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**Network-as-a-Service Runbook**

***Fiber Construction Technical Specifications***

**<NaaS Operator’s Name>**

**

*<Release Date>*

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# Construction

The technical requirements in this document describe specifications applicable to different construction solutions and techniques. The Construction Management team may select to share a limited subset of them with vendors during the RFx process, based on the project needs identified during the design phase.

## Aerial Installations

Fiber deployed above ground on poles or towers removes the need for underground digging. Aerial installations are less costly than underground installations and easily accommodate to the terrain undulations. However, aerial installations have a significant visual impact, and are significantly affected by weather conditions, such as wind, dryness, rain, snow, ice, temperature oscillations, and erosion. For this type of install, references should be made to IEC specification 60794-1-1 Annex C.3.5 “Installation of aerial optical cables”. Polyethylene (PE) cable jackets are required for aerial installations to prevent degradation due to sunlight exposure.

Aerial installations commence with a terrain survey, where route information is gathered. This survey does not replace the planning survey already described in section 3.2.2, but complements the initially gathered information with specific information for this type of installation. Following, the installation is detailly planned and the materials taken to the installation site.

### Survey

The survey for aerial installation defines the location of the supporting poles and stays. As such, it is considered a technical review of the installation and must be carefully planned and executed. Surveys must be documented using the template provided as annex to this module, named “*Template A-Path Survey Report*”.

1. Survey rods must be planted in line at selected pole positions so that, when erected, the poles will be in a straight line.
2. A spirit level must be used to verify that there is no lean to the rods.
3. As the survey advances, the rear rods used for lining up will be withdrawn and survey pegs driven into the ground in the exact position previously occupied by the survey rod.
4. The location of the poles to be erected along roads shall be in accordance with the rights of way and conditions stipulated by the authorities concerned
5. Wooden pegs shall be used to mark the position of every pole, stay or strut
6. The numbering and marking of the wooden pegs shall be done as agreed upon by both the NaaS Operator and construction vendor.
7. The tops of pegs that show the positions of angle poles must be clearly marked for easy identification
8. A survey peg for a strut position must show the approximate spread of the strut.
9. It is advisable to maintain a uniform span length and depart from this only when it is rendered necessary by conditions such as: (1) uneven ground (2) sharp bends (3) or to avoid dangerous positions. This may necessitate the planting of additional poles or omitting of poles. Refer to Table 3 for typical pole spacing.
10. Steel measuring wires for standard span lengths should be made up locally. When the length of span has been chosen the appropriate wire should be used to determine the distance between successive poles.
11. A steel tape measure should be used for checking the length of the measuring wire daily during the construction survey.

Table 4. Pole Spacing

| Type or Route | Pole Spacing |
| --- | --- |
| Short Span | 80 m |
| Medium Span | 250 m |
| Long Span | 500 m |

### Pre-Install Checklist

A pre-install meeting must be held to discuss the survey results, the optimum pulling sites, span lengths, installation equipment and hardware requirements, logistics, splice locations, terrain and other vital installation topics. A checklist covering the key question than need to be addressed before commencement of the construction works shall be filled by the Contractor and verified by the Naas Operator.

1. Does the contractor have approved aerial route drawings, signed by the NaaS Operator?
2. Do the drawings show the alignment of the aerial route within the wayleave specification?
3. Are the wayleaves in place?
4. Have the locations of existing services been marked and shown on drawings?
5. Are the aerial route drawings being marked indicated on which side of existing road/pathway to stay?
6. Has the accessibility of poles to splicing vehicles been considered?
7. Does the cable have a UV resistant cable jacket?

### Wooden pole inspection

Prior to planting, the Contractor must carry out a pole inspection

1. Correct type of pole supplied? (length and thickness)
2. Is there an excessively bent or is the pole cracked? Does it have a large knot or several smaller ones at the same height which may be evidence of a weak point on the pole?
3. Has the pole been inspected for evidence of termites or ants?
4. Are the poles fitted with ‘end plates’ and strapping at both ends?
5. Have the poles been off loaded and stacked on the ground for long periods, possibly damaging them?
6. Has a Hammer Test been run on erected poles? The test, consisting on rapping the pole sharply with a hammer weighing about 1kg, starting near the ground line, and continuing upwards around the pole to a height of approximately 1.5m should produce a clear sound and rebound sharply when striking sound wood. Decayed areas will be indicated by a dull sound or a less pronounced hammer rebound.

### Pole Holes

1. All excavations for pole holes will be such that the survey peg indicates the center of the hole.
2. Poles holes should have a recommended diameter of 400mm. If the holes are too large, the soil will be unnecessarily disturbed, and the poles will not be supported by solid earth.
3. Where a hole is dug on sloping ground, the depth of the hole shall be measured from the lowest point on the ground surface.
4. In extreme rocky conditions where holes cannot be excavated to the specified depth, an arrangement between contractor and client can be reached for poles to be set in concrete.

Table 5. Pole Hole Depth

| Length of Poles | Plant Depth |
| --- | --- |
| < 6 m | 0.9 m |
| 6 - 9 | 1.2 m |
| > 9 | 1.5 m |

### Poles set in Concrete

1. Where poles are planted in soil that is difficult to compact, such as sand and swampy areas and in extreme rocky conditions, the poles can be cast in concrete. Only new wooden poles can be set in concrete.
2. The hole must be circular in shape. The hole diameter must be kept to a minimum but be sufficiently wide to accommodate at least 85mm of concrete between the sides of the pole and the undisturbed ground.
3. The concrete to be used must be made from a mixture of 1-part cement, three parts sand and three parts crushed stone (1:3:3 mix - 15MPa).
4. Concrete must not be compacted around the poles, but thoroughly tamped around the pole with a suitable wooden stick, until the hole is filled.
5. The bottom of the pole must be allowed to “breathe” – therefore, backfill with 10cm of soil before pouring concrete.

### Pole Planting Process and Work Practices

1. Ensure that all holes necessary for pole dressing are drilled prior to erection.
2. A pole should be erected by laying it on the ground in such a position that by raising the top section, the base should slide into the hole.
3. Backfilling and ramming must take place in 300mm intervals.
4. Where stones are available, they should be used to stiffen the holding.
5. During the backfill and ramming process, always ensure that pole plumbness is maintained.

### Pole Planting Work Practices

1. Avoid dongas, culverts, drains or water channels.
2. Avoid obstructing private roads and entrances.
3. Restrict road crossings to a bare minimum, and if possible, stick to the same side of the road throughout.
4. Avoid trees and where not possible, select a position which will minimize interference from trees – even at the expense of construction costs being increased slightly by this action.
5. Along national and other proclaimed roads the poles and stays should be located in the position agreed to by the Road Authority and as indicated on the wayleave.
6. Keep the route as far away as practically possible from power lines.
7. Where the ground is very soft, poles may be planted 300mm deeper than specified, but only if the necessary vertical clearance is maintained.
8. Ensure that all holes necessary for pole dressing are drilled prior to erection.
9. Maintain a distance of at least 1m from trig beacons and stations.
10. The principle to be followed in all cases is that neither stays nor poles are to be planted where they are likely to cause obstruction or to be dangerous to users of the road, or where they are likely to interfere with ordinary road maintenance such as the clearing and trimming of the edges of the road or the cutting of drains, gutters, etc.
11. In railway reserves, the poles should be located as close as possible to the boundary fence.

### Pole Stays

1. Terminal stays are provided where the route starts and ends. This stay must be on the side of the pole opposite to the direction of the cable route
2. Line stays should be installed at every 13th pole along the route. Line stays must be installed on poles either side of rivers and road crossings where normal span lengths are exceeded
3. Wind stays used to stabilize a cable route against wind must be fitted at 90˚ against the direction of the cable route and on either side of a pole.
4. Angle stays are used to counter-act a change in direction of the cable route by more than 15˚.
5. Stay guards must be fitted on all stays exposed to pedestrians or vehicles, to make them more visible
6. The depth of stay holes shall be 1.5m.

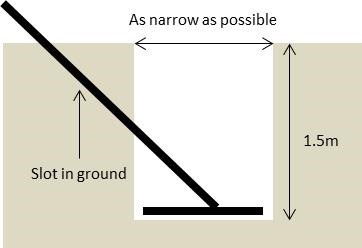


Figure 6. Stay Holes

1. Stay rods without plates may be used where solid rock is encountered; in such case, the stay rod shall be inserted in a hole drilled into the rock and secured with cement. In difficult to dig ground conditions shallower holes are allowed and shall then be backfilled using concrete.
2. Wind stays shall have a spread/height ratio of 0.6:1. Terminal and line stays has a spread/height ratio of 1:1.

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Figure 7. Spread to Height Ratio

1. Struts can be used as an alternative to where stays create traffic hazards, block roads or where a property owner objects to the fitting of a stay.
2. Struts must be installed on the opposite side of the pole to where the angle stay would have been fitted, to counter-act cable strain

### Messenger Wires

If the cable is to be lashed to a messenger wire, such wire must be sufficiently strong to support the cable under expected environmental conditions, including wind.

### All-Dielectric Self-Supporting (ADSS) Cable

ADSS is a special OSP (Outside Plant) cable that is designed to sustain larger tension loads over long periods of time. This type of cable does not require additional support, as it is small, lightweight and easy to install. Being non-conductive, it can be installed on towers or poles near electric wires. It can be installed in long spans. A UV resistant cable jacket is required for all aerial applications.

The installation process must be defined in accordance to the following guidelines:

1. Orientate the drum so that the natural payoff direction faces the pulling direction.
2. To eliminate possible cable contact with the ground, play the cable off from the top of the drum.
3. Fit specially designed cable pulley boxes to every pole on the route, for the length of cable to be erected.
4. Feed the pulling rope through the pulleys. It is extremely important that the pulling rope and the ADSS cable have the same diameter.
5. Make a hauling eye at the end of the cable by removing a piece of the cable sheath (250-300mm). Next, the Kevlar of the cable is then wound around the cable and attached to the cable using a 25/8 heat shrink sleeve.
6. Place the drum at least 50m away from the pole where the cable is to go through the first pulley. This will prevent the cable from bending too much while being pulled.
7. Attach a break-away swivel to the end of the hauling rope and then attach the other end of the break-away swivel to the hauling eye of the cable - erecting can now begin.
8. Cable lengths of up to 6000m can be erected with one haul, if the terrain allows for it.
9. Radio Communication between persons at the drum, alongside the cable-end and the hauling team must be maintained.
10. When hauling the cable, a person with a two-way radio must walk alongside the cable-end to ensure that the cable is not twisting with the rope, especially at angle-poles.
11. The hauling team must haul the cable evenly and prevent jerking. The person(s) at the cable drum must "feed" the cable off the drum at the same speed at which the cable is being hauled. There must be no strain on the cable between the drum and the first pulley.
12. A good rule of thumb is to keep the pulling tension to 1⁄2 that of the sagging tension (see sagging).
13. When removing a pulling grip, 3-5 meters of adjacent cable must be cut-off and discarded.

### Cable Pole Support Hardware

Support hardware can include tension clamps (to anchor a span of cable to a pole or to control a change of pole direction) and intermediate suspension clamps (to support the cable between the tensioning points). Both types of clamps should be carefully selected for the particular diameter and construction of the cable. Vibration dampers may be needed for spans in open country that is prone to Aeolian or galloping effects.

The cable may need protection if it is routed down the pole, for example by covering with a narrow metal plate.

## Civil Works

Underground fiber optic cables play a huge role in cross country cabling, in urban areas, and even in particular areas where cables need to be protected from hostile weather conditions. Underground cables can be installed by burying them directly in the ground or by placing the fiber optic inside a duct buried underground. For applications such as cross-country installation, it is prevalent to see the direct burial of the cables. Commonly made of steel armor, the fiber cables are buried into a trench dug at a certain depth. The steel armor is meant to protect the fiber optic cable from the harsh environment and burrowing animals.

Careful planning of the installation will lead to an efficient and safe operation. Liaison with the Local Authorities prior to installation is recommended, where appropriate.

A full appreciation of nearby utility services must be obtained both from the local authorities and by on-site confirmation using suitable detection equipment.

### Direct Buried Installations

Direct bury cables are built to specific tolerances to heat, moisture, conductivity, and soil acidity. Direct-buried cable is cheaper and easier to install than other kinds of cable that require protection from the earth. The main advantage of direct-buried cable is that this solution can be installed with relatively little effort since there is no need to prepare the ground where the cable is laid by installing piping or making other accommodations. Essentially, the cable is buried directly in the earth below ground level, then covered and immediately ready for use.

This type of cable requires a narrow trench to be excavated in order to effectively bury and protect the cable. A number of excavation techniques are available including mole-plough, open trenching, slotting and directional boring. A combination of these options is possible over an area of deployment. Direct burial offers a safe protected and hidden environment for cables but requires careful planning and survey to avoid damaging other buried services.

1. On all direct-buried installations, Armored Cable must be deployed - which provides for both crush and rodent protection.
2. In general, the most desirable and economical method of cable placement in open or rural areas is ploughing- where there likely to be fewer obstacles to impede the progress of the ploughing equipment. In urban or sub-urban areas where there can be many obstacles such as underground utilities, sidewalks, road crossings etc., trenching by hand has advantages.

A group of people standing on a dirt road

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Figure 8. Cable placement by ploughing

1. Should only an armored cable be placed, a trench no wider than 375mm will suffice.
2. The trench shall be 1.2m deep or as stipulated in the wayleave.
3. Grade off abrupt changes in terrain ahead of the plough.
4. Excavate at least 5m at the starting point, to allow for the plough to immediately lay the cable at the correct depth.
5. Always start the plough tractor’s movement slowly and increase speed gradually only after the cable slack is taken up from the cable delivery system.
6. Ploughing operations must be observed continuously for: obstructions, proper feeding of the cable, specified depth, following of the marked route, and the safety of the crew.
7. Warning Tape must be placed approximately 300mm below the ground surface, directly above the cable.
8. It is critically important for manholes and handholes to be built only after the plough in of the cable. Pre-fabricated handholes are recommended.
9. Each section, after ploughed-in, must be checked with an OTDR for possible damage.
10. After the plough in process is completed, the trench must be levelled by one of the following methods:

* Back blading with the plough-in machine.
* Using a TLB to level the disturbed areas.

1. Strength members must be bonded and grounded.

### Trenches

Trenching is recommended to be accomplished with specialized trenching tractors, which cut the trench and remove the soil in a single action. A trench can be used to place multiple cables over long or short distances. Detailed equipment operation and excavation procedures are specified by the construction equipment manufacturer.

1. All bores and crossings should be installed prior to the start of the trenching process.
2. Excavate the trench to the desired depth. Remove all rocks and large stones from the bottom of the trench to prevent damage to the cable. Push some clean fill into the trench or backfill with sand (to cushion the cable), as it is installed in the trench.
3. Supplemental trenches should be made to all offset enclosure locations. Trench intersections should be excavated to provide adequate space to make sweeping bends in the cable/conduit.
4. Place the cable trailers or cable reels in line with the trench to prevent any unnecessary bending of the cable. Pay the cable off the bottom of the reel.
5. When routing cables to enclosure locations, leave adequate cable lengths for splicing and storage. Remember to distribute 5% of the total length of the cable at these locations throughout the installation.
6. Monitor the bending radius of the cable when going around corners and upward at enclosure locations.
7. Cap the cable as needed to prevent contamination from dirt and moisture.
8. Place warning tape above the cable during the back-fill process.
9. Fill the trench with sand/loose dirt and compact it as required. Tamp or flood the trench to provide compaction that will prevent the trench from receding.
10. When the trench has been set out, Pilot Holes needs to be dug at 30 - 50m intervals, particularly at points where the new trench crosses existing services. The pilot holes should be at least 150mm deeper and wider than the proposed trench.
11. Pilot holes are one of the most effective methods utilized not only for the location of services, but also to determine the position of a trench, relative to other services.
12. It’s important for trenches to be excavated to such a depth that the crown of the duct has at least 800mm of backfill cover, in all soil conditions, except for where hard rock conditions are encountered.
13. The trench depth in hard rock conditions can be relaxed to a minimum depth of 300mm backfill cover over the uppermost duct. This being said, it requires protection in the form of a concrete slab (either pre-cast or cast in situ) placed on top of the padding material before backfilling. This concrete slab must be reinforced with high tensile wires and measure.
14. Concrete encasing is to be avoided whenever possible, since it could turn the flexible ducts into a long unreinforced concrete beam of little strength, prone to fracture with ground movement.

A screenshot of a cell phone

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Figure 9: Sample backfilling section on duct trenching

1. The width of the trench is dependent on the duct diameter. Trenches that are too narrow will not allow for proper duct installation, whereas trenches that are overly wide are unnecessarily costly. On top of this, a too wide a trench will allow for too much duct snaking from the reel memory.
2. It is recommended to allow for 50mm horizontal spacing between ducts, and 100mm to the trench limit. The actual trench width shall depend on the size and number of ducts. The conduit prism will lay ducts in base 2 configuration (two ducts horizontally laid at N vertical levels).

A close up of a logo

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Figure 10: Duct separation and trench size

1. The material used for bedding and padding must be of a granular, non-cohesive nature, graded between 0.6 mm and 13 mm. Care must be taken to place padding material simultaneously on both sides of the duct to prevent lateral movement.

#### Trench Backfill

1. After padding tampering, backfilling of the trench can be done. Material excavated from trenches may be used as backfill, provided that it contains stones no greater than 150mm in diameter, trash, or organic matter that could potentially damage ducts. Backfill material is to be installed in layers not exceeding 300 mm, with each layer compacted before the next is added.
2. After compacting the first layer of backfill, the warning/marking tape is placed so that in case of a later excavation, the warning tape will be encountered before damaging the ducts or cable.

A person riding a bike down a dirt road

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Figure 11: Warning tape placement on a trench

1. Once a poorly compacted layer is in place, it is difficult if not impossible to achieve good compaction in the layers above. This is a key point; a consequence of poor backfill compaction is high % air voids. This potentially makes the duct vulnerable to veld fires.
2. Moisture conditioning of the backfill material shall be carried out by the contractor.
3. A handful of backfill tightly squeezed in the hand, shall be wet enough so that it binds together with no more than slight crumbling when the hand is opened. When well shaken in the hand, it shall not weep water.
4. In the case of clayey material; roll it into a 2mm in diameter worm and when an attempt is made to bend it, it must break without any obvious effort.
5. Manual compaction is performed until the ducts are covered by both a 150mm layer of padding and 300mm of backfill, at which point a vibratory plate compactor can be used.
6. The compaction of the final backfill layer shall be by means of a compaction machine and shall be compacted to a density higher than or at least equal to that of the virgin soil parallel to the trench.
7. After completion of the backfill, a DCP test must be done. This test must be documented.

#### Road crossings

1. The angle of the crossing should be as near a right angle to the road centerline as possible. The minimum depth that any service may be placed under a road is 800 mm. Ducts must extend a distance of at least 0.5m beyond the edge of the road.
2. The contractor shall inform the relevant road authority 48-hours prior to the commencement of the work.
3. Directional drilling is the preferred method for crossing roads.
4. It is the responsibility of the Contractor to ensure that every law regarding traffic, safety, traffic signs and barricading is complied with.
5. The angle of the crossing should be as near a right angle to the road centerline as possible.
6. The edge of the trench must be cut using asphalt/concrete cutters to deliver smooth, uniform edges.
7. The minimum depth that any service may be placed under a road is 800 mm.
8. The duct/s shall extend a distance of at least 0.5m or 1m beyond the edge of the road.
9. All excavated material and equipment must be placed and demarcated in such a way to not inconvenience vehicles and pedestrians.
10. No person may off-load on a public road, any materials that are likely to cause damage to a road surface.

#### Trenching Near Power Cables

1. Where no physical barrier exists, no duct or cable shall be laid within a distance of 600mm measured horizontally, nor cross within a distance of 300mm measured vertically from any high voltage power cable.
2. Where this separation is compromised, the duct or cable must be separated by concrete slabs.
3. The standard protection slab is 900mm x 300mm x 75mm thick. This slab will be reinforced with 3.55mm high tensile wires.

### Utility Tunnels

1. Tunnels and galleries are constructions containing one or generally more conduits belonging to different networks. Tunnels which can be inspected (inspectable tunnels) include one or more gangways for initial assembly work and for subsequent control, maintenance and repair operations. Conduits laid in tunnels generally offer high durability and a low risk of deterioration. They may be repaired rapidly.
2. Tunnels may contain ducts belonging to the following types of networks:
   * Telecommunications
   * Electricity
   * Gas
   * Water
   * Sewage
   * Drainage water
3. Tunnel routing must consider the structure of networks and their levels of priority. The conduits of different networks do not generally follow the same itinerary, since neither the production units (e.g., power plants, pumping stations or telecommunication exchanges) nor the transit points from transport to primary distribution coincide. Thus, it is advisable (and assumed though this document) to run tunnels under main city streets, where interconnection to distribution ducts will be available.

### Manholes, handholes and chambers

Suitable sized access chambers are required to be positioned at regular intervals along the duct route. These can be located to provide the optimum position for connection to the cables.

The duct chambers must be sized large enough to enable all duct cable installation operations, storage of slack cable loops for jointing and maintenance, cable hangers and bearers, and the storage of the cable splice closure. The chambers may be constructed “on site” or be provided as pre-fabricated units to minimize construction costs and site disruption. On site constructed modular chamber units are also available.

## Stream and river crossings

1. Before initiating the installation of ducts at a river crossing, a geotechnical expert must be consulted to conduct a comprehensive study.
2. Horizontal directional drilling (HDD) has become a popular river crossing option; in very simple terms, HDD is a drilling process where a drill head is steered underground.
3. HDD is the preferred method to cross roads, highways, railway lines, rivers and all other services that may prove to be too dangerous or costly to cross using conventional methods like trenching and/or ploughing.
4. At river crossings the distance between the bottom of the water and the drilling hole should be 10-times the diameter of the pipe and not less than 3m.

## Bridge crossings

1. The use of existing ducts or service culverts within bridges is recommended. In all cases, ducts attached to the underside of bridges must not affect its load bearing capacity, reduce the clearance or cause other issues.
2. The use of existing service ducts within bridges must be fully explored.
3. The contractor shall inform the bridge owner 48-hours prior to the commencement of the work.
4. Ducts attached to the underside of bridges must not affect its load bearing capacity, reduce the clearance or cause other issues.
5. Not all bridge structures will have the exact same installation configuration and procedures may vary to accommodate your specific requirements.
6. Steel or ultra-high-density polyvinyl chloride (UPVC) duct of continuous length of duct (no joints permitted) must be secured to the bridge underside. Microducts should be hauled through the base carrier ducts.
7. Both duct ends will be encased in concrete where they traverse the bridge and enter the ground. It is desirable for the end-product to be both safe and visually appeasing.

## Ducting

When no direct burial of the cable is considered, ducting is the most conventional method of underground cable installation, especially in short spans near or inside urban areas. It involves the creation of a duct network to enable subsequent installation of cables by pulling, blowing or using floatation techniques. This may comprise a large main duct that contains smaller sub-ducts (for individual cable installation), a large main duct into which cables are progressively pulled one over the other as the network grows or a small sub-duct for the installation of a single cable. Duct installation provides the easiest and safest deployment method and also enables further access and reconfiguration. As with direct burial, consideration needs to be given to other buried services. Efficiency of cable installation in ducts relies heavily on the quality of the duct placement.

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Figure 12 ducting Alternatives

The use of a single duct maximizes the number of cables that can be installed but full ducts make it difficult to extract older cables (typically at the bottom of the duct) to create room for new cables. Using sub-duct may reduce the total number of cables that can be installed, but at least older cables can be removed, and new ones installed. It also allows the use of cable blowing as well as cable pulling, since it is easier to obtain an airtight connection to the sub-duct.

Typical duct sizes are 110mm, 100mm or 90mm for main duct and 50/43mm (50mm outer diameter, 43mm inner diameter), 40/33mm, 33/26mm or 25/20mm for sub-duct. Smaller “microducts” may also be deployed (see below).

Cables are installed into the ducts by pulling, blowing or floating. If they are to be pulled, then the duct either needs to contain a pre-installed draw-rope or to have one installed by rodding and roping. If they are to be blown in or floated, then the duct and any connections between sections of duct need to be airtight.

The inner wall of the sub-duct is manufactured to ensure low friction with the cable sheath. This is typically achieved with a low friction coating. Alternatively, the sub-duct could contain a low friction extruded profile and/or special duct lubricants can be used.

A number of factors govern the continuous length that can be pulled or blown, including coefficient of friction, bends in the duct route (vertical as well as horizontal), the strength or weight of the cables and the installation equipment used. The cable diameter should not be too large compared to the duct inner diameter. Fill ratios should be calculated as part of the planning process. For cable blowing operations the duct joints must be airtight. For existing networks, the condition of the ducts should be checked for any potential damage and suitable space and capacity for future cabling.

### Ducts

1. The conduit prism will consist of a number of ducts in base 2 (two ducts horizontally laid at multiple vertical levels).
2. Up to three subducts could be inserted on each duct, each sub-duct carrying a single fiber cable.

A close up of a device

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Figure 13: Feeder trenches section with 8 ducts

1. Ducts shall be made from high quality HDPE o PVC with low friction interior, to enable easy cable placement. Ducts shall be watertight to prevent ingress of contamination or foreign bodies likely to cause problems when cabling. Ducts shall be available with a standard 8kN pull-rope pre-installed.
2. The main characteristics are:
   * Solid wall construction (minimum of 2.4mm)
   * Cable blowable
   * Smooth bore ensuring safe installation of sub-ducts and cables owing to lower internal friction
3. Subducts are inserted into ducts to provide separation and isolation of cables, and to facilitate installation and removal. Subducts must be made from PEAs, with 40 mm diameter, 2.2mm walls, and preinstalled wireline for installation in 110mm PVC or HDPE ducts.
4. Spacers should be used when placing multiple ducts in a trench. They prevent ducts from twisting over and around each other. By keeping the ducts in straight alignment, cable jetting and/or pulling tensions will be reduced. Spacers will maintain separation between the ducts, to ensure alignment with the conduit and to facilitate the flow of concrete between the ducts when required. The snapping resistance of the spacers shall not be lower than 30N.
5. Spacers must be installed according to the manufacture’s specifications. Spacers are mandatory at the access point of a manhole, handhole or chamber, to ensure proper alignment and sealing with the infrastructure access element.



Figure 14: Duct Spacers

### Duct termination on manhole

1. The PVC or HDPE ducts will be terminated into the manholes through their sides
2. The manhole side which ensures the required bending radius will be used
3. Concrete will be used to fix and seal the interconnection between the duct and the manhole. A spacer must be used on the outer part of the manhole to ensure perfect alignment of the ducts before applying concrete.
4. The ducts will penetrate 10 cm inside the manhole
5. The subducts ducts will penetrate 30 cm inside the manhole.

A close up of a green traffic light

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Figure 15: Ducts penetrating the manhole side

### Management of cable slack

1. When cables are installed in or across a manhole, enough cable slack will be stored to facilitate operation and future splicing.
2. Never exceed the recommended cable bend radius: as a rule of thumb, consider 10 times the cable output diameter as minimal radius
3. A total length of 17m (15m for slack and 2m for splicing) of cable slack is traditionally required in a manhole housing a splice enclosure, as it is the case of Primary FCP
4. Slack brackets must be installed on the manhole walls to secure cables
5. The slack in the manhole must be tied together using a tie wrap or PVC tape at 1m intervals
6. The fiber cable slack inside the manhole should be coiled in a ‘clock-wise’ direction with minimal back tension
7. Used ducts must be sealed between cable and duct

A picture containing indoor, doughnut, cup, chocolate

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Figure 16: Samples of cable slack at manholes, with and without splice enclosure

# Cabling

Cabling is the process of laying out optical fiber cables in the physical infrastructure supporting them. Depending on the construction technique, cabling may be performed simultaneously with the civil infrastructure, or deferred once the construction works have been completed.

## ADSS (Aerial) Installation Process

Cables are installed typically by pulling them over pre-attached pulleys, and then clamped via tension and suspension clamps to the poles. The installation is typically carried out in reasonably benign weather conditions and the installation loading is often referred to as the everyday stress (EDS).

1. Place the drum at least 50m away from the pole where the cable is to go through the first pulley. This will prevent the cable from bending too much while being pulled.
2. Orientate the drum so that the natural payoff direction faces the pulling direction. To eliminate possible cable contact with the ground, play the cable off from the top of the drum.
3. Fit specially designed cable pulley boxes to every pole on the route, for the length of cable to be erected.
4. Feed the pulling rope through the pulleys. It is extremely important that the pulling rope and the ADSS cable have the same diameter.
5. Make a hauling eye at the end of the cable by removing a piece of the cable sheath (250-300mm). Next, the Kevlar of the cable is then wound around the cable and attached to the cable using a 25/8 heat shrink sleeve.
6. Attach a break-away swivel to the end of the hauling rope and then attach the other end of the break-away swivel to the hauling eye of the cable - erecting can now begin.
7. Cable lengths of up to 6000m can be erected with one haul, if the terrain allows for it.
8. Radio Communication between persons at the drum, alongside the cable-end and the hauling team must be maintained.
9. When hauling the cable, a person with a two-way radio must walk alongside the cable-end to ensure that the cable is not twisting with the rope, especially at angle-poles.
10. The hauling team must haul the cable evenly and prevent jerking. The person(s) at the cable drum must feed"the cable off the drum at the same speed at which the cable is being hauled. There must be no strain on the cable between the drum and the first pulley.
11. A good rule of thumb is to keep the pulling tension to 1⁄2 that of the sagging tension (see sagging).
12. When removing a pulling grip, 3-5 meters of adjacent cable must be cut-off and discarded.

### ADSS Terminations and Support Types

1. Where an aerial cable ends (i.e. goes underground or into a splice joint), it is a True Termination. If the span continues (i.e. the cable is not cut) and is called a False Termination. False Terminations are found on either side of road crossings and/or every 500m and/or on ≤ 10°angles.

A picture containing screen, bird, building, sitting

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Figure 17. False termination

A picture containing outdoor, light, traffic, bird

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Figure 18. True Termination

1. At False Terminations, a 100mm loop (goose neck, drip loop) in the cable, must be left at the pole between the two dead-ends.
2. At an angled pole, the cable must always pass on the front of the pole - never behind.
3. After a cable is terminated, wait for 10min to allow the cable to stabilize, before securing the cable in the tangent support or support clamp, for intermediate support.

A picture containing outdoor, fence, building, train

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Figure 19. Support Clamp

### ADSS Line of Sight sagging method

1. The installation sag is typically 1% of a span length. Less sag will require stronger cables.
2. Establish the exact distance between poles. The far-side pole is marked using bright colored tape with the appropriate mid-span sag distance from the attachment height, being 1% of the span length.

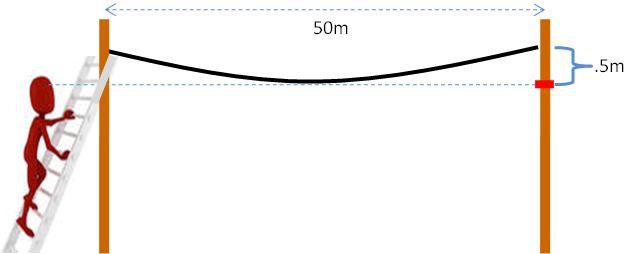


Figure 20. ADSS Sagging

1. Next, the installer returns to the first pole and places the line of sight at that same height as the marker tape on the second pole, to line-up the mid-span sag distance.
2. This person must have radio contact with the team tensioning the cable and give instructions of how much to tighten the cable, for the belly of the sag to rise and match the colored tape mark on the opposite pole.
3. If the sagging operation takes place from the pulling end back to the payoff end, then the maximum amount of cable can be recovered.
4. When removing the pulling grip, 3-5 meters of adjacent cable must always be cut-off and discarded.

## Installation in Ducts

When using ducts in an underground installation, the following considerations must be observed:

1. A full survey of the complete underground duct system should be carried out prior to installation.
2. Manhole and cable chambers with excess levels of water should be pumped out.
3. Ducts should be checked for damage and potential obstructions. Rodding of the duct sections using a test mandrel or brush is recommended prior to installation.
4. Manholes should be checked to ensure suitable space for coiling slack cables, provision of cable supports and space for mounting Splice Joint Closures.
5. A plan should be established to optimally position the cable payoff, mid-point fleeting and cable take-up/ winching equipment. The same also applies if the cables are to be blown into the duct which requires Blowing Head and Compressor Equipment. Allowances for elevation changes should be taken into account accordingly.
6. The duct or inner duct manufacturer should be contacted for established cable installation guidelines.
7. Ribbed, corrugated ducts and ducts with a low friction liner are designed to reduce cable/duct friction during installation. Smooth non lined ducts may require a suitable compatible cable lubricant.
8. Pulling grips are used to attach the pulling rope to the end of the cable. These are often mesh/weave based or mechanically attach to the cable end minimizing the diameter and thus space of duct used. A “fused swivel” device should also be applied between the cable pulling grip and pulling rope.
9. The swivels are designed to release any pulling generated torque and thus protect the cable. A mechanical breakaway fuse protects the cable from excess pulling forces by breaking a “sacrificial” shear pin. Pins are available in different tensile values.
10. A Pulling Winch with a suitable capacity should be used. These should be fitted with a dynamometer to monitor tension during pulling.
11. Sheaves, capstans and quadrant blocks should be used to guide the cable under tension from the pay- off, to and from the duct entry and to the take-up equipment to ensure that the cable’s minimum bend diameter is maintained.
12. Communication radios, mobile phones or similar should be available at all locations in the operation.
13. Use of mid-point or assist winches may be recommended in cases where the cable tensile load is approaching its limit and could expedite a longer pull section.
14. Cable Payoff Device: a reel or drum trailer is recommended.

## Cable Installation by Pulling

The information below is an outline of the required installation and equipment considerations. Reference should also be made to IEC specification 60794-1-1 Annex C “Guide to the installation of optical fiber cables”. Such standard document should be used as the main reference for installation using this technique.

When cables are pulled into a duct, there needs to be either a pre-existing draw-rope or this needs to be installed prior to cable winching. The cable should be fitted with a swivel, that allows the cable to freely twist as it is installed, and a fuse rated at or below the cable’s tensile strength. Long cable section lengths can be installed if the cable is rated to take the additional tensile pulling load or by “fleeting” the cable at suitable section mid points to allow a secondary installation pull operation, or by using intermediate assist pullers (capstans or cables pushers).

When installing cables, due account should be taken of their given mechanical and environmental performances as given by the supplier’s datasheets. These should not be exceeded. The tensile load represents the maximum tension that should be applied to a cable during the installation process and ensures that any strain imparted to the fibers is within a safe working limit. The use of a swivel and mechanical fuse will protect the cable if the pulling force is exceeded. Cable lubricants can be used to reduce the friction between the cable and the sub-duct, hence reducing the tensile load. The minimum bend diameter represents the smallest coil for cable storage within a cable chamber. Suitable pulleys and guidance devices should be used to ensure that the minimum dynamic bend radius is maintained during installation. If the cable outer diameter exceeds 65% of the duct inner diameter the pulling length may be reduced.

1. Communication, directed by a team leader with team members positioned at each manhole / handhole is essential, for that the pulling action to be achieved in a synchronized manner. Communication via the use of either a walkie-talkie or two-way radio is desirable.
2. In a center-pull operation, set up the cable reel near the center of the duct run to be pulled. In a back-feeding operation, a series of shorter, lower-tension pulls in one direction will be required.
3. The drum should be oriented so that natural payoff direction is towards the pulling direction. The drum should be aligned so that the cable can be routed from the top of the reel into the duct in as straight a path as possible.
4. Make use of a flexible cable guide – placed between the manhole lid and duct to be used. Ensure that there is a swivel between the cable sock and the hauling rope. Pull the cable in one direction to the intended manhole.
5. A warning marker (colored tape or similar material) may be attached to the pull-line at ± 10m in front of the pulling grip to alert observers at manholes that the cable is approaching.
6. Place an end cap on all bare cable ends in manholes to prevent moisture and/or dirt intrusion.
7. The maximum allowable pulling tension on fiber cable can vary and is dependent on the cable construction. The maximum tension for a particular cable can be found on the cable spec sheet.
8. Cable lubricant is recommended for most fiber optic cable pulls as a means of lowering pulling tension.
9. Pulling a new fiber optic cable over an existing one is never recommended due to the possibility of entanglement.
10. An 8mm polyester or polyaramid pull rope must to be used for optical fiber cables that are to be pulled in by hand. When using a hauling winch, a 12.5mm or thicker polyester or polyaramid rope must be used as hauling rope.
11. Ski-ropes manufactured from nylon are not suitable, as their stretch factor is too high, and they can potentially cut into ducts. Steel hauling rope or galvanized wire must never be used as they can damage ducts and/or cables.

## Cable Installation by Air Blowing

Traditionally, cables were pulled into ducts. More recently, particularly with the growth of lightweight non-metallic designs, a considerable proportion of cables are now installed by blowing. This can be quicker than pulling and may allow longer continuous lengths to be installed (thus reducing the amount of cable jointing). If a number of spare ducts are installed, then subsequent cables can be installed as the need arises.

When cables are blown into a duct, it is important that the duct network is airtight along its length. This should be the case for new-build but may need to be checked for existing ducts, particularly if they belong to a legacy network. A balance needs to be struck between the inner diameter of the duct and the outer diameter of the cable. If the cable outer diameter exceeds 75% of the duct inner diameter, air pressures higher than those provided by conventional compressors are required or the blow length may be reduced. If the cable is too small then this can lead to other installation difficulties, particular if the cable is too flexible. In such cases, a semi-open shuttle attached to the cable end can resolve these difficulties.

A cable blowing head is required to both blow and push the cable into the duct. The pushing overcomes the friction between the cable and duct in the first few hundred meters and hauls-off the cable from the drum. The ducts and connections must be sufficiently airtight to ensure an appropriate flow of air through the duct. A suitable air compressor is required at the cable payoff end of the duct section and will connect to the blowing head. Hydraulic pressure at the blowing head used to provide drive/push traction to the cable must be strictly controlled to ensure no damage to the cable.

## Cable Installation by Floating

Considering that most outside plant underground cables are exposed to water over a major part of their life, floating is an alternative method to blowing. Floating can be done with machinery originally designed for blowing. Air is simply replaced by water. Compared to blowing, floating enables to place considerably longer cables sections in ducts without intermediate access point. Floating can prove very efficient for over laying cable in many situations. Also, with floating the performance decreases when placing cables having an outer diameter exceeding 75 % of the duct inner diameter. It enables to safely remove cables out of their duct (float out), thus making possible the re-use of such cable. Blowing out cable is by comparison a hazardous operation.

## Cable placement at tunnels & galleries

1. Cable location: telecommunication cables should be installed in the upper part of the tunnel, always above the water distribution and sewer services. Use of cable ladders, cable raceway or hangers is required
2. Distances from other services: Minimum distances from main ducts should be applied:

* 25cm to power lines
* 30cm to water supply and sewerage systems
* 100cm to gas lines and oil pipelines

1. Protection against thermal load: Since cables are vulnerable to thermal load, thermal conditions in tunnels must be considered. This applies especially for optical cables
2. Protection against corrosion and lightning: cables should generally be protected by metal sheaths or shields. This protection may be applied, but the use of joint earth electrodes is either not required or not permissible. Note that even though optical fiber is not a metallic conductor, the cable cover may include metal shields, which can provoke electric discharges
3. Protection against mechanical forces: Metal shields may be used to protect cables against mechanical effects such as vibrations or impacts. Additionally, proper fixing through plastic brackets of flanges must be applied.
4. Protection against outside effects: Plastic-covered cables may be protected against rodents with fiberglass or aramid-fiber shielding. Contractible cable joints may provide protection against earthquakes
5. Bends: Since cable curvature is limited, layout plans must take account of permitted curvature radii
6. Specialized work: Since work must be done relatively frequently on telecommunication installations, particularly on sleeves, enough working space should be provided (e.g. manholes or chambers)

A close up of a map

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Figure 21: Sample Utility Tunnel section

## Cable ladders / Raceways

1. Plastic raceways or cable ladders will be used to route cables through the tunneling system.
2. No ducts are required in the tunnel system
3. The cable ladder / raceway must be dimensioned to comfortably allocate multiple cables of up to 25mm diameter, with enough additional space for expansions.
4. Plastic brackets of flanges must be installed every 40cm to secure the cables on the ladder.

A close up of a logo

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Figure 22: Fiber Optic Cable Raceway with cover

## Cable Joint Closures

As cables are not endless in length and need to be branched off at several locations, intermediate splice closures are needed. These are environmental and mechanically protected housings for outdoor use that offer a small compact means of managing fibers for storage within underground chambers and on overhead poles. Security risks are low and easy access is possible if the underground chamber in which the enclosure is stored is well managed. Closures are available in many different sizes and shapes. The typical splice capacity may rise above 500 fiber circuits per joint closure. The fiber management system allows for fiber identification and to protect against and avoid accidental interference of fiber circuits when specific fibers are accessed.

Some closures offer the opportunity to access only selected fibers out of a complete cable for splicing while all other fibers in the cable are left uncut during the installation of the closure. This is mostly referred to as mid- span cable access. This capability reduces drastically the installation time of a branch and the required down time of a link.

For overhead applications specialist equipment may be required to access the closure for configuration. The environmental protection level can depend on the application and deployment area (underground versus pedestal, versus aerial mount).

A differentiation between closures can also be made on the cable sealing features. Today most joint closures seal the cables using heat shrinkable tubing or are cold sealable using gel or rubber sealing elements.

The fiber deployment technology used will also influence the joint closure features. For example, deployments in sewer systems require closures that are suitable to deal with very harsh chemical environments. Blown fiber closures need to handle the blown fiber tubes and allow for access of the blowing equipment. For this reason, each application might require a different closure solution.

# Building Connectivity

The endpoints of the optical infrastructure are relevant network locations where transmission nodes are installed. The outside plant construction finalizes at a demarcation point in the entry point to the network building, with the fiber extending to the interconnection ODF installed in the telecommunications equipment room.

## Building Entry Demarcation Point

1. A manhole must be located outside the building, in the sidewalk, defining the demarcation point with the outside plant fiber network. The manhole must be connected to a building access register which defines the point from which there is a clear distinction between the external conduit, under the sidewalk, and the internal conduits leading to the telecom room.
2. When the distance between the building access register and the lower telecom room is longer than 10m, and whenever there is a significant direction change (with an angle larger than 45 degrees), a passing register should be projected to facilitate cable installation and repairs.
3. Critical buildings are designated buildings that require extraordinary levels of reliability and availability. This will be provided through dual entry facilities and diverse routes. These buildings will typically be served by Point to Point fiber Ethernet connections at >= 10 Gbps. Special buildings should be served by two building access manholes, connected to two different sections of the distribution network, which permit the building access by independently routed fibers.

## ODF

An optical distribution frame (ODF) is the interface between the outside plant cables (outdoor network) and the active transmission equipment. Typically, these locations are somewhat larger in size and bring together several hundreds to several thousands of fibers.

Outdoor cables are generally terminated within an ODF using an optical connector. This normally consists of splicing a connectorized optical fiber pigtail to each individual fiber end.

In most cases, the ODF offers flexible patching between active equipment ports and the field fiber connectors. Fibers are identified and typically stored in physically separated housings or shelves to simplify fiber circuit maintenance and protect or avoid accidental interference to sensitive fiber circuits.

The responsibility of the fiber construction ends by delivering the fiber cables to the ODF location. The interconnection to the ODF fiber splices is out of scope, and will be managed by the building engineering team.

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Figure 23. Examples of ODF Modules