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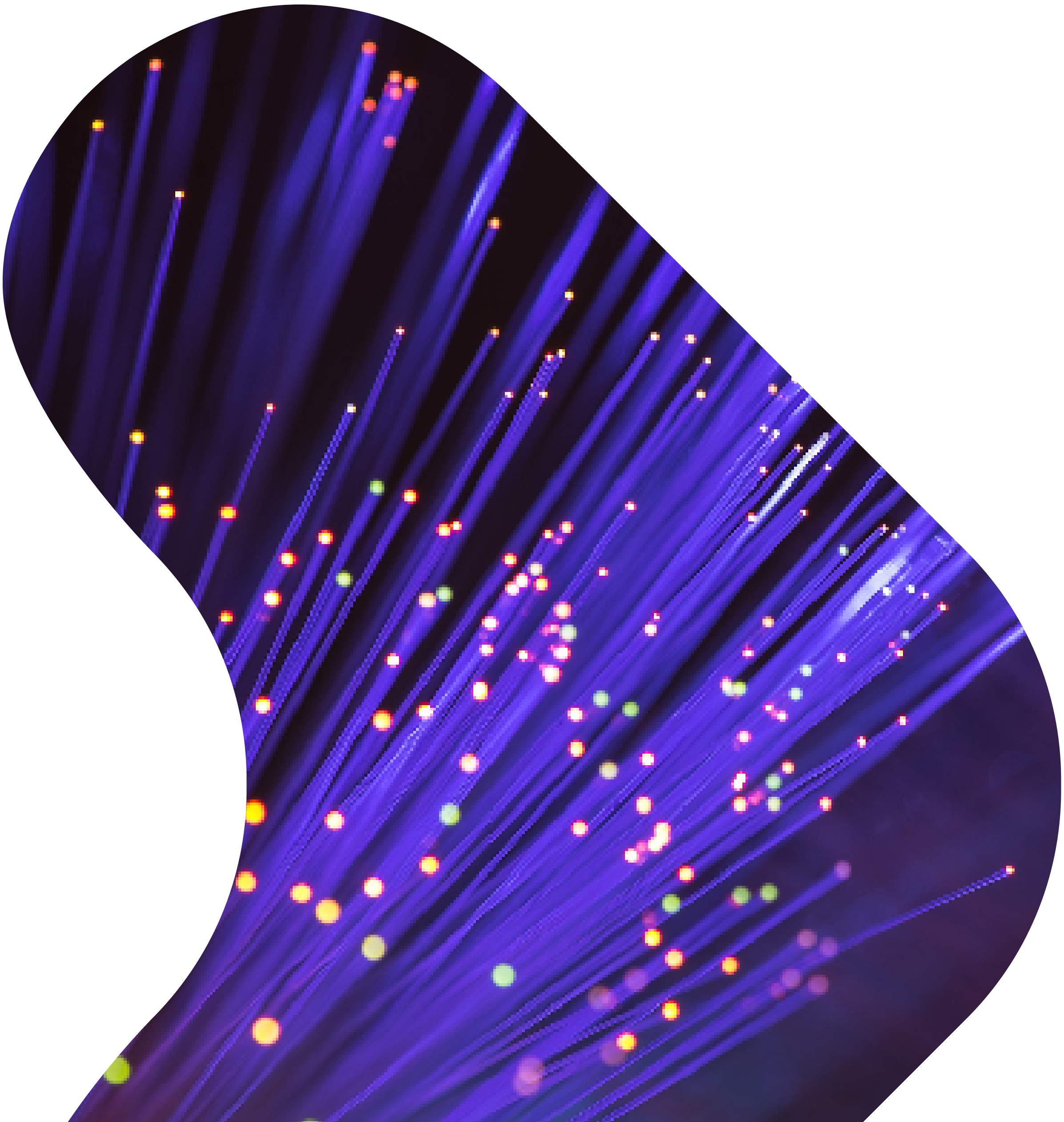
Underground Installation of Optic Fiber Cable Placing



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Abstract

Underground placement is necessary and unavoidable in certain areas for various reasons such as nature and heritage conservation, natural obstacles, aesthetics, space and safety. Placing cables underground has the added benefits of reducing transmission losses, aiding planning consent and reduced risk of service supply loss through extreme weather. This practice covers the basic guidelines for installation of fiber-optic cable in underground cable.

Keywords
Manholes, winches, Sheaves, Jetting Method

Introduction

Underground cable is placed into ducts which are being built below the ground surface. In urban areas where space for telecommunications cable is limited, it needs to be used more efficiently. In underground installation, the conduit provides protection from both physical and environmental abuse. The conduit protects cable from shifting rocks, aggressive rodents, and/or damage from hand shovels. Underground cable that is in conduit is easy to replace or upgrade. The old cable can be pulled out of the conduit and the new pulled in without extensive and expensive digging. Underground cable and ducts are part of the underground conduit system. Telecommunication conduits are made from various materials and buried directly into the soil or encased in concrete. Fiber optic cables have provided a more optimal use of available underground conduit space because of its small cable diameter and the much higher communications traffic capacity of each cable.

Optical cable is usually placed in a 25 to 40 mm inside diameter (ID) sub-duct which is placed into an existing larger diameter communications conduit. Most communications conduits can be fitted with three or four sub-ducts. Sub-ducts are often referred to as innerducts. An innerduct provides a more efficient use of the conduit system space, with a clean low coefficient-of-friction pathway and an extra measure of mechanical protection for an optical cable.

If micro-duct cables are used, they are usually placed into small diameter ducts that are placed inside of the innerducts, nested two levels within a communications conduit system. These small diameter ducts are usually from approx 5 mm to 14 mm inside diameter and called micro ducts. Micro-duct cable is blown (jetted) into the micro-duct. Normally, standard size fiber optic cables are pulled into innerduct (sub-ducts).

Underground Cable	Urban	New Suburban	Old Suburban	Campuses	Rural
• Innerduct	🟢	🟢	🟢	🟢	
• Micro-Ducts	🟢	🟢	🟢	🟢	🟡

🟢 = Used often in this application
🟡 = Can be used in the application under certain circumstances

Table 1– Commonly Used Cable Types for Various OSP Applications

Micro-ducts can also be placed directly into larger telecommunications conduits or can be factory assembled into a composite unit of multiple micro-ducts.

General

The underground placing methods described in this document are intended as guidelines. National, state, local, and corporate specifications, regulations, and industry recommendations normally take precedence over these. It is impossible to cover all the conditions that may arise during a placing operation. Individual company practices for placing fiber optic cable should supersede any conflicting instructions in this document whenever they do not exceed the cable's optical and mechanical performance specifications.

The methods used to place fiber optic cables in ducts are similar to those used to place copper cable. Optical cable is a high capacity transport medium that is sensitive to excessive pulling force, tight bends, and crushing forces, therefore, proper care must be taken during the installation procedure.

Fiber optic cables are ordered in specific lengths as calculated by an OSP (Outside Plant) Engineer. Their lengths are determined by measuring the distance between splice manholes plus the excess cable length required for racking the cable at all manhole locations and slack storage for maintenance. Additional cable length is required at each splice manhole to reach to the actual splice location (often in a trailer or tent adjacent to the manhole). In addition, extra length should be included in the ordered length to be available if errors are made during the splicing operation. If the excess splice length is not known, the splicing foreman should be consulted. Never cut a fiber cable without first consulting the OSP Engineer responsible for the job.

Precautions

Cable Handling

All optical fiber cables are sensitive to damage during shipping, handling, and installation. Some of the important parameters that need special attention during cable installation are:

• **Cable bending radius:** Optical fiber cables are designed with a minimum bending radius and maximum tensile strength. The cable should never be bent below its minimum bending radius. Doing so can result in bending losses and/or breaks in the cable's fibers. Generally the minimum bending radius of a fiber cable under load is 20 × D, where D is the diameter of cable; the minimum bending radius of a fiber cable under no load is 15 × D

• **Cable Placing Tension:** Optical fiber cables are designed with a maximum tensile strength. The cable should never be loaded beyond its maximum tensile strength. Exceeding the cable's placing tension provided by Sterlite in the Cable Data Sheet/Specification, can alter cable and fiber performance and shorten its service lifetime.

LED and Laser Precaution

LED and Laser beams used in fiber optic testing and transmission systems are invisible to the human eye and can seriously damage the eye. Viewing these beams directly may not cause any pain and the iris of the eye does not close automatically as it does while viewing a bright light. As a result the eye may not react to protect itself causing serious damage to result to the retina.
Therefore,

• Never look directly into a fiber end that has a laser or LED coupled to it.
• Never look directly into a fiber end using any magnifying lense.
• If an eye is accidentally exposed to an LED or laser beam, immediately seek medical attention.

Optical Fiber Handling Precautions

Broken fiber ends created during termination and splicing can be dangerous. These ends are extremely sharp and can easily penetrate the skin. They invariably break off and are very hard to find and remove. Often tweezers and a magnifying glass are needed to remove them from the skin. Any delay in their removal could lead to an infection, which is dangerous. Hence,

• Be careful while handling the fibers.
• Dispose of all scraps safely and properly.
• Do not eat or drink near the installation area.

Material Safety

Fiber optic splicing and termination processes often use various chemical cleaners and adhesives. The safety instructions developed for these substances should be followed. If there is confusion in the usage of these products, ask their manufacturer for a Material Safety Data Sheet (MSDS). Remember the following instructions while working with these chemicals.

- Always work in well-ventilated areas.
- Avoid skin contact with these cleaning materials as much as possible.
- Avoid using chemicals that cause allergic reactions.
- Isopropyl alcohol, used as a cleaner is flammable and should be handled carefully.

Primary treatments for exposure to Isopropyl alcohol or Hexane used to clean fibers or cables are presented in Table 2.

Type of Exposure	Hexane		Isopropyl	
	Effect of Exposure	Emergency Treatment[2]	Effect of Exposure	Emergency Treatment[2]
Inhalation	Irritation of the respiratory tract, cough.	Maintain respiration, bed rest.	Irritation of the upper respiratory tract.	Move victim to area containing fresh air. Administer artificial respiration if breathing is irregular.
Ingestion	Nausea,Vomiting Headache.	Do not induce vomiting, immediately seek medical assistance.	Drunkenness and vomiting.	Have victim drink water and milk. Seek medical assistance.
Contact with Skin	Irritation.	Wipe off affected area of skin and wash with soap and water.	Harmless to skin.	Wipe off affected area of skin and wash with soap and water.
Contact with Eyes	Irritation.	Wash eyes with plenty of water for 15 minutes.	Irritation.	Wash eyes with plenty of water for 15 minutes.

Table 2- Primary Treatments for Hexane and Isopropyl Exposure

Safety During Installation

Manhole/Underground Vault Safety:

- Explosive gases or vapors might be present in manholes or handholes due to gas leaking from nearby pipelines, tanks, or the soil. Before entering any manhole test its atmosphere with an approved test kit for flammable, explosive, and poisonous gases.

- Avoid usage of any device that produces a spark or flame in or near a manhole.

Working Safely:

- To minimize the risks of an accident in the work area, follow the existing rules for setting up warning signs, barricades, manhole guards, and cones.

- Before pulling cable directly from a figure-8 configuration, make sure that the area inside the loop of the cable (figure-8) is clear of personnel and equipment. Failure to do so may result in injury to the personnel or damage to the cable.

- Ensure that the tools and equipment used for the cable installation are in proper working order. Improperly functioning equipment may damage cables or cause injury to personnel.

- Be careful when working near electrical hazards, if electric lines are passing through or near the right-of-way where installation is being performed.

- Bond all metallic components in the underground system together. At all points where anyone may come in contact with the metallic components of the underground cable system, ground the bonded metallic components to a proper earth ground to avoid electric hazards produced by power lines or any other means.

Personal Protective Equipment

Placing optical cable and jetting micro-duct cable require sophisticated operations and use equipment that many placing crews may not be experienced with. As a result, Sterlite recommends using a placing crew that is familiar with and has experience with the cable being placed and the procedures and equipment being used. Approved personal safety equipment, such as hard hats, safety shoes, safety glasses, reflective traffic vests, and gloves shall be used for all outside plant construction activities.

Traffic Safety

All applicable federal, state, and local departments of transportation regulations and codes shall be met including the use of safety equipment such as reflective safety vests, warning signs, barricades, and lighting if work is being performed during non-daylight hours. All traffic control requirements shall be met.

Placing Equipment

Most of the equipment used is more sophisticated than conventional placing equipment. High pressures are used to drive hydraulic motors as well as the use of high pressure air lines. If a failure occurs to a high pressure hose or connection, it is potentially dangerous to those working around the equipment. Therefore, the placing crew needs to read, understand, and be familiar with all operating procedures as well the safety issues outlined by the placing equipment manufacturer.

Cable Protection and Handling

While loading or unloading cable reels, care must be taken to prevent collision with other reels, or damage to the reel or cable.

The reel should not be rolled over a long distance. If it is necessary to roll the reel, it should be rolled on both flanges in the direction indicated by the arrow on the flange.

The reel should never be stored on its side (do not store a reel flat on one flange).

Cable reels should always be stored on a flat surface with blocks placed under the flanges to prevent rolling in either direction.

The cable on the reel should be covered at the factory with a UV/thermal wrap until just prior to installation to protect it from exposure to the sun and high temperatures. The reel should never be dropped (i.e. off of a flatbed truck).

Preparation for Cable Placing

Pre-Construction Survey

One of the most important steps in the engineering and placement of optical cable is the pre construction site survey. During this visit the placing supervisor and/or OSP engineer will be able to observe any unusual situations that require special attention. The proposed placing route will be evaluated for its ability to support the planned placing procedure. One of the main objectives of the survey is to discover all potential pit-falls in the proposed placing operation so they may be accounted for in the final procedure.

General Issues

• If possible, select a route that follows existing telecommunications infrastructure.

• Before any visit is made to a prospective construction site, an up-to-date plot plan showing the location of existing utilities shall be obtained from each of the utilities that will affect the construction operation. The plot plan shall be noted with details characterizing each utility and phone numbers to call if there are problems.

• Select a route that provides easy access for workers, equipment, and materials.

• The placing route shall have a spacious and safe staging area convenient to the job site.

• The staging area shall be a location in which cable reels can be unloaded and stored prior to use with an all-weather surface. It shall also be a location at which fiber measurements can be made. It shall be secure from vandalism and theft.

• The job site and staging area shall be protected from both pedestrian and vehicular traffic.

• Splice locations shall be selected on the basis of their ability to serve as a good cable feed and/or cable pulling location or as the location where fiber branching occurs.

• Placing operations in all types of cable (aerial, buried, and underground) is normally easier when done downhill. Try to configure the placing operation downhill.

• As optical cable is placed, care must be taken not to kink, distort, or crush the cable. The cable manufacturer's recommended minimum diameter shall be maintained. If no diameter is recommended, use the following limits for the minimum bend diameter of the cable.

Cable under no load, Minimum bend radius 15 Cable Diameter

Cable under load, Minimum bend radius 20 Cable Diameter

• All splice locations and points where human contact may result in exposure to metallic components in the cable, splice closure, or underground infrastructure need to be properly bonded and grounded to an earth ground.

• Sufficient space must be provided around the start of the cable placement location (manhole or handhole) to provide a gentle transition for the cable being placed to feed from the reel into the sub-duct system. Usually 20 to 50 feet of unobstructed space should be available for the pulling equipment for unobstructed and smooth cable transition.

• When pulling cable, the placing operation shall be arranged to have the cable enter the most difficult bends first (bends with the largest central angle), as early in the placing operation as possible. This will allow the cable placing loads to be as low as possible.

• New construction must follow the National Electric Safety Code; OSHA Safety Requirements; and state, local, and federal guidelines.

• All placing operations require constant high quality communications for the entire placing operation. Radios are the most common means of communications for placing operations. The pre-construction survey should ensure that the radios will work properly in the area that will be encountered during the installation.

Underground Pre-Construction Survey

• If possible, select a conduit with empty innerducts or micro-ducts already installed.

• If any new excavation is anticipated, underground and buried utilities should be marked on the ground surface so the construction crew can easily determine where it is safe to dig. Most areas have a "Call Before You Dig" phone number to call for contractors to use to avoid damaging underground utilities during construction. 811 is the designated phone number to call before digging that connects a contractor to their local one call center. Each state has different rules and regulations concerning digging.

• The pre-construction survey of feed, pull, intermediate assist, and backfeed manholes must include an inspection of the respective manhole to be assured that the appropriate equipment is chosen and the appropriate tie down hardware is available to enable these manholes to function as required. In addition, there must be sufficient space on the ground surface adjacent to the manhole to support the proposed operation at the manhole.

• Intermediate manholes are those manholes where cable is expressed through without being spliced. They often require considerable "rigging" to setup sheaves, quadrant blocks, or pulling frames to accommodate any conduit misalignments in the route of cable placement. All of the hardware used to assist in safely making these directional changes need to be securely chained or tied in place.

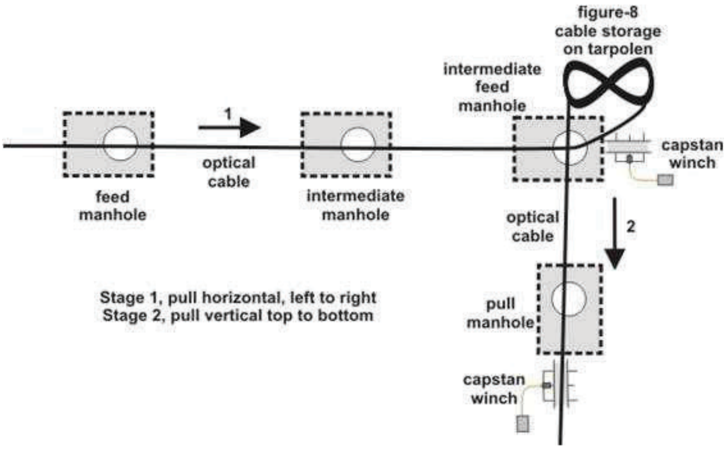


Figure 1– Schematic Showing Different Types of Manholes

Intermediate-feed manholes are those manholes where cable is pulled to in the first stage of a multi-stage cable placing operation. The remaining cable not in place (for use beyond the intermediate-feed manhole) is stored on the ground at these manholes. Finally, the intermediate-feed manhole is the location from which the stored cable is fed into the remainder of the conduit system in the next stage of the pulling operation.

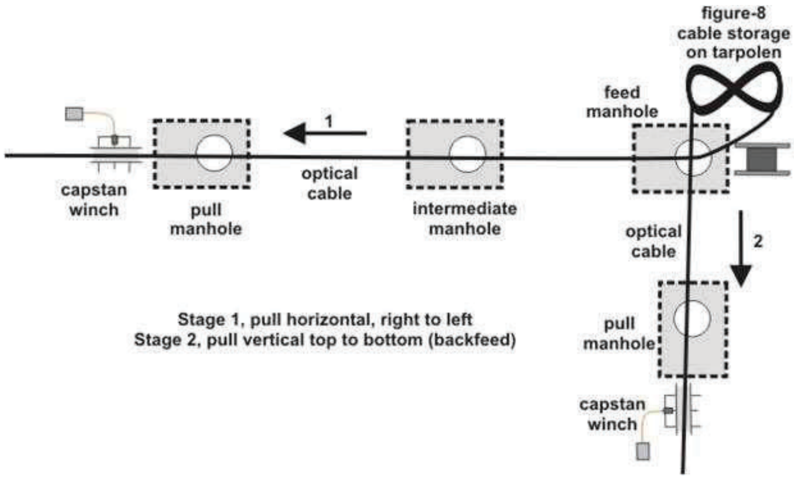


Figure 2– Schematic Showing Intermediate-Feed Manhole

• Backfeed manholes are located within the cable run from which cable is fed in both directions. Normally, backfeed manholes are located at major changes in direction of the cable run, often closer to one end of the cable run than the other. The longer segment is pulled first. The remaining cable is manually pulled off the cable reel and stored temporarily on the ground in a figure-8 pattern. Cable from the figure-8 is re-fed into the backfeed manhole in the direction of segment 2. Each end manhole in the cable run serves as a pull manhole for the respective pulling operations.

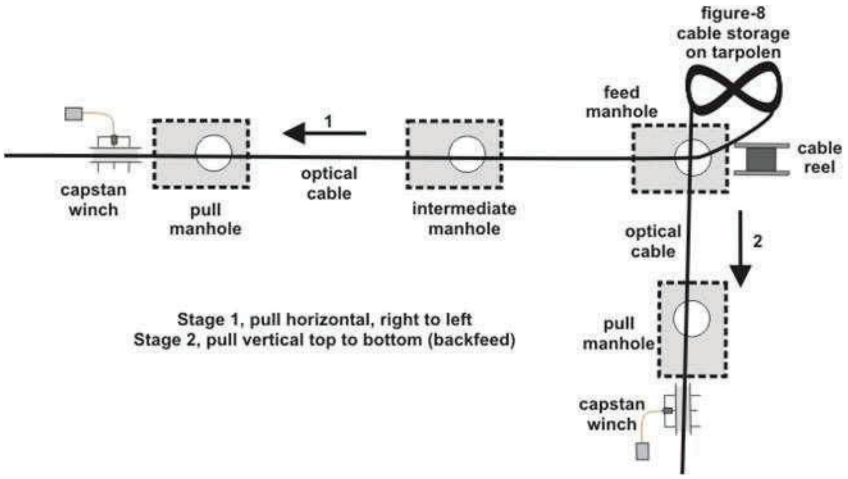


Figure 3– Schematic Showing Backfeed Feed Manhole

• Intermediate-assist manholes are those manholes near mid-span to provide an assist to the cable placing operation. The assist can either be a manual push assist or a mechanical push assist. More than one assist manhole can be used. It is possible to use mechanical assist equipment to place micro-duct cables that provide air pressure and a push force to assist the cable placement. Intermediate-assist manholes require considerable “rigging” to properly align the assist equipment with the sub-duct system.

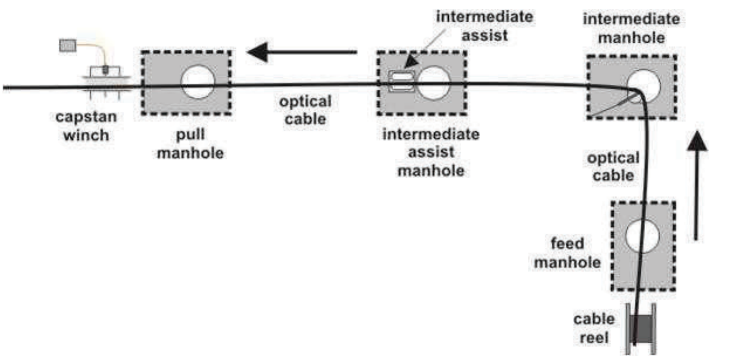


Figure 4– Schematic Showing Intermediate-Assist Manhole

• The plan developed as a result of the pre-survey along with comments shall be summarized in drawings made available to the placing crew.

• Cables and sub-duct (if required) shall be delivered to a staging area designated in the pre placement survey by the service provider or contractor installing the cable.

• All Sterlite cables are shipped with loss information on each fiber. The information is provided electronically or as a hard copy attached to the cable reel.

Cable on all reels need to be inspected for damage as they are received. As a precaution and to avoid costly extra cable removal operations, all fibers should be measured on the reel using an OTDR. Measurements on single-mode fiber cables should be made at 1550 nm and 1300 nm on multimode fiber cables. If discrepancies are found with respect to the factory “as shipped” test results on the cabled fiber, contact Sterlite Technologies.

Cable Staging Area
New cables, sub-ducts, and micro-ducts will be staged at selected areas in a safe, convenient location with respect to the right-of-way prior to their installation.

Staging locations shall be safe from vandalism and free of pedestrian and vehicular traffic interaction. If possible, the staging area shall be flat and covered with an all-weather surface.

The staging location shall be large enough to store the reels and placing equipment and materials being used in the construction operation.

Reels shall be stored on the edge of both of their flanges with access to the side of the reel for pre-construction testing of the cable on the reel.

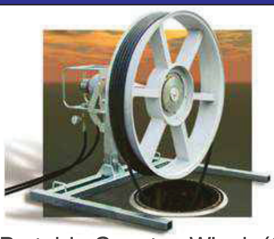
The thermal wrap shall be kept on the cable reel as long as possible to provide thermal and solar protection to the cable as long as possible.

Pre-Construction measurements shall be made on all fibers in each new cable reel at the staging location.

Tools and Materials

Underground cable placement is characterized by pulling or blowing cables into underground conduit systems with conduit access in manholes or handholes. Standard size fiber cables are normally placed in innerducts which are housed in the conduit system. Micro-duct cables are placed into micro-ducts which are housed directly in innerducts or micro-ducts in the larger diameter telecommunications conduit that make up the conduit system. Placing equipment is specially tuned to be effective placing standard fiber cables or the smaller micro-duct cables. Procedures and equipment are used to keep bending and tensile stresses under the threshold values that could begin to be a problem if violated.

Table 3– Standard Fiber Optic Cable Underground Placing Equipment

Underground Standard Fiber Optic Cable Placing Equipment	
Pulling Winches	
 Portable Capstan Winch (GMP)	 Trailer mounted Capstan Winch (GMP)
 Pushing and Air Winch	 Cable Reel Trailer (Plumett)
 Cable Placing Truck (Canada)	 Side take-off winch with slip clutch (Condux)

Associated Materials and Equipment	
 Pull Line	 Rodding Cord
 Duct Cutter	 Fiberglass Duct Rodder

Underground Standard Fiber Optic Cable Placing	
Equipment  Duct Lubricant	 Pulling Eyes for Sub-Ducts
 Duct Plugs	 Pneumatic Missiles (“Pigs” or “Birdies”)
 Ball Bearing Swivel	 Manhole Sheave and Quadrent Block (GMP)
 Large Diameter Splittable Sheave	 Intermediate Cable Storage Device (GMP)
 Sheaves and quadrant block in manhole	 Pulling frame in manhole

Associated Materials and Equipment	
 Duct Lubricant	 Pulling Eyes for Sub-Ducts
 Duct Plugs	 Pneumatic Missiles (“Pigs” or “Bir
 Ball Bearing Swivel	 Large Diameter Splittable She and Quadrent Block

Innerduct and Micro-Ducts

Conduit systems are generally made from formations of 3.5 inch to 4 inch diameter single-bore telecommunications conduit that is arranged into multiple duct conduit systems. Innerduct is often smooth wall polyethylene tubing ranging in diameter from 1 inch to 2 inches in diameter. Micro-ducts are small bor e polyethylene tubes ranging in diameter from 6 mm to 14 mm.

SDR		SDR 11		SDR 13.5		SDR 15	
Size	OD	Wall	Safe working Pull Strength	Wall	Safe working Pull Strength	Wall	Safe working Pull Strength
1.00”	1.315”	0.120”	1078 lbs	0.097”	894 lbs	0.085”	792 lbs
1.25”	1.660”	0.151”	1717 lbs	0.123”	1425 lbs	0.107”	1234 lbs
1.50”	1.900”	0.173”	2279 lbs	0.141”	1867 lbs	0.123”	1607 lbs
2.00”	2.375”	0.216”	3515 lbs	0.176”	2917 lbs	0.153”	2466 lbs

Table 5- Typical Placing Equipment Used to Place Micro-Ducts and Micro-Duct Cabl

Figure 5- HDPE Innerduct

Micro-Duct Nominal Diameter	
Size	OD
7 mm	5.5 mm
10 mm	8 mm
12 mm	10 mm
14 mm	10 mm
16 mm	13 mm

Table 6- Geometry of Most Common Micro-Ducts

Lubricant

As always, the encasing conduit, sub-duct, innerduct, or micro-duct must be lubricated prior to the start of any placing operation following the lubrication schedule in Table 7 or Table 8. Once the placing operation begins, lubrication must continue to be applied to the cable being placed as it is placed.

American Polywater provides this formula for estimating the quantity of lubricant that should be used to place a standard size optical cable or micro-duct into a sub-duct.

Quantity of Lubricant in Gallons = $0.0015 \times D \times L$
Where: D = Diameter of Conduit in Inches Housing the
Item Being Placed L = Length of Placement in Feet

Polywater also provides the information contained in Table 7 showing an estimate of the volume of lubricant used to place standard size fiber optic cable or micro-ducts in various size sub ducts or innerducts. Approximately 75 percent of the lubricant should be placed in the sub-duct ahead of the swivel and the remainder of the lubricant placed on the cable or micro-duct as it enters the sub-duct.

Duct ID or Cable OD	Gallons of Polywater® F Needed for Continuous 10-mil Coating on a 1,000-foot Length Pull
0.50”	0.8 Gallons
1.00”	1.6 Gallons
1.25”	2.0 Gallons
1.50”	2.4 Gallons
2.00”	3.3 Gallons

Table 7– Approximate Volume of Lubricant Required to Place Standard Fiber Optic Cable or Micro-Duct into Innerduct or Sub-Duct

Polywater offers the micro-duct cable placing lubrication estimate shown in Table 8 to jet micro duct cable into various size micro-ducts. Pour approximately 75 percent of the lubricant indicated in Table 8 directly into the micro-duct ahead of the missile with the remainder of the lubricant being placed on the cable during the placing operation. Note, the actual quantity of lubrication used in any placing operation varies and is dependent upon the size, condition, length, wall type of the micro-duct, and the material in the duct and cable jacket.

Micro-Duct Size (MM) (OD/ID)	Amount of Lubrication Required Per 100 ft
14/12 mm	0.30 fl. oz (9 ml)
12/10 mm	0.25 fl. oz (7 ml)
10/8 mm	0.20 fl. oz (5 ml)
8/6 mm	0.15 fl. oz (4 ml)
7/5 mm	0.13 fl. oz (4 ml)
5/3.5 mm	0.09 fl. oz (3 ml)

Table 8– Approximate Volume of Lubrication Required For Cable Jetting Micro-Duct Cable in Various Size Micro-Ducts

Sheaves, Quadrant Block, and Manhole Frame

The cable manufacturer's recommended minimum bend diameter shall be maintained. If no minimum bend diameter is recommended, use the minimum diameter recommended below.

Cable under no load, Minimum bend radius 15 × Cable Diameter

Cable under load, Minimum bend radius 20 × Cable Diameter

Winches

Since optical cables are lighter in weight and smaller in diameter than their copper counter parts, smaller winches are generally used to place optical cables. Most standard size optical cables have a maximum cable placing force of 600 pounds or greater (some optical cables do have higher loads and some lower, consult the cable specification provided by Sterlite to determine the maximum placing load for each cable). Fiber optic cable winches tend to be smaller than the line truck bed winches used for copper cables. Capstan winches are popular. Some of these winches are stand alone, using portable power packs (electric or hydraulic) and some are truck or trailer mounted using the hydraulic power take-off from the support truck. Fiber winches should all have or be coupled to cable tension monitoring systems to ensure that the maximum cable tension is not violated. Slip clutches are often used for side take-off winches on line trucks.

Cable Blowing and Pushing Engine

The micro-duct system is based on the use of a combination of smaller diameter sub-ducts and more compact optical cables using more efficient placing methods and equipment specifically tuned to micro- duct and micro-cables. It is possible to use equipment similar to that used to place micro-duct cable to place standard size optical cables; it is specially tuned to the standard diameter optical cables and innerduct.

Cable Placing Methods

The force to install a cable into a duct is caused by sidewall forces between cable and duct, other adjacent cables (for ducts containing more than one cable), and the friction coefficient between the interacting materials. Micro-ducts and micro-duct cables are designed to optimize the fiber capacity of the available underground space. The placing methods discussed in this section have been developed to enable standard size optical cables and micro-duct cables to be placed efficiently, safely, and economically. Standard size optical cables, innerducts, micro duct cables and micro-ducts can be placed using several procedures:

- **Pulling-** A system to place cables or ducts for shorter length runs of underground plant and in previously installed underground, buried, and aerial micro-ducts using a winch and winchline. Both ducts and cables can be placed with this pulling method. Pulling tends to be more popular for standard optical cables and in larger diameter communication ducts and innerducts (sub-ducts). Depending upon the pulling method used and the geometry of the conduit plant encountered, lengths of 1,500 to 3,000 feet can be placed using this approach.

- **Jetting (blowing) –** A system used in longer lengths of underground cable and in previously installed micro-ducts using air pressure. Standard optical cables, micro-duct cables, and micro-ducts can be placed using jetting. Jetting is most effective in smaller ducts of 50 mm diameter or less (micro-ducts). It is possible to place micro-duct cable using jetting in continuous lengths of 4,000 to 6,000 feet, depending upon the geometry of the right-of-way.

The following effects contribute to the pulling force build-up in the cable:

- **Cable weight (gravity)-** This results in a pulling force that is proportional to the installed weight of the cable which is directly related to the cable size, design, and the length of the cable.

- **Coefficient of friction-** The material property that relates the normal force to frictional force between cable and duct (or adjacent cable when several cables are present in the same duct). The coefficient of friction affects the cable tension linearly in straight runs. In bends and undulations of the duct, the tensile pulling force increases exponentially with respect to the undulation's curvature and the coefficient of friction. This effect is known as the capstan effect. It can dominate most cable pulls

- **Cable tensile force-** The resulting pulling load on a cable is the combination of cable weight, curvature of the bends, location of the bends, coefficient of friction, and weight of cable (unit weight and length). The total cable tensile force required to place the cable must not exceed the rated cable tensile strength.

• **Cable compressive force-** The cable can buckle under the compressive forces of a cable pusher and become crushed from additional sidewall forces that build up on the inside of a bend. This can also lead to a pulling force built-up that limits the distance it can be pushed. If a cable pusher is used to assist cable placing as it enters the sub-duct and if it continues to work if a cable jam occurs, the compressive force could cause the cable to buckle, unless the placing engine is adjusted to stop pushing when cable compressive load reaches a set safe level.

• **Cable stiffness in bends and undulations in the duct trajectory-** The greater the cable stiffness, the larger the frictional force from cable stiffness in bends and undulations in the duct.

Normal Cable Pulling Method

If cables are pulled into conduit or innerduct, the maximum cable diameter attempted will normally not exceed 50 to 60 percent of the conduit or innerduct Id . Table 9 contains the fiber count of the largest conventional Sterlite fiber optic cable that can be pulled into innerducts of various sizes using a fill ratio of 50 and 60 percent.

3 FILL RATIO = (d2/D2) x 100

Where: d = outside diameter of cable and, D = inside diameter of micro-duct.

Innerduct Nominal Diameter	Innerduct Inside Diameter	Cable Diameter 50 % of Micro-Duct Diameter	Cable Diameter 60 % of Micro-Duct Diameter
¾”	21.3 mm	None	96 Fibers
1”	26.7 mm	144 Fibers	144 Fibers
1¼”	33.8 mm	216 Fibers	288 Fibers
1½”	38.8 mm	288 Fibers	288 Fibers
2”	48.7 mm	576 Fibers	864 Fibers

Table 9– Maximum Fiber Count of conventional Sterlite Fiber Optic Cable that can be placed into various sized Innerducts

Before the cable placing operation begins, the innerduct or micro-duct system should be checked to be assured that the cable's minimum bend radius is not violated during handling, feeding, placing, and final positioning. The placing equipment and all pressure fittings should be checked. The winch shall be adjusted to stop placing the cable if the placing load reaches a level close to the maximum rated cable placing tension. If a placing engine is used, it should be checked to confirm that the compression limits safely match the limits of the cable being placed and have been properly and accurately set. Radios should be checked to confirm that all manned positions along the right-of-way are in communications and prepared to start the placement. Figure 6 shows a typical unassisted standard optical cable pulling operation.

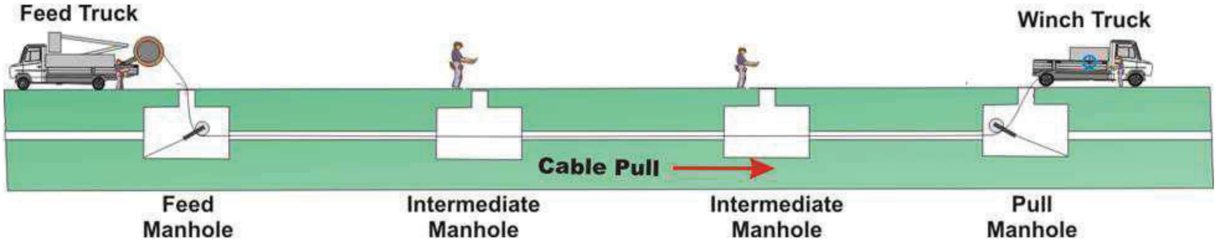


Figure 6– Cable Pulling Showing Placement Without Intermediate Assist

The leading end of the cable shall be connected to the pulling line using a basket grip sized for the cable that slips over the cable end. A wrap of vinyl tape shall be wrapped around the grip which has been pulled tight over the cable. The pulling line shall be connected to the basket grip with a ball-bearing swivel.

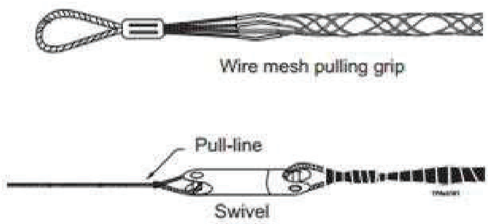


Figure 7– Basket Grip and Ball-Bearing Swivel at Lead End of Cable

Figure 8 shows a typical unassisted micro-duct cable jetting operation.

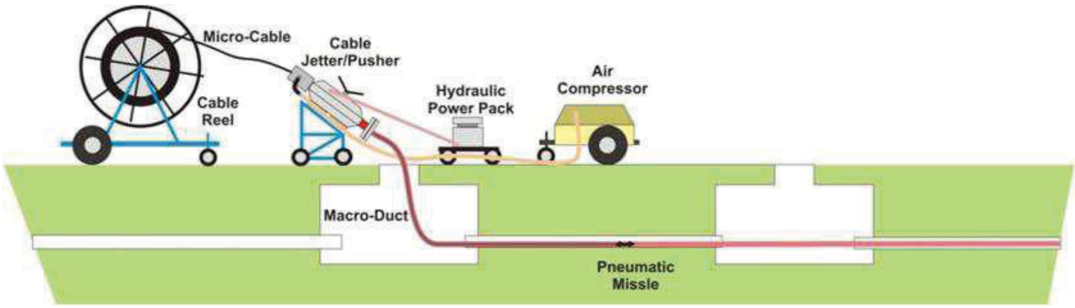


Figure 8– Cable Jetting Schematic Showing Placement Without Intermediate Assist

All transitions into and out of manholes shall be direct and smooth, not violating any of the cable's mechanical or geometrical limits. Air pressures and hydraulic pressures shall be set according to the winch and placing engine manufacturer's instructions. The operation of the winch and placing engine during placement shall follow its manufacturer's instructions.

The placing operation shall begin slowly and continue at the slow speed until it is clear that the placing operation is progressing smoothly and properly. The placing speed can be increased gradually until the operation reaches a fast, but completely under control speed. Sterlite and the placing equipment manufacturer recommend that the placing operation be performed at a safe and controllable speed. See the winch or placing engine manufacturer's instructions for an estimate of a safe maximum placing speed.

Once the cable has been placed, sufficient slack cable should be provided on each end of the cable route to enable the splice to be made to the adjoining cable, to rack cable in intermediate manholes, and to store the standard amount of slack at each splice required by the cable's end-user for maintenance operations.
If the placing operation is too difficult to accomplish in a single, unassisted operation, three alternative methods can be considered:
1. Bidirectional Placement (Figure-Eight)
2. Backfeed Procedure
3. Intermediate Assist (automated or manual)

Individual conduit segments in both the intermediate assist and bidirectional placement methods need to be kept shorter in length than the unassisted placement route. As a rule of thumb, placing cable using either procedure should be limited to 1.5 km or shorter for each pull segment.

Since each intermediate assist method uses a sub-duct system that is discontinuous at each assist manhole, each discontinuous duct segment needs to be lubricated independently, i.e., they need to have lubrication applied ahead of the cable, and then on the cable as it passes through the intermediate assist manhole or figure-eight manhole that leads into the next duct segment. Each placing winch or engine used in an intermediate assist procedure needs to be adjusted with the mechanical limitations determined for the cable being placed, i.e., maximum compression and tensile force.

Bidirectional Figure-Eight Procedure

If necessary, a placing plan listing the pulling locations, intermediate assist, and figure-8 locations should be developed during the pre-survey of the placing project. The placing plan will indicate the length of cable to be coiled at the "figure-8" location.

For bidirectional placing, a convenient intermediate manhole is selected for the figure-8 location. It should be near mid-span and, if possible the duct section in both directions out from the figure-8 manhole should be placeable in a single operation.

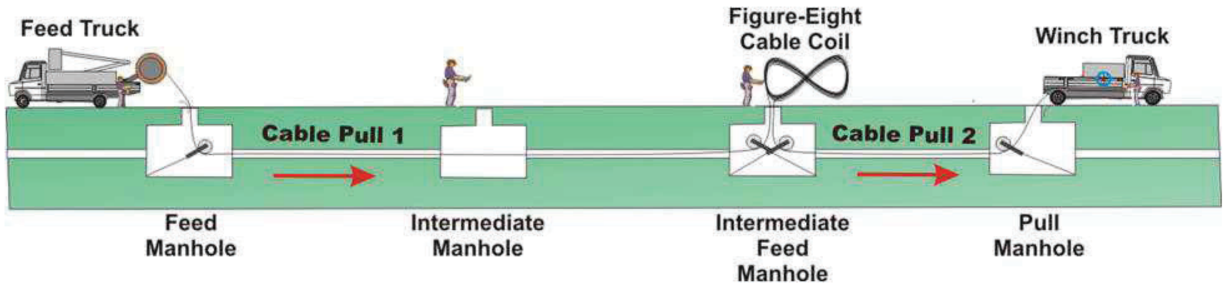


Figure 9- Cable Pulling Showing Cable Placement with Intermediate Figure-8 Feed

Segment 1 of the cable placing operation requires pulling cable from the cable feed manhole to the figure-eight manhole. The placing winch must be positioned at the figure-eight manhole for this operation.

Cable is pulled or jetted to the intermediate figure-eight manhole following the procedures outlined in Figure 9. All cable is pulled off the reel with the excess cable figure eighted in a coil about 10 meters long at the intermediate figure-eight manhole. Care is required to avoid damaging the cable as the excess cable is pulled out of and, in the next step, back into the intermediate manhole. During this operation, a significant length of cable is being pulled around a capstan winch, so care must be taken to avoid over bending the cable. In addition, the manhole must be rigged to provide a gentile passage for the cable out, then back into the manhole and duct system. The figure-eighting of the cable shall be done carefully, in a safe location free from access by the public.

Sufficient cable shall be left in the initial cable feed manhole to complete the splice to its neighboring cable and to provide cable slack for future maintenance and racking operations.After all cable has been pulled off the reel and the excess cable figure eighted, the pulling equipment shall be moved from the figure-eight manhole to the end manhole to complete the cable placing operation from the figure-eight coil at the intermediate figure-eight manhole as segment 2.

Before the segment 2 placing operation can begin, the figure eight coil must be carefully turned over ("flipped") so that the cable that was on the bottom is now on top. This cable coil "flip" will enable cable to be fed off the top of the coil to the far manhole to complete the placing operation.
The final segment of micro-duct will be placed from the figure-eight manhole to the far end manhole. The operation shall be conducted as described above. As always, the encasing conduit, sub-duct, innerduct, or micro-duct must be lubricated prior to the start of any placing operation following the lubrication schedule in Table7 or Table8. Once the placing operation
begins, lubrication must continue to be applied to the cable as it is placed.

Placing Assistance

A placing plan determining pulling locations, including the intermediate assist location should be developed during the pre-survey of the placing project. Figure 10 and Figure 11, show a cable jetting operation with intermediate assist, both manual and automatic.

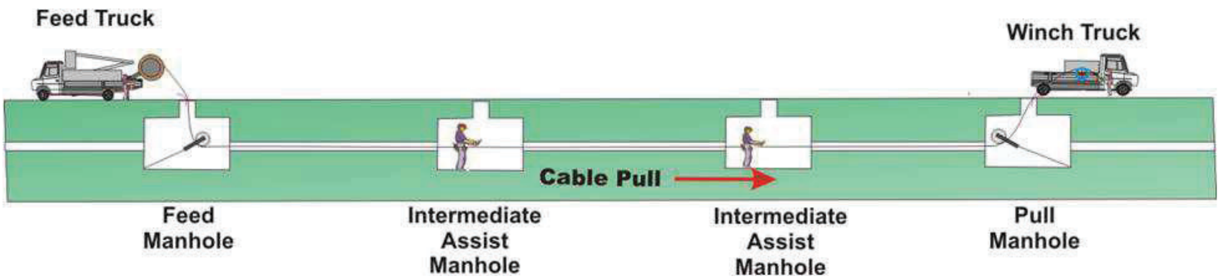


Figure 10- Cable Placement Showing Placement with Manual Intermediate Assist

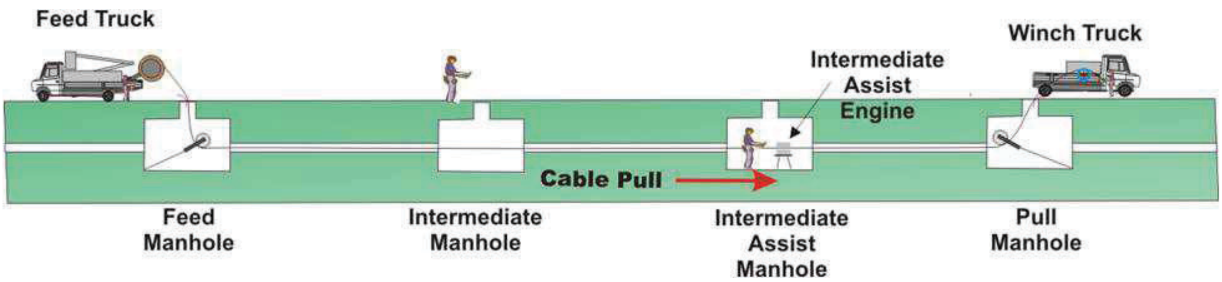


Figure 11- Cable Placement Showing Placement Using Intermediate Assist Engine

An intermediate manhole can be selected as an intermediate assist location. It should be near mid-span and, if possible, the duct section in both directions out from the intermediate assist manhole should be place able in a single operation. The area around the intermediate assist location should be sufficient to stage the ground support equipment (air compressor and hydraulic pump) for the placing operation.

For an automated intermediate assist procedure to be successful, the placing engines (primary and assist engine) need to be coordinated, so compressive forces do not build up causing the cable to buckle or kink. This is a procedure that is difficult to perform safely and should only be attempted by an experience placing crew. If used, the assist equipment manufacturer's instructions must be carefully followed. Once the cable has been placed, sufficient slack cable should be provided on each end of the cable to enable the splice to be made to the adjoining cable, to rack cable in all manholes to the assist manhole, and to store the standard amount of slack at each splice required by the cable's end-user for maintenance operations. Sufficient slack must be provided in intermediate manholes to rack the cable and sub-duct (either innerduct or micro-duct) along the sides of the manhole, out of the way from harm and still have sufficient slack stored to accommodate the end-users requirements.

All ducts should be plugged at the conclusion of the placing operation. If a cable has been pulled into the duct, the duct plug should be sized for both the ID of the duct and the OD of the cable.

Micro-duct shall be left intact through intermediate manholes during placing and racking, whenever possible unless the micro-duct was removed to enable intermediate assistance or a portion of the cable is branched off the cable route being placed.

Typically, a cable coil will be placed in a manhole or hand-hole to provide extra cable in the event of network damage or extra cable for splicing fibers. In certain environments, it may be determined that cable protection for the coiled slack is required due to the threat of rodent damage. If possible, protect any slack coils with split flexible conduit and store the coil in a safe position in the manhole or hand hole.

Back Feeding Assist to Cable Pullin

Backfeeding is a placing procedure in which the cable feed truck is set up at an intermediate manhole. The entire cable is pulled in two operations. Generally, the longest and most difficult segment is pulled first. Sufficient cable must be pulled out of the first pull manhole to accommodate the splicing operation, racking, and sufficient slack for future maintenance operations.
Once segment 1 has been placed, the remaining cable is spooled off the cable reel and stored in a figure-8 coil next to the feed manhole. The cable coiled in the figure-8 is placed in the second segment of the conduit run. Again, sufficient cable must be pulled out of the second pull manhole at the far-end of the cable run to accommodate the splicing operation, racking, and sufficient slack for future maintenance operations.

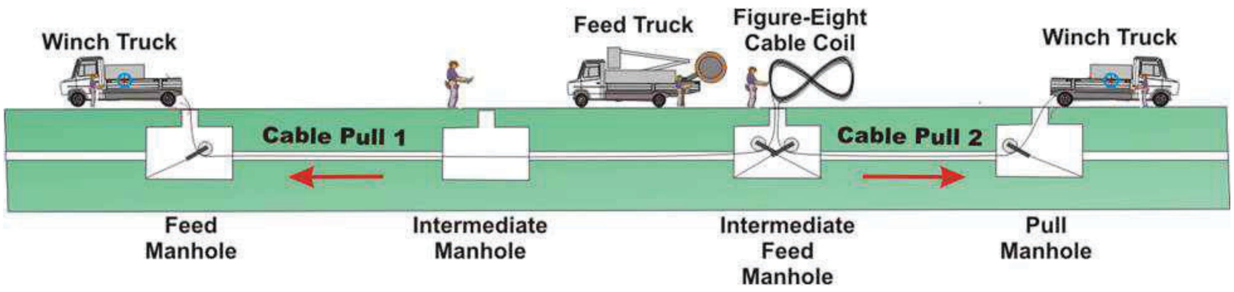


Figure 12- Cable Pulling Showing Cable Placement using Backfeed Placement

Manhole Housekeeping

Cable Coiling

Spare cable from the cable placing operation should be stored in intermediate and splice manholes (end manholes during placing) in a neat coil wrapped with a radius greater than the minimum bend radius of the cable. Forms for the cable coiling operation can be commercially purchased.

Cable coils should be stored in a safe location, away from the normal work operations in the manhole. If possible the cable coil can be stored behind the racked cable. The cable coils should be cable tied in place.

Racking Cable and Innerduct

Once the cable has been placed, sufficient slack cable should be provided in each end manhole to enable the splice to be made, to rack cable in each manhole, and to store the standard amount of slack at each splice required by the cable's owner to perform maintenance operations. Also, sufficient slack must be provided in intermediate manholes to rack the cable inside sub-duct (either innerduct or micro-duct) along the sides of the manhole, away from harm and still have sufficient slack stored to accommodate the end-user's requirements.

The cable must be properly terminated in a splice closure. The proper clamping of the cable's central strength member is necessary to prevent CSM pistoning. In addition, the jacket must be properly secured to prevent jacket retraction or cable slippage.

Cable racking normally begins in an intermediate manhole or backfeed manhole and proceeds one manhole at a time toward each end manhole (or location where cable slack is being stored). Normally slack for cable racking is pulled by hand or if that becomes too difficult, using a split basket grip and a hand operated cable hoist. Care must be taken to avoid over tensioning the cable during slack pulling, or over bending the cable when forming it to the side wall of the manhole.

When racking cables, the innerduct should be continuous through intermediate manholes. The innerduct will provide the cable with an extra layer of protection during future work activities and from rodents. Form the innerduct and enclosed cable to the sides of the manhole, being careful to maintain the cable's minimum bend radius. Once the cable and innerduct is formed along the manhole walls in a safe location, secure them to the manhole racks using plastic cable ties. If the innerduct is insufficient in length to be formed to a safe pathway along the sides of the manhole, it can be ring cut to allow the racking to be completed. Pulling slack innerduct from adjacent manholes is not recommended. Cut the innerduct just beyond the first manhole rack on both sides of the manhole. The racked, cut innerduct can be cable tied to the first manhole rack to keep it secured. The opening in the innerduct should be covered with a split duct.

Expressing micro-duct cable buffer tubes through a splice closure is not permitted. The buffer tubes should be opened in the splice closure and the express fibers stored in the closure's splice trays or routed in furcation tubing through the closure. If the buffer tubes are expressed through the splice closure, an increase in attenuation may occur at colder temperatures.

Additional Information

If there are additional questions on this topic or other fiber optic issues, please contact Sterlite Technologies at:

Contact Information

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www.sterlitetechnologies.com

beyond tomorrow

About STL - Sterlite Technologies Ltd

STL is a leading global optical and digital solutions company providing advanced offerings to build 5G, Rural, FTTx, Enterprise and Data Centre networks. The company, driven by its purpose of 'Transforming Billions of Lives by Connecting the World', designs and manufactures in 4 continents with customers in more than 100 countries. Telecom operators, cloud companies, citizen networks, and large enterprises recognize and rely on STL for advanced capabilities in Optical Connectivity, Global Services, and Digital and Technology solutions to build ubiquitous and future-ready digital networks.
STL's business goals are driven by customer-centricity, R&D and sustainability.

Championing sustainable manufacturing, the company has committed to achieve Net Zero emissions by 2030.
With top talent from 30+ nationalities, STL has earned numerous 'Great Place to Work' awards and been voted as the 'Best Organisation for Women'.

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