and get passed through it bouncing off the walls lining that surrounds the core. This is possible because the refractive index difference between core and cladding, and because the refractive index of the coating is less than the core. Finally, the light rays reach the opposite end of the fiber, which arrive at the receiver and they are transformed into electrical signals.

In short, the principle of operation of the optical fiber is based on the principle total internal reflection, which has been explained in the previous section. The transmitter emits rays of light at an angle of incidence greater than critical angle allowing the transmitted beam is reflected first in the coating.

This same process is repeated again and again through the entire cable. Since angles of incidence and reflection are equal, some beams continue to be reflected and transmitted in a zigzag pattern through the entire length of the fiber. Thus, the light energy from the transmitting source is contained in the nucleus.

However, not all the beams of light from the power source Light enter to the core, or they enter but cannot be transmitted through internal reflections in the fiber. This is because the light hitting the interfaces core-cladding, it makes this with a less angle than the critical angle, losing that energy into the coating by refraction.

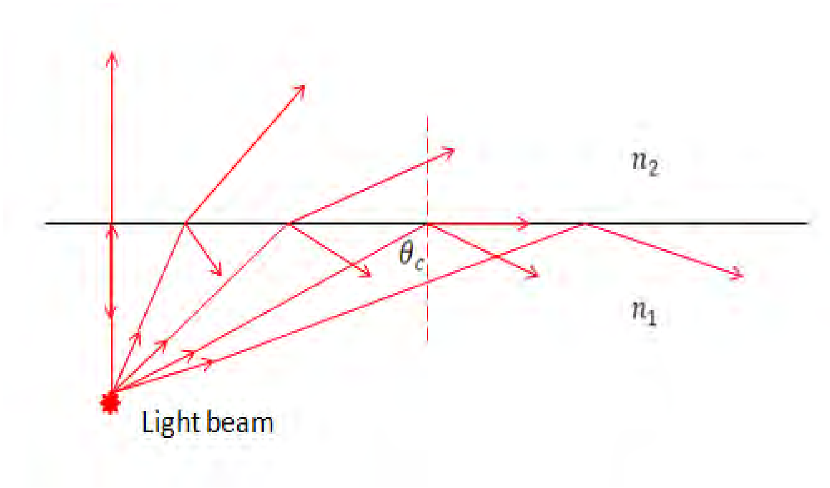


Figure 1-4: principle of propagation through optical fiber based on Snell's law:

In Figure 1-4, a reference rays are taken with different incident angles on the fiber core, which holds that n1 > n2.

Looking from left to right, the first three rays have a lower incidence angle than the critical angle, so that the beam is refracted on the cladding, losing energy in the core of the fiber.

The fourth beam, has an incidence angle exactly equal to the critical angle, therefore the phenomenon of total internal reflection occurs for the first time but dissipates energy at the boundaries.

The fifth ray, which has an incidence angle greater than the critical angle, it obeys the Law of Total Reflection for the remainder confined to the core.

If we consider that all light rays impinge at an angle above the critical angle are trapped inside the nucleus, a virtual cone is generated and is called the cone of acceptance. Therefore, all rays impinging on the fiber outside the cone of acceptance do not propagate through it lengthwise. It can be represented as graphically follows:

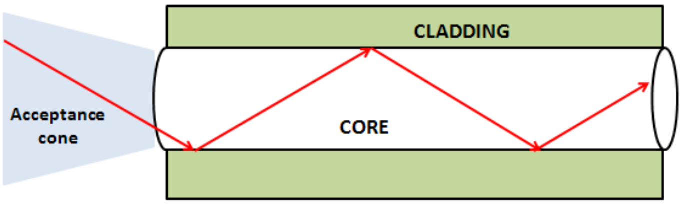


Figure 1-5: Composition and geometry

The larger the cone of acceptance of an optical fiber, the greater the amount of rays can be transmitted by such mediums, and therefore does not need to be so precisely at the time of emitting light from the transmitter. Moreover, a greater number of beams of light inside the fiber, it involves a variation in the directions of propagation of the rays, and their quality decreases.

2.2.4. Classification and types of optical fibers

If the diameter of the fiber core is large enough to allow multiple different pathways for light to travel along the fiber, the fiber is called “multimode”. Single-mode fiber has a much smaller core that allows light rays traveling exclusively by a single mode. In the following sections it will detail these types of fiber:

2.2.4.1. Multimode optical fiber

This type of fiber can propagate several transmission modes simultaneously. This is possible because the core diameter of such fibers is wide (50 microns or 62.5 microns), so that the coupling of light into its different modes is simpler. The following figure shows a section of a multimode optical fiber.

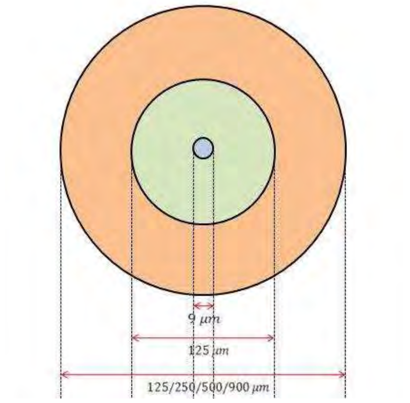


Figure 1-6: Section of multimode optical fiber

2.2.4.2. Single-mode optical fiber

As its name suggests, this type of fiber allows propagation of only one single mode of transmission. This is possible because the core diameter of such fibers is very small (between 8 µm to 10 µm), that allow the propagation of a fundamental beam.

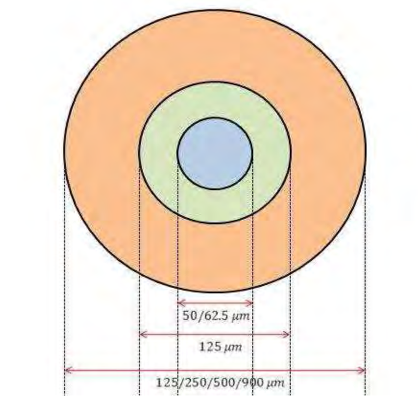


Figure 1-7: Section of single-mode optical fiber

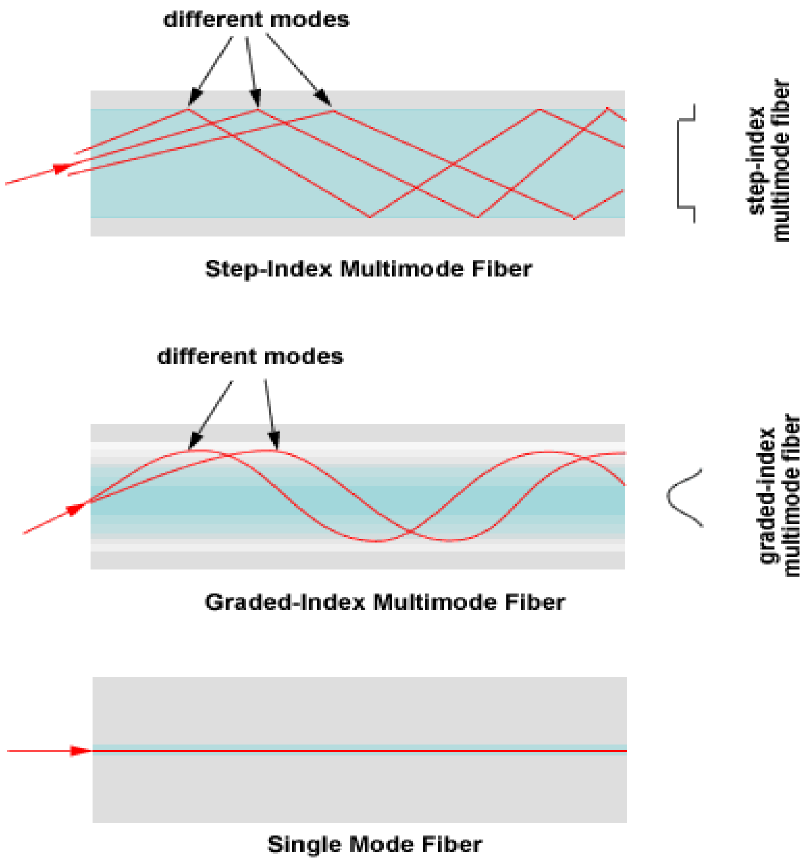


Figure 1-8: Multimode and single-mode optical fibers

The standard fiber optic cables attenuation characteristics are that the minimum attenuation occurs at wavelengths around 1310nm and 1550nm. Laser manufacturers have consequently designed a wide range of lasers for these specific wavelengths, where attenuation is less than 0.4dB per km.

2.3. Advantages of Fiber Optic Systems

A fiber optic transmitter and receiver, connected by fiber optic cable offer a wide range of benefits not offered by traditional copper wire or coaxial cable. These include:

Fiber optic can support unlimited bandwidth.

The ability to carry much more information and deliver it with greater fidelity than a twisted pair wire or coaxial cable.

Fiber optic cable can support much higher data rates, and at greater distances, than coaxial cable, making it ideal for transmission of serial digital data.

The fiber is totally immune to virtually all kinds of interference, including lightning, and will not conduct electricity. It can therefore come in direct contact with high voltage electrical equipment and power lines. It will also not create ground loops of any kind.

As the basic fiber is made of glass, it will not corrode and is unaffected by most chemicals. It can be buried directly in most kinds of soil or exposed to most corrosive atmospheres in chemical plants without significant concern.

Since the only signal in the fiber is light, there is no possibility of a spark from a broken fiber. Even in the most explosive of atmospheres, there is no fire hazard, and no danger of electrical shock to personnel repairing broken fibers.

Fiber optic cables are virtually unaffected by outdoor atmospheric conditions, allowing them to be lashed directly to telephone poles or existing electrical cables without concern for extraneous signal pickup.

3. GPON Technology

3.1 Introduction

The application of GPON technology for providing broadband connectivity in the access network to homes, multiple-occupancy units, and small businesses commonly is called Fiber-to-the-x.

One way of providing fiber to the home is through a Gigabit Passive Optical Network, or GPON. GPON is a point-to-multipoint access mechanism. Its main characteristic is the use of passive splitters in the fiber distribution network, enabling one single feeding fiber from the provider's central office to serve multiple homes and small businesses.

The GPON standard is issued by the ITU. The line rates are 2.5 Gbps and 1.25 Gbps in the downstream and upstream directions, respectively. The GPON data packets are sent time-division multiplexed (TDM) onto the network and the total available bandwidth is shared following the dynamic bandwidth assignment (DBA) protocol. It has concurrencies with the Gigabit Ethernet PTP wavelength allocation scheme because the 1310, 1490 and 1550-nm channels are occupied in GPON for upstream, downstream and CATV overlay transmission. The GPON line cards typically hold 8 OLT ports and the number of line cards per chassis can be well above 10. It is clear that several 1000's of users can be served by a single OLT; however, one has to work with high oversubscription factors to be able to offer high bandwidth connectivity.

3.2 FTTx Fiber Architecture

FTTX is a generic term for the allocation of transmission network architectures based on optical technology. It is a transmission system within the world of telecommunications. These networks, which are considered broadband, have the ability to transport large amounts of data and information at very high bit rates up to a point close to the end user.

The PON architecture is commonly used for FTTx networks because it employs optical splitters to deliver signals to multiple users without conversion or intervention. Unlike traditional networks where services are direct point-to-point links between customer and provider, PONs share a common distribution segment before being split to several users, therefore reducing installation costs. FTTx networks feature active and passive components. The OLT and ONT segments are active while the PON, as the name states, is passive.

All FTTx networks support a logical network configuration of tree, star, bus and ring, and all with the ever present possibility of using active components depending on the location of users or end customers.

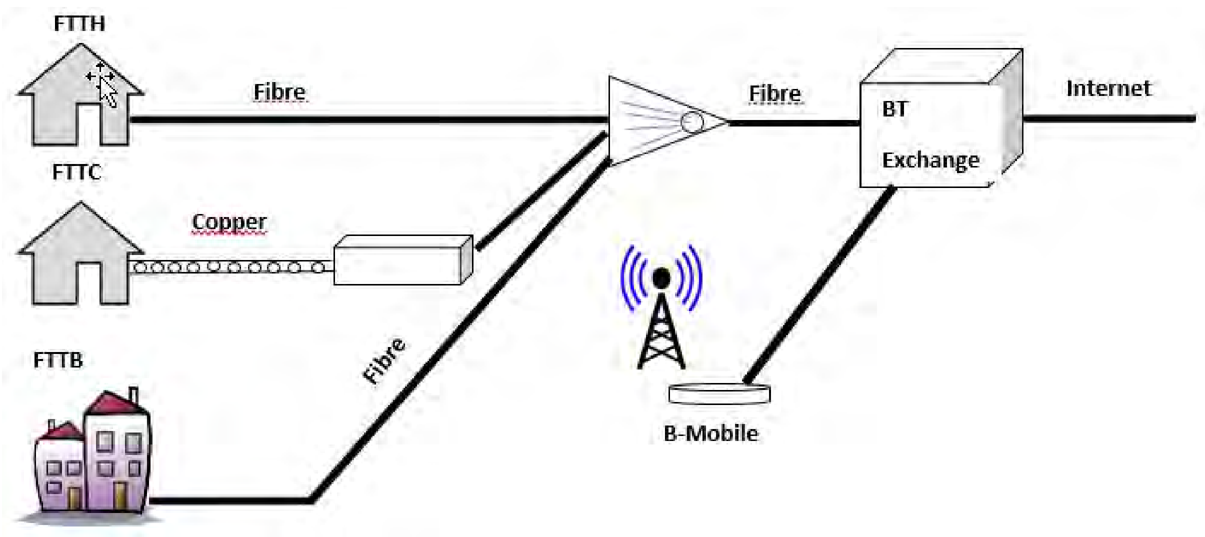


Figure 1-9: FTTx Architecture

Depending on the degree of penetration of FTTx, these networks can be classified into the following categories:

3.2.1. FTTC:

Fiber-to-the-cabinet, describes running optical fiber cables from central office equipment to a communication switch located within1000 ft (about 300 m) of a home or enterprise. FTTC networks are sometimes referred to as deep-fiber network architectures because their deployment involves extending access to the core network on backhaul connectivity using optical fiber cables deep into the access network. The fiber cable provides high capacity backhaul connectivity to Digital Subscriber Loop Access Multiplexer (DSLAM) equipment housed in roadside cabinets. This is done in order to access relatively short copper end user connections that can support high bandwidths close to the maximum capabilities of the DSL technologies used to provide broadband services. FTTC networks utilise existing copper end user connections and this provides a significant saving in deployment costs.

FTTC broadband means that most of the 'local loop' (the phone line from your premises to the central office) is using fiber-optic cable, with the last few meters being copper. This means we get faster speed as the short copper line can run VDSL rather than ADSL technology.

NOTE: - In actual designing of FTTC, we never use primary cross connection point

3.2.2. FTTB:

Fiber to the building (FTTB) is a type of fiber-optic cable installation where the fiber cable goes to a point on a shared property and the other cabling provides the connection to single homes, offices or other spaces. FTTB applications often use active or passive optical networks to distribute signals over a shared fiber-optic cable to individual households or offices.

FTTB stands for “Fiber to the Building”, which is a communications architecture in which the fiber reaches the boundary of the building, such as the basement of a multi-dwelling unit, with the final connection to the individual living space being made using any non-optical medium, such as twisted pair, coaxial cable, wireless, or power line communication. This is sometimes also called “Fiber to the basement”.

Fiber to the building is just one of a number of fiber deployment setups collectively called FTTx. Others include fiber to the home (FTTH), where a fiber cable may carry a signal to an individual home, or fiber to the node (FTTN), where the fiber cable carries a shared connection to a street box that is then distributed to several properties. Other fiber setups include local networks and methods like fiber to the desk (FTTD), where a fiber cable carries a signal locally from an onsite box to a particular workstation. Another choice is direct fiber, where an individual signal is carried exclusively to one customer from a provider’s central office. Fiber-optic setups enable higher speeds of delivery and greater bandwidth than some other kinds of infrastructure. Some of the fiber networks deploying signals to the most sophisticated equipment can benefit from a multimode fiber connection, where a specific kind of fiber-optic cable may be used for optimal speed.

3.2.3 FTTH

FTTH, fiber-to-the-home, refers to the deployment of optical fiber from a central office switch directly into a home. The difference between FTTB and FTTH is that typically, businesses demand larger bandwidths over a greater part of the day than do home users. As a result, a network service provider can collect more revenues from FTTB networks and thus recover the installation costs sooner than for FTTH networks.

The use of fiber optics as medium of transmission to homes, and so, to end users, ensures network completely adapted to the needs of both current and future.

The reuse of this physical infrastructure saves money over time despite strong outlay in initial phase, amortizing it in a short time.

FTTH technology involves the introduction of fiber optic in global network, both the backbone network operator as the last mile. In relation to the last mile, it includes the fiber from the central office to each household that requires services.

4.FTTX Network Design

4.1. Introduction

FTTX Network Design requires careful evaluation of all the Outside Plant fundamentals from the central office to ONT at customer premises.

Before Designing of FTTX network, it is very important to analyses the Demand forecast for particular area where the FTTX needs to deploy.

4.2. Study of Demand Forecast

During the study of demand forecast, one should know the potential number of subscribers and subscriber's need to include cheap facility development and economical based regard to affordability from subscribers end. Besides, we need to consider the growing trend in ISP service provider in the country, it is crucial to compare the facilities to retain the customers.

After Calculating the demand, then the potential volume of new subscribers in one area either single exchange or multi exchanges area will be known.

The output of the forecasting result is the potential applications in the "0 year"(when survey is done),and the reference to this, forecast for 5 years, 10 years, and 20 years which will help in Planning the overall FTTX cable network.

If there exist any old exchange, the result of demand forecasting can be used to correct the existing capacity by adding to the capacity or changing the old system to make the demand(voice/data) in the formulation equal to the actual subscribers plus waiting potential(Waiting list) plus expected new connections in 5 years, 10 years, and 20 years(suppressed demand) See Formula

4.3 Demand calculation

To calculate the services demand in an exchange area, use the following formula.

D = $\sum \mathrm{SIT} + \mathrm{CP} + \mathrm{SP}$

Where D = Demand (Service demand)

SIT = Installed main service connection (voice & data)

CP = Waiting Subscribers

SP = Suppressed Demand (based on interviews, surveys, other data, etc.)

The results of this demand forecast can be applied directly to calculate network traffic on each exchange, and also for upgrading the existing exchange capacity.

4.4 The Method of FTTX network Design Pattern

a. Collecting Data

Collect data from demand forecasting in addition to the existing network data, existing traffic status, and current subscribers.

b. Preliminary Study of Data

It is recommended to collect the demand data first, however, if it is not calculated, then we must estimate based on the data provided. In order to process fast data, preliminary study of data can be performed.

Recheck the resulting data until it satisfies the requirement before moving further with other processes.

c. System Allocation

System allocation refers to past fundamental plan that recommends using the current technology system for the next development.

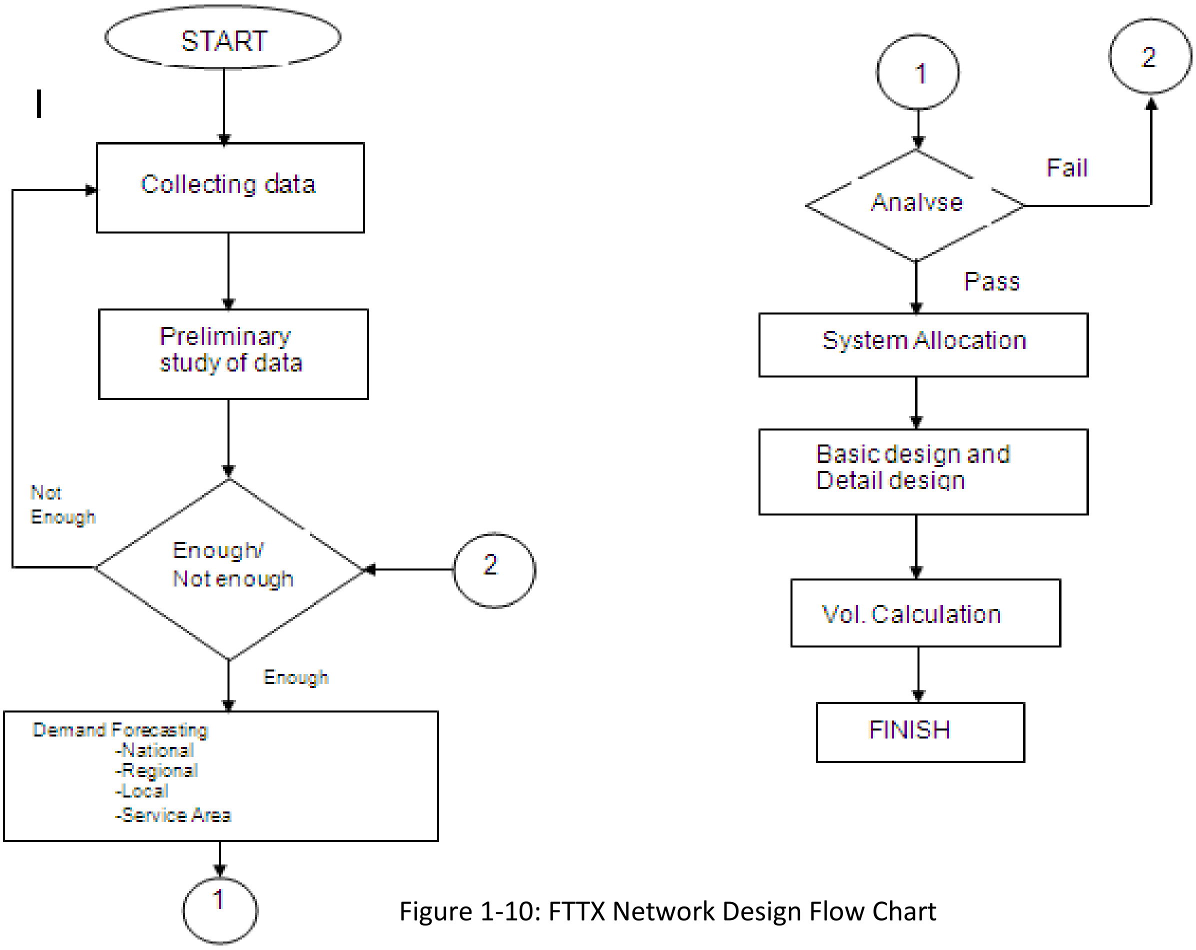


Figure 1-10: FTTX Network Design Flow Chart

4.5 FTTX Network Environment

Design comprises of selecting the route, deployment of FTTX infrastructure according to the environment, be it on public or private land, urban or rural areas.

The type of site will be a key factor in deciding the most appropriate network design and architecture. Types include:

Greenfield – new build where the network will be introduced at the same time as the buildings.

Brownfield – where there are existing buildings and infrastructure but the infrastructure is to a lower standard.

Overbuild – adding to the existing infrastructure

Greenfield - It is always a good opportunity to plan and design our network infrastructure in Greenfield stage, where we can in cooperate with other utility agency to deploy our equipment and design our route accordingly by understanding the network.

Brownfield - In this situation, we need to carefully look at how we should improve our network standard by replacing the existing network with some better techniques. For example our network may be in poor aerial condition that case we can re-design with underground technology or replacing the old aerial and accessories with the new one.

Overbuild - Overbuild situation refers to one where the customer demand might have already exceeded and there is a need to expand the network infrastructure. In this regard, referencing of existing network in GIS or CAD format is very important to see the possibilities of network expansion. On the other hand, poor planning and designing cause overbuild situation. Example Chanjiji Area. But there is always a possibility to overcome such situation as long as we have up to date network information

4.6 Standard Fiber Loss Table

Table 1-1 Standard Fiber Loss Table

Type of Loss	1310 nm	1550 nm
1. Transmission Loss	29.5 dB	29.5dB
2. Line Loss	25.5 dB	25.5 dB
3. Allowable Line Loss	23.0 dB	23.0 dB

4.6 a Line Loss Calculation

After determining the location of the transmission equipment at the Exchange, then the line loss value among FODP from the exchange is calculated to see whether the allowable capacity among the line areas is satisfying or not.

Example:

If the cable length is 40 Km, the loss equation will be:

According to the cable specification:

1310 nm--------0.4db/km

1550 nm--------0.3db/km

And if every 2 km cable span has a splicing point and the average splicing loss to be considered is 0.2 db then,

For a 1310 nm Line Loss System:

0,4 x 40 +0,2 x 40/2 = 16+4 = 20dB

In this case, the allowed loss for the system of 1310 nm is within the limit of 23 dB, thus this result for the distance of 40 km is acceptable.

If the cable length is 50 km

Line Loss = 0.4 x 50 + 0.2 x 50/2 + 20 = 20 + 5 = 25 dB

This result exceeds the limit of 23dB. Thus, the 1550 nm system has to be applied.

Line Loss = 0.3 x 50 + 0.2 x 50/2 = 15 + 5 = 20 dB

Therefore, the result is adequate.

4.7 Layers of an FTTx network

An FTTx network can be considered to have different layers: the passive infrastructure comprising the ducts, p r i m a r y fiber, secondary fiber enclosures, joint box, poles aerial cable etc.

FTTX designing involves outside plant fundamentals that should be well taken care and design as per the BTL norms and at the same time meets the municipality standard.

Designer should have in-depth knowledge of fiber optic components and systems and installation processes as well as all applicable standards. They must be familiar with most telecom technology including site surveys, besides fiber optic network designer must be familiar with the electrical power system.

Following are some of the basic FTTX infrastructures that one should maintain and design by looking at the present scenario and future provisions.

4.7.1 Selection of Fiber Cable Route

Cable route is determined looking at the suitability to the field condition, whether a new route is needed or the existing route is adequate. From this, cable loss is determined and using cable loss value cable required can be worked out.

During the designing phase, if the duct route does not exist then make a new route considering the following:

a) Route conditions
b) Bridges if there are any
c) Route Security

If there exist a duct route, then it is checked to determine whether the duct pipe is blocked or not. If it blocked then, it can be fixed or duct pipe is added or joint box is enlarged if possible.

While designing, we need to consider the diameter of the duct. If the duct pipe diameter is 100mm, it will be too big for the optic fiber cables, so look for laying sub ducts of up to three numbers to maximize the utility of the duct and at the same time spare duct for the future expansion is created.

Sub duct

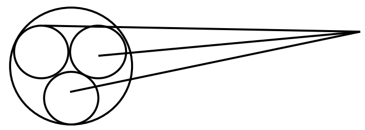


Figure 1-11: Sub duct

Sub-duct protects the cable from damage due to friction or by becoming tangled while pulling more than one fiber in the same duct. Use of sub-duct makes it easier to install or pull out multi cable in one duct without causing damage as it is free from tangling.

4.7.2 Design Procedures for Sub-duct

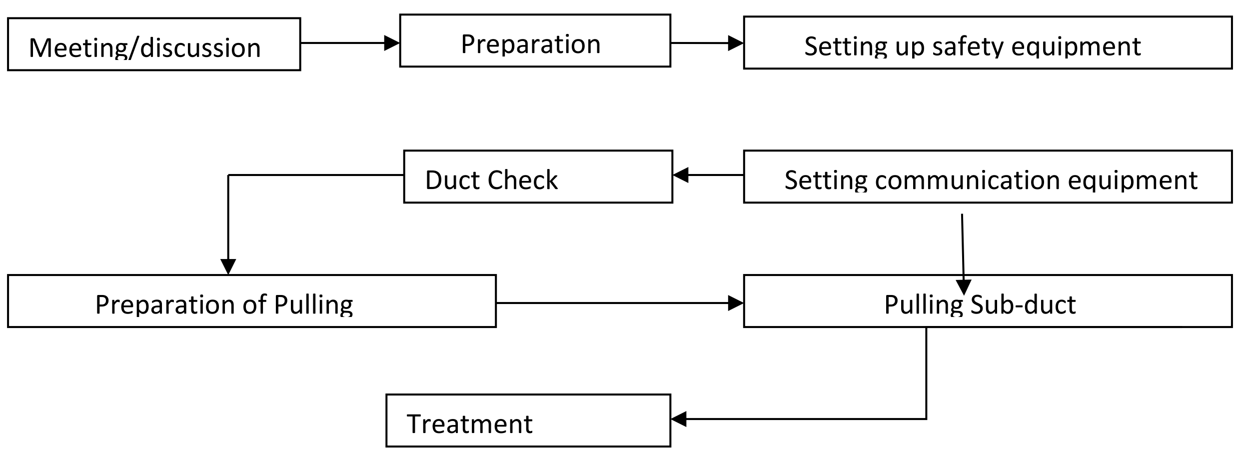
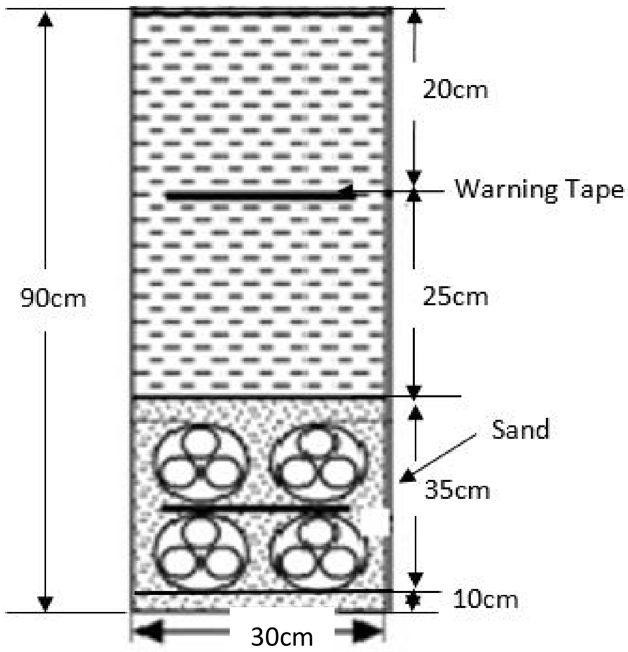


Figure 1-12: Trench Specification

4.7.3 Duct installations- Although the initial duct installation is more expensive than a direct-burial installation, the use of ducts makes it much easier to add or remove cables. While designing the duct installation, it is always a best practice to keep the spare duct and maintain the standard depth. As per the BTL standard we usually maintain the 3 feet depth. Any underground conduit run needs careful planning, especially the location of pulling points, which, in turn, influence the location of maintenance holes (formerly called manholes), hand holes, and splice points. Follow the separation from other utility requirements. When fiber optic cable is the media to be placed, always consider the use of inner duct within the conduit. The burial depth of a Conduit system must satisfy local code requirements, which is generally a minimum depth of 90cm. The alignment of the duct run should as straight as possible in the horizontal or vertical direction. The warning tape should be laid directly above each section of duct at a depth of 300 mm above the top of the duct. The warning tape should be not less than 200 mm wide and preferably coloured high visibility yellow or orange with the following words printed in large black block capitals i.e "TELECOMMUNICATION CABLE". We should cap conduit at the ends to prevent infiltration of debris or water.



4.7.4. Feeder Cable (Primary Cable) – In terms of BTL contest we consider feeder cable as a main primary cable that runs from central office to the cabinets, joint box, etc.

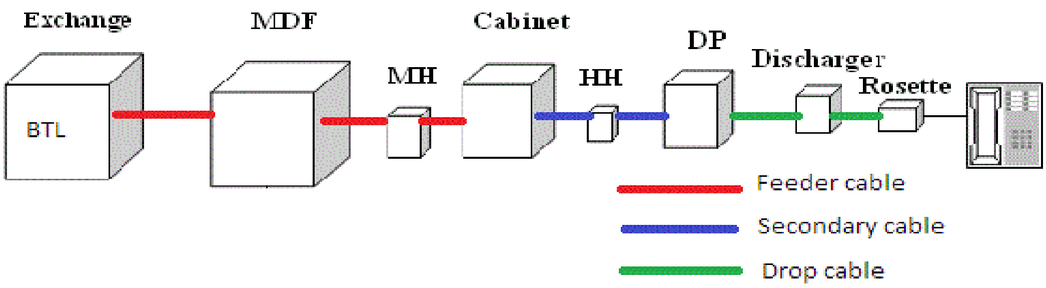


Figure 1-13:Feeder Cable

During the designing phase it is very crucial to keep the available fiber in the feeder cables thus to allow the possibility of other services to use spare fiber and for future upgrades or expansions as per demand forecast. Spare fibers in the feeder cables may be used for other applications which are not related to the FTTX network. At least one feeder fiber is needed between the central office and the optical splitter in order to reach the premises.

Figure 1-14: Feeder Cable

4.7.5. Distribution Cable (Secondary cable) – The term secondary cable is referred to as direct buried cable after cabinet to the Distribution point.

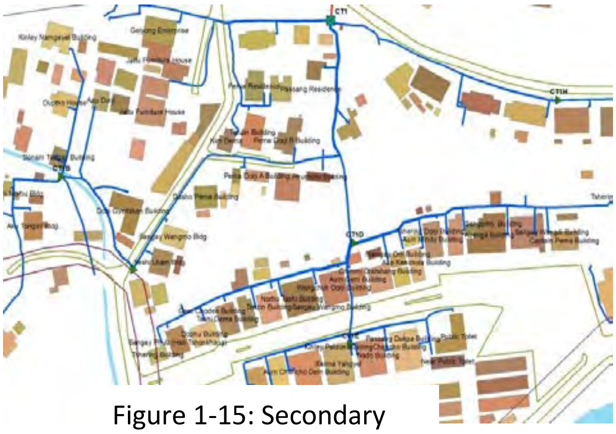


Figure 1-15: Secondary

Secondary cable from the cabinet should be laid enough to meet all the customer demand as per the demand forecast for designated area or location. While designing the FTTC network it is very important to analyze the secondary network to facilitate the customers.

As per BTL secondary network we have covered almost all core area with secondary cable. Therefore, the FTTC network would be very efficient if we design the FTTC network based on existing secondary network.

For densely populated areas with particular right-of-way challenges, several alternative methods are also available. For example, cable can be installed in grooves that have been cut into the pavement or inside drainpipes, sewer pipes.

a. Factors to consider are: type of soil and subsurface conditions, the minimum depth of the trench should be 2 feet. Greater depth may be considered if there is a need for additional protection from someone accidentally digging up the cable. A warning tape or a mechanical barrier such as continuous plank should be used above the cable (placed 1 ft below grade level), but experience shows that this visual warning is often ignored, or not observed, by backhoe operators.

A specific recommendation is given for a direct-burial fiber optic cable: Put down a cable or conductor along with the fiber optic cable, so that in the future, a cable locating instrument could be used to find the buried cable.

While backfilling use clean backfill material, that is, the soil should not have any sharp objects or large rocks that could pierce the cable jacketing or cause other damage to the cable construction.

4.7.6 Joint Box– Joint Box is a node in terms of fiber network, where joint splicing is done or splitter are kept.

Joint boxes should be design as per the standard specified by the civil engineers, the people should work comfortable while jointing or splicing of fiber cable, if necessary keep enough space for the cable spare to avoid bending of fiber cables. Provide adequate cable rack and hanger inside the joint box as shown in the figure. It is also necessary to keep the access whole or opening at the base to drain out the rain water etc.

A hand hole should be at least 6-ft wide, 8-ft long and 6-ft deep, and made of 3500 lb/sq with concrete, and the maximum distance between two of them should be 500 ft. It should be at least 4 ft in all dimensions, with pulling irons and bonding inserts. It should have a free opening (not a center-entrance type), to make cable pulling easier. Design joint boxes in such way that, it should withstand the weight of the heavy vehicles and machinery and level as per the ground surface and design its cover with cast iron in circular shape to withstand any force applied on it.

4.7.7 Aerial installation–We must plan a route that provides enough stabilized ground so that a line or splicing truck can be supported during installation and later, when maintenance of the aerial run is required.

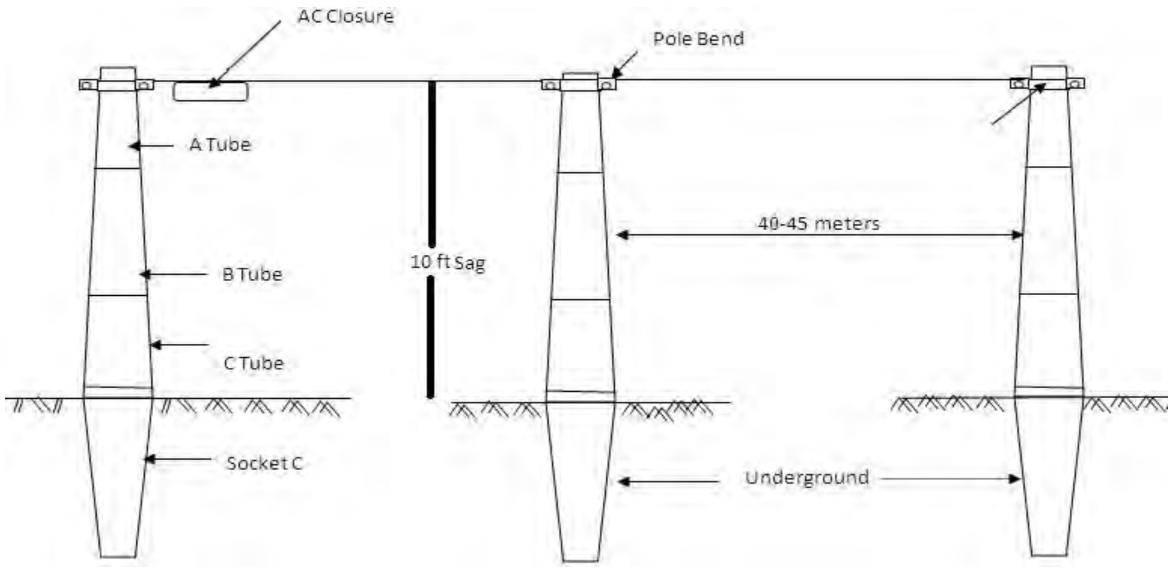


Figure 1-16: Aerial cable

Pole placement should take into account for future cable capacity requirements, the classification of pole type, storm loading requirement, optimum span lengths and minimum height clearance requirements. The installed cable must maintain a specific distance known as sag clearance; from the ground and from other utilities. These distances vary, based on what's traversed (refer construction and safety manual for clearance). As more cable runs are added to the pole, line clearances must continue to be observed.

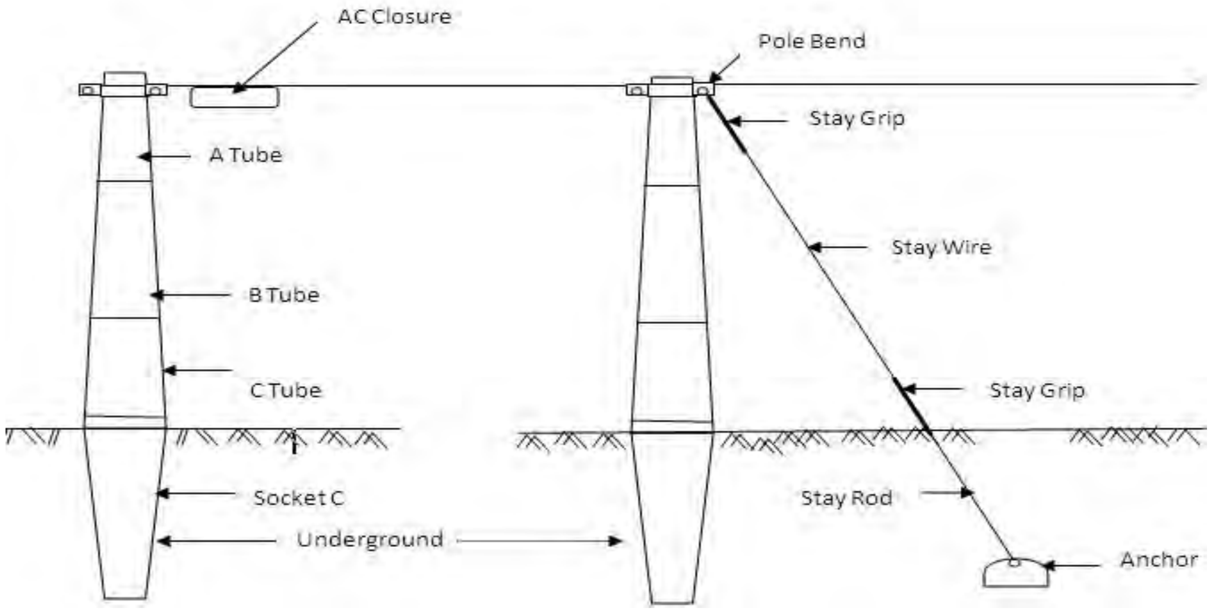


Figure 1-17: Aerial cable

If we set a pole in sloping ground, the depth of the pole set must be increased over the depth used for flat ground installation. A designer should be aware of three definitions of pole loading: transverse storm loading, vertical loading and bending moments.

The selection of span length should follow these guidelines: Strand tension should not exceed 60% of breaking strength under storm loading conditions. Strand tension should not exceed 70% of breaking strength with cable in place and a 300 lb load concentrated at mid span. Sag should not exceed 10 ft at a 60 Degree F temperature, without any wind loading.

For self-supporting cable, span length is limited by the simultaneous application of the two previous factors. Self-supporting cable is a special construction in which the sheath covers both the support strand and the telecom conductors. When tensioning a self-supporting cable, special clamping devices are required for the come-along (a small chain tackle that is tied to a pole and clamps to the strand) to avoid cutting the polyethylene strand covering. In many cases, a pole will require some type of guying hardware, which is available as side, head, anchor, pole-to-pole, or pole-to-stub guy.

4.7.8 FTTC Shelter OR FTTC Cabinet

The Function of the osp distribution shelter or a cabinet is the termination point of the feeder cables, where both voice and data equipment are installed. Outgoing cables from the cabinets to the customer premises would be a metallic cable in most of the cases. While designing this shelter or placing the equipment we have to carefully study, where we have enough secondary cable to meet the customer demand and often we know it by the name FTTC technology. In order to maintain the temperature of the equipment installed in the shelter we have to install Air condition (AC) as well.

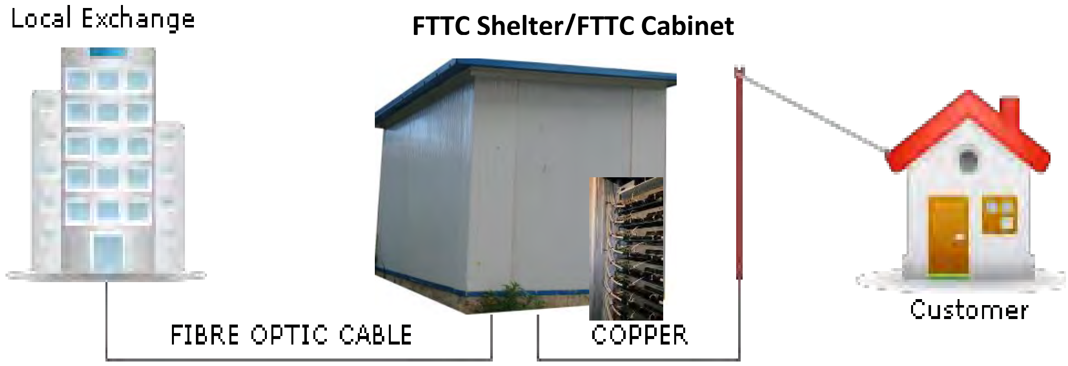


Figure 1-18: FTTC Shelter

a. Standard design of the osp distribution cabinet includes:

1. Resistant to moisture, wind, rodents, intruders, and fires
2. Easy access but with wind-resistant doors.
3. Natural Shape and colors so that it is not an eyesore.
4. Enough or free space to accommodate required equipment and also for technician to work comfortable inside the cabinet.
5. Location of the cabinet should be at the safe place or near the road side so that it should not disturb pedestrians or vehicles.
6. It is always necessary to install rectifier and battery bank as per the specification inside the cabinets, if in case commercial power fails the service must be in operation as normal for the valued customers.

4.7.9 Comparative synthesis among xPON standards

This is the xPON standard comparative table that we must follow before designing where our PON is categorized under.

Table 1-2: XPON Comparative table

Features	BPON	EPON	GPON
Standard	ITU-T G.983.x	IEEE 802.3ah	ITU-T G.984.x
Transmission rate (Mbps)	Down: 155, 622, 1244 Up: 155, 622	Down: 1250 Up: 1250	Down: 1244, 2488 Up: 155, 622, 1244, 2488
Fiber type	Single-mode (ITU-T G.652)	Single-mode (ITU-T G.652)	Single-mode (ITU-T G.652)
Number of fibers per ONT	1 or 2	1	1 or 2
	For 1 fiber: Down: 1480-1500 nm Up: 1260-1360 nm Video: 1550 nm For 2 fibers: Down: 1260-1360 nm Up: 1260-1360 nm Video: 1550-1560 nm	Down: 1480-1500 nm Up: 1260-1460 nm Video: 1550-560 nm	For 1 fiber: Down: 1480-1500 nm Up: 1260-1360 nm Video: 1550-1560 nm For 2 fibers: Down: 1260-1360 nm Up: 1260-1360 nm Video: 1550-1560 nm
Max. Number of splitters per ONT	32	16	128
Max. reach (OLT-ONT)	20 km	10 km (prev. 20 km)	60 km
Max. Distance among ONTs	20 km	10 km (prev. 20 km)	20 km
Max. insertion losses	0 dB	15/20 dB	15/20/25 dB
Traffic mode between OLT and ONT	ATM	Ethernet	ATM, Ethernet, TDM
Transmission architecture	Symmetric, asymmetric	Ethernet (symmetric)	Symmetric, asymmetric
	Improvement of APON. Support for other services than just ATM- based	Very popular in Asia. GE-PON is a special case of EPON	Upgrade of BPON. Improved OAM&P. Dominating in the US

4.7.10 Network elements

While designing of FTTx network or link, one needs to establish and accomplish the following parameters:

a) Maximum transmission distance
b) Optical attenuation balance for the system
c) Fiber type
d) Attenuation for connectors
e) Attenuation by union or splice
f) Maximum reflection (backward)
g) Connector types
h) Range of aging or mechanical lifetime

a. Optical Fiber Types

The choice of optical fiber is determined by various parameters, the single mode fiber having high transmission capacity and low optical attenuation makes this medium as the most attractive for FTTx networks. Therefore, always single mode fibers are used for FTTx networks.

While designing FTTH networks, always recommend single-mode optical fiber as it allows homogenizing access to rest of the network which already uses same type of fiber, giving it transparency and uniformity. It also simplifies the operation, maintenance and development. Therefore, it recommends the usage of this type of fiber for FTTH access network, as recommended by IEEE 1000Base-LX and 10GBASE-LX. It can identify as the best options the usage of fibers G.652D or G.657A and G.657B for FTTH (refer specification manual for this spec.)

b. Number of fibers per user

When designing a network, you have to take into account the current needs and projections regarding future service requirements referred, such as expansion of basic services etc.

The total number of fibers per end user or subscriber is determined by the degree of utilization of active components that exist on the network. Most point to point systems are based on the use of two fibers per link, one dedicated to upstream and the other for downstream. We may perhaps design to adapt WDM technology where both uplink and downlink travel through same channel but at different wavelengths. This implies that the number of fibers and the connectors are cut in half, saving cost and space.

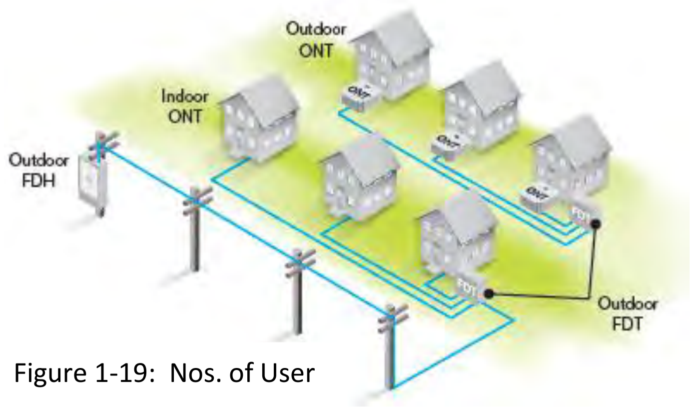


Figure 1-19: Nos. of User

c. **Connector type**

In our FTTx network, it can use different types of connectors: SC, LC, MU depending on the price, performance, life expectancy and usage, although there are some recommendations for choosing one based on the final network, and are listed below:

Use SC, LC or MU connectors for WDM single-mode systems that have one fiber per subscriber.

Figure 1-20: Types of Connectors

Use any type of duplex connectors for systems with two single-mode fibers per subscriber.

Use duplex SC, LC or MT connectors for multi-mode systems with two fibers per subscriber.

d. **Fiber Splicing**

Jointing of fiber that gives better performance in terms of minimum fiber losses are referred as fusion splices, which are most commonly used today.

A good fusion should typically have a loss of about 0.1 to 0.15 dB of attenuation for single-mode optical fiber according to ITU. The attenuation produced by the union of fibers is not critical in many systems, but in order to ensure a lifetime of more durable splice, it is recommended to fusion if attenuation is greater than 0.3 db.

Moreover the maximum recommended attenuation for any kind of fusion or mechanical splice should not exceed 0.3 dB loss. And it is the fusion joints which offer better performance.

e. **Optical Splitters**

They are designed to introduce insertion losses approximately equal in all its output branches. Since the splitters involve a significant loss of power in relation to other network components, the design of a network must be carefully balanced between: high branching fibers, distances to customers and powers managed by equipment, so that it meets the main specifications.

e1. Location of Splitters

Splitters needs to be placed in lockers located in strategic places, which has the advantage of lower costs of deployment and on-site maintenance required.

Finally, it just needs to decide how many splitters will be placed on the network and what will be the ratio of division based on distance and power loss calculation

For example like business area, we needs a couple of splitters with division ratio of1:2 for each of the two fibers can connect the two buildings.

In the case of the residential area, it will need a 1:32 optical splitter to encompass a division of 1 to 20. Therefore, the minimum splitters are necessary i.e. (1:2, 1:4, 1:8, 1:16, 1:32, 1:64 even 1:128 division ratios, but it's strongly recommended to have minimum possible ratio to get the minimum losses).

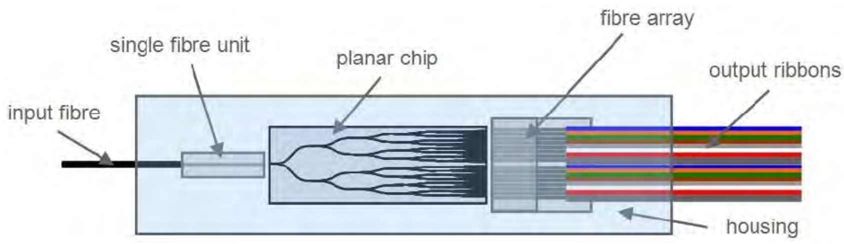


Figure 1-21: Splitter

In the mall-school area is needed another 1:2 splitter to distribute the traffic to the two buildings.

As in the case of the offices, in the buildings area the optical fiber will need a splitter with division ratio of 1:2 for each of the two fibers that will reach ONT.

e2. Outdoor Cabinet for FTTC:

One fiber from the splitter is enough to cater service to all the customers under FTTC, depending on the secondary cable from the cabinet we have to design and plan the voice and data equipment. We can provide the maximum of 500-1000 customers from the FTTC cabinet.

4.8 Analyzing Power Budget

Once the basic design of the network is done, the next step is to do a “Link Loss Budget” which calculates the expected loss of the cable plant and checks to see if the chosen communications equipment will work on that cable plant link. Loss budget analysis is the verification of a fiber optic system’s operating characteristics. This encompasses items such as routing, circuit length, and fiber type, number of connectors and splices, wavelengths of operation and communications optoelectronics specifications.

Both the passive and active components of the circuit have to be included in the loss budget calculation. Passive loss is made up of fiber loss, connector loss, and splice loss. Also include any couplers or splitters in the link, as in passive optical LANs (POL) or FTTx PON networks. Active components specifications of interest are system wavelength, transmitter power, receiver sensitivity, and dynamic range – the difference between transmitter power and receiver sensitivity.

Loss budget is actually the first thing to consider, as it is an essential requirement that the signals get from point A to point B and still retain a healthy margin of signal strength. It is best to start with a simple calculation of the laser power at the source, minus the anticipated losses in the fiber (calculated from published specifications for the fiber being used).The remaining signal power can then be compared with the sensitivity of the receiver to see how much margin is available. Here is an example:

Laser power: -7.5dBm

Fiber attenuation: 0.4dB per kilometer

Fiber length: 20Km

Receiver sensitivity: -29dBm

Connector loss: 0.5dB

Number of connectors: 2

The loss in the fiber cable is 20 x 0.4 = 8dB. We need to add an allowance for connector loss and there are 2 connectors. At 0.5dB loss per connector, this adds 1dB to our loss budget. The power level at the input to the receiver is therefore -7.5dBm -8dB -1dB = -16.5dBm.

The receiver sensitivity is -29dBm, so the margin is 29-16.5 = 12.5dB. Typically we would like to leave a 3dB safety margin, so in this case we still have 8.5dB of margin to play with. The margin decides how many other products could be added. These might be multiplexors, splitters, patch panels, etc and by looking up the insertion loss of each of these devices, we can easily determine if they can be employed in our system. If the loss budget is exceeded, we might need to choose a more powerful laser option.

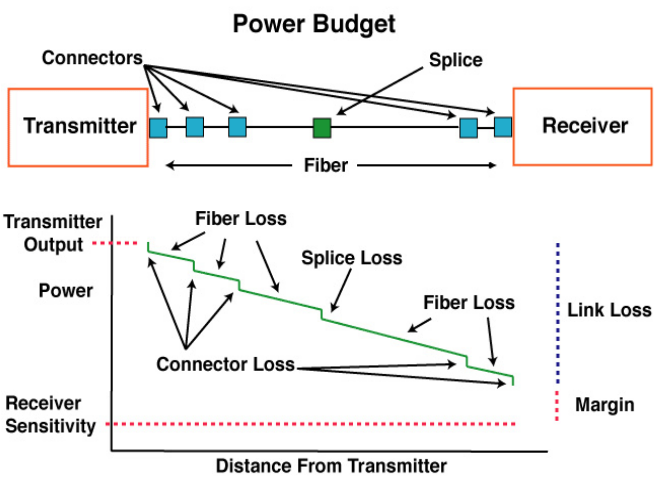


Figure 1-22: Power Budget

a. Calculate fiber loss at the operating wavelengths (length time's standard estimates of loss at each wavelength)

Cable Length (km)	2.0	2.0	2.0	2.0
Fiber Type	Multimode		Singlemode	
Wavelength (nm)	850	1300	1300	1550
Fiber Atten. (dB/km)	3 [3.5]	1 [1.5]	0.4 [1/0.5]	0.3 [1/0.5]
Total Fiber Loss (dB)	6.0 [7.0]	2.0 [3.0]	0.8 [2/1	0.6 [2/1]

b. Connector Loss

Multimode connectors will have losses of 0.2-0.5 dB typically. Single mode connectors, which are factory made and fusion spliced on will have losses of 0.1-0.2 db. Field terminated single mode connectors may have losses as high as 0.5-1.0 db. Let's Calculate it at both typical and worst case values.

Connector Loss	0.3 dB (typical adhesive/polish connector)	0.75 dB (prepolished/splice connector and TIA-568 max acceptable)
Total # of Connectors	5	5
Total Connector Loss	1.5 dB	3.75 dB

(All connectors are allowed 0.75 max per EIA/TIA 568 standard)

Many designers and technicians forget when doing a loss budget that the connectors on the end of the cable plant must be included in the loss budget. When the cable plant is tested, the reference cables will mate with those connectors and their loss will be included in the measurements.

Splice Loss

Multimode splices are usually made with mechanical splices, although some fusion splicing is used. The larger core and multiple layers make fusion splicing about the same loss as mechanical splicing, but fusion is more reliable in adverse environments. Figure 0.1-0.5 dB for multimode splices, 0.3 being a good average for an experienced installer. Fusion splicing of single mode fiber will typically have less than 0.05 dB (that's right, less than a tenth of a dB!) All splices are allowed 0.3 max per EIA/TIA 568 standard)

Splice Loss	0.3 dB
Total # splices	1
Total Splice Loss	0.3 dB

5. GIS (Designing & Planning)

5.1. Introduction

A Geographic Information System or GIS is a computer system that allows you to map, model, query, and analyze large quantities of data within a single database according to their location. GIS gives you the power to:

1. create maps
2. integrate information
3. visualize scenarios
4. present powerful ideas, and
5. develop effective solutions

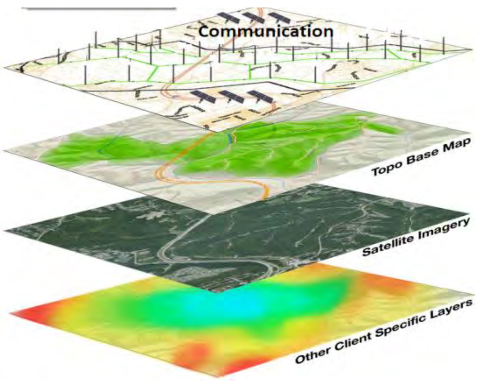


Figure 1-23: GIS

GIS is a tool used by individuals and organizations, schools, governments, and businesses seeking innovative ways to solve their problems. GIS stores information about the world as a collection of layers that can be linked together by a common location component such as latitude and longitude. These geographic references allow you to locate features on the earth's surface for analysis of patterns and trends.

5.2 Designing and Planning

In order to plan and design FTTX network in GIS system, we need to have topographical map in GIS or CAD format of that area consisting of spatial features like road network, building structures, footpath, drainage, utilities etc. Satellite images overlaid on roads are much better, like “Google Maps” in creating a route map is the first step.

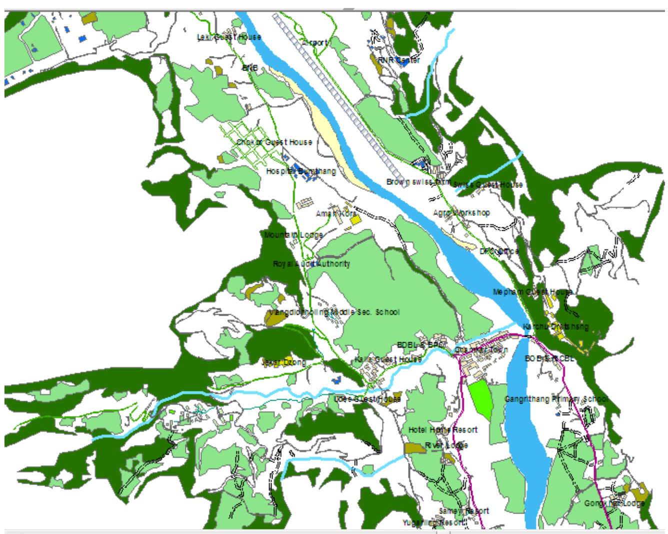


Figure 1-24: Topographic map

5.3 Projection OR Coordinate System

Projection is the next step we should process in GIS system to bring all the spatial features in the same coordinate system i.e. Drukref parameters to have accurate information and measurement on the real ground.

5.4 Design procedures

Before we get into designing part It is very important to know all the existing network information of that area and further to make a joint field visit is one of the vital task that we have to carry out in presence of other utility agencies and also to check the other utilities to prevent contractors from damaging currently installed pipes and cables.

5.5. Data Collection

GPS is an excellent data collection tool for creating and maintaining a GIS. It provides accurate positions for point, line, and polygon features. By verifying the location of previously recorded sites, GPS can be used for inspecting, maintaining, and updating GIS data. GPS provides an excellent tool for validating features, updating attributes, and collecting new features.

In terms of BTL, we consider towers, pole Joint boxes, cabinets and exchanges as point features, Primary cable, secondary cables and Fiber Optic cables as line features by creating its data dictionary (attribute tables) in GPS.

GPS data overlaid on satellite Image

Figure 1-25: DGPS & Satellite

5.6. Data Conversion

Raw data from GPS is imported from GPS to GIS platform for further analysis in designing the FTTX network. Once we have collected all the existing infrastructures, it is very easy to overlay the data on topographical map so that we can integrate multiple information to visualize overall scenario, present powerful ideas plan and develop effective solutions

5.7. Demand Forecast Analysis

Based on demand forecast with respect to locations, we have plot on the GIS map to sum up and analyse such as, how many customers wanted to avail our FTTX services like FTTC, FTTB and FTTH. As per the demand forecast we have to calculate how many potential customers are there for both voice and data, demand in current scenario, and demand after 5 years, 10 years and 20 years based on current populations and development to undertake in near future.

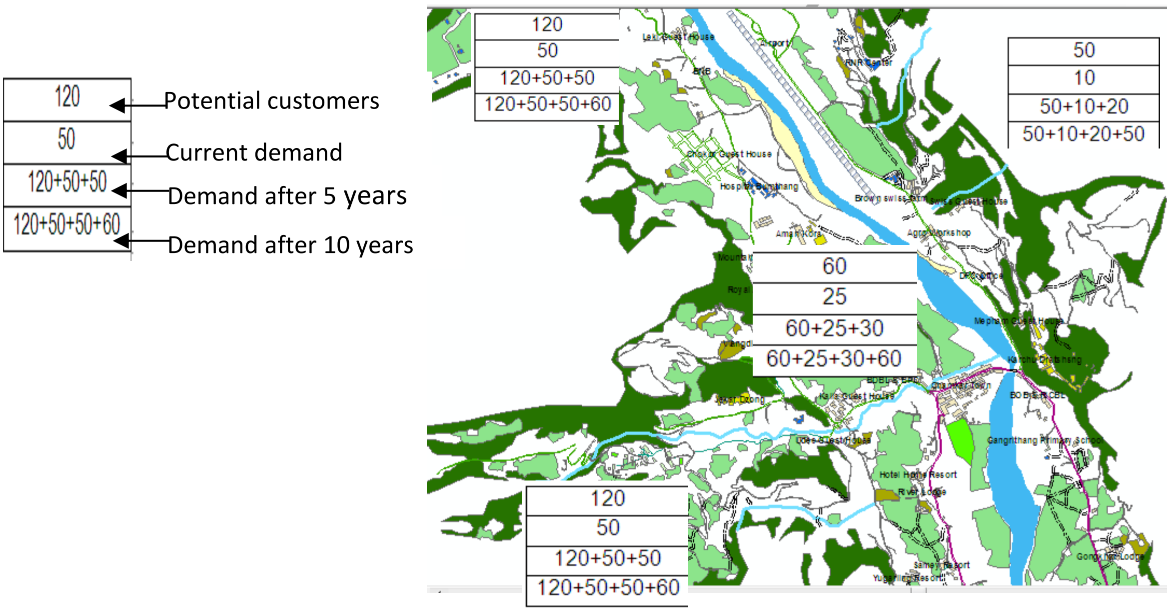


Figure 1-26: Demand Forecast

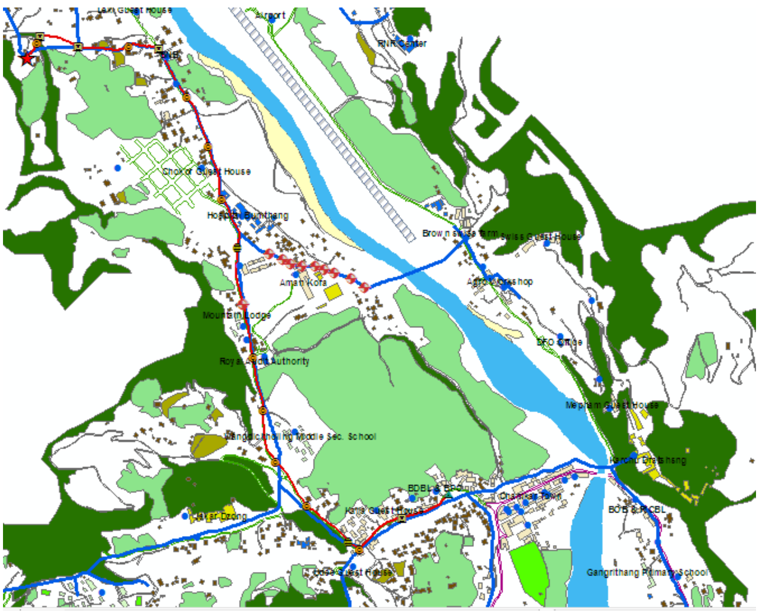


Figure 1-27: Superimpose of Btl infra

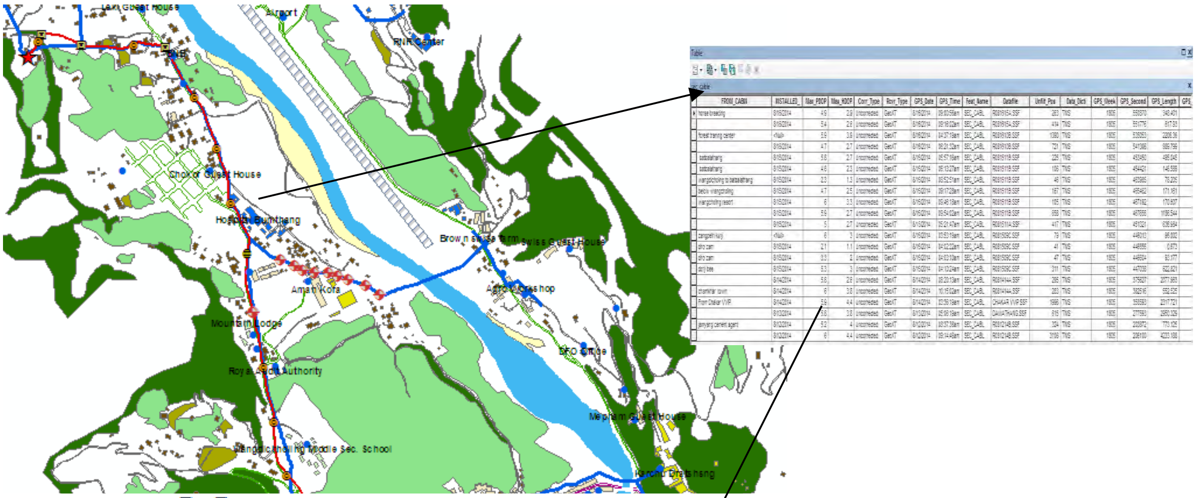
After calculating the overall demand forecast of the location we have to design the suitable network topology that meets the customers demand.

5.8. Adding Features and components

After the existing data is digitized and overlaid on the topological map consisting of feeder cable, distribution cables, joint boxes and number of poles used. We can find out the distance of both the cables, distance between each junction box. Having all the existing network information in the GIS system, we can easily add additional network by digitizing line features for both feeder and distribution cable as per the demand forecast.

5.9. Features and Attributes

Each features generates its own attributes based on data dictionary created at initial stage in DGPS. All the information on particular feature exist in attribute table. Report on each feature can be generated from the attribute table for further analyses.



Primary cable

FID	INSTALLED_	GPS_Length
0	12:00:00 AM	2918.424
1	12:00:00 AM	138.271

Average GPS_Length 1528.348 Count GPS_Length 2 Max GPS_Length 2918.424 Standard Deviation GPS_Length 1965.865

Sum GPS_Length 3056.695

Secondary cable

		GPS_3DLeng
27	12:00:00 AM	715.191
28	12:00:00 AM	494.026
29	12:00:00 AM	104.474
30	12:00:00 AM	93.542

Average GPS_3DLeng 1010.712 Count GPS_3DLeng 31 Max GPS_3DLeng 5842.683 Min GPS_3DLeng 71.533

Standard Deviation GPS_3DLeng 1114.056 Sum GPS_3DLeng 31332.065

Figure 1-28: Data Analysis

The above report shows the total length of the feeder and distribution cable for whole network after digitizing additional feature covering all the FTTX network.

Total Distance coverage and the demand forecast helps designer to choose the FTTX architecture, length of new cables, allocation of street cabinets, total no. of splitters, length of drop cables, enclosures , end terminals etc. i.e. through calculating the power loss as per standard mentioned earlier.

5.10. Schematic Diagram

As per the data and network analysis in GIS system designer will prepare the Schematic diagram especially for the construction engineering section. All the cables and FTTx components are included in the schematic diagram for easy understanding of network architecture for installation team.

Installation team will carry out the installation work as per the schematic network diagram and if any changes does occur during the installation, it has to inform the designer and update for the same in the GIS system as well.

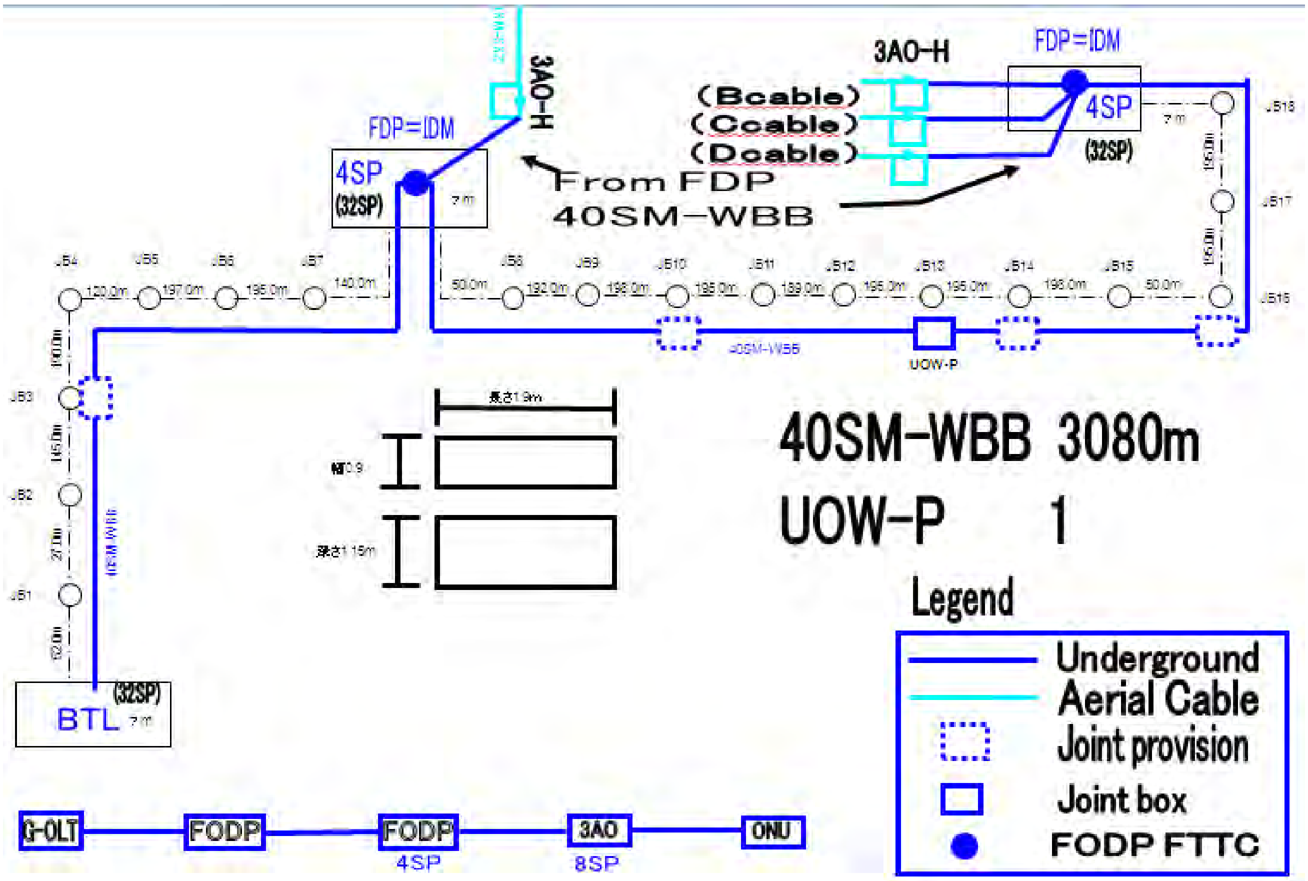


Figure 1-29: Underground Design (Jakar Trial Site)

5.10.1 Underground Designing

The above schematic diagram shows the lay structures of 40 core single mode fiber optic underground primary cable (40SM-WBB) from the BTL to last cabinet shelter having a distance of 3080 meters in length.

Designer has included two street cabinets (FDP-IDM) within 1.5 km range and used 1:4 splitter in each cabinets and used aerial cable for distribution to customer premises. As per the collected data records we have 18 numbers of Joint boxes having different distance in between each JB. It is necessary to keep the provision of joints in between for future use and has kept four points at different identified points.

5.10.2 Aerial Designing

As per the designer recommendation 24 core single mode fiber cable is enough to meet the customer demand which we have worked out earlier. And thus to cater to all the existing customers and current demand forecast, designer used two number of 1:8 aerial splitter for a distance of 5.5 km within secondary distributions.

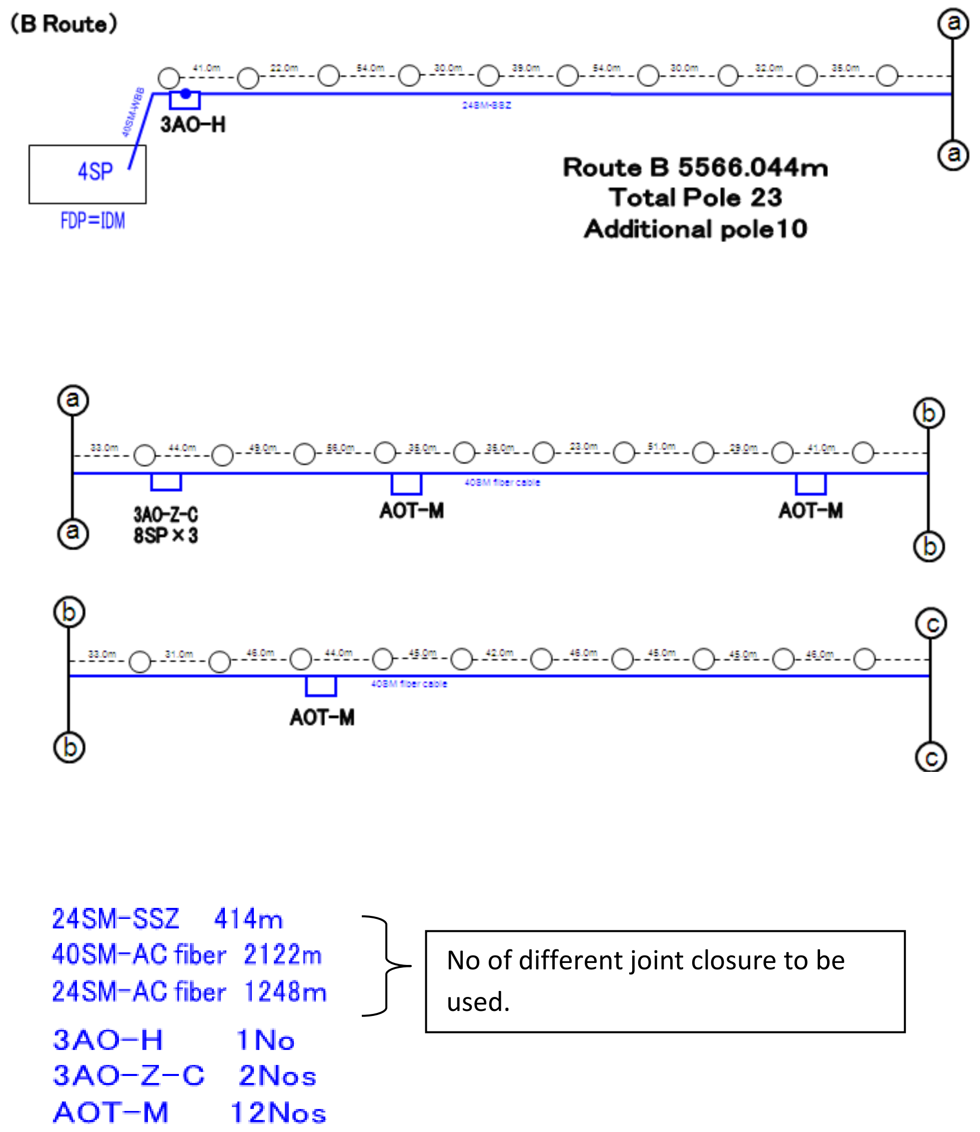


Figure 1-30: Aerial Design

5.10.2a Detail Distribution of underground Fiber optic cable

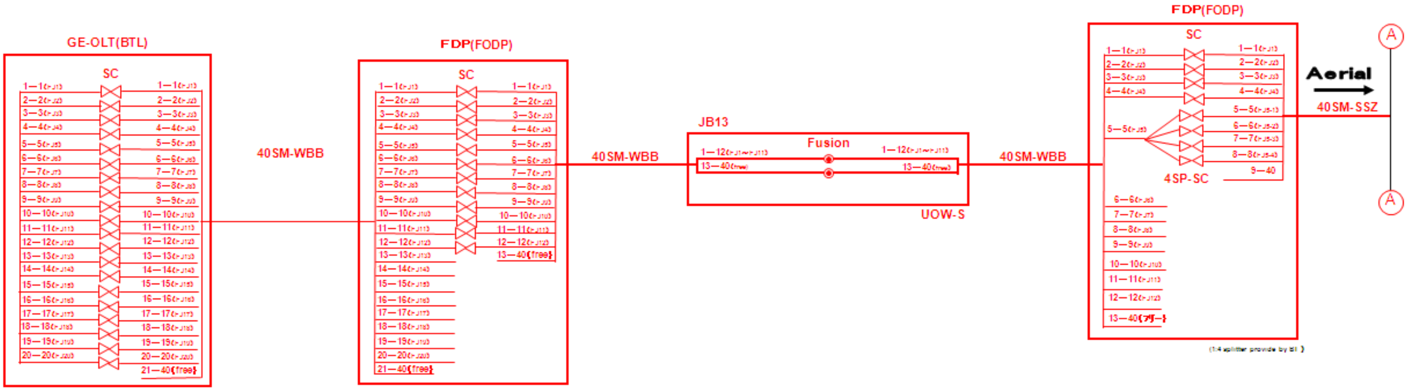


Figure 1-31: Fiber Distribution Format (Underground)

The main aim and objectives of designing the underground fiber cable distribution is to know and understand how many core and what cores are connected to each subscribers. It helps in tracing out the cables while carrying out the operation and maintenance. Besides, easy planning and designing of network in the future.

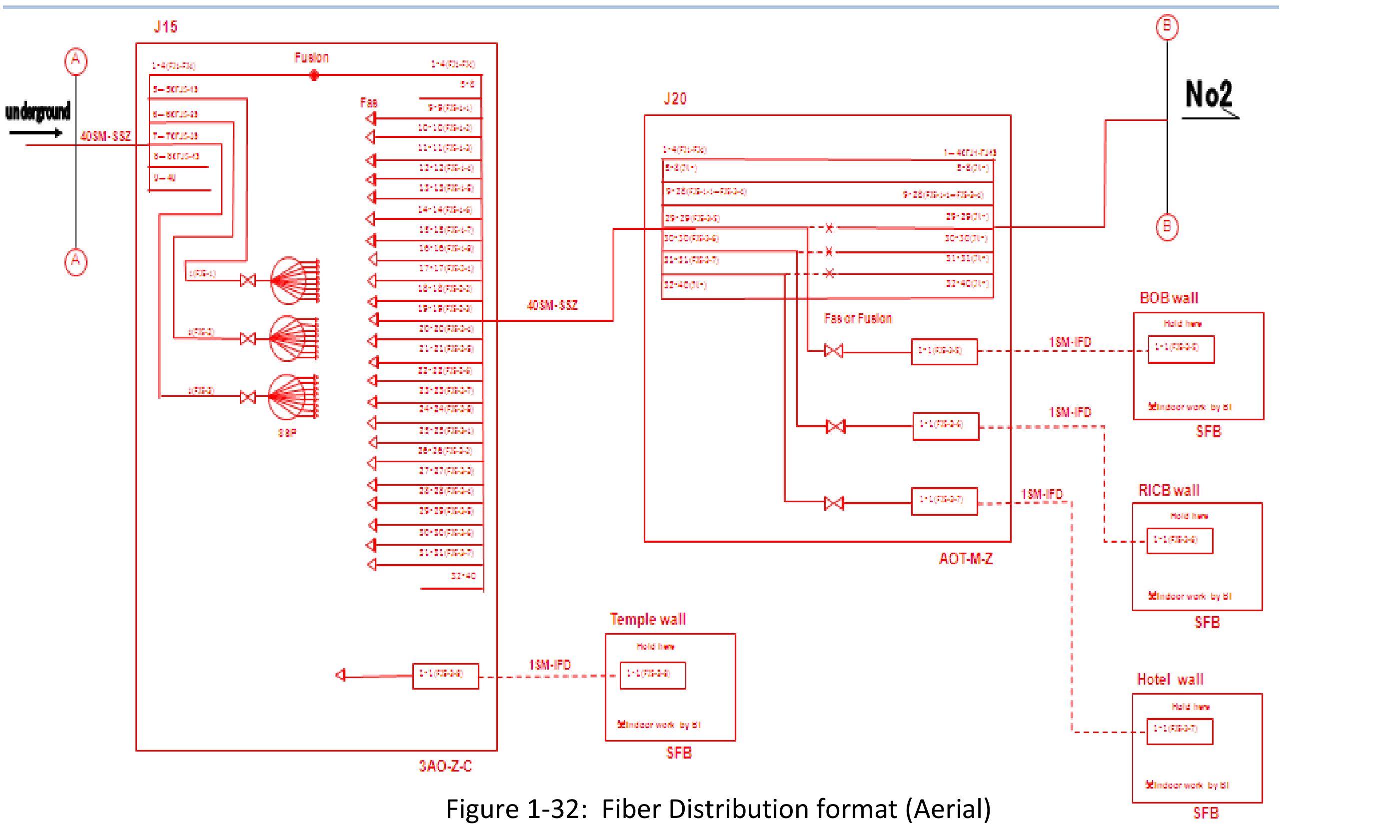


Figure 1-32: Fiber Distribution format (Aerial)

5.10.2b Detail Distribution of Aerial cable

It is very important for a designer to make a fiber cable distribution as per the network layout and provide to the construction engineer. Construction engineer should follow and carry out the work as per the distribution format submitted by the design engineer and keep the record for operation, maintenance and future reference.

The same data record needs to be updated in the GIS system so that it can be useful for further designing and planning of network as and when required.

5.11 Actual Estimate for Cables and Accessories

After completing the network design for underground and the aerial cable it is always important to work out for actual requirements of cables and accessories by keeping some standard tolerance.

The main aim and objective of analyzing such procedure is that we get actual cable length required for identified area by avoiding wastage and access materials and accessories.

5.11.1 Underground cable ref: sheet 01

While laying underground cable it is very important to keep every cable slack in the joint box and during designing phase considering the cable slack is a priority measures that we should include while working out the actual length of the cable.

5.11.2 Aerial cable ref: sheet 02

During the installation, always remember to keep the appropriate cable slack when cable is clamped on the pole, whereby the slack is to be considered while calculating the actual length.

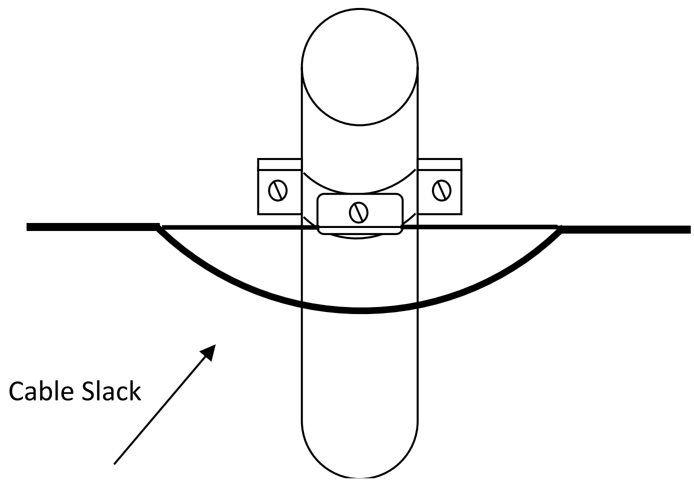


Figure 1-33: Cable Slack

5.11.3 Identify the Safety measures

During the Designing Phase, always identify the safety work place and indicate where there is a risk while carrying out the job. Before installation, designer should brief the safety measures and submit the map indicting where the risk involves such as.

1. Pole corrosion(damage of pole)
2. Where there exists high voltage in line with the services.
3. Corrosions of stay and guy grip, tension etc.
4. Avoid tensioning cable over roof top.
5. Warn regarding the toxic gas inside manhole and hand hole.
6. Indication of underground utilities.

5.12 Documentation

The documentation process begins at the initiation of the project and continues through to the finish. It must begin with the actual cable plant path or location. OSP cables require documentation as to the overall route, but also details on exact locations, e.g. on which side of streets, which cable on poles, where and how deep buried cables and splice closures lay and if markers or tracing tape is buried with the cable. Premises cables require similar details inside a building in order for the cable to be located anywhere in the path.

Most of this data can be kept in GIS or CAD drawings and a database or commercial software that stores component, connection and test data. Long outside plant links that include splices may also have OTDR traces which should be stored as printouts and possibly in computer files archived on disks for later viewing in case of problems? A computer with proper software for viewing traces must be available, so a copy of the viewing program should be on the disks with the files. If the OTDR data is stored digitally, a listing of data files should be kept with the documentation to allow finding specific OTDR traces more easily.

Documentation is more than records. All components should be labeled with color-coded permanent labels in accessible locations. Once a scheme of labeling fibers has been determined, each cable, accessible fiber and termination point requires some labeling for identification. A simple scheme is preferred and if possible, explanations provided on patch panels or inside the cover of termination boxes.

5.12.1. Protecting Records

Cable plant documentation records are very important documents. Keep several backup copies of each document, whether it is stored in a computer or on paper, in different locations for safekeeping. If a copy is presented to the customer, the installer should maintain their own records for future work on the project. One complete set on paper should be kept with a “restoration kit” of appropriate components, tools directions in case of outages or cable damage. Documentation should be kept up to date to be useful so that task should be assigned to one on-site person with instructions to inform all parties keeping copies of the records of updates needed. Access to modify records should be restricted to stop unauthorized changes to the documentation.

NEW CONNNNECTION FLOWCHART

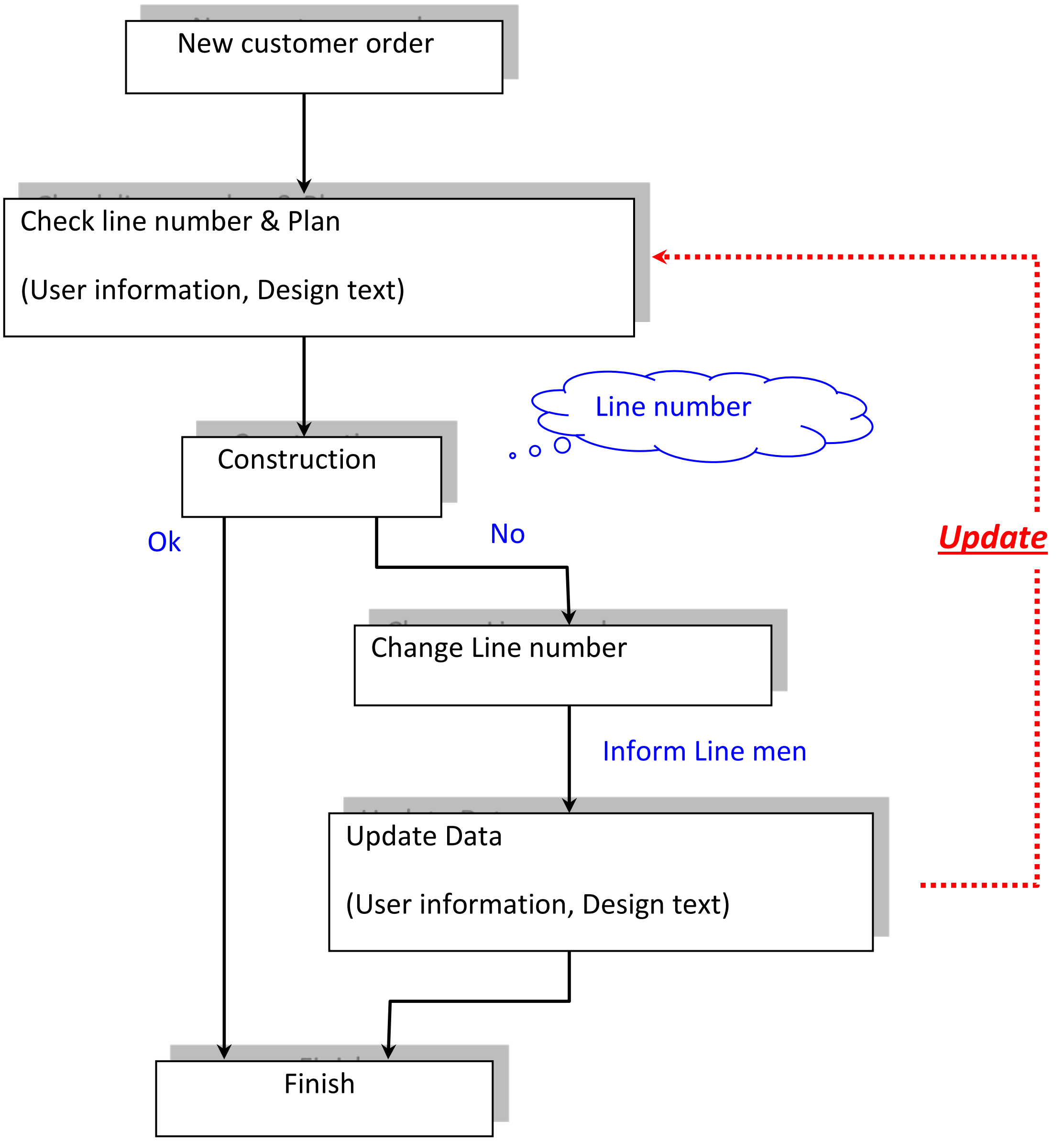


Figure 1-34: DGPS & Satellite

CHAPTER – II

FTTX CONSTRUCTION

CONTENT Page

1. Installation of Optic fiber cable

Fiber optic cable may be installed indoors or outdoors using several different installation proce Outdoor cable may be direct buried, pulled or blown into conduit or inner duct, or installed aerial between poles. The installation process will depend on the nature of the installation and the type of cable being used. Installation methods for both wire and optical fiber communications cables are similar. Fiber cable is designed to be pulled with much greater force than copper wire if pulled correctly, but excess stress may harm the fibers, potentially causing eventual failure.

Table 2-1:

Standard check List of New Items

・To be use at: ______

・Specification: ______

Remarks		OK?NO	OK・NO	Verified by	

Items	Items status	Checked Items OK/NO	Date	Name	OK/NO	Date	Name
・cable	・Damage or not?						
	・Total lenth(include attached list)						
	・Specification						
	・Cable cap include or not?						
・Materials	・Nut&bolt include or not?						
	・Is bolt with proper thread to close/ope						
	・damange or not?						
	・Is materals adjust as per specification?						
	・Is maerials rust or not?						
・Cabinet	・Damage or spoil?						
	・Are all parts abailable or not?						
	・Materials do open/close properly or no						
	・Is materials bend or not?						

・Mark circule on OK status and write remarks if the materials is not in good condition

Damaged/spoiled materials

Date	Remarks on damaged items

Damaged/spoiled materials

Date	Remarks on damaged items

1.1 Standard Check list for new Items

The table shows the list of new items to be check and verified by the managers and supervisor before the actual work is implemented. The status of the materials is to be entered in the form and submit to the concerned authority whether or not the materials are transported in good condition and include all the required materials are intact as per the specification designed.

1.2 General Guidelines

The following contains information on the placement of fiber optic cables in various outdoor environments. In general, fiber optic cable can be installed with many of the same techniques used with conventional copper cables. Basic guidelines that can be applied to any type of cable installation are as follows:

- Conduct a detailed site survey prior to cable placement.
- Develop a cable pulling plan.
- Follow proper procedures.
- Do not exceed cable minimum bend radius.
- Do not exceed cable maximum recommended load.
- Document the installation.

2. Installation of Duct cable

The condition and geometry of duct routes is of great importance. Where the infrastructure includes ducts in poor condition, contains excessive curve, includes ducts already containing cables or access points, the maximum pull distance will be reduced accordingly. Provision of long cable lengths in underground duct situations may involve installation methods that require access to the cable at intermediate points for the application of figure-of-eight techniques.

2.1. Tools and Materials for duct cable installation

The tools and materials for the installation of duct cable are shown in the Table 1 and Table 2

Table 2-2: Tools for duct cable installation

Name of Tools	Function
Cable Jack and roller	Reeling out the cable drum
Cable grip	To grip the cable
Pulling rope	Pulling the cable
Cable roller	Rolling the cable smoothly into trench
Cable cutter	Cutting the cable
Nipper / Plier	Cutting wire
Fiber duct rod	Roding the cable inside the duct
Gas Detector	Checking the Man hole before entering from poisonous gas
Safety corn	For safety purpose use
Transceiver(Handy Talkie)	Proper communication while pulling cable

Table 2-3: Materials for duct cable Installation

Name of materials	Function
PVC tape	Sealing the end of cut cable
Galvanized iron wire	Tie the cable end and making cable pulling end
Guy Grip	For pulling the cable

2.2 Procedure of Duct Cable Installation

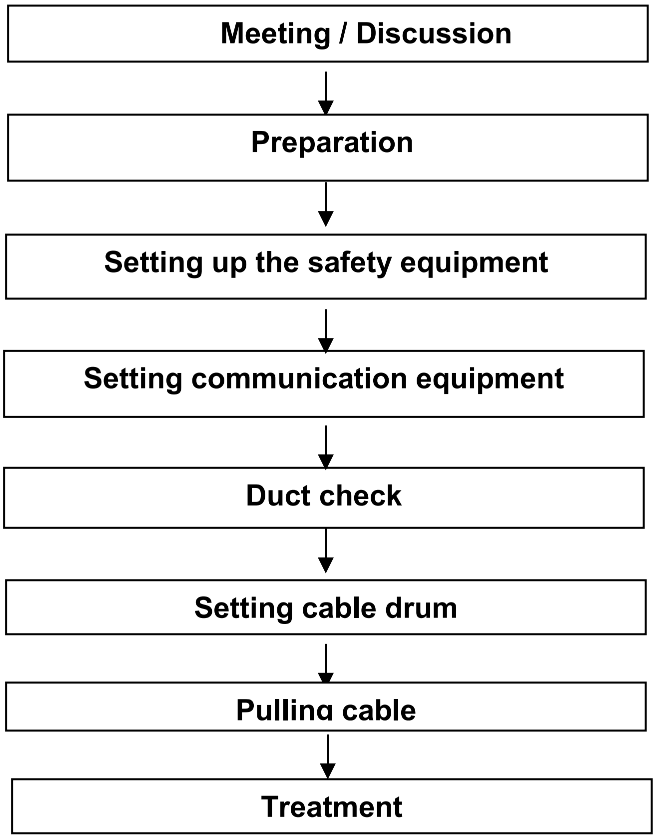


Figure 2-1: Working Flow

2.2.1 Meeting / Discussion

Supervisor and working staff confirm the working schedule for that day as schedule. They should discuss about the safety measure that should be taken while working for a successful completion of their work plan.

General information.

2.2.2 Preparation

Preparation refers to transportation of materials and tools prior to installation that are to be used during the installation of cable. It is more effective if we do the same preparation for all the installation work like aerial and direct buried installation. Moreover it is important to check the joint box, duct and traffic condition. It is recommended that the joint box should be checked before getting inside from a poisonous gas.

2.2.3 Setting up safety equipment

Before installation work is put into place, the construction materials, tools, warning signs and safety are to be placed effectively. For more detail refer to the safety manual.

2.2.4 Setting communication equipment

We should have communication equipment (Handy talkie) in order to avoid accident in the joint box.

2.2.5 Duct check

Duct check consist of “Rodding” ,“Duct cleaning” and Duct Test

a. Rodding

In the installation work of duct cable, the first thing to do is rodding. It is passing the steel wire or rope into a duct for a smooth pulling of cable. While rodding is in place the person on the next joint box should be taking extreme care in order to avoid accident, like peeping through duct and taking your ear close to the duct. Roding may be required to verify duct suitability and accurate length.

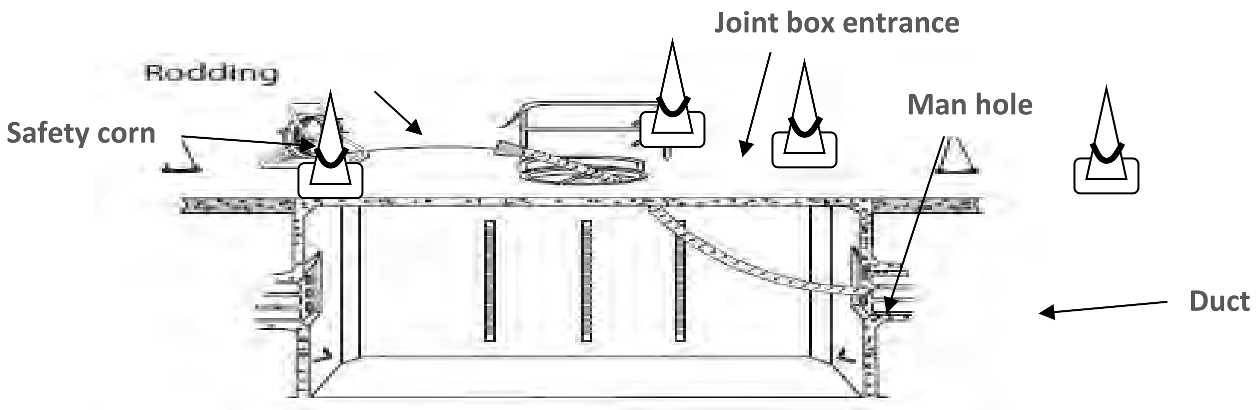


Figure 2-2: Rodding fiber from one man hole to joint box hole

Based upon the preparation and safety, develop a fiber rodding plan. See in Figure 2-2

b. Duct cleaning and Duct test

After rodding work finished, clean the surface of duct by using rodding steel wire. The purpose of cleaning is to remove the mud and small obstacles, besides checking the condition of the duct for bending in order to make the cable installation easy.

2.2.6 Setting cable drum

The cable jack should be placed properly on the plain surface area in order to avoid from falling while pulling cable and also the cable drum should be placed straight to the joint box to avoid cable bend. The direction of the arrow point of a cable drum should be placed to the joint box direction for pulling see in figure.3

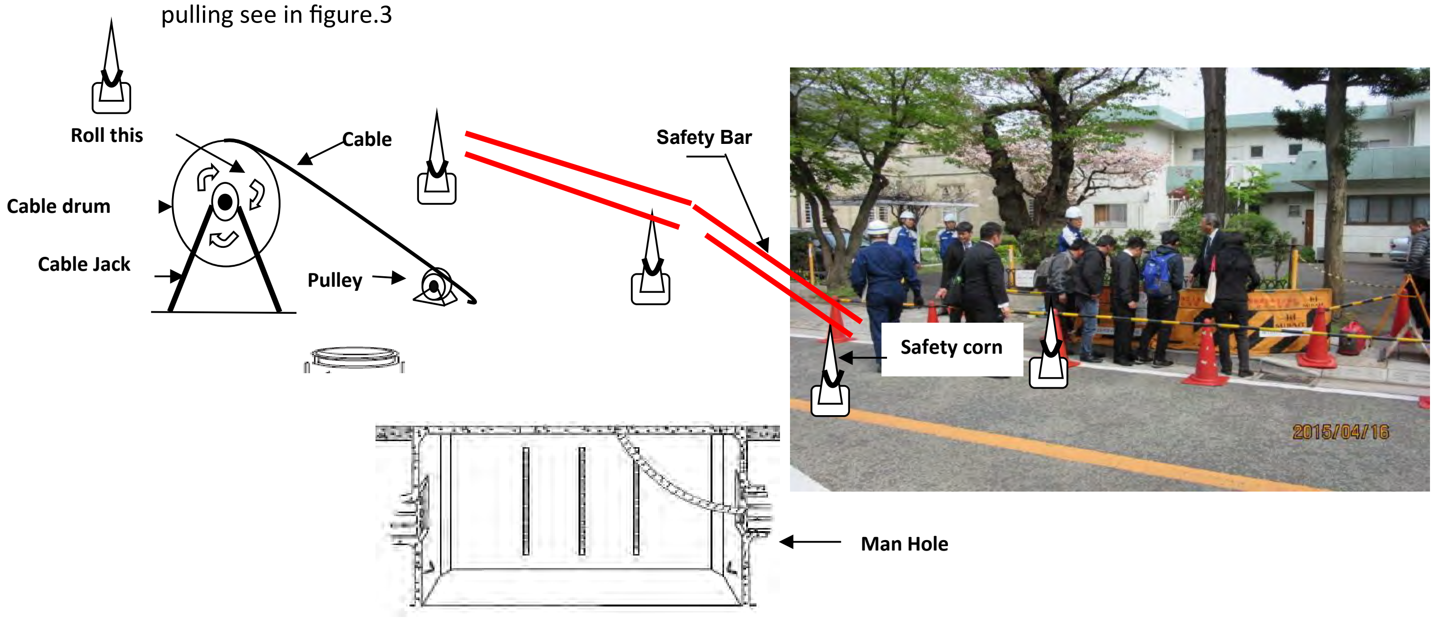


Figure 2-3 Cable Drum Setting

2.2.7 Pulling cable

a. Pull the cable gradually. During the work, communicate each other (Pulling cable site, Cable drum side) by communication equipment and keeping each staff on the appropriate site. See in Figure.4

b. The Figure – eight techniques is used between the joint box to joint box on the expected distance of 1 km. The figure-eight techniques should be used to prevent twisting when the cable must be unreeled.

c. Whenever unreeled cable is placed on the pavement or surface above a joint box, provide safety corn or other means of preventing vehicular or pedestrian traffic through the area.

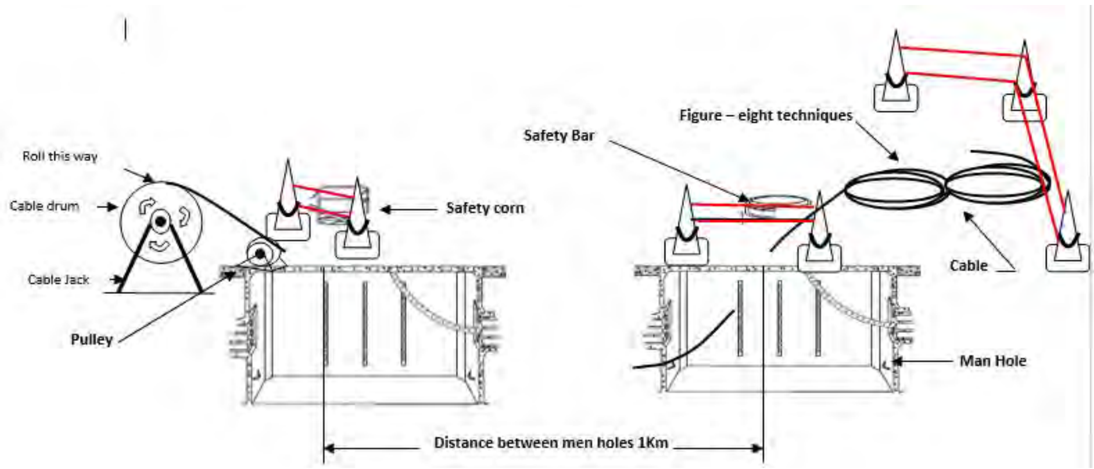


Figure 2-4: Distance between man holes to man hole using figure-eight techniques

2.2.8 Treatment

After the pulling of cable is completed then we should use insulation tape to bind the cable at the edge of the cable from entering water or moist inside the cable core. The cable should be properly looped inside the joint box and it should be properly mount with the help of cable tie. Make sure when making loop the standard bending radius must be maintain, see Fig.6

At splice points, pull sufficient slack (typically 40 ft [12 m] of slack from the edge of the joint box) to reach the intended splicing location, plus enough slack to permit closure preparation and splicing.

While pulling cable from joint box to joint box we should keep extra length of cable inside the joint box and mount the cable on the joint box wall. See figure 5 to avoid from falling heavy and sharp object inside the joint box and damage the cable underneath. Besides, there is also high risk of damaging the existing cable when new cables being pull from the same duct.

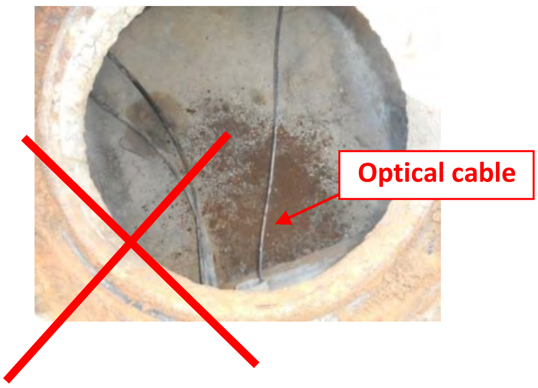


Figure 2-5: No extra fiber cable maintain inside the joint

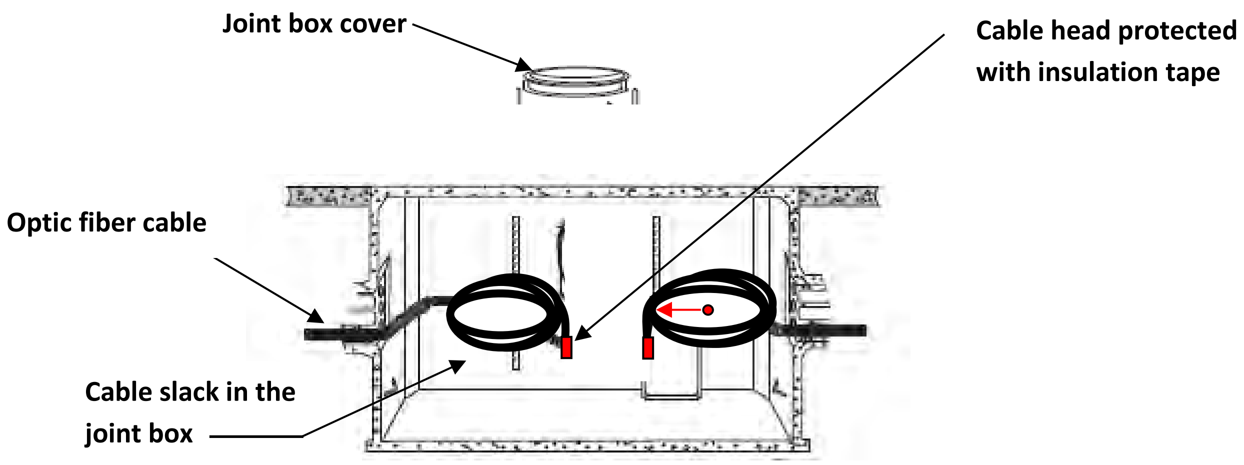


Figure 2-6: Treatment of Cable inside the joint box

Begin racking at the center manhole and proceed to the end joint box. Maintain the cable specific minimum bend radius.

Inspect joint box in which cables will be spliced and make plans for closure and cable slack racking. Fiber optic cable must be protected in intermediate joint box. Carefully choose racking space so that it will provide maximum protection for the cable and maintain its minimum bend radius.

2.3 Cable Binding radius

As per the Corning Cabling Systems' cable specification sheets also list the minimum cable bend radius. It depends upon the size of cable when we calculate the bending radius. To arrive at a working bend radius for cable installation, multiply 20 times (20 x) the cable outside diameter.

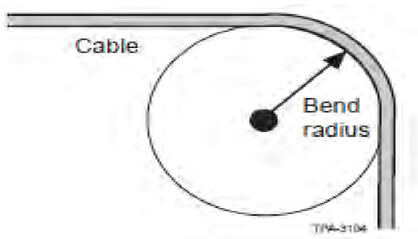
Example:

Cable Diameter = 0.46 in (11.8 mm)

20 x 0.46 in = 9.2 in (234 mm)

Minimum Working Bend Radius = 9.2 in (23.4 cm)

To find the minimum diameter requirement for pull wheels or rollers, simply double the minimum working bend radius.



2 X 9.2 in =

18.4 in (46.7 cm)

During pulling of cable if the pulley / roller is not sufficient then we should gradually pull the cable maintaining the minimum bending radius.

2.4 Minimum Bend Radius

Excessively sharp bends can damage fibers within fiber optic cable and render the cable useless. The minimum bend radius for both tensioned and no-tension conditions is stated on the cable specification sheet. These values can also be determined using Table 1.

Table 2-4 Minimum Bend Radius

Minimum Bend Radius					
Cable Component Diameter		Minimum Bend Radius (No Tension)		Minimum Bend Radius (Under Tension)	
Millimeters	Inches	Centimeters	Inches	Centimeters	Inches
6.0 -10.0	1/4 - 3/8	10.0	4	15.0	6
10.0 - 15.0	3/8 - 9/16	15.0	6	22.5	9
15.0 - 20.0	9/16 - 13/16	20.0	8	30.0	12
20.0 - 23.0	13/16 - 7/8	23.0	9	34.5	13 1/2
23.0 - 25.0	7/8 - 1	25.0	10	37.5	15

3. Installation of Aerial cable

This procedure provides general information for the installation of aerial cables. Placement methods for fiber cable are very similar to those of strand-supported copper cable. However it must be kept in mind that fiber optic cable is a high capacity transmission medium which can have its transmission characteristics degraded when subjected to excessive pulling force, sharp bends, and crushing forces. These losses may not be revealed until long after installation is complete. For these reasons extra care must be taken during the entire installation procedure.

3.1 Tools and Materials for aerial cable installation

The tools for the installation of fiber aerial cable are shown in the Table 2-5

Table 2-5: Tools for fiber aerial cable installation

Name of Tools	Function
Pulley for aerial cable	Cable role on the pole
Cable grip	To grip the cable at every end
Tension vice	Aerial cable pulling instrument
Cable jack	To set the cable drum
Transceiver(Handy Talkie)	Proper communication while pulling cable
Ladder	To work on the pole
Cable cutter	Cutting the cable
Adjustable wrench	Fastening the nut and bolts
Nipper / Plier	Cutting wire
Safety belt	Safety while working on the pole
Safety corn	For safety purpose use
Wab cutter	To separate the cable messenger and cable

The Materials for the installation of fiber aerial cable are shown in the Table 6

Table 2-6: Materials for the Installation of aerial fiber cable

Name of materials	Function
Cable clamp	Support the cable on pole
GI Wire	Tie up the pulley
Guy grip	Connect the cable to the pole
Pole band	Support the cable clamp
PVC tape	Wrap the end of the cable

3.2 Procedure of Aerial Cable Installation

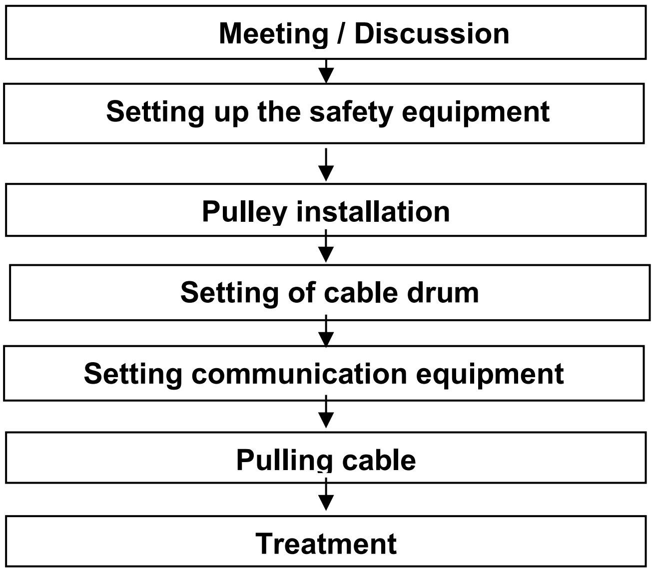


Figure 2-7: Work flow of fiber aerial cable installation

3.2.1 Meeting and Discussion.

a. Discuss how to carry out the work, importance and safety measures, and appointment of team leader and distribution of work.

b. Discuss how to carry out the work without having any problem at the site.

3.2.2 Setting up the safety equipment.

a. Check the pole before climbing the pole

b. Use proper tools

3.2.3 Pulley installation.

a. Attached a pole strap at the pole and hang pulley (10 cm from the top of the pole) with the help of GI wire. As shown in Figure 2-8.

b. When we install the cable across the road point, we should install temporary rope and a pulley. As shown in Figure 2-8.

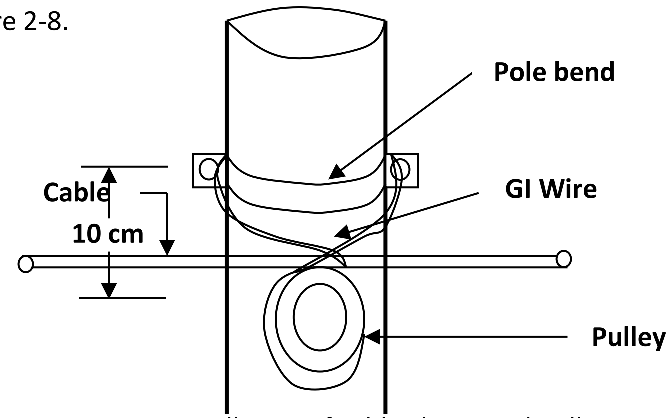


Fig2-8: Installation of cable clamp and pulley

3.2.4 Setting the cable drum.

The entire cable drum shall be set on the cable jack steadily, with straight direction and horizontally as shown in Figure 2-9. Before setting cable drum the site should be properly inspected whether it is label or not.

The cable is pull in the roll this way direction as marked on the cable drum

The edge of the cable which is marked with green must be set to the FODP or at the customer site.

The edge of the cable which is marked with the red must be set to the OLT or switch site.

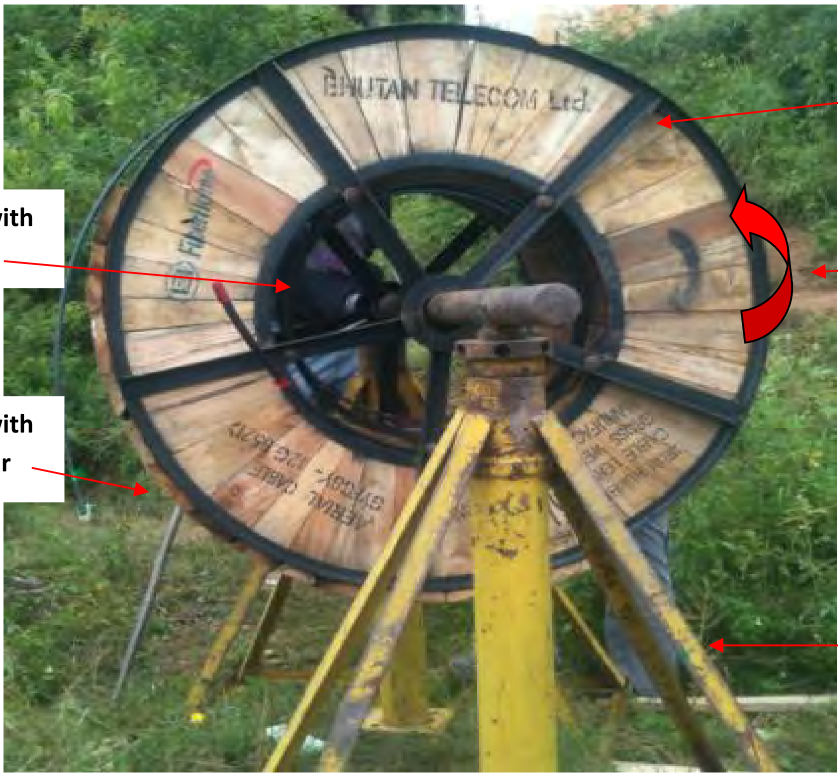


Figure 2-9: setting of cable drum and pulling direction

3.2.5 Setting of communication equipment

We should have a communication equipment (Handy talkie) in order to have a smooth laying of cable and to avoid any accident on the site.

3.2.6 Pulling cable

a. Pull the cable gradually. During the work, communicate each other (Pulling cable site, Cable drum side, and head of the cable side) by communication equipment and keeping each staff on the appropriate site. See in Figure 2-10.

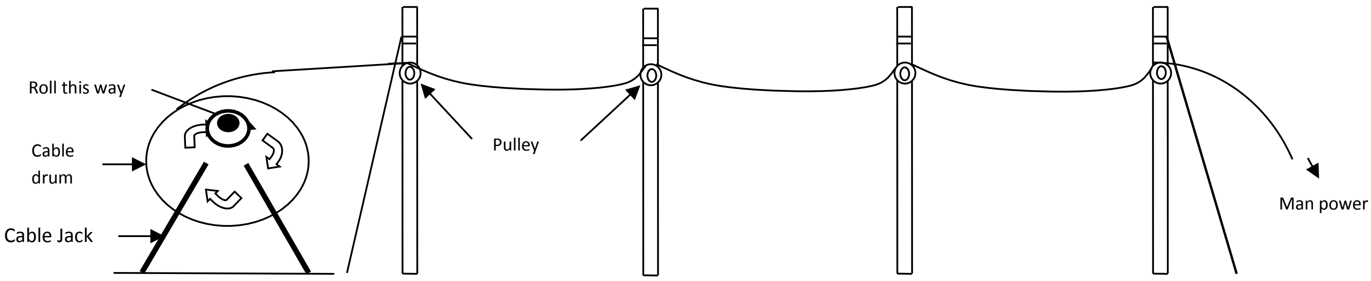


Figure 2-10: Aerial cable pulling

b. Suppose while pulling cable on the road crossing and electric cable, in order to avoid any obstruction use the GI wire at the end of each pole and tie the roller on the GI wire to maintain the pulling height from the road surface as illustrated in Figure 2-11 must be applied. The sag should be of 6 meter from the road surface.

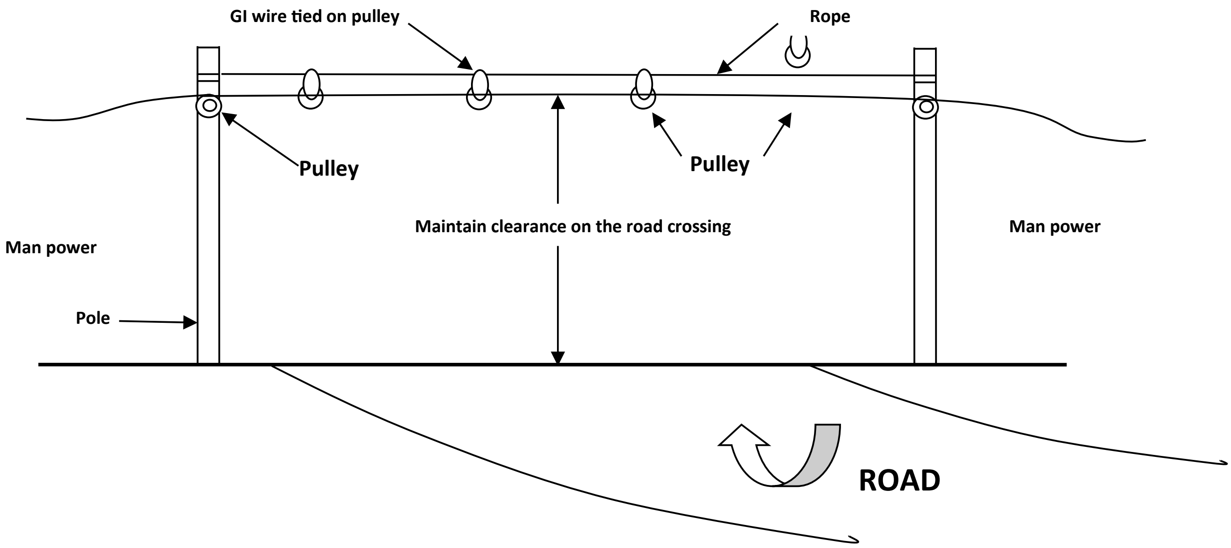


Figure 2-11: Method for crossing road

c. While pulling the cable on the road crossing, we should remember few points.

a. Make sure that the roller is placed in the correct position.

b. The curve point must be watched carefully in order to avoid cable twist. Communicate immediately to stop the pulling work and check the condition and try to put back everything in order.

c. While pulling cable on the sharp curve the minimum bending radius of around twenty times the cable diameter is considered, but when being installed under tension, it is suggested that this ratio should be double, see Figure 2-12.

d. During pulling of cable if the pulley / roller is not sufficient then we should gradually pull the cable maintaining the minimum bending radius.

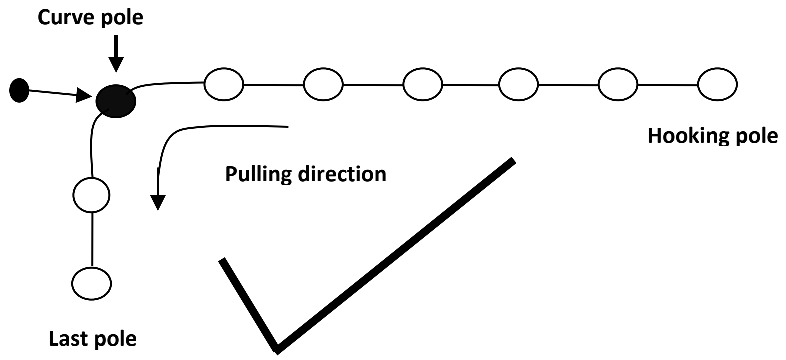


Figure 2-12: Right way of pulling aerial cable direction at a sharp curve

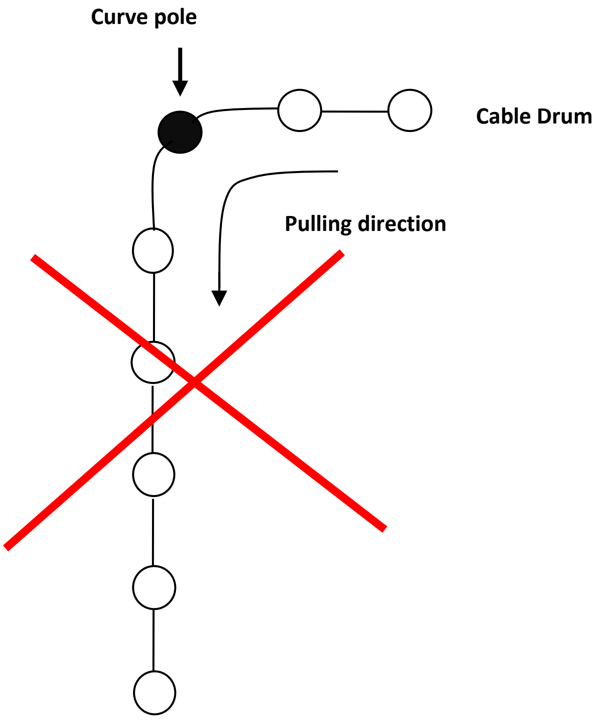


Figure 2-13: Wrong way of pulling aerial cable direction at a sharp curve

3.2.7 Treatment

a. Guy Grip (Wrap-type) Dead-end

The Guy grip consists of spirally formed high strength steel wires which are applied to the bare messenger strand in two wraps (Figure 2-12). The portion of the wires between the two legs forms an eye when installed. This type of dead-end can be used to terminate a messenger strand onto guy hook. See Figure 2-12, how to prepare the cable for this device. It is especially used at the end of the pole and also in between of the pole where we keep the provision for splicing purpose.

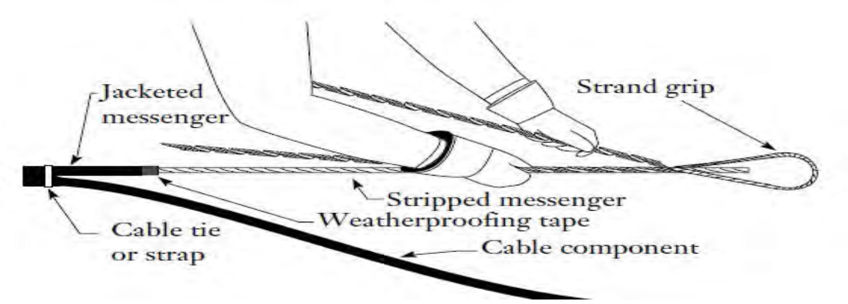


Figure 2-14: steps preparing strand grip

b. Termination of cable on the pole

When we terminate the cable on the pole we should always maintain loop to avoid cable damage. See figure 2-13, with the help of guy grip the cable should be properly tie up on the pole and maintain proper loop and use spiral tube to protect the cable from damage. Where ever there is a crossing of cable, and trees make sure the cables are properly protected by using cable spiral tube.

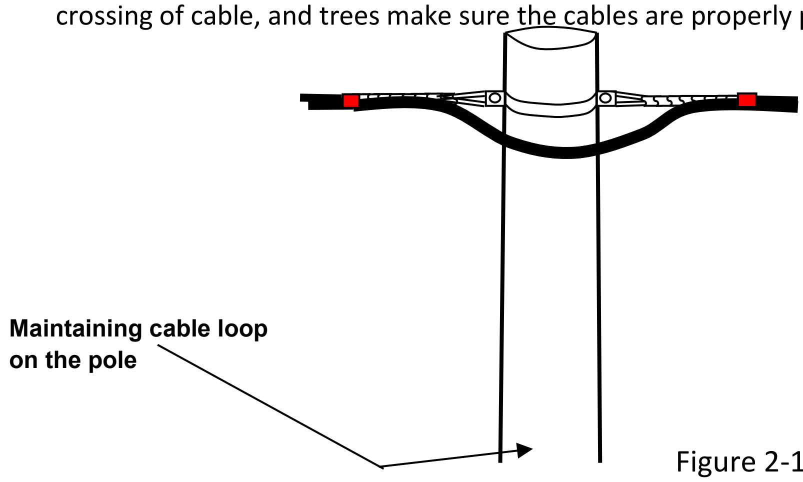


Figure 2-15: cable loop on the pole

If the cables are passing through the trees and bushed the trees should be cut and if it's not possible to cut the tree then we have to use spiral tube in order to protect the cable from damage. See figure 2-17 how to use the spiral tube form protecting cable.

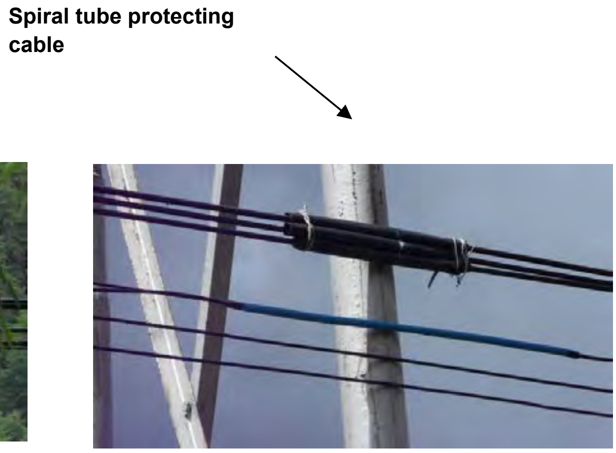
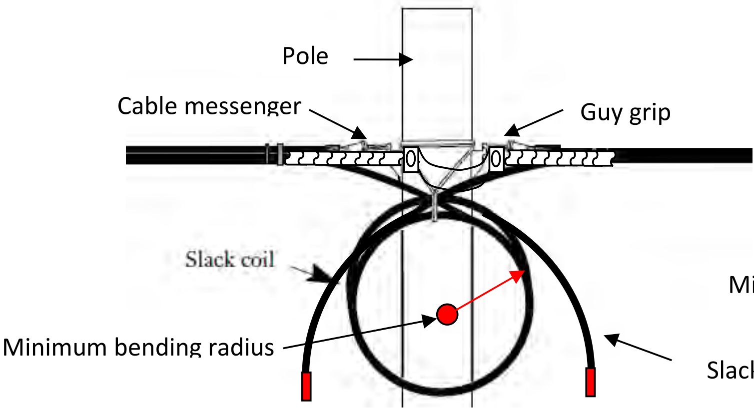


Figure 2-16: Cable passing through trees and bushes &CATV   Figure 2-17: Using spiral tube

C. Provisioning cable for splicing in middle of the pole and end of the pole

Before installing cable clamp to the pole, a pole band and the suspension clamp should be install at 10 cm from top of the pole. The suspension wire of an aerial cable is tied up by the cable clamp. The 7 meter of extra cable should be kept for splicing at every end of the pole.



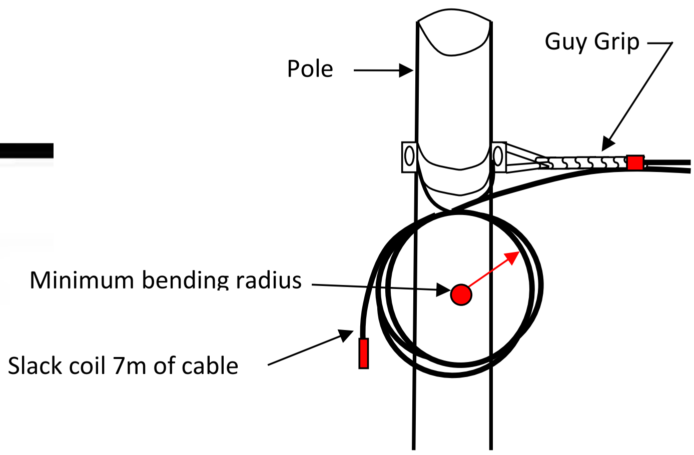


Figure 2-18: Treatment of cable between pole   Figure 2-19: Treatment of cable at the end of pole

D: Method of cable placing after installation of Aerial closure

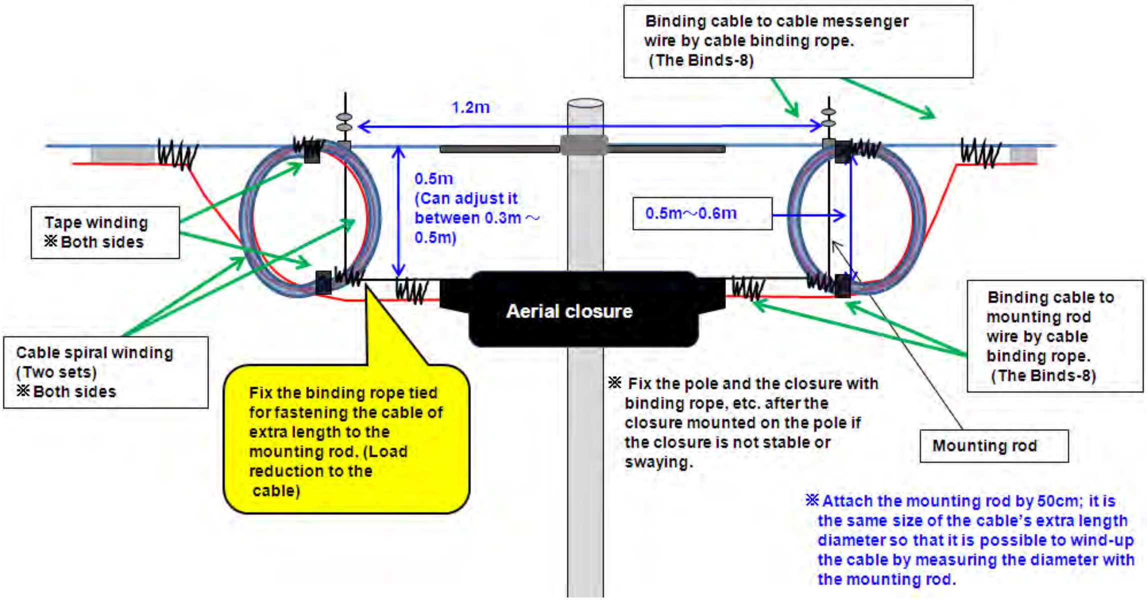


Figure 2-20

E: The drop cable installation

Arrangement of the drop wore extra length and a completed shape

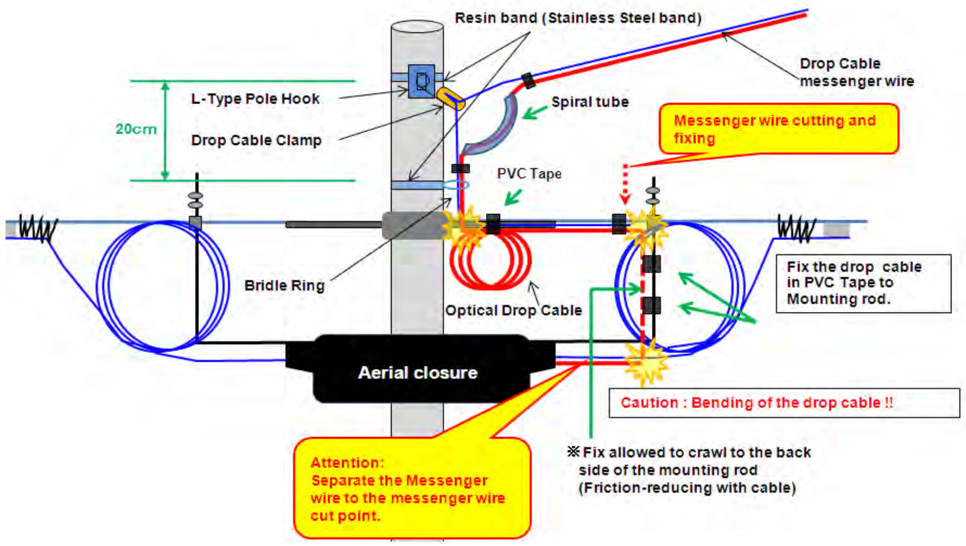


Figure 2-21

4. Installation of Direct buried cable

4.1 Outline of Direct buried cable

Normal buried cable installation methods include excavation or manual digging of trench. In directly buried cable installation, it is recommended that a cable is designed to protect from external damage, or any other harsh environmental conditions, should be chosen. Armor with corrugated steel tape or any other type should be considered. The same depth of cover as for metallic cables is usually adequate, but traffic capacity or other considerations of security may indicate a requirement for greater depth. Where a trench method is used, back filling materials and practices may require particular consideration so that fibre strain limits are not reached during this operation.

4.1.1 Matters to be taken care in general.

a. Do not pull the cable over any sharp objects, which could damage the cable.

b. Remove large stones from the soil before backfilling.

c. Smooth the trench bottom prior to installing the cable.

d. Permission should be obtain from the concern agency before starting the work

e. Road and trenches shall be restored to the original condition in accordance with the Specification of roads authority concerned.

4.2. Position of Direct Buried Cable

4.2.1 On the road side /Side – Walk in case the direct buried cable is installed on the road side / side walk, put the cable as Figure 2-22.

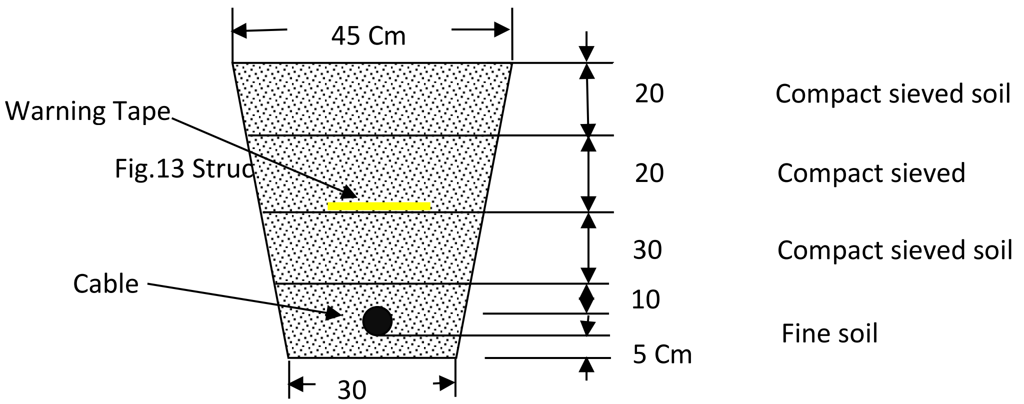


Figure 2-22

4.2.2 near the building or inside the private compound

Where it is too difficult and problematical to maintain the specific depth near the building area, the cable protection method shown below will have to be adopted. See figure 2-23

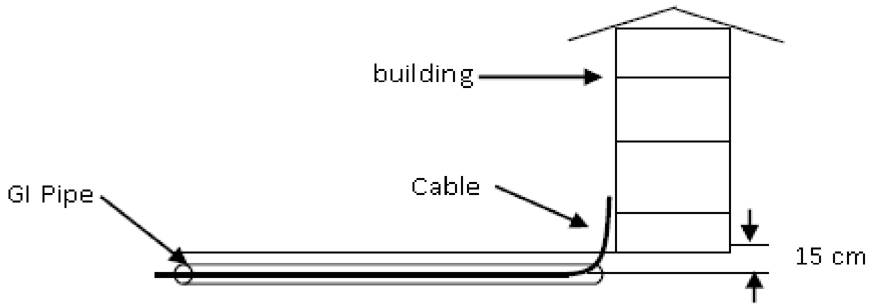


Figure 2-23: Cable protection with the help of GI pipe

4.2.3 Road crossing

In case the direct buried cable is installed across a road, where it is difficult to maintain the standard depth GI pipe is used to protect the cable as shown in figure 2-24.

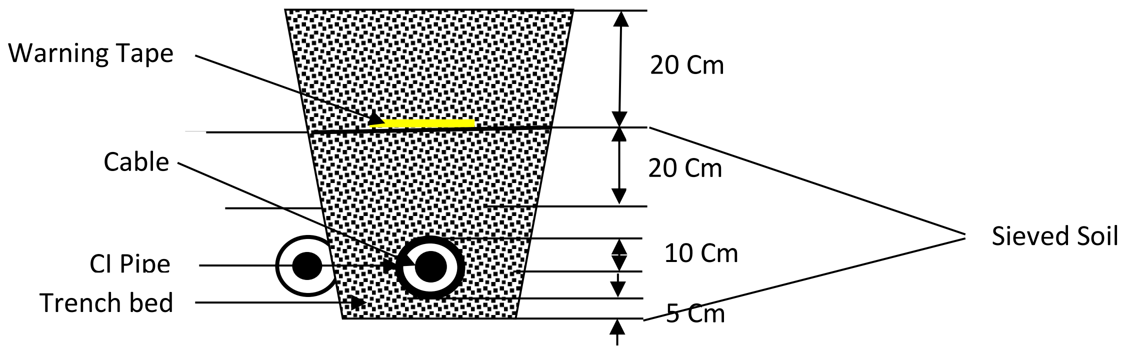


Figure 2-24: Installation of protective GI pipe for road

4.3. Tools and Materials

The tools and materials for the installation of direct buried cable are shown in the Table 2-7, Table 2-8 and Table 2-9.

Table 2-7: Tools for direct buried cable installation

Name of Tools	Function
Cable Jack and roller	Reeling out the cable drum
Cable grip	To grip the cable
Swivel	Preventing the cable from twisting while pulling
Shackle	Connecting the pulling wire rope to swivel
Pulling rope	Pulling the cable
Cable roller	Rolling the cable smoothly into trench
Cable cutter	Cutting the cable
Adjustable wrench	Fastening the bolt and nut
Nipper / Plier	Cutting wire
Measuring tape	Measure length and height

Table 2-8: Materials for the Installation of direct buried fiber cable

Name of materials	Function
PVC tape	Sealing the end of cut cable
Galvanized iron wire	Tie the cable end and making cable pulling end
Warning tape	Sign warning of cable presence

Table 2-9: Materials for back filling and protection

Name of materials	Function
Fine sand	For trench bed and covering
PVC pipe	Protecting cable
PVC pipe coupling	Joining PVC pipe
Adhesive cement	Adhering pipe and coupling
GI Pipe	Protection cable for cross section

4.4 Procedure of Direct Buried Cable Installation

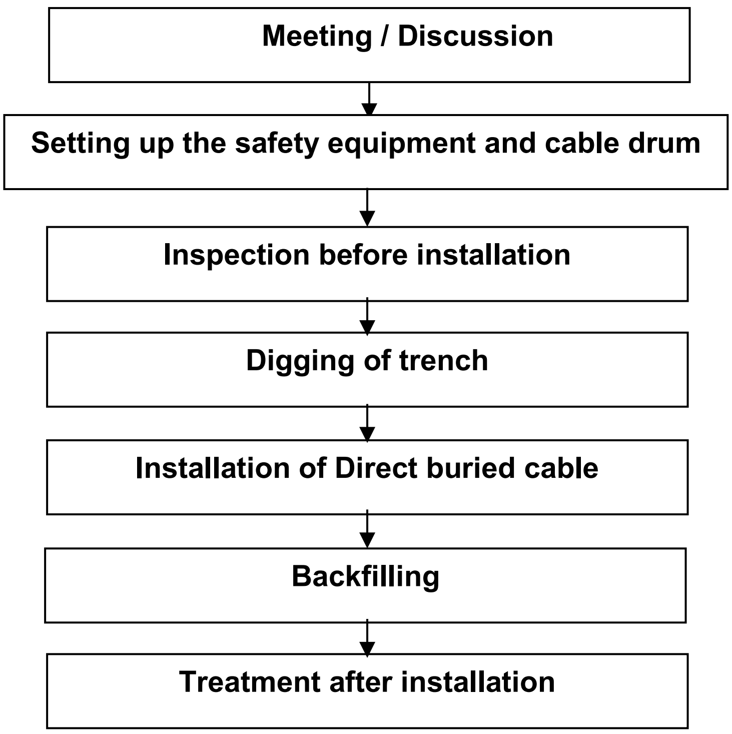


Figure 2-25: Working Flow

4.4.1 Meeting / Discussion

Supervisor and working staff confirm the working schedule for that day as schedule.

They should discuss about the safety measure that should be taken while working for a successful completion of their work plan.

4.4.2 Setting up safety equipment

Before excavating, the construction materials, tools, warning signs and safety are to be placed effectively.

When excavating along or across street or lane, perform the work in such a manner that with the traffic could be minimized. For further refer to safety manual.

4.4.3 Inspection before installation

A pilot excavation should be perform can help you stay safe. Calling before you dig can prevent:

a. Service outages
b. Equipment damage
c. Costly repair
d. Personal injuries or death

Before excavating you should inform the relevant stack holder and have a visual survey. If there are any services going along your plan route then excavate carefully using hand tools.

Digging tools should have a handle made of wood or other insulating materials to avoid from accident due to power leakage.

4.4.4 Digging of trench

a) This Recommendation describes the main techniques that allow an investigation of the soil in order to get information about the position of buried objects and the nature of the ground.

b) The bottom of the trench is to be leveled and sharp cutting stones or obstacles that may damage the cable should be removed.

c) A trench bed is made using fine sand bed.

d) If the work cannot be performed safely, or too difficult to be performed based on the construction drawings.

i) Modify the construction drawing.

ii) Consultation between engineers and supervisor.

iii) Request for the relocation of the other company’s facilities, utilities, etc.

e) If the buried facilities are damaged

i) Immediately inform the concern organization and municipalities.

ii) Carry out the restoration work immediately.

iii) Inform to supervisor.

4.4.5 Installation of Direct buried cable

a) After the trenching work is complete then the cable drum should be led at the end of the trench.

b) After deposition of roller in the trench, gently pull the cable passed over the roller. See figure 2-26

c) After reaching the far end of the trench, the cable is put into the trench. In which there is sand with a depth of 5 cm.

d) It is important where installing directly buried optical fiber cable to make proper arrangement for an adequate extra length of cable at both ends of a section for testing and jointing. This length must be sufficient to enable construction of joints and sheath closures at a convenient work position

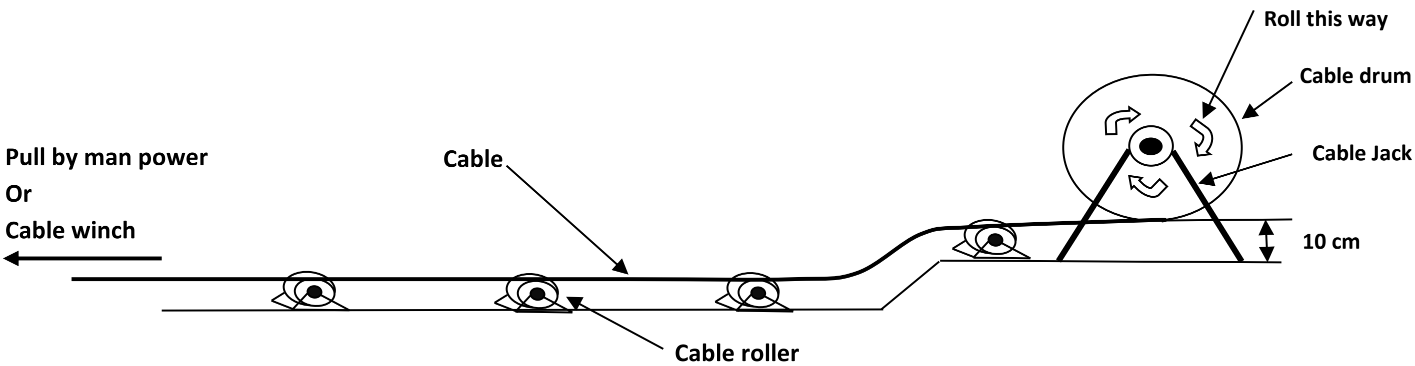


Figure 2-26: Cable laying into trench

4.4.6 Back filling of trench

a. Back filling for standard trench

Back filling for trench in which a buried cable been installed shall be performed as shown in figure 2-27

i) Fine sand shall be filled to a depth of at least 10 cm from the above surface of the cable.

ii) The second or other layers shall be filled with sieved soil.

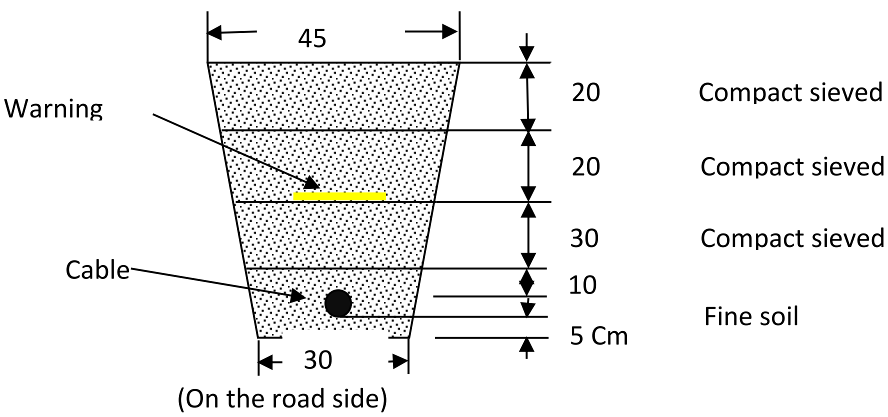


Figure 2-27: back filling for standard trench

b. Back filling for road crossing

Back filling for the trench in which a buried cable protected with GI pipe has been installed shall be performing as shown in figure 2-28

a) The sand bedding is not necessary especially while cable protected with using a GI pipe is used.

b) The depth can be of 60cm, since it has a GI pipe which can protect cable.

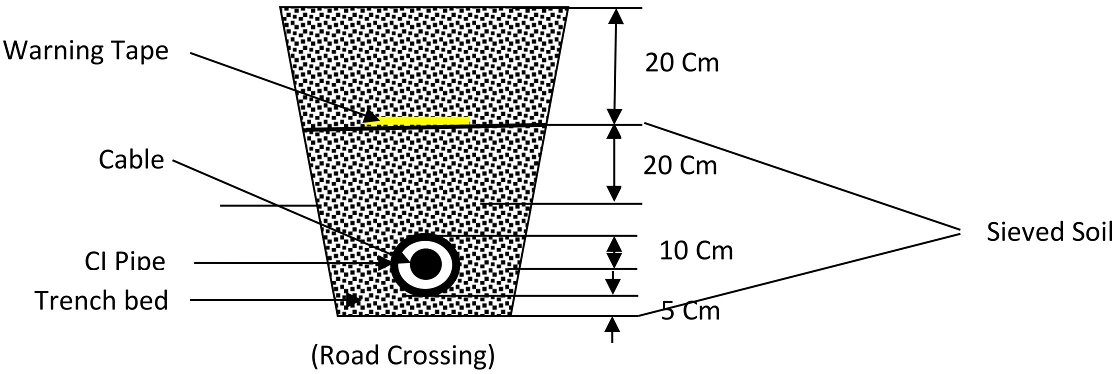


Figure 2-28: Backfilling for protected trench

4.4.7 Procedure for back filling

a) The first layer or back filled soil shall be compact firmly using compacting machine with adequate watering.

b) Lay a warning tape throughout the trench over the first layer of sieved soil.

c) The second or the third layer of the trench is filled with the sieved soil shall be back filled in the same way as the first layer.

d) In a similar way, the back filling and compacting shall be performed until the trench is filled up.

4.4.8 Treatment after installation

a. The excavation soil left out after being used for burying cable should be removed to an appropriate place.

After cable construction work has been finished, the construction location should be cleared and returned to its original condition.

5. Termination

5.1 General

Cable termination devices are essential part of the telecommunication network. These link the switching systems in the exchange to the subscriber cable network. They are classified into three categories.

I. GPON/OLT/FODP

II. FTTC

III. FTTB

IV. FTTH

Locations of these termination places are shown in Figure 2-28

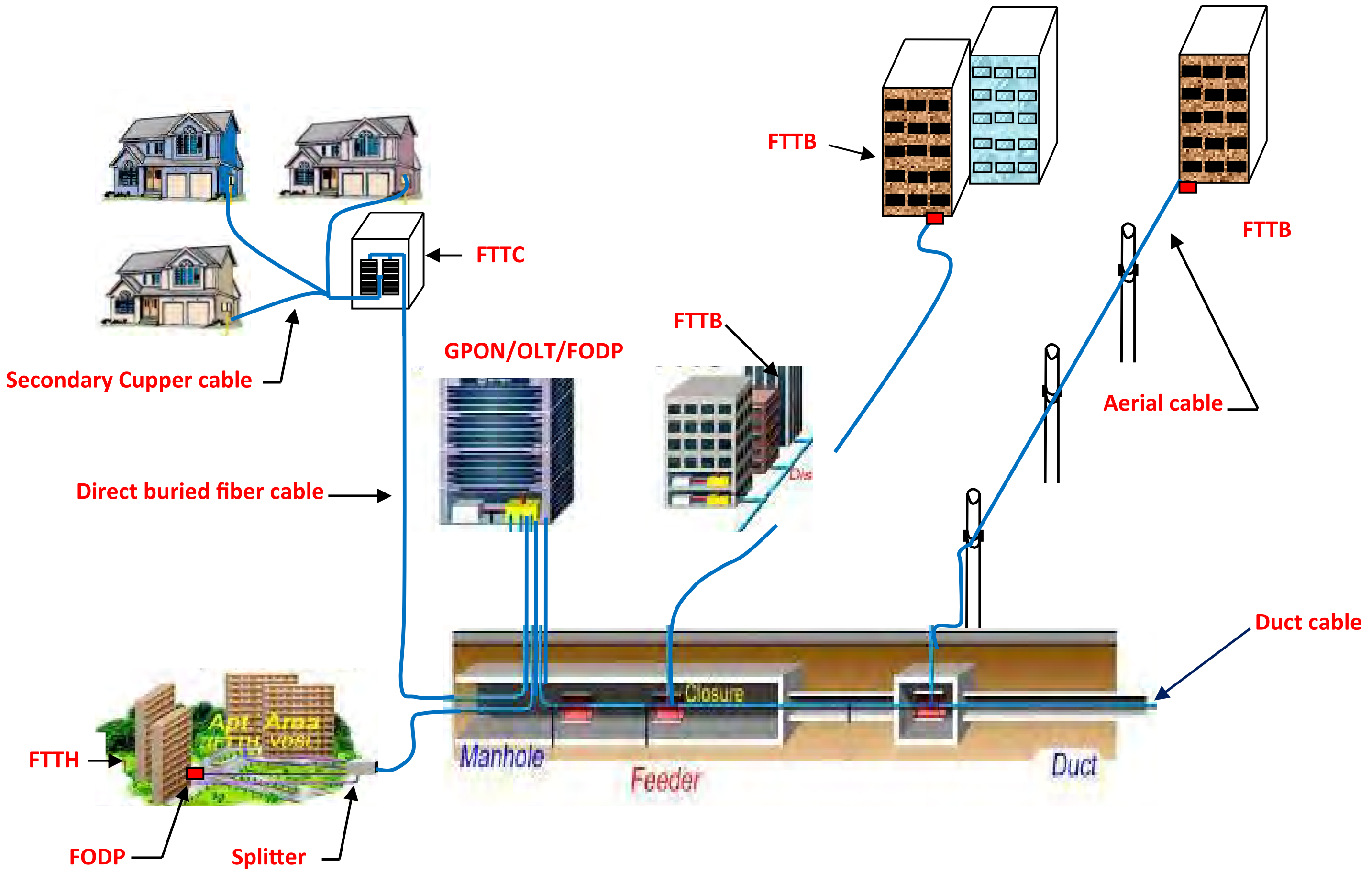


Figure 2-29: Location of termination spots

5.2 Location to be paid attention

a. When we will fix the cable to a cable rack, we must ensure the bending radius (minimum 20 times of the cable outer diameter).

b. Do not damage cable sheath and cable core

c. Do not mistake the cable core number (Check the color code of the cable)

5.3. FODP Installation

5.3.1 Out Line

The fiber optic panel utilizes an internal splicing system that creates a compact, feature-rich, high-density solution. FODF achieves density of 2~48 core termination or splices using SC connectors. FODF achieves densities of 48 core terminations/splices in each 1U using SC connectors. These densities are attained easy cable access, protect bend radius and provide individual fiber access. (See fig. 2.1). It not only functions as a connection point but also testing terminals.

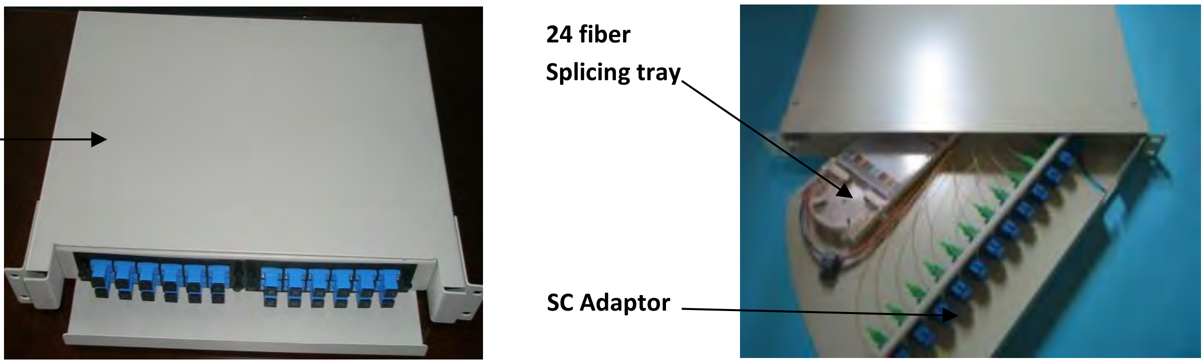


Figure 2-30: 24 core terminations/splices in each 1U using SC connectors.

5.4 FTTC Installation

5.4.1 General Remarks

FTTC (Fiber to the Cabinet) is a connection point of the fiber as a main and secondary as a cupper cable. It is placed on the roadside or sidewalk as shown in figure 2-31.

Figure 2-31: Outside feature of FTTC (Unit: m)

5.4.2 Active and Passive equipment

- FTTC capacity for 32 - 1024 subscriber

. GPON OLT, ONU, EMS

. (Cable, Splitter, etc)

. ADSL2+ DSLAM

. PSTN IDLC Mux, Media G/W

5.4 3 Services

- Voice service (PSTN, VoIP)
- High-speed Internet service (ADSL2+) and lease line
- CCTV (Future provision)

5. 4.4 Tools and Materials for FTTC

The tools and materials required for FTTC are shown in the Table 2-5 and Table 2-6

5.5 Termination Procedure

The work flow of termination work is as shown in figure 2-32

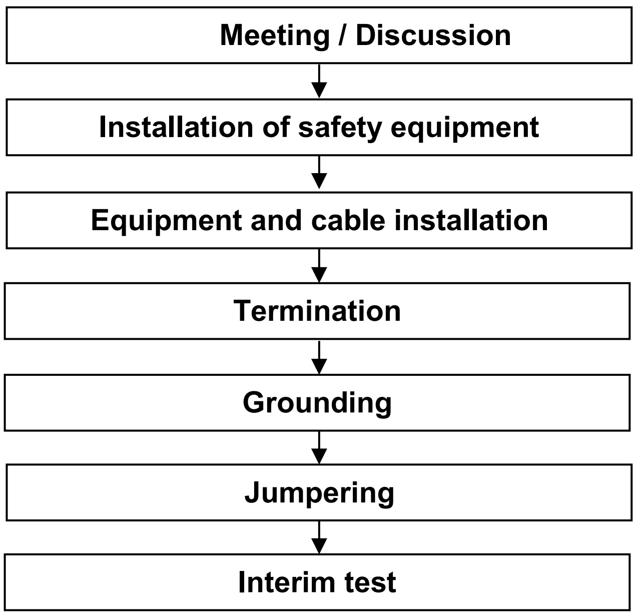


Figure 2-32: Termination procedure

5.5.1 Meeting and Discussion

The meeting is held to discuss the following.

a. Materials preparation

b. The decision of the location for the cabinet

c. Work order which must be performed

d. Necessary safety equipment

e. Transportation of materials to the site

5.5.2 Anticipating problems

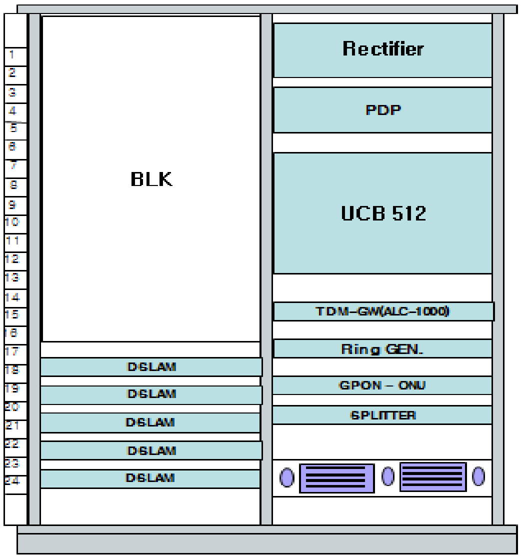
a. Safety equipment

Refer to the textbook of “Safety Manual“.

b. Equipment and cable installation

Equipment must be transport safely and install in the cabinet as per the plan.

All the rack must be properly mount on the concert basement and the installation of equipment should be done as per the design. See figure 2-33



Layout

Front View of equipment inside FTTC

Figure 2-33: Rack and Equipment installation inside the FTTC

5.5.3 Termination

- A block terminal is installed on the frame inside the Cabinet.
- The block terminal must be fixed firmly, while the cable are inserted and will be terminated to the block terminal.

5.5.4. Grounding

The ground is the most important factor to guarantee the quality of the service. In addition, to save all the equipment in FTTC cabinet from Thunder Bolt, the lightning rod or similar one should be installed around the FTTC. See figure 2-34

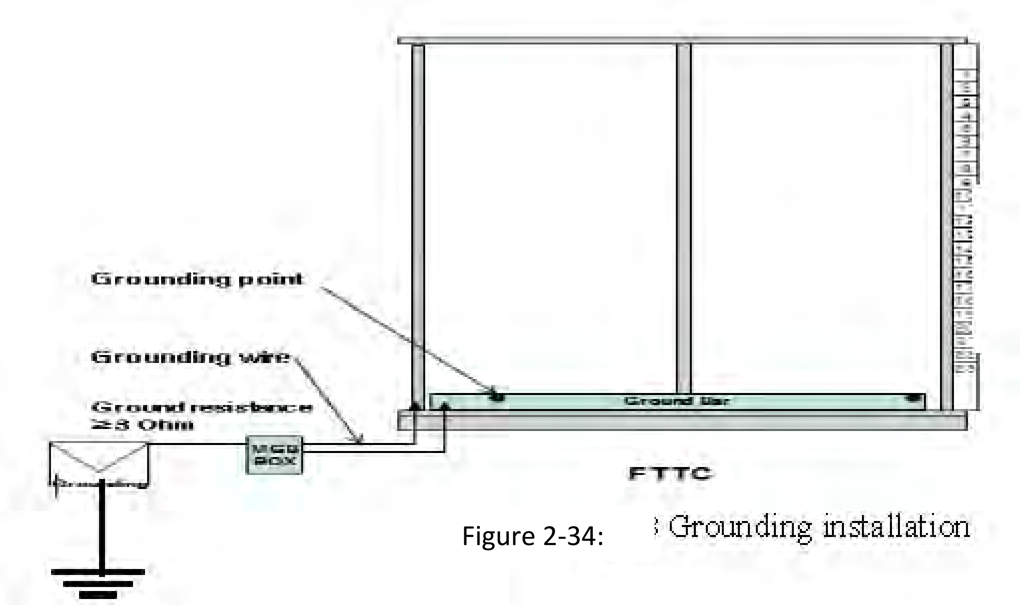


Figure 2-34: Grounding installation

All the equipment should be properly ground where the resistance must be less than or equal to 3 Ohm.

5.5.6 Jumpering

- Using a Jumper wire can perform the connection between the PSTN to Line and then to Fuse block terminal.
- The insertion from a Line block to fuse block must have adequate length. This makes it easy when changing and removing the jumper wire.

5.5.7. Interim Test

After termination all the fiber are being test once in the FTTC. If the loss are high than it need to be rectify immediately before we commission the site.

6. OPTICAL SPLICING

6.1 Introduction

Splices are critical points in the optical fibre network, as they strongly affect not only the quality of the links, but also their lifetime. In fact, the splice shall ensure high quality and stability of performance with time. High quality in splicing is usually defined as low splice loss. At present, two technologies, fusion and mechanical, can be used for splicing glass optical fibers and the choice between them depends upon the expected functional performance and considerations of installation and maintenance. These splices are designed to provide permanent connections.

- Fusion splicing
- Mechanical splicing

6.2 Fusion splicing

- Most popular splicing technique.
- Achieved through electrical arc.
- Splicing loss can be minimized as low as 0.01dB – 0.03dB/joint.
- Splice joint needs protection from moisture.
- The splice loss indicated by the splicing machine is only an estimated loss.
- After every splicing is over, the splice loss measurement is to be taken by an OTDR.

6.3 Tools and Materials for Splicing

Table 2-10: Splicing tools

Name of Tools	Function
Buffer Stripper	A precise stripper used to remove the coating of the fiber
Cleaver	Tools to break the fiber to produce a flat end for splicing
Splicer / Splicing machine	An instrument that joint two fiber into a permanent joint
ODTR	To check the fiber distance

Table 2-11: Splicing materials

Name of Materials	Function
Tissue paper	For cleaning the strip fiber from dust
Isopropyl alcohol or sprit	For cleaning the strip fiber from dust
Jointing sleeves	Used between two joints
Enclosure	To disclose the fiber joints from breaking

6.4 The Fusion Splicing Process

Process flow chart of optic fiber jointing works is summarized briefly, which serves as a model case for reference. See figure 2-35

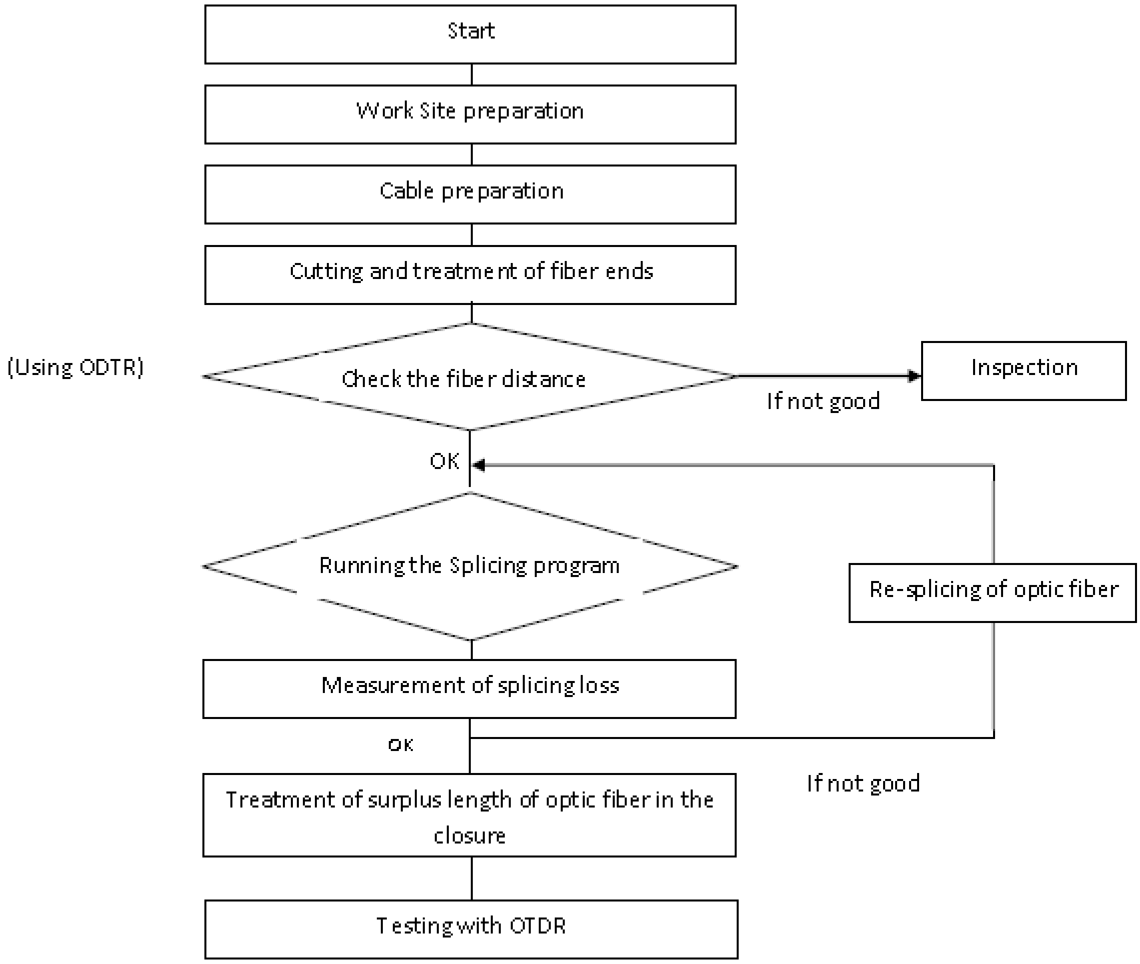


Figure 2-35: Fusion Splicing Process

6.4.1 Work site preparation

Careful site preparation is essential to produce a reliable fusion splice. Adverse environmental condition such as dust, precipitation, high wind should be controlled to avoid problems with fiber alignment and contamination.

6.4.2 Cable preparation

Cable preparation and handling procedures for a particular cable normally are recommended by the specific cable manufacturer, and should be followed carefully. However, some general fiber-related precautions apply for all cable design. Sufficient individual fiber lengths should be available such that when each spliced fiber pair is completed, the slack fiber will mount properly into the organizer without sharp bend. Also, some excess fiber length may be required should an unacceptable splice need to be remade.

6.4.3 Cutting and treatment of fiber ends

I. Fiber stripping

The fiber coating can be removed by a buffer stripping tool. It is important to note that, when stripping fiber, care must be taken to avoid damaging the fiber surface. The stripping tool should be the proper size and design for fiber. Also, to avoid damage to the glass surface, no more than three inches (30 mm – 35 mm) of the coating should be striped at one time. (See figure 2-36 & 37)

Figure 2-36: Removing fiber coating with help of buffer stripping tool

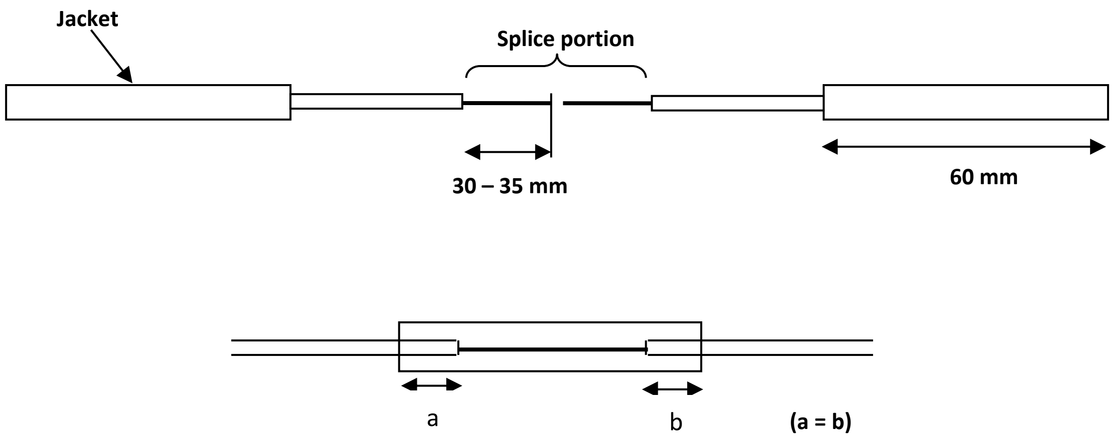


Figure 2-37: stripping of spliced portion as per the measurement

II. Surface cleaning

Any coating residue that remains after stripping should be removed from the bare fiber surface. With the help of tissue paper soaked on the Isopropyl alcohol or sprit, gently pulled over the fiber surface. Taking this precaution will minimize the chance of contaminating the fiber with dust, which may contribute to higher splice losses. It is also important to complete the remaining splice process as quickly as possible, since delay will expose the fiber to additional airborne contamination. Failure to utilize careful cleaning practices may lead to lower splice strength.

III. Fiber-end angle

Since the primary *attribute* affecting fusion splicing is end angle, proper fiber-end preparation is a fundamental step in obtaining an acceptable fusion splice. The stripe fiber should be place properly on the cleaver and it should be well-controlled while cutting fiber end.

6.4.4 Check the fiber distance

It is important to check the fiber distance with the help of using ODTR before splicing in order to check whether there is a fiber breakage in between. If there is a fiber breakage in between then we have to carry out inspection at what distance the fiber have been damage. If the fiber is through then we can carry out the splicing work.

6.4.5 Running the splicing program

I. Fiber Alignment

The initial alignment step for fiber splicing is to mount the clean cleaved fibers into the alignment blocks. First visually align the fibers in the lateral (X-Y) directions. Visual alignment requires maintaining the smallest gap possible between the fibers.

Apply a slight tension and place the splice in the heater, close the right hand heater clamp by pressing down with the right hand fiber. See figure 2-39

Fiber placing on the Splicing

Figure 2-38: Fiber placing on the splicing machine for alignment

<u>Note</u>

- ✓ Fiber should be straight.
- ✓ Make sure that there is no dust, or jelly in the protection sleeve.

II. Running the splicer program

First choose the proper program for the fiber types being spliced. The splicer will show the fibers being spliced on a video screen. Fiber ends will be inspected for proper cleaves and bad ones will be rejected. That fiber must be cleaved again. The fibers will be moved into position, pre fused to remove any dirt on the fiber ends and preheat the fibers for splicing. The fibers will be aligned using the core alignment method used on that splicer. Then the fibers will be fused by an automatic arc cycle that heats them in an electric arc and feeds the fibers together at a controlled rate.

6.4.6 Measurement of splicing loss

When fusion is completed, the splicing machine will inspect the splice and estimate the optical loss of the splice. Splicing loss can be minimized as low as 0.01dB – 0.03dB/joint. If the loss is more than 0.03dB then it will tell the splice needs to be remade.

If the loss is less than 0.03dB the operator then removes the fibers from the guides and attaches a permanent splice protector (Jointing sleeves) by heat-shrinking or clamping clam shell protectors.

6.4.7 Treatment of surplus length of optic fiber in the closure

I. Arrangement of optic fiber

Once the fiber is satisfactorily spliced and properly protected (typically with a heat shrink sleeves) the complete assembly should be secured into the splice organizer. Routing of the fibers must be checked within the splice organizer to assure that the proper fiber bending radius is maintained. The bending radius is 20 times the size of the fiber diameter and that the fibers are not accidentally bent over any sharp edges.

II. SPLICING OF FIBER CABLE: - While splicing of fiber cable in the closures, always keep required core in front of the splicing tray and others at the back of the splicing tray to avoid mismatching of core during splicing.

6.4.8 Check Point

- ✓ Check the status of water proof.
- ✓ Fusion splice working is protection against dirt, grit and moisture.
- ✓ Lift the joint box using the eye bolt of lid.
- ✓ Proper fixing of joint enclosure on the wall.
- ✓ Looping of balanced length of fiber inside the manhole with the help of cable tie.

6.5 Splice losses

As shown in Table 2-12 splice losses can be divided into two categories.

Table 2-12: Extrinsic and intrinsic splice loss factors

Extrinsic joint loss factors –	– transverse offset
	– longitudinal offset
	– axial tilt
	– fibre end quality
	– Fresnel reflections
Intrinsic joint loss factors–	– fibre diameter variation (core and cladding)
	– refractive index profile mismatch (multimode)
	– Numerical Aperture (NA) mismatch (multimode)
	– mode field diameter mismatch (single-mode)
	– non-circularity and non-concentricity of fibre mode field (single-mode)

6.6 CONNECTORS AND PASSIVE NODES




FC SC LC ST

1. Fixed Connection (FC)

FC stands for Fixed Connection. It is fixed by way of threaded barrel housing. FC connectors are typical in test environments and for single mode applications. FC connectors were designed for use in high-vibration environments. The FC connector is the most popular connector used today. It can be seen in every area of the communications environment, from a telecoms distribution room to a LAN closet the FC has set the standard for optical fiber connectors. FCs are being replaced by SC and LC connectors.

2. Subscriber Connector (SC)

SC stands for Subscriber Connector- a general purpose push/pull style connector developed by NTT. SC has an advantage in keyed duplexibility to support send/receive channels. SC Connectors are frequently used for newer network applications. The SC is a snap-in connector that is widely used in single mode systems for its performance. The SC connector is also available in a duplex configuration.

3. Lucent Connector (LC)

LC stands for Lucent Connector. The LC is a small form-factor fiber optic connector. The LC connector uses a 1.25 mm ferrule, half the size of the ST. Otherwise; it is a standard ceramic ferrule connector. The LC has good performance and is highly favored for single mode.

4. Straight Tip (ST)

ST stands for Straight Tip- a quick release bayonet style connector developed by AT&T. STs were predominant in the late 80s and early 90s. ST Connectors are among the most commonly used fiber optic connectors in networking applications. They are cylindrical with twist lock coupling, 2.5mm keyed ferrule. ST Connectors are used both short distance applications and long line systems. The ST connector has a bayonet mount and a long cylindrical ferrule to hold the fiber. Because they are spring-loaded, you have to make sure they are seated properly. They are easily inserted and removed due to their design. If you experience high light loss, try reconnecting.

CHAPTER - III

FTTX SAFETY MEASURES

CONTENTS Page

1. GENERAL SAFETY MEASURES

1.1 INTRODUCTION

Safety is the first priority while executing any type of work not only in fiber optic cable. Safety measure should be taken care before installing any type of equipment .It is the policy of the company to comply with local, national safety management while installing fiber optic cable .The site supervisor should ensure that all employees should maintain the safety measures while working on site

The two major safety issues are proper disposal of the glasses strands created by cutting and trimming the fiber or accidentally breaking it and cleaning chemicals used during installation. Always dispose of fiber scraps carefully in proper disposal container.

1.2 Safety Rules

- Always use appropriate safety tools while working in different work place.
- Always wear safety glasses to protect your eyes from fiber.
- Keep track of all fiber and cable scraps and dispose of them properly. Fiber particles on your clothing can later get into food, and drink which is dangerous to health.
- Never look directly into the end of fiber cables.
- Do not touch your eyes while working with fiber optic systems until your hands have been thoroughly washed.
- Only work in well-ventilated joint box.
- Keep all fire produce materials safely away from the fusion splicer.
- After completion of work, dispose of all scraps properly. Put all fiber scraps in a properly marked container for disposal.
- Do not smoke while working with fiber optic systems.
- Make sure the cloths are properly dressed.
- Make sure you are fit and healthy.
- Keep all the tools and equipment's in good condition (timely servicing should be done).

1.3. Safety Instrument and tools

- Helmet

Figure 3-1

Purpose:

Helmet should wear while working in any type of working environment like working on pole, rooftop, joint box, etc.

➢ Safety Cones

Purpose:

Safety cone are used while working on roads.eg

Splicing and cable installation

Figure 3-2

➢ Safety boot

Purpose:

Safety boots should be used while working at poles,

laying cables, working inside joint box, rooftop etc.

Figure 3-3

➢ Safety belt

Purpose:

Safety belts are used while working at poles and

higher height.

Figure 3-4

➢ Sign Board with various signals

Purpose:

These safety sign are used while working in road, laying cable, erecting pole, working at Joint box.

Figure 3-5

1.4 Safety On storage of fiber optic cable.

- Fiber optic cable should be kept in dry place where there is no harmful climatic condition and mechanical damage if the cable is not used immediately or always keep unpacked. Any moisture entering will reduce the effectiveness while installing. Also if water get inside the cable it will break if the temperature get below 0° Celsius.
- If the storage is not proper such as open space, marshy place and high humid use flowing preventive measures.
- Construct temporary basement with stone and woods.
- Cover the materials with plastic or CGI sheet.
- Provide proper ventilation.
- Use chain rope and fencings.

2. How to maintain Safety work at the site

2.1 Step by Step procedure to follow safety measures.

1. Make sure the safety equipment's are taken from the office before leaving to the sites.
2. Place Safety cone within the work area and put the safety bars to each cone to avoid accident while working on road and pedestrian.
3. Place the Sign board at visible end of each work area so that drives could see the warning signs.
4. In case of Underground maintenance work, we have to use the partition sign board, Gas detector and air blower to avoid in contact with poisonous gas inside the joint box.
5. Keep all the required materials and tools within the protected safety area.

Figure 3-6: Safety measures on Aerial & Underground work

Figure 3-7: Detecting poisonous gas inside the joint box

6. Open the Joint box and wait for five minutes before entering and check poisonous gases using gas detector.
7. Place the fiber rod wheel in stable condition (eg Flat area and hard basement)
8. Never stay side of the fiber rod wheel while rodding.
9. Do not listen the rod approaching from other end of the duct. Use proper communication method like handy talkies (Transceiver).
10. Never stay inside the Joint box of the other joint box while Roding.
11. Provide Traffic control staff to avoid collision with vehicles

2.2 Installation safety (Underground cable installation)

- Keep the safety cone around the joint box, Cable drum and others if any.
- Remove the joint box cover and keep the cover in safe place.
- Before entering the joint box supervisor should check numbers of workers entering and exiting after completion of work.
- Do not bend the cable when inserting in the duct.
- Always work in free ventilation and clean the place after work is complete.
- Never stand opposite to the pulling line under tension to avoid injuries.
- Do not stand aside of rolling cable drum, it may stuck the cloth and get injure.
- Closed the joint box cover after completing the work.
- If you are working at night wear reflective cloth and use appropriate sign to alert the people and vehicle passing by.

2.3 Safety while laying direct buried cable.

- Do not lay the cables over any sharp objects, which could damage the cable.
- Remove large stones from the soil before backfilling.
- Smooth by sand the trench bottom for safety of cable.
- Use cable roller while pulling cable for safety of damaging cable (Refer construction manual for diagram)
- If you are working at night wear reflective cloth and use appropriate sign to alert the people and vehicle passing by.

3. Installation of Pole

3.1. Safety on installation of pole

- Avoid installation of poles near electrical poles and cables.
- All the fitting of pole should be done on the ground and the pole should be kept safely after fitting the pole.
- Before starting digging work consult with agency (BPC, City corporation) the presence of underground utilities.
- Avoid installing pole on soft soil and change the location if required.
- Avoid touching the power line while erecting pole (maintain distance of minimum 3M LT line and 6M for HT line (refer below fig)

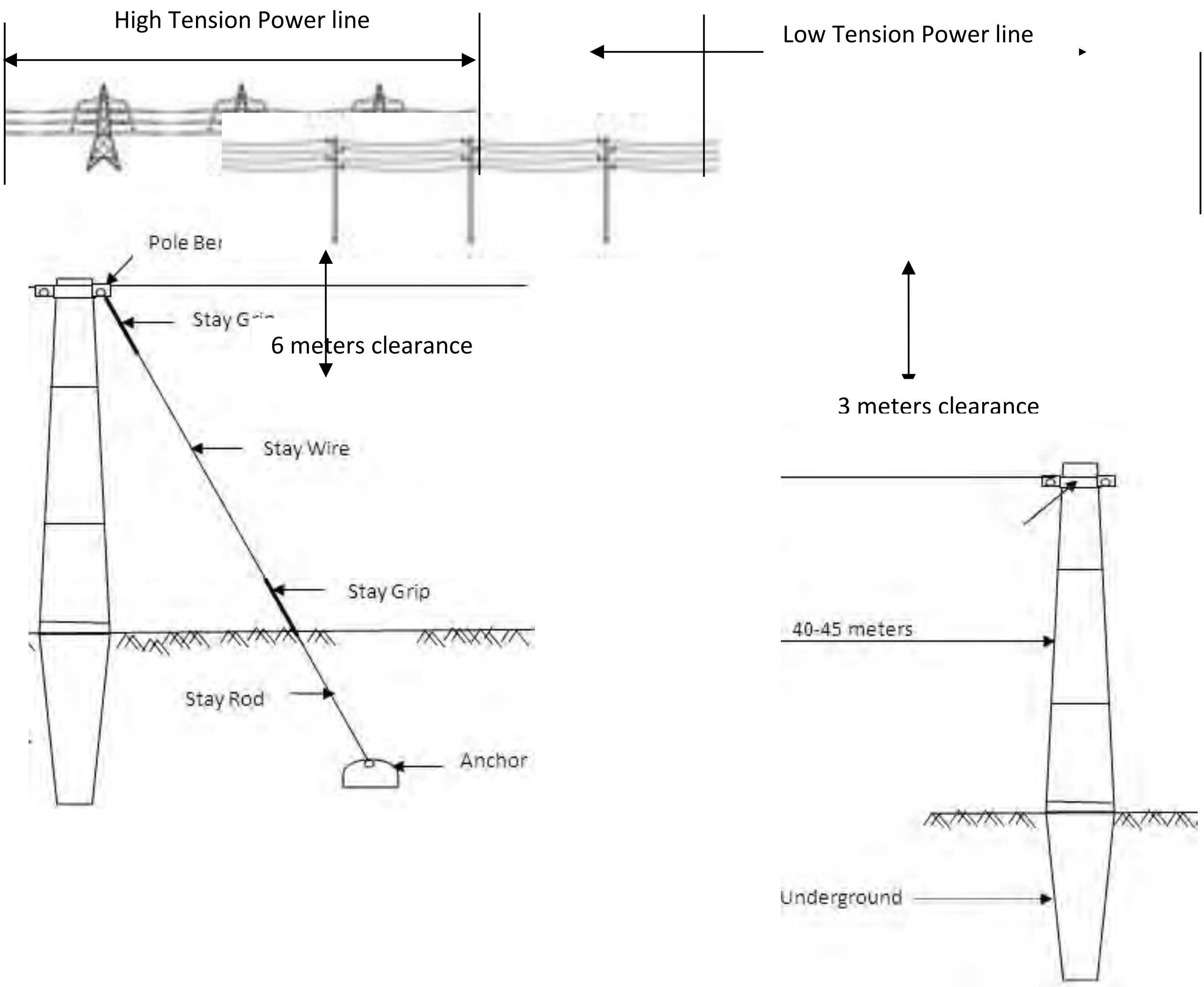


Figure 3-8: Power Line and Pole Position

3.2. Arial Cable installation.

- Inspect all the poles before start laying the cable. Make sure poles are firmly fixed and strong enough to carry weight of the cable and people working on it.
- Always use proper dress code while working in the field.
- Supervisor should always guide his co-workers to remain alert throughout the installation time.
- At crossing road, maintain the standard cable height installation to avoid the traffic.

4. Others safety measures

4.1 Safety measure while working on the roof top.

Always inspect the strength of the roof truss. If the ceiling top is not strong enough to hold, try to use strong planks between roof trusses. Don`t try to see the ground level if you are working in high level this cause giddiness and may fall down.

4.2 Safety measure handling bare fiber optic cable

The broken ends of fibers and scraps of fiber created during termination and splicing can be extremely dangerous. The ends are extremely sharp and can easily penetrate your skin. Broken fiber end which penetrate the skin are very hard to find and remove. Sometimes a pair of tweezers and perhaps a magnifying glass will get them out. Be careful when handling fibers to not stick the broken ends into your fingers. Dispose of all scraps properly. Follow the safety rule strictly. Use proper joint closer, FODP and keep them properly.

Figure 3-9

5. Safety Measures

5.1 Safety in splicing and testing

- Splicing should be done in clean and ventilated place.
- Do not smoke or keep explosive things while doing splicing.
- Power meter can make heavy Laser light. Do not try to look closely with naked eyes it may affect your eyes and even make blind.
- Make use of goggles while doing splicing
- Clean the place properly after finishing splicing and put the fiber particles in proper dustbin.

CHAPTER - IV

QUALITY INSPECTION

AND

FTTX SPECIFICATION

Contents page

Single-Mode Fibers Standard Specifications

Parameter	Standard per ITU-T G.652D	Units
Attenuation @1310 nm @1550 nm	≤ 0.38 ≤ 0.28	dB/km
Dispersion: between 1260 and 1360 nm (O Band): between 1530 and 1565 nm (C Band) between 1565 and 1625 nm (L Band)	≤3.5 ≤18 ≤22	ps/(nm*km)
Zero Dispersion Wavelength	1311±11	nm
Mode Field Diameter @ 1300 nm @1550 nm	9.2±0.5 10.4±1.0	µm
Cable Cut-off Wavelength	≤1260	nm
PMD (Individual fiber)	≤0.2	ps/km1/2
Cladding Diameter	125±1.0	µm
Core/Cladding Concentricity Error	≤0.5	µm
Cladding Non-Circularity	≤1.0	%
Coating Diameter	245±10	µm
Polarization mode dispersion	≤0.20	Ps/root km

Central Tube Single Jacket Armored Cable

Product Construction:

Fiber:

- 2–12 fibers
- Central tube gel-filled
- Color-coding per TIA/EIA 598 B

Armor:

- Corrugated coated steel tape

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Compact, user-friendly design
- Central tube armored design provides excellent fiber protection

Performance:

Temperature:

- Storage -40˚C (-40˚F) to +70˚C (+158˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- 20 X OD—Installation
- 10 X OD—In-Service

Maximum Crush Resistance:

- 150 lbs/in (440 N/cm)

Applications:

- Inter building voice or data communication backbones
- Installed in ducts, underground conduits, aerial / lashed or direct buried
- FTTX

Compliances:

- Tested in accordance with EIA/TIA-455
- Sequential meter markings available upon request

Loose Tube Single Jacket Cable

Fiber:

- 4–96 fibers
- Loose tube gel-filled
- Color-coding per TIA/EIA 598 B

Central Strength Member:

- FRP

Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Loose tube gel-filled construction for superior fiber protection
- UV- and moisture-resistant design
- Dry Water Block cable core for ease of handling

Performance:

Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- 20 X OD—Installation
- 10 X OD—In-Service

Maximum Crush Resistance:

- Short - 125 lbs/in (220 N/cm)
- Long - 63 lbs/in (110 N/cm)

Applications:

- Interbuilding voice or data communication backbones
- Installed in ducts, underground conduitor aerial/lashed

Compliances:

- Tested in accordance with EIA/TIA-455
- Alternate 6-fiber per tube available upon request
- Sequential meter markings available upon request

Loose Tube Dual Jacket Cable

Product Construction:
Fiber:

- 2–96 fibers
- Loose tube gel-filled
- Color-coding per TIA/EIA 598 B

Central Strength Member:

- FRP

Inner Jacket:

- Black UV- and moisture-resistant polyethylene (PE)

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Loose tube gel-filled construction for superior fiber protection
- UV- and moisture-resistant design
- Added protection of an inner jacket
- Dry Water Block cable core for ease of handling

Performance:
Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- 20 X OD—Installation
- 10 X OD—In-Service

Maximum Crush Resistance:

- Short - 125 lbs/in (220 N/cm)
- Long - 63 lbs/in (110 N/cm)

Applications:

- Interbuilding voice or data communication backbones
- Installed in ducts, underground conduits or aerial/lashed

Compliances:

- Tested in accordance with EIA/TIA-455
- Alternate 6-fiber per tube available upon request
- Options:
- Sequential meter markings available upon request

Loose Tube Single Jacket Armored Cable

Product Construction:

Fiber:

- 4–96 fibers
- Loose tube gel-filled
- Color-coding per TIA/EIA 598 B

Central Strength Member:

- FRP

Armor:

- Corrugated coated steel tape

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Loose tube gel-filled construction for superior fiber protection
- UV- and moisture-resistant design
- Rodent-resistant construction
- Dry Water Block cable core for ease of handling

Performance:
Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

  Minimum Bend Radius:
- 20 X OD—Installation
- 10 X OD—In-Service

  Maximum Crush Resistance:
- Short - 125 lbs/in (220 N/cm)
- Long - 63 lbs/in (110 N/cm)

Applications:

- Interbuilding voice or data communication backbones
- Installed in ducts, underground conduits or aerial/lashed

Compliances:

- Tested in accordance with EIA/TIA-455
- Alternate 6-fiber per tube available upon request
- Options:
- Sequential meter markings available upon request

Loose Tube Dual Jacket Armored Cable

Product Construction:

Fiber:
- 2–96 fibers
- Loose tube gel-filled
- Color-coding per TIA/EIA 598 B

Central Strength Member:
- Epoxy/glass rod

Inner Jacket:
- Black UV- and moisture-resistant polyethylene (PE)

Armor:
- Corrugated coated steel tape

Outer Jacket:
- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:
- Loose tube gel-filled construction for superior fiber protection
- UV- and moisture-resistant design
- Rodent-resistant construction
- Dry Water Block cable core for ease of handling

Performance:

Temperature:
- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:
- 20 X OD—Installation
- 10 X OD—In-Service

Maximum Crush Resistance:
- Short - 125 lbs/in (220 N/cm)
- Long - 63 lbs/in (110 N/cm)

Applications:
- Interbuilding voice or data communication backbones
- Installed in ducts, underground conduits, aerial/lashed or direct buried

Compliances:
- Tested in accordance with EIA/TIA-455
- Alternate 6-fiber per tube available upon request

Options:
- Sequential meter markings available upon request

Loose Tube Single Jacket Self-Supporting Cable

Product Construction:

Fiber:

- 2–216 fibers
- Loose tube gel-filled
- Color-coding per TIA/EIA 598 B

Central Strength Member:

- FRP
- Jacket:
- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*
- Messenger Wire:
- 1/7" stranded EHS galvanized steel

Features:

- Loose tube gel-filled construction for superior fiber protection
- UV- and moisture-resistant design
- Self-supporting figure-8 design

Performance:

Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- 20 X OD—Installation
- 10 X OD—In-Service

Maximum Crush Resistance:

- Short - 125 lbs/in (220 N/cm)
- Long - 63 lbs/in (110 N/cm)

Applications:

- Interbuilding voice or data communication backbones
- Installed aerially

Compliances:

- Tested in accordance with EIA/TIA-455
- Alternate 6-fiber per tube available upon request

Options:

- Sequential meter markings available upon request

Flat Drop Cable

Product Construction:

Fiber:

- 2–12 fibers
- Central tube gel-filled
- Color-coding per TIA/EIA 598 B

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Compact, user-friendly design
- Central tube armored design provides excellent fiber protection
- Easy to install

Performance:

Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- X OD—Installation
- 3.9 X OD—In-Service
- Highly crush-resistant

Applications:

- Broadband network
- Installed in ducts
- FTTX

Compliances:

- Sequential meter markings available upon request

All-Dielectric Flat Drop Cable

Product Construction:

Fiber:

- 2–12 fibers
- Central tube gel-filled
- Color-coding per TIA/EIA 598 B

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Compact, user-friendly design
- Easy to install

Performance:

Temperature:

- Storage -40˚C (-40˚F) to +75˚C (+167˚F)
- Installation -30˚C (-22˚F) to +60˚C (+140˚F)
- Operating -40˚C (-40˚F) to +70˚C (+158˚F)

Minimum Bend Radius:

- X OD—Installation
- 3.9 X OD—In-Service
- Highly crush-resistant

Applications:

- Broadband network
- Installed in ducts or aerial/lashed
- FTTX

Compliances:

- Sequential meter markings available upon request

Mini (Figure-8) Drop Cable

Product Construction:

Fiber:

- 2–12 fibers
- Color-coding per TIA/EIA 598 B

Outer Jacket:

- Black UV- and moisture-resistant polyethylene (PE)
- Sequential footage markings*

Features:

- Compact, user-friendly design
- Easy to install

Performance:

• Temperature:

Storage -40˚C (-40˚F) to +75˚C (+167˚F)
Installation -20˚C (-4˚F) to +60˚C (+140˚F)
Operating -40˚C (-40˚F) to +70˚C (+158˚F)

• Minimum Bend Radius:

6.7 X OD—Installation
2.6 X OD—In-Service

Applications:

- Broadband network
- Installed in ducts or aerial/lashed
- FTTX

Compliances:

* Sequential meter markings available upon request

Typical Cross-Section

Stranded Stainless Steel

Messenger

Outer

Tight Buffer 3.0 mm Simplex/Duplex Riser and Plenum Cable

Product Construction:

Fiber:

- 1 or 2 fibers
- 900 µm tight buffer

Overall Strength Member:

- Aramid fiber yarn

Jacket:

- 3.0 mm unit diameters
- Flame-retardant compound
- Sequential footage markings*
- Yellow jacket—singlemode fibers

Features:

- Industry-standard design
- Ideal for interconnect and Fiber-To-The- Desk (FTTD)

Performance:

• Temperature:

Storage -40˚C (-40˚F) to +70˚C (+158˚F)
Installation 0˚C (+32˚F) to +50˚C (+122˚F)
Operating -20˚C (-4˚F) to +70˚C (+158˚F)
• Minimum Bend Radius:

20 X OD—Installation
10 X OD—In-Service
• Maximum Crush Resistance:

500 lbs/in (875 N/cm)

Applications:

- Interconnect design compatible with connectors requiring 3.0 mm jacket diameter
- Fiber-To-The-Desk (FTTD)

Compliances:

- TIA 568 C.3
    - Sequential meter markings available upon request

Packing and Marking

a. Each single length of cable shall be wound on a pure drum.
b. Standard drum length is 2000m ±1%, or it can be delivered according to custo mer requirement but not longer than 6000m with a tolerance.
c. Covered by plastic buffer sheet.
d. Sealed by strong wooden battens
e. At least 1m of inner end of cable should be reserved for testing.

Drum marking

a. Custmer' s name & logo;
b. Manufacturing year and month;
c. Roll-direction arrow;
d. Cable outer end position indicating arrow;
e. The word "OPTICAL FIBER CABLE";
f. Cable type and size;
g. Drum numbers
h. Drum length;
i. Gross / net weight;

Caution plate indicating the correct method for loading, unloading and convey the cable;
Other customer information such as contract no., project no., and delivery destination. (if needed)

Cable quality certificate documents

I. Quality certificate;
II. Test report.

Cable Testing Methods (Quality Assurance Test)

Tensile performance

The apparatus and Procedure:

- An attenuation measuring apparatus, typically an OTDR.
- A fiber elongation strain measuring apparatus based on dispersion testing equipment
- A specially designed tensile test machine capable of tensioning 150 meters of optical cable in six legs of 25 meters each. The machine is equipped with a motor for controlled tensioning and a load cell for measuring the actual tension applied on the cable

Pass/Fail criteria

- Under load, the fiber attenuation is not increased more than a predetermined value, typically 0.05 dB over the fiber length measured.
- Under load, the fiber does elongate by more than a pre-determined value over its initial
- length. The allowed elongation under installation load is typically 0.25%.

Crush (Compression)

The apparatus and Procedure:

The apparatus allows a sample of cable to be crushed between a flat steel base plate and a movable 100 mm long steel plate. The edges of the movable plate are rounded with a radius of bout 5 mm.

The maximum applied force is typically maintained for 10 minutes.
Two types of measurements may be defined:

- The fiber attenuation is measured at the end of the 10-minute period while the cable is still under pressure
- The fiber attenuation is measured 5 minutes after pressure release. This requirement is usually carried out at higher compressive loads than the previously described measurement

Pass/Fail criteria

- The attenuation must not change by more than a pre-determined value, typically 0.05 dB.
- In all cases, the cable elements should not fracture or crack. Signs of compression are no considered as damage to the cable elements

Impact

The apparatus and Procedure:

Optical fiber cable to withstand impact,
allows a hammer with a 25 mm rounded edge to drop vertically on a cable
sample fixed on a flat steel plate. The apparatus may allow a single or multiple repeated
impacts to be imparted on the cable sample.
The energy of the impact is determined by the drop height and by the weight of the hammer

Two procedures are commonly used:

- A repeated impact test whereby the hammer drops on the same location in the cable samle 25 times.
- The hammer is allowed to drop on 3 different locations in the cable, typically separated by 50 cm from each other. The number of impacts in each location is limited (1 to 3).
- A typical impact test set-up

Pass/Fail criteria

- The fiber attenuation does not increase by more than a predetermined value, typically 0.05dB.
- In some case, the cable passes the test if there are no fiber breaks. This requirement is usually applied when very high impact energy is used.
- There are no breaks or cracks in the cable elements. Signs of the impact are considered normal.

Repeated bending (Cyclic Flexing)

Apparatus

The apparatus allows a cable sample to be bent backwards and forwards through at an angle of 180 digree the two extreme positions making an angle of 90 digree on both sides of the vertical, while the

The bending arm is designed to permit holding the cable securely during the entire test, without

crushing the optical fibers or inducing optical loss. The bending radius is controlled by replaceable cushioning reels chosen to match the cable bending radius.
The apparatus is capable of cycling at a rate of 30 cycles per minute.

A cable sample is secured to the bending arm while it is in an upright position. A predetermine weight is attached to the bottom of the cable sample. The motor is turned on and the arm oscillates between the two extreme positions flexing the cable. The number of flexing cycles depends on the cable design

Pass/Fail criteria

The fiber attenuation does not increase by more than a predetermined value, typically 0.05 dB

Torsion

Apparatus and Procedure

The twisting apparatus consists of two cable gripping devices or clamps, one fixed and one that can rotate. The distance between the clamps defines the cable length under twist and is adjustable. The rotating clamp is connected to suitable turning equipment. The clamps are desiged to prevent crushing force on the cable and toallow the cable end to exit from both sides to allow optical measurements.

The rotating clamp is then rotated as follows:

- 180 digree in one direction
- back to the starting position
- 180 digree in the opposite direction
- Back to the starting position.

These four steps constitute a cycle. The cable sample is subjected to a predetermined number of such cycles, typically 10.

Pass/Fail criteria

- The attenuation must not change by more than a pre-determined value, typically 0.05 dB.
- The cable should not show any indications of mechanical failure, such as jacket cracks, armor opening etc.

Bend Method

Apparatus and Procedure

The apparatus is a simple mandrel of the specified diameter on which a cable sample can be wrapped tangentially in a close helix.

The sample is wrapped in a close helix around the mandrel at a uniform rate. Sufficient tension

is applied to ensure that the sample contours the mandrel. The sample is then unwrapped.

Acycle consists of one wrapping and one unwrapping.
This test is often performed at low temperature to verify the cable ability to be installed at such temperatures without being damaged

Pass/Fail criteria

The attenuation must not change by more than a pre-determined value, typically 0.05 dB.

The cable should not show any indications of mechanical failure, such as jacket cracks.

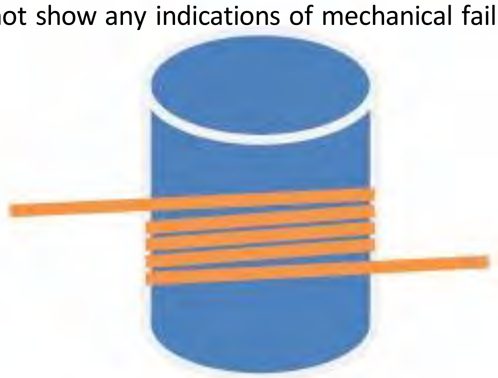


Figure: A mandrel and bend cable sample

Temperature Cycling Method

Apparatus and Procedure

A climate chamber is used of a suitable size to accommodate the sample. The chamber temperature can be controlled to within ±3 °C The fiber attenuation may be monitored using a stabilized light source / power meter combination or, preferably, an OTDR.

Procedure

- A reference value for attenuation is determined on the cable sample already installed in the climate chamber and ready for the temperature cycling.
- The temperature in the chamber is then lowered to the appropriate low temperature TA at the appropriate rate of cooling.
- After temperature stability in the chamber has been reached, the sample is exposed to the low temperature conditions for the appropriate period t1.
- The temperature in the chamber is then raised to the appropriate high temperature TB at the appropriate rate of heating.

- After temperature stability in the chamber has been reached, the sample is exposed to the high temperature conditions for the appropriate period t1.
- The temperature in the chamber is lowered to ambient temperature at the appropriate rate of cooling.This procedure constitutes one cycle. Typically, cables are exposed to 2 such cycles.

Pass / Fail Criteria

- The attenuation of the fibers in the cable should not increase by more than a pre-determined value.

Water penetration Method

Apparatus and Procudure

The apparatus consists of a vertical pipe containing water at a height of 1 meter. The pipe is connected at its bottom to a flexible tube that allows watertight connection to the cable under test. up. The cable sample is laid flat and asuitable arrangement is made in order to determine if water leaks f rom its exposed end.

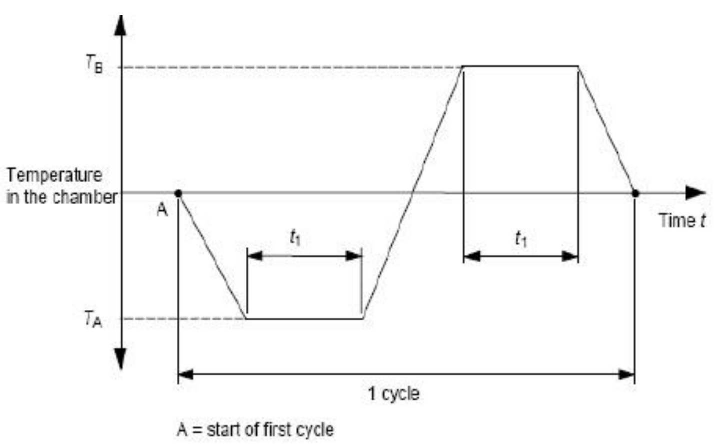
The sample is supported horizontally and a 1 m height of water is applied for 24 h. A water-soluble fluorescent dye or other suitable coloring agent may be used to aid in the detection of water seepage.

Pass / Fail Criteria

No water leaks are detected from the exposed cable end

Pass / Fail Criteria

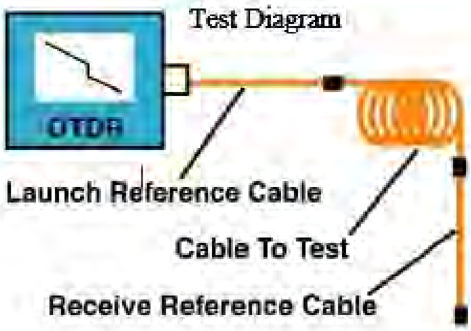
No water leaks are detected from the exposed cable end.



Testing Loss of Installed Fiber Optic Cable Plant by OTDR Machine

z

OTDR testing creates a snapshot of a fiber optic cable. This test is commonly used to verify the quality of the installation and troubleshoot problems. OTDR testing requires interpretation of the data acquired, called the trace or signature, by a skilled operator.



Equipment Needed To Perform This Test

1. OTDR with modules appropriate for the cable plant (e.g. multimode: 850 and/or 1300nm, singlemode, 1310, 1550 and/or 1625nm.)
2. Launch and/or receive reference cables of the same fiber type and size as the cable plant and with connectors compatible to those on the cable plant.
3. Cleaning supplies

Test Procedure

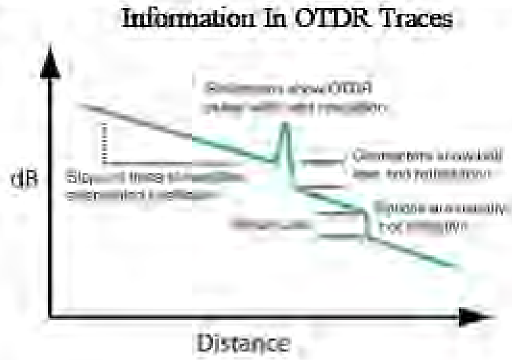
1. Turn on OTDR and allow time to warm-up
2. Set parameters on OTDR appropriate for the cable plant being tested (range, wavelength, number of averages, etc.)
3. Clean all connectors and mating adapters.
4. Attach launch reference cable to OTDR and to cable plant under test.
5. Attach optional receive cable to far end of cable under test.
6. Acquire trace and analyze.

Options For Testing

1. Use of the receive reference cable is optional, it is required if the far end connector loss is to be measured and included in total cable plant loss
2. Testing at more than one wavelength may be required. Longer wavelength testing is often used to find stress related to installation problems. Traces may be compared for analysis.

Documentation

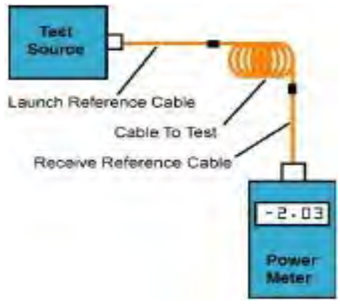
Record the date of the test, operator, test equipment used, cable and fiber identification, test wavelength(s) and all traces for the fiber under test.

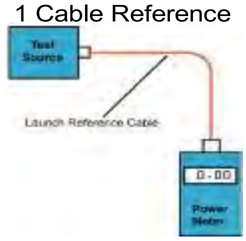


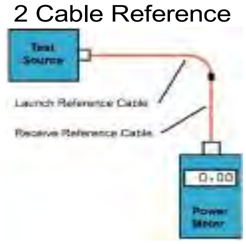
Notes

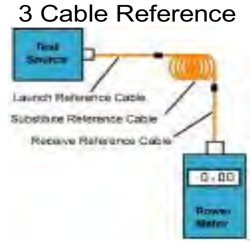
1. Insertion loss testing of the cable plant is recommended for acceptance testing.
2. Not all cable plants are long enough for OTDR testing. Ensure the OTDR has sufficient resolution for the cables being tested.
3. Always use a launch cable long enough to allow the OTDR to recover from test pulse overload and permit proper testing of the cable plant.
4. Do not use the OTDR automatic cable analysis until a skilled technician analyzes a trace and confirms it is appropriate for the cable plant under test.

Testing Loss of Installed Fiber Optic Cable Plant by POWER METER/LIGHT SOURCE

<table>
<tr><td>This test will measure the loss of an installed fiber optic cable plant, singlemode or multimode, including the loss of all fiber, splices and connectors.</td><td rowspan="2">Test Diagram

</td></tr>
<tr><td>Equipment Needed To Perform This Test
1. Test source appropriate for the fiber being tested (Multimode: 850 and/or 1300nm LED, singlemode, 1310 and/or 1550 nm laser)
2. Optical power meter calibrated at the same wavelengths as the source output.
3. Launch and receive reference cables of the same fiber type and size as the cable plant and have connectors compatible to those on the cable plant.
4. Mating adapters compatible to connectors
5. Cleaning supplies</td></tr>
<tr><td>Test Procedure
1. Turn on equipment and allow time to warm-up
2. Attach launch cable to source. This should remain connected to source for the duration of the test.
3. Clean all connectors and mating adapters.
4. Set “0 dB” reference using method shown to the right. Meter may be set to read “0 dB.”
5. Attach source/ref cable and meter/ref cable to the cable plant under test and make loss measurement.</td><td rowspan="4">Setting “0 dB” Reference

1 Cable Reference


2 Cable Reference


3 Cable Reference

</td></tr>
<tr><td>Options For “0 dB Reference” - Set Before Testing
1. Use the “1 Cable Reference” if connectors are the same on the cable plant as the testers and reference cables or may be adapted using hybrid adapters.
2. Use the “2 Cable Reference” if connectors are not the same on the cable plant as the testers but can be mated to each other with adapters and hybrid reference cables are being used.
3. Use the “3 Cable Reference” if connectors are plug/jack styles and reference cables are both ended in either plugs or jacks.</td></tr>
<tr><td>Reducing Measurement Uncertainty
1. Clean all connectors regularly before and while testing.
2. Use modal control on launch cable, e.g. small loop on SM fiber or mandrel wrap on MM fiber.
3. Check “0 dB Reference” periodically during testing.
4. 4. Periodically check reference cables to verify their condition.</td></tr>
<tr><td>Documentation
Record the date of the test, operator, test equipment used, reference method, cable and fiber identification, test wavelength and measured loss.</td></tr>
</table>