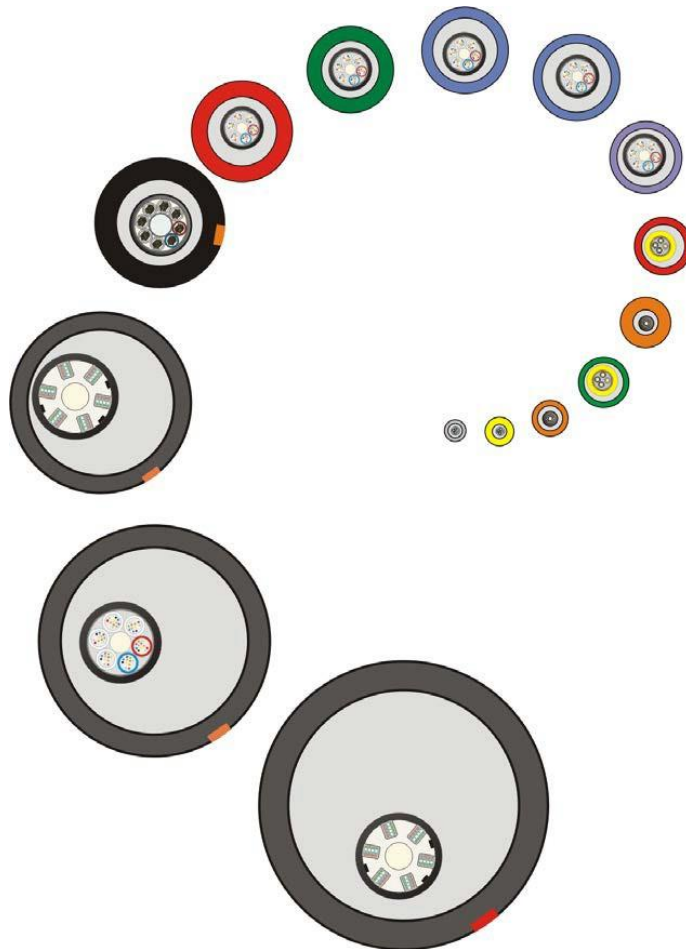




Instructions for Robust Fiber

Appendix 2 Robust networks

Ver 1.3.1



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1. INTRODUCTION

The document "*Instructions for Robust Fiber*" comprises one main document and a number of appendices.

This appendix, Robust networks, contains minimum requirements regarding how ducts and fibre optic cables are to be selected, routed, handled, labelled and measured. The appendix also contains recommendations and examples of what it might look like when building a robust fibre installation.

Minimum requirements within the following areas are defined in the appendix:

- Preparations
- Ducting (ducts, manholes and outdoor splice cabinets)
- Position measurement
- Marking
- Sealing of ducts
- Routing ducts in the ground
- Backfill height
- Connection to buildings
- Routing in lakes or watercourses
- Routing on poles
- Installation at bridges
- Routing in tunnels and culverts
- Fibre optic cables
- Cable management
- Splicing
- Splicing units
- Termination
- Delivery measurement of fibres
- Labelling
- Safety

2. NETWORKS

2.1 Preparations for routing of ducts and fibre optic cables

Prior to commencing the work of routing ducts and fibre optic cables, a number of activities have to be performed.

2.1.1 Plan network structure

A rough projection is produced including the number of potential customers, a proposed network structure to cover the area, suitable routing technique, excavation lengths and the material in which excavation is taking place.

Based on the network structure in the rough projection, detailed planning is conducted that leads to the selection of the size of fibre optic cables and the number of splicing units. The types of cabinets or manholes are then selected. Ducts must then be selected to suit the fibre optic cables that have been selected for the installation. It is recommended to plan some over-capacity for both fibres and ducts.

2.1.2 Land investigation

A decisive factor in the choice of equipment and routing technique is the implementation of a visual land investigation of the planned cable section.

Before commencing the earthworks, a visual inspection of the work area is therefore conducted. The visual inspection is conducted by appointed representatives of the client and the contractor. Representatives of affected land owners should also be present. The results of the visual inspection are documented in a report, which should be supplemented with pictures of the work area.

Consultation with the Country Administrative Board and/or the local authority regarding culture and the environment is required in certain cases.

This applies in particular in locations where there may be archaeological sites, by watercourses, in the case of unsuitable land, unique vegetation, etc.

MINIMUM REQUIREMENTS, LAND INVESTIGATION

- Visual inspection prior to implementation must be conducted and reported.
- Necessary contacts in respect of culture and the environment must be made by the network owner.

2.1.3 Permits

Depending on the cable route, it is necessary to consult with and obtain permits from affected stakeholders, such as landowners and road operators. Land agreements are entered into between the network owner and affected land owners. The network owner is responsible for obtaining land agreements. The network owner may engage another party to carry out this work, e.g. the contractor.

Examples of permits include an opening permit, excavation permit, start permit and TA plan (traffic arrangement plan). Different stakeholders may administer permits differently. There may be local regulations for the relevant landowner or road operator.

List of the requisite permits that may be required in a project.

- General land permit from the local authority regarding the right to have cables in municipal land.
- Cable location from landowner, e.g. local authority, Swedish Transport Administration or road operator. Regulates where the cable may be located.
- Start permit (opening notification) from the landowner, e.g. local authority or road association.
- Approved TA plan. For the Swedish Transport Administration see Permission for the placement of telecommunication lines.
- Permission from the Swedish Transport Administration regarding the placement of telecommunication lines. The conditions for traffic and protective devices are obtained together with the decision on Permission for the placement of telecommunication lines.
- Building consents.
- Permits from pole route owners.
- Consultation with the Country Administrative Board and/or the local authority regarding culture and the environment (watercourses, archaeological sites, alleys, unsuitable land, unique vegetation, cultural monuments).

MINIMUM REQUIREMENTS, PERMITS:

- Necessary permits must be obtained by the contractor.
- Land agreements must be drawn up between the network owner and affected landowners/road operators.
- Local regulations must be complied with.
- Cable indication queries are created in Ledningskollen (see Appendix 8 Ledningskollen) and any local procedures.

2.1.4 Cable indication query

Before commencing the work of routing ducts and fibre optic cables, a query is created in the national service Ledningskollen (see Appendix 8 Ledningskollen) and in accordance with any other local procedures. Other cable owners in the area can thereby receive information about the planned work.

Cable indication queries from affected cable owners are ordered by the contractor where necessary. This is done to minimise the risk of damaging existing cables.

2.1.5 Choice of routing technique

Applicable routing methods are determined based on the results of the land investigation and local regulations. Agreements regarding the selected routing method per section are documented in the minutes of a Construction meeting or equivalent. Information about the relevant routing method and when the method is most suitable can be found in the appendix Routing methods.

2.2 Ducting

Ducting refers to the components that jointly form the transfer route and protection for one or more fibre optic cables. Ducts (standard or microducts) emerge from a node, manhole or cabinet and constitute the transfer route to the next node, manhole, cabinet or to the end customer.

2.2.1 Ducts

Ducts in which fibre optic cables are to be laid can be divided into standard ducts and microducts. They are normally made of high-density polyethylene (HDPE). The inside of the ducts is made from low-friction, anti-static plastic in order to promote the maximum length of cable installation sections.

More robust ducts are also available, and these are used in the ground to surround standard ducts and microducts. Dimensions with an outer diameter ranging from 50 mm up to 160 mm are most common.

When selecting ducts for routing in the ground, consideration is given to the ground conditions where routing is to take place, the method with which the ducts are to be routed and that the ducts are appropriate for the technique that is to be used to install the fibre optic cable.

When selecting duct, it is important to ensure that the supplier has mechanical seals that fit the selected fibre optic cable, see also under Outdoor splice cabinets and Sealing of ducts.

Ducts for direct installation in soil shall, as a rule of thumb, have a thickness of at least 1.8 mm. If the ducts are to be used for blowing or flushing in fibre optic cable, it is recommended that:

- The diameter of the fibre optic cable should not exceed 75% of the inner diameter of the ducts when blowing fibre optic cable. Follow the manufacturer's recommendation.
- The ducts can cope with the air pressure that is required to blow in a micro-cable or fibre optic cable. The air pressure when blowing in fibre optic cable is normally 8–10 bar. The ducts should therefore be specified as able to cope with 50% higher air pressure for a limited period. Prior to blowing, it is therefore necessary to check with the material supplier what is recommended as manhole as the maximum air pressure for the relevant duct's dimensions.

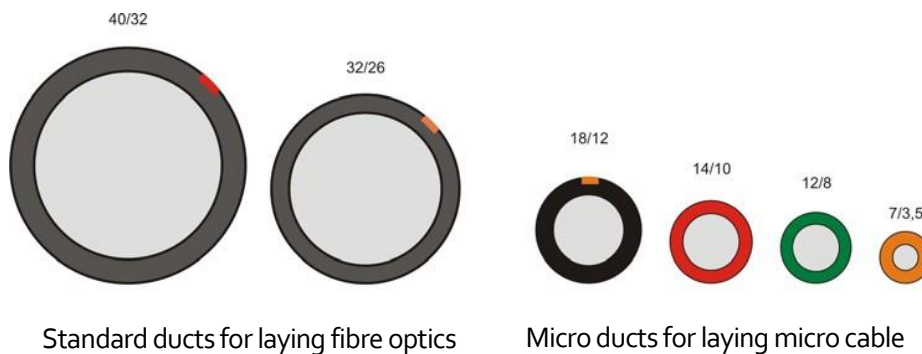
MINIMUM REQUIREMENTS, DUCTS:

- Underground splice connections must be safeguarded in accordance with the manufacturer's instructions.
- The ducts must be designed for the routing of fibre optic cables and must have low internal friction.
- The type of duct must be selected according to the method being used for routing the ducts. The manufacturer's recommendations must always be followed.
- Annular rigidity and wall thickness must be of the correct dimensions for the conditions the ducts have to handle after routing. The manufacturer's specifications must be followed.
- The material manufacturer must be able to demonstrate that the ducts are ageing-resistant and specified for an anticipated service life of at least 30 years.
- The ducts must not contain environmentally hazardous materials, e.g. lead stabilisers.
- Where there is a risk of attack by pests, ducts with high resistance to attack must be selected. Alternatively, additional protection must be installed outside the existing ducts.
- The storage and handling of ducts must take place in accordance with the manufacturer's specifications in respect of UV light, temperature, environment, routing, winding, etc.
- Ducts must be spliced with a sealed splice connection according to the manufacturer's instructions.
- When cutting ducts, cut the ducts with tools for cutting ducts. This is to avoid degrees, cuts, etc. which in turn can lead to blow problems.

One problem that can arise is that moisture penetrates into the duct when blowing in (if there is no dehumidification), at splices, at ends or through the plastic material. If the moisture freezes to ice in the duct, the fibre optic cable can be damaged through tensile or crushing damage.

For this reason, the following requirements must also be satisfied:

- In order to minimise the risk of damage, the fibre optic cable must have sufficient strain relief and be longitudinally watertight, for example with filler or a swelling material. If the fibre optic cable does not have this, the duct must be fully moisture protected, e.g. with metal foil in the material and carefully sealed splices. This applies in particular when routing in small microducts, e.g. in the dimension 7/3.5 mm.



Examples of ducts in various dimensions.

2.2.1.1 Standard ducts

Standard ducts are intended for routing directly in the ground, water or air.

Ducts designed for routing directly in the ground must have a material thickness that is dimensioned to cope with the pressure from the surrounding soil. This must be specified in the product description from the manufacturer of the standard duct. It is generally the case that, in the event of larger outer diameters, a greater material thickness is required in order to retain annular rigidity.

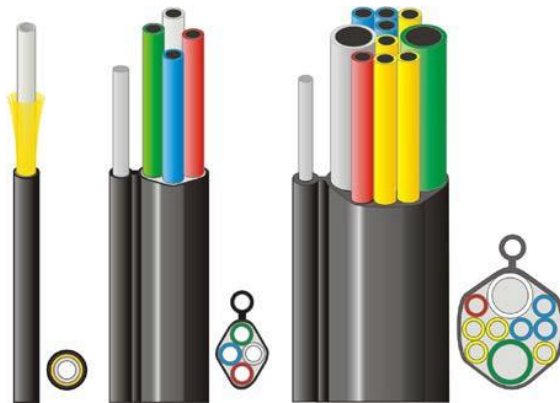
MINIMUM REQUIREMENTS

The manufacturer must state in his duct specification that the duct is dimensioned with a thickness of goods to withstand pressure from the surrounding soil.

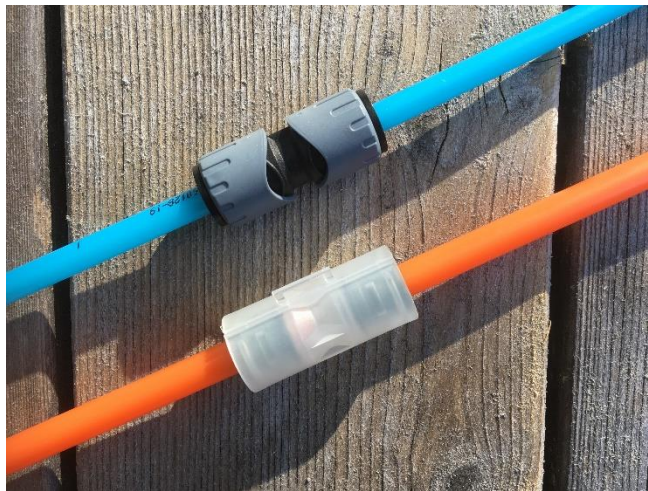
2.2.1.2 Microducts

Microducts are thin-walled ducts (sub-ducts or for indoor use) or thick-walled ducts (for direct routing in the ground, water or air), with inner dimensions from approx. 3 mm up to approx. 18 mm. 16/12 and 7/3.5 mm are common. Microducts are used to blow (in certain cases also to pull) micro-cables or blow fibres.

Microducts for above ground installation have in-built strain relief in the form of aramid yarn or fibreglass-reinforced plastic rods. Always use the tensioning and mounting devices recommended by the manufacturer for the microduct being installed.



Microducts for above ground installation



Examples of splicing of microducts

2.2.1.3 Labelling and identification of ducts

Labelling of ducts will aid the identification of ducts in the network. Identification is achieved through e.g. coloured, corrugated or numbered ducts in order that the ducts can be distinguished in the event they are excavated or damaged and, for example, when fibre optic cables being blown in from outdoor splice cabinets.

2.2.2 Distribution point

A distribution point is a space, a node, a manhole or a cabinet in which ducts and fibre optic cables start, branch or terminate. Examples include access nodes, cable manholes or outdoor splice cabinets.

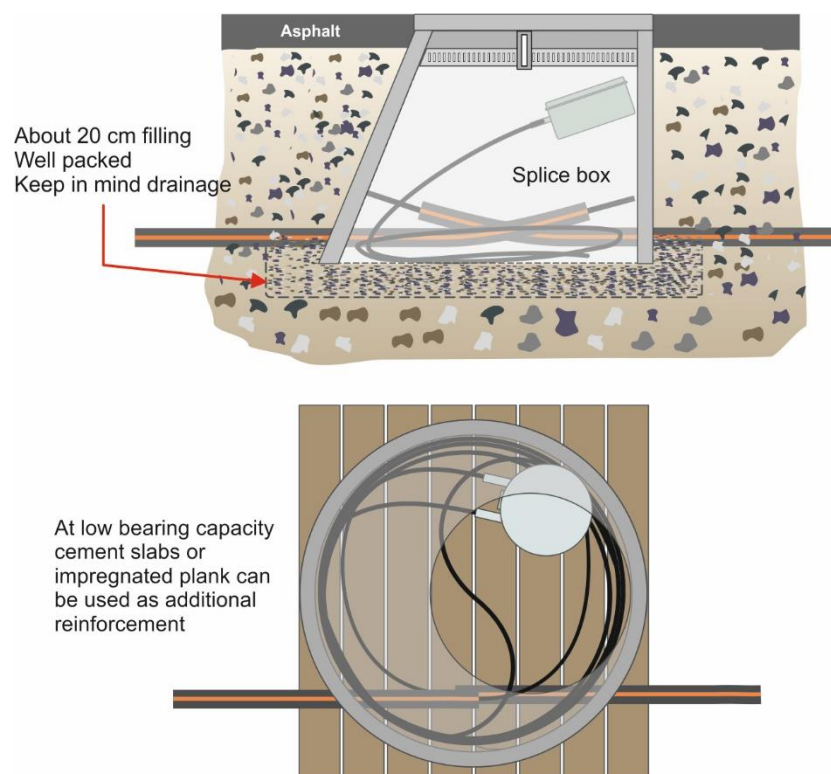
The type of distribution point is selected on the basis of the geographic location as well as the number of ducts, fibre optic cables and splicing units that are to be included at the distribution point.

2.2.2.1 Cable manholes

A cable manhole is part of the ducting.

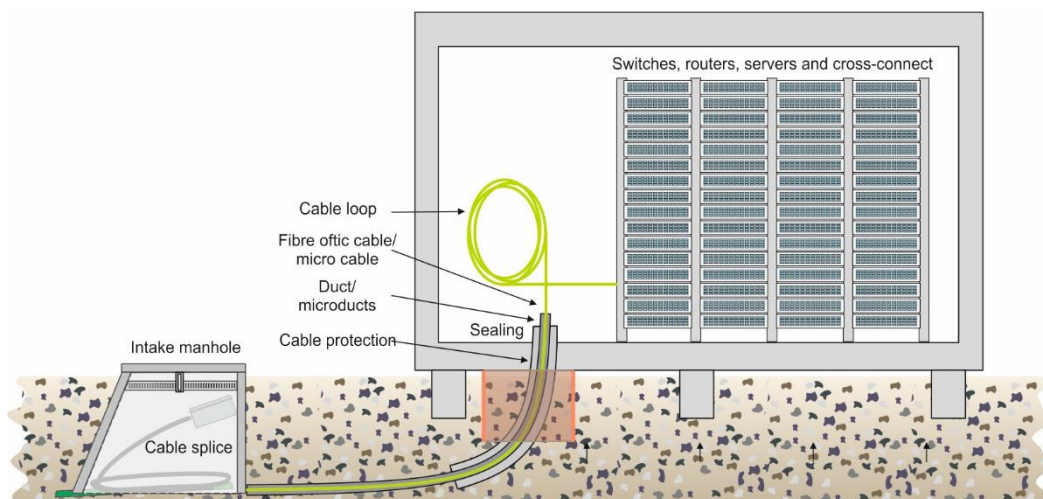
Cable manholes are available in several different versions and are adapted according to where they are to be located and what they are to contain. The manhole can be made of concrete, cast iron or plastic. Ideally select a manhole body that is sectioned, which provides a flexible solution in terms of depth and the creation of holes for incoming ducts.

Manholes are available that are intended for placing in various environments, e.g. hard surfacing (roadway, pavements) or for burying in greenfield sites. The shape of manholes can vary, e.g. round or square.



Examples of manholes

Intake manholes should be located close to a node. Ducts should be interrupted there to avoid the risk of water penetrating into the node.



Example of intake manhole

MINIMUM REQUIREMENTS, MANHOLES:

- The manhole type must be designed for the environment in which it is located, e.g. roadway, pavement or buried in a greenfield site.
- Particular consideration must be given to strength. The manufacturer's regulations and recommendations must be followed.
- When choosing a cable manhole, consideration must be given to the types of ducts and fibre optic cables that may be installed in the manhole, bearing in mind minimum bend radius, type of splicing box as manhole as the number of ducts and fibre optic cables.
- Visible cable manholes (not covered) must be locked to prevent unauthorised access.
- The contents of the manhole must not be evident from the outside of the manhole.

2.2.2.2 Outdoor splice cabinet

An outdoor splice cabinet is part of the ducting.

The choice of outdoor splice cabinet is made on the basis of the number of cables and fibres as well as the number of splices that are to be handled. Then select cabinet type and the size of the outdoor splice cabinet. There must be enough space for a loop with a sufficient minimum bend radius as well as for splicing units.



Example of outdoor splice cabinet with splicing unit

MINIMUM REQUIREMENTS, OUTDOOR SPLICE CABINET:

- The cabinet must be of class IP₃₄ or higher.
- The cabinet be of class IK₁₀ or equivalent.
- The cabinet must achieve corrosion class C₃ for the specified service life of the ducting.
- Outdoor splice cabinets must be made of corrosion-resistant material or have a corrosion-inhibiting surface treatment.
- Outdoor splice cabinets must be locked mechanically or electromechanically.
- Outdoor splice cabinet must be adapted for simplicity of post-connection.
- Installation work in outdoor splice cabinets must be possible without affecting the function of existing installation.
- Splice unit in outdoor splice cabinets must be installed according to the manufacturer's instructions.

Indoor cabinets do not need to be locked if the premises are locked and only authorised parties are granted access.

2.2.2.3 *Moisture in outdoor splice cabinet*

Moisture in outdoor splice cabinets can cause problems in terminations, splicing units, splices and cables. This can lead to operational problems and a reduced service life. Ground moisture is one of the major sources of problems.

For this reason, the following requirements must also be satisfied:

- If a cabinet has been supplied with a ground insulation plate, this must always be installed in accordance with the manufacturer's regulations. All openings between the plate and cabinet, cable and other bushings must be sealed.
- If a cabinet has been supplied without a ground insulation plate, some other ground insulation must be installed, e.g. in the form of Leca granules. Where Leca granules are used, the backfill must be at least 35 cm thick and must reach above ground level.
- The sealing of ducts in outdoor splice cabinets must be performed above the ground insulation plate or other insulation and must be carried out through mechanical sealing that is appropriate for the ducts in question.
- In the event thick-walled microducts that are bundled through a plastic casing are used, the plastic casing must be cut below the ground insulation plate during installation in an outdoor splice cabinet. This is to prevent water from making its way up into the cabinet, see image below.



Example of correctly slotted casing



Example of correct sealing of duct

2.2.3 Traceability

In order to facilitate the tracing of underground ducts, position measurement must always be conducted. As a complement, a search wire should be installed together with the ducts. Warning mesh, warning net or other clear marking should be placed above the ducts to reduce the risk of damage to the cable infrastructure.

2.2.3.1 Position measurement

Position measurement means that the geographic location of the fibre installation is measured in the form of coordinates that can be displayed on a map.

MINIMUM REQUIREMENTS, POSITION MEASUREMENT:

- Measurement of the position of the fibre installation must be carried out using geodetic measurement with a DGPS (differential GPS) measuring instrument.
- Measurement must be carried out with accuracy class 2 (≤ 0.25 metres) or even greater precision. For this reason, it may be necessary in certain cases to measure the actual position before the trench is refilled in order to ensure the quality of the measurement.
- The coordinate system that is used must be specified, e.g. WGS 84, RT 90 2.5 gon V, SWEREF 99 TM or SWEREF 99 (local zone).
- When drilling and pressing, the depth must be measured.
- The fibre installation must be measured, i.e. ducts, all termination points for ducts, cabinets, cable manholes and cable trays, ducts end points as well as cable fixation points.
- The position of the ends of ducts that are left in the ground for future use must be measured.
- For manholes, cabinets and cable trays, the mid-point must be measured.
- For ducts, the start and end points, waypoints, all crossings of streets and roads as well as the location of intakes in buildings must be measured.
- Between waypoints, measurements must be performed at intervals of at least every 50 metres within built-up areas and within at least every 100 metres outside of built-up areas.
- Turns/bends/curves must be measured at intervals of 5–10 metres depending on the radius or the distance that is appropriate for the specific point.

Recommendation for position measurement:

- For standard ducts, it is recommended that all splices be measured.

2.2.3.2 Marking

Marking refers to the placing of clear marking above the ducts when routing in the ground.

MINIMUM REQUIREMENTS, CABLE MARKING IN THE GROUND

- Warning mesh, warning net or other clear marking should be placed above ducts to reduce the risk of damage to the cable infrastructure.
- The warning must be centred, at least 10 cm above the ducts.
- The warning must be made of a material that is ageing-resistant in the ground, and must have good handling properties, even at low temperatures.
- The colour of the warning must be clear.

In order to simplify traceability, the warning mesh should include search wire so that its location can be found with the aid of a tone transmitter and cable locator. Alternatively, a separate search wire can be routed above or below the ducts.

MINIMUM REQUIREMENTS IF SEARCH WIRE IS USED:

- The search wire must be made of acid-resistant, stainless steel wire.
- The search wire must be accessible (at screw or similar) in nodes, manholes, cabinets or cable fixation points.
- The search wire must be insulated from earth in order not to short-circuit the cable locator's signal.
- Each sub-section with search wire must not exceed 1,000 metres, as cable locators can normally only manage 500–700 metres.
- The search wire's sub-section may not exceed 500 m when crossing electricity lines greater than 130 kV or in the case of extended distances parallel with and closer than 150 m to an electricity line greater than 130 kV.
- The search wire must be spliced in accordance with the supplier's regulations using tools and splicing accessories designated for this purpose.
- If there are several search wires in the same location, these must be labelled to indicate which section the search wire is following.
- When crossing (drilling/pressing) roads where the fibre optic cable is routed in ducts, the search wire must be included in the duct.
- Search wire must generally not be inside a protective duct except in the case of pressing and drilling, when it is placed in the duct.



Cable fixation point for accessing search wire

Another way of marking buried ducts is to use search balls or search pegs. These are entirely passive and require no energy, and so they have an extremely long service life. The search field around the ball or peg has a radius of approx. 1.5 m. This means that it is extremely practical to place search balls in covered manholes and at buried duct ends. A special search instrument is used to locate a search ball or search peg. These are available for various purposes and work at various frequencies in order to distinguish different infrastructure.

<u>Colour</u>	<u>Frequency</u>	<u>Area of application</u>
red	169.8 kHz	electricity
blue	145.7 kHz	water
green	121.6 kHz	drain
orange	101.4 kHz	telecommunications
yellow	83 kHz	Gas
black and red	77 kHz	cable TV
lilac	66.35 kHz	often used by private users



Examples of search balls and search pegs

2.3 Routing

Ducts and fibre optic cables are normally routed in the ground, although there are several alternatives, see below.

The duct is routed such that the risk of attack by pests is minimised, for example through additional rodent protection and end sealing of ducts.

2.3.1 Sealing of ducts

MINIMUM REQUIREMENTS FOR SEALING OF DUCTS:

- Ducts must be sealed so that dirt and water cannot penetrate into the ducts. This applies to all end points where new or existing ducts are used.
- The seals must be able to cope with a water column of at least 5 m.
- The duct ends in any sub-ducts (ducting arranged within an existing duct) must be properly sealed during and after installation.

2.3.2 Underground routing

The basic purpose of burying ducts is that the fibre installation is then protected in the safest way. This means that the fibre installation is as robust as possible.

For underground routing, there are a number of methods that are suitable to differing degrees depending on ground conditions, local regulations, etc. More detailed information about methods and when they are appropriate to use can be found in the appendix "Routing methods".

The planned routing method is adapted if necessary to the actual conditions in conjunction with implementation in order e.g. to achieve more efficient routing or meet the requirements regarding backfill height.

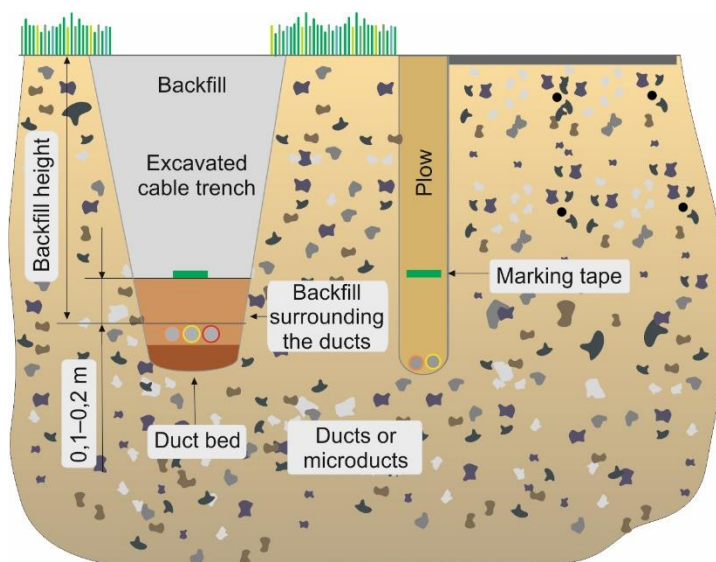
It is important to comply with local regulations regarding backfill height, methods, distance to existing ducts, etc.

MINIMUM REQUIREMENTS FOR UNDERGROUND ROUTING:

- When routing in the ground, ducts must be laid flat in the duct bedding.
- Asphalt must not be laid on top of cable manholes.
- In snowy areas or in the case of dense vegetation, outdoor splice cabinets must be supplied with a marker rod to avoid collision damage and to make the cabinets easier to find.
- Outdoor splice cabinets must be labelled in accordance with the client's instructions.
- Labelling must take place in such a way that the contents are not disclosed.
- Ducts may not be spliced in curves or bends.
- Avoid placing manholes in dips due to the risk of water penetration.
- When pressing through a railway bank, the Swedish Transport Administration's instructions must be followed.

Recommendations for underground routing:

- Placing manholes in roadways, bus stops or car parks should be avoided as far as possible, as special requirements apply regarding strength and permits are required from road operators.
Such locations are also unsuitable from a maintenance or a working environment perspective.
- Locating outdoor splice cabinets by road intersections, by snow deposits and in positions where visibility is obscured for road users and residents should be avoided. Consideration must also be given to the work environment of those who will be working at the cabinet. Position the cabinet in a well protected location in order to minimise the risk of e.g. damage, collision damage or injuries caused by snow and brushwood clearance vehicles.
- The duct must be routed at such an incline that water cannot accumulate in the duct.
- Avoid routing ducts over tree root systems. There is a considerable risk of damage if the tree falls over.



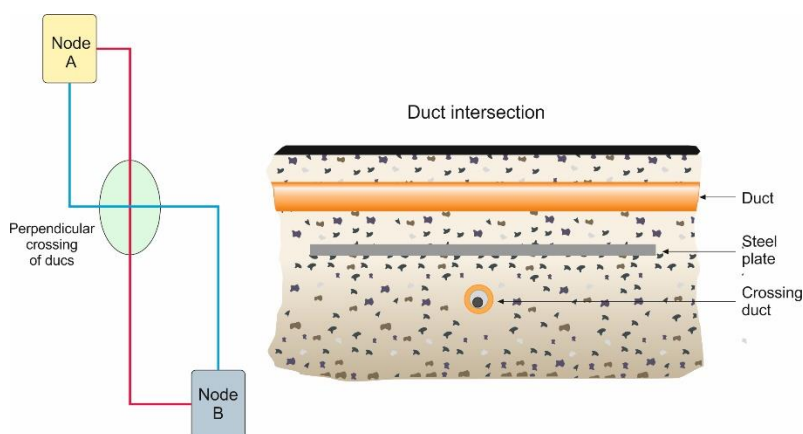
Examples of excavations

During underground routing, it is important to bear in mind that ducts are affected by changes in temperature. This is particularly important when routing over extended distances in warm weather and direct sunlight. Warm ducts can contract when they are placed in cooler ground and covered. You are recommended to leave splices and ends uncovered until the ducts have been adapted to the ambient temperature. Always comply with the manufacturer's recommendations regarding the handling of ducts.

Redundancy is used to minimise the risk of interruptions if a transfer route is damaged. Connections that are supplied with redundancy have two or more transfer routes. Particular requirements then apply in order to keep the various transfer routes separate from each other within the fibre installation.

MINIMUM REQUIREMENTS AT DUCTING INTERSECTIONS IN ORDER TO SATISFY THE DEMANDS FOR REDUNDANCY:

- Ducting intersections must be arranged at a 90° angle.
- One metre before and after the intersection, special mechanical protection must be arranged if the distance between the ducts is less than 2 metres (e.g. vertically). Special mechanical protection means some form of excavation-safe protection, e.g. a 10 mm thick steel plate or equivalent.



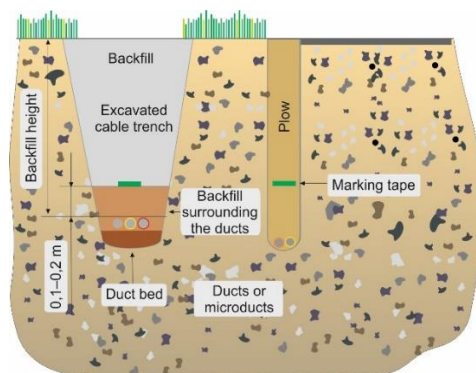
Example of intersecting ducts

2.3.2.1 Bed in ducts

Depending on the routing method, there is a requirement for backfilling and duct bedding.

MINIMUM REQUIREMENTS FOR SELECTED SANDFILL AND DUCT BEDDING:

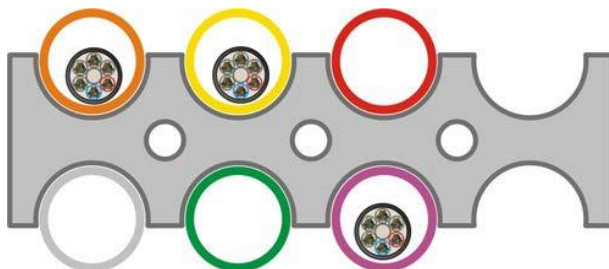
- Duct bedding and Selected Sandfill must comprise natural sand or rock dust with a grain size of 0–18 mm.
- Measures must be taken so that backfill and duct bedding remain intact throughout the service life of the duct.
- When routing several ducts at the same time, there must be backfill around the entire ducts, such that there are no air pockets between them.



Examples of duct bedding and backfill

Incorrectly conducted backfilling entails a risk of the ducts being pressed together when the refill material is compressed.

In order to maintain the distance between the ducts during compression, spacers are also recommended for the ducts.



Example of spacers for ducts

2.3.2.2 Positioning of manholes and cabinets

The following applies when positioning cable manholes and outdoor splice cabinets.

MINIMUM REQUIREMENTS WHEN POSITIONING CABLE MANHOLES:

- The bottom section must be positioned on a bed comprising the same material as for the duct bedding, with a grain size of 0–18 mm. The bed must be well compacted and levelled off, and must be at least 200 mm thick. Consideration must be given to any differences in level at the surface when creating the bed.
- Instructions from the supplier must be complied with when positioning cable manholes.

Recommendations when positioning cable manholes:

- If the ground/surface has a low bearing capacity, impregnated planks or cement slabs should be placed below the manhole body in order to reduce ground pressure.
- In order to keep the inside of the manhole cleaner and to increase the bearing capacity, non-woven fabric can also be placed beneath the bed.
- If necessary, drainage of the bed must be carried out.

MINIMUM REQUIREMENTS WHEN POSITIONING OUTDOOR GROUND CABINETS:

- Outdoor ground cabinets must be positioned on a bed similar to that used for manholes.
- A base or plinth must be fully laid out and installed in accordance with the manufacturer's instructions.
- Outdoor ground cabinets must be installed with the cabinet opening facing the street/road.
- Outdoor ground cabinets must be installed at the correct height and the correct incline in accordance with the manufacturer's instructions, and with the correct gravel type packed around the cabinet to ensure it is secure and steady.
- The top layer of the ground around the cabinet must be the same as the existing ground surface so that it blends into the environment.
- Backfilling must be performed using Selected Sandfill, medium gravel.
- If the ground conditions are such that there is a risk of the foundations/cabinet becoming unstable, the installation must be reinforced with concrete slabs or impregnated planks.

2.3.2.3 Gauging

One way of checking that the ducts has not been damaged in conjunction with routing is to conduct gauging. An item (a gauge) with a diameter that is slightly smaller than the inner diameter of the duct is pulled or blown through. Gauging should be performed using a gauge of a certain length, not with a gauge in the form of a ball. A ball can easily pass through sections in the ducts that are subsequently impossible for a cable to get through.

Recommendations when performing gauging:

- The diameter of the gauge should be approx. 20% less than the inner diameter of the duct.
- The gauge should be in the shape of a duct with cones at either end. Each end should comprise an eyelet for attaching a line.



Example of gauge

2.3.2.4 Frost thawing

Before conducting frost thawing, it is important to check what local regulations exist regarding methods for thawing frost.

Ducts and fibre optic cables are sensitive to high heat. It is therefore necessary to always check with the relevant manufacturer before performing frost thawing.

If another cable owner is to perform frost thawing for a cable located deeper than the fibre installation, it is important to point out that ducts and fibre optic cables are sensitive to high temperatures. This is particularly important where the fibre optic cable is routed with little backfill height, e.g. in the case of microtrenching.

2.3.2.5 Collocation

Collocation means that ducts and cables that are owned by several network owners are routed in the same trench. Agreement regarding terms and conditions for collocation is reached between the parties on a case-by-case basis.

The requirements regarding collocation must be at least in accordance with “*Instructions for Robust Fiber*”. It is important to consider different colour marking in the event of collocation.

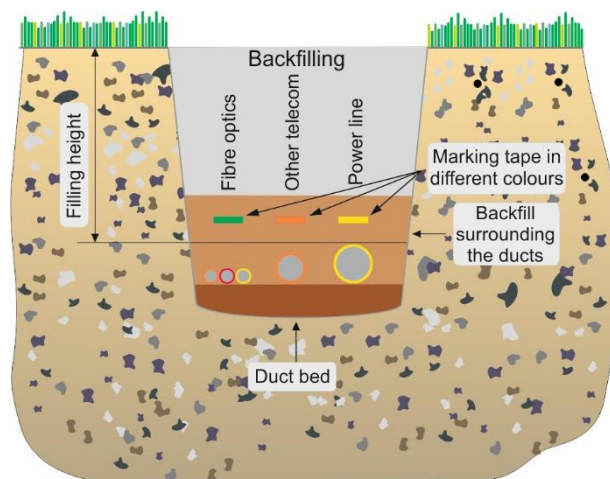


Image of Collocation

2.3.2.6 selected sandfill

Selected sandfill is generally required in order to form a bed of gravel with a dimension of \emptyset 0–18 mm. Where the instructions specify selected sandfill with a dimension of \emptyset 0–18 mm, adaptations should be made according to the selected sandfill recommendations.

In order to clarify the application of selected sandfill depending on what is being installed in the ground, AMA Site works and the table describing soil types are used. For Robust Fiber, sand, fine gravel and medium gravel are used.

Classification of soils based on grain fractions			
Main fraction	Sub-fraction	Designation	Limit of fractions (mm)
rough soil	Gravel	Gr	>2 to 63
	Coarse gravel	CGr	>20 to 63
	Middle gravel	MGr	>6.3 to 20
	Fine gravel	FGr	>2 to 6.3
	Sand	Sa	>0.063 to 2.0
	Coarse sand	Csa	>0.63 to 2.0
	Middle sand	Msa	>0.2 to 0.63
	Fine sand	Fsa	>0.063 to 0.2

Sheet of different types of soil for selected sandfill

Selected sandfill recommendations

- **Sand, fine gravel or medium gravel** is used as Selected Sandfill for excavations, generally \emptyset 0–18 mm.
- **Medium gravel** should be used for standard ducts (larger dimensions) and when positioning manholes and cabinets.
- **Fine gravel** should be used for duct bedding and Selected Sandfill in the case of excavation and the routing of microducts
- **Sand** should be used as Selected Sandfill in the case of microtrenching.

2.3.3 Minimum backfill height

Backfill height is the distance between the upper edge of a duct and the finished ground level. General requirements regarding minimum backfill height can be seen from the table below. Other requirements and regulations may be determined by road operators and land owners regarding routing and the placement of cables in e.g. urban areas, by major roads and in farmland.

Local rules and regulations must always be followed.

2.3.3.1 General requirements regarding minimum backfill height:

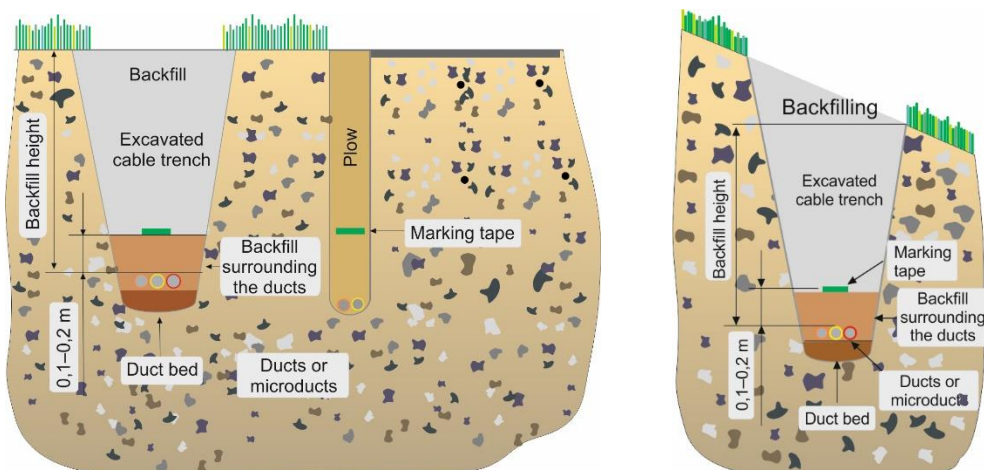
Minimum backfill height requirements

- When pressing through a road or railway embankment, the road operator's and the Swedish Transport Administration's regulations must be followed.
- For minimum backfill height requirements, see Table Backfill Height below.

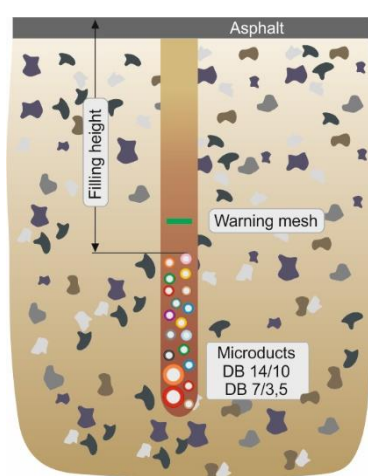
At intersections with other lines, fibre optic cables are normally routed above power cables, water and sewage ducts as well as district heating. Additional protection around the ducts may be required. A risk analysis is recommended to ensure that the correct measures are implemented.

Surface	Backfill height	Method	Information
Building land adjacent to residential buildings	30 cm	All	
Roadway and pedestrian/cycle path	25 cm	Microtrenching End milling	An additional 10 cm in the case of non-paved surface (gravel road).
Pedestrian/cycle path	30 cm	All	
Crossing of minor road	70 cm	All	Smaller roads such as farm, field or forest road.
Roadway	45 cm	All	
Crossing of ditch	55 cm	All	Calculated from a properly cleared ditch bottom.
Greenfield sites (not farmland)	45 cm	All	
Green spaces outside of building land	45 cm	All	
Farmland	75 cm	All	Consideration must be given to any drainage

Table, Backfill height



Examples of backfill heights



Shows backfill height during microtrenching

2.3.4 Connection to buildings

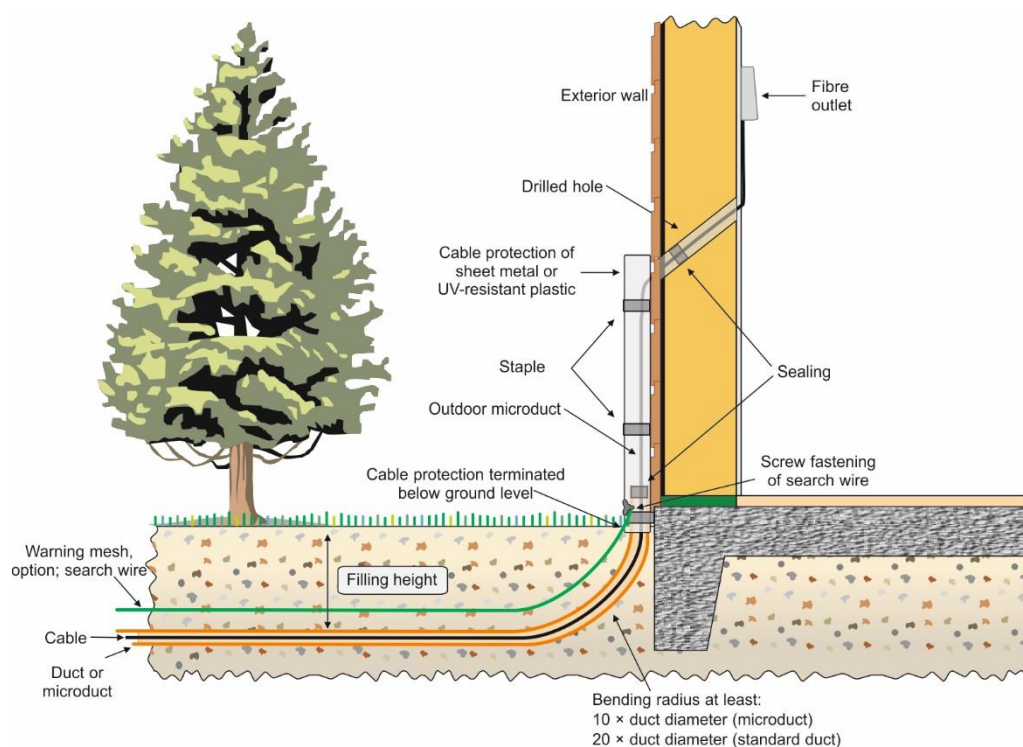
The position of the intake of the duct in a building (a property) is determined by the property owner in consultation with the contractor.

2.3.4.1 Intake of duct above ground level in property

MINIMUM REQUIREMENTS REGARDING INTAKE OF DUCTS ABOVE GROUND LEVEL:

- The bend radius of standard ducts must be at least 20 times the duct's outer diameter, while the bend radius of microducts must be at least 10 times the duct's outer diameter. If not, drawing the fibre optic cable through the duct is rendered more difficult or, in the worst-case scenario, impossible.
- At building foundations, the duct must terminate at least 10 cm above ground level.
- For introduction into the property, a hole must be drilled at an incline of at least 30°, with the highest point inside the property.
- Ducts must be sealed against the hole through the building wall. The space around the duct must therefore be sufficiently large to provide space for a sufficient amount of sealing compound or a mechanical seal.
- Sealing must be performed as close to the inner wall and outer wall as possible.

- The ends of ducts must be sealed until the fibre optic cable is routed to prevent dirt or similar penetrating. Ducts must also be sealed after fibre installation.
- Ducts must be sealed against the fibre optic cable in the fibre outlet to prevent water leaking in from the duct.
- Cable protection that can cope with an outdoor environment must be used to cover visible duct on house walls.
- Warning mesh must be placed up to the building shell.
- Any search wire must be terminated at a screw or cable protection at the building shell.
- Ducts must be UV-protected where they are exposed to direct sunlight. Otherwise, mechanical protection (e.g. sheet metal chute) must cover the duct.
- In the case of overhead cables, connections must be made in accordance with the manufacturer's instructions.



Example of intake into building

2.3.4.2 Intake of duct below ground level

Intake of duct below ground level must only be used in exceptional cases due to the risk of, among other things, moisture damage.

MINIMUM REQUIREMENTS REGARDING INTAKE OF DUCT BELOW GROUND LEVEL:

- The cable trench must be dug up to the building shell with a backfill height of at least 30 cm above the duct.
- A hole must be drilled into the property at an incline of at least 30°, with the highest point inside the property. If the hole is drilled through the foundation's existing drainage protection, the protection must not be impaired, rather it must be reinstated.
- The duct must be sealed against the hole through the building foundations. The space around the duct must therefore be sufficiently large to provide space for a sufficient amount of sealing compound or a mechanical seal.

- The ends of ducts must be sealed until the fibre optic cable is routed to prevent dirt or similar penetrating. Ducts must also be sealed after fibre installation.
- Warning mesh must be placed up to the building shell.
- Any search wire must be terminated at a screw at the building shell.
- If the property has ground cover such as Isodrän or Platon membrane, the manufacturer's recommendations regarding sealing must be followed.

2.3.5 Routing in lakes or watercourses

Before starting routing in lakes or watercourses, it is important to conduct a thorough check of the section in question in order to ensure that the section is suitable with regard to bottom conditions, maritime traffic, etc. It is also common to employ pressing or directional drilling when routing below watercourses. Below is a description of minimum requirements when routing along the bottom.

MINIMUM REQUIREMENTS WHEN ROUTING IN LAKES OR WATERCOURSES:

- When routing fibre optic cable in lakes or large watercourses, it is necessary to obtain the consent of the County Administrative Board. In certain cases, an environmental impact plan must also be drawn up.
- Contact must be made with the responsible authorities for the maritime traffic area to discuss the need for cable marking and signs. The network owner is the sign manager and is responsible for erecting and maintaining the signs.
- Contact must also be made with the responsible authorities for the maritime traffic area in order to discuss the need for landmarking and information for the updating of nautical charts, both after laying and after removal/decommissioning. Requirements for position indication and delivery of digital data must also be established.
- When routing fibre optic cable (underwater cable) or ducts in water, it is necessary to use a design approved for the purpose for placing in water in respect of water depth, the nature of the bottom, future dredging, etc. You must therefore always consult with the cable manufacturer.
- If ducts are intended for water in watercourses, fibre optic cables need not be adapted to water more than the requirements for long-waterproof optocables for ground.
- On lake bottoms where there may be wrecks, rocks or similar, a bottom survey must be conducted to ensure that the cable/duct is routed outside of the risk area.
- When routing underwater cables, a loop must be located at both land attachments, ideally around the outside of a cement ring or equivalent, which then also has an anchoring function.
- After routing, the duct/underwater cable must follow the bottom contours and be securely anchored.
- Duct/underwater cables must be routed at the authorised distance from all types of buoys and beacons.
- When crossing other ducts, such as water and sewage ducts, the duct/underwater cable must be routed under these.

Recommendations when routing in lakes and watercourses:

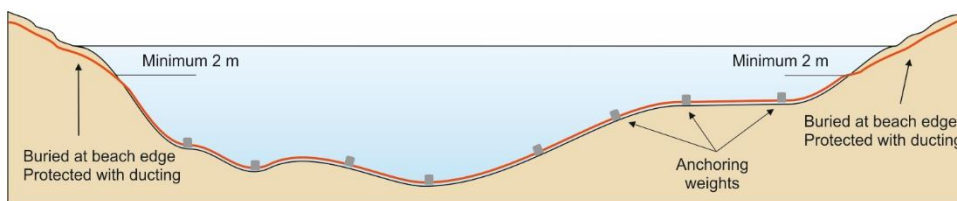
- If there is an obvious risk of damage to cables (e.g. harbour entrances, harbour basins, etc.), an application for an anchoring ban may be considered.
- In navigable channels and in the event of rocky bottom conditions, divers should be used in conjunction with routing to lay the cable properly and, if possible, to secure it.
- When routing cables in lakes, additional duct is not normally required when using an

underwater cable. Under certain circumstances, ducts may also be a suitable alternative when routing in a lake. The duct is anchored to the bottom or routed in the lake bed. The duct is normally anchored with weights where there is a risk of it floating up to the surface. The cable can then be flushed into the duct.

- When routing lightly armoured underwater cable, the cable should be anchored to the bottom bearing in mind the cable's low specific weight.
- In order to facilitate marking out, the duct should be routed in a straight line between the duct's land attachments.
- When crossing a specifically marked navigable channel or in heavily trafficked channels, crossing should take place at right angles to the channel's or the maritime traffic's main direction.
- When crossing smaller watercourses, such as large ditches or streams, re-splicing to maritime cable is not normally required if the cable is routed in a duct intended for underwater routing.
- When crossing larger watercourses, such as rivers or canals where the water is often so deep that normal excavation cannot be performed, the cable is routed in the same way as when routing in lakes.

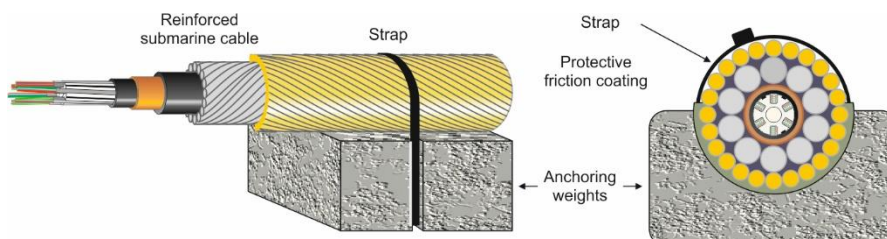
Example of routing with duct in water:

Ducts are routed on the bottom by anchoring them with weights. The weight of the weights is dimensioned according to the diameter of the ducts and with regard to the prevailing water conditions. The weight of the weights and the interval between them must be set out in the planning documentation. Ducts may need to be protected against external effects from e.g. bottom conditions by means of suitable Selected Sandfill, which must be set out in the planning documentation.



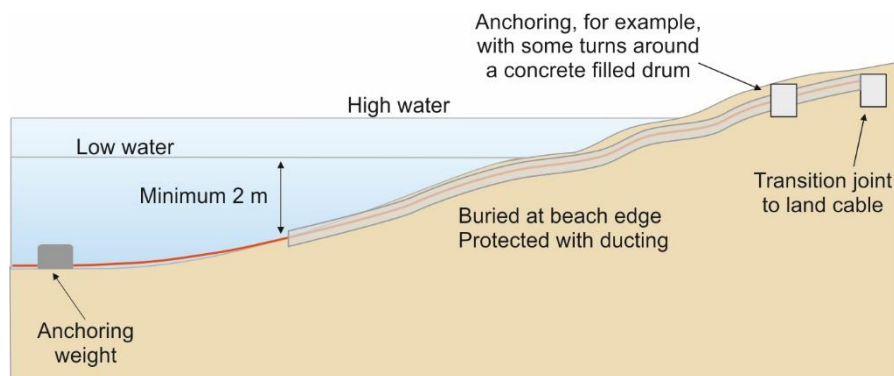
Example showing how a duct is routed on the bottom with the aid of weights

The duct is placed on a weight with a protective friction lining, and then secured with cable ties.



Example showing how a cable can be secured to a weight. The same principle applies to ducts.

From the land, the duct must be pressed or drilled out into the lake or excavated down where this is possible. The duct is routed at a recommended depth of approx. 2 metres below the low water level. This is to ensure that the duct is not affected by ice formation.



Example showing the routing of a duct 2 m below low water level

2.3.5.1 Extremely fast-flowing water

In extremely fast-flowing water, it is particularly important to select the correct weights to secure the duct to the bottom.

2.3.5.2 Checking routing in lakes or watercourses with regulated maritime traffic in accordance with the regulations of the Maritime Administration.

During or after routing, the duct must be checked by divers. During checking, particular attention must be paid to how the duct is anchored, sufficient routing at the banks, protection and sufficient space between weights. A report of the inspection must be prepared and documented.

MINIMUM REQUIREMENTS WHEN CHECKING ROUTING IN LAKES AND WATERCOURSES WITH REGULATED MARITIME TRANSPORT:

- Ducts or cables must be inspected by divers.
- A report of the inspection must be prepared.

2.3.6 Routing on poles

From a robustness perspective, routing on poles should be avoided.

When using a pole route, it is necessary to ensure that the pole route's cable corridor is cleared of trees and branches to minimise the risk of damage to the fibre optic cable.

If a pole route is being used for ducts, routing can take place in several different ways.

- Installation on separate poles (separate pole route).
- Joint construction with an electricity grid owner's pole routes for low and medium voltage.
- Utilise phase or earth wire in power line poles through joint construction with an electricity grid owner.
- Joint construction with a telecommunications operator's poles.
- Joint construction with the Swedish Transport Administration or other railway companies' poles.

MINIMUM REQUIREMENTS FOR ROUTING ON POLES:

- Ensure that the owner of the pole route has procedures for clearing the cable corridor to prevent damage from trees and branches.
- Guys must be present to counteract lateral forces in the event of branching or bends.

2.3.6.1 Joint construction

In the event of joint construction with another owner of poles, it is necessary for responsibility issues, demarcations and maintenance measures to be clarified and documented in an agreement between the owners.

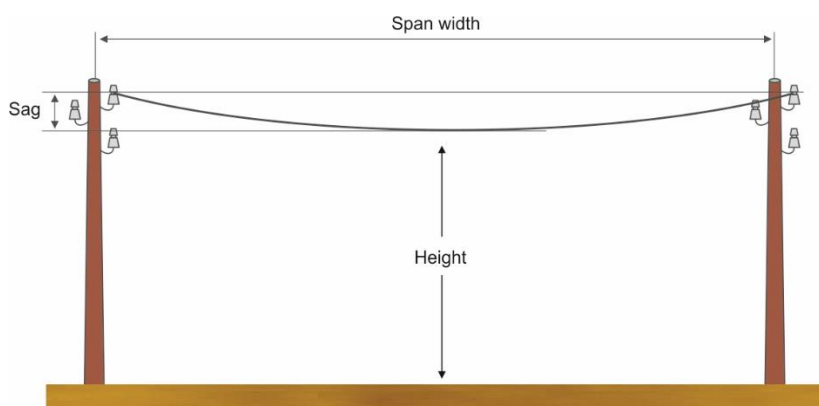
Consult with the relevant party in the event of joint construction to obtain information about which rules and regulations apply. It must be clear from the agreement who owns, maintains and is responsible for inspection, as well as the terms and conditions in the event of any transfer. There must also be a reference to the applicable safety requirements. Particular attention must be paid to authorisation for service and maintenance personnel.

MINIMUM REQUIREMENTS IN THE EVENT OF JOINT CONSTRUCTION:

- Agreements with other cable owners must be drawn up.
- The regulations of other cable owners must be complied with.

2.3.6.2 Height above ground of overhead cables

The distance between cable and ground applies at maximum load, and must be calculated from the surface of any snow cover.



Example of overhead cable

Requirements regarding height above ground of overhead cables:

- The minimum height above ground or water of overhead cables must not be less than 3.5 metres. From the final pole to the building, however, the height may be less.
- In the case of land where vehicles may pass, such as arable land, agricultural land or park environment, the minimum height above ground must be 5 m. Consultation must be held with landowners before installation is carried out.
- The minimum height of the overhead cables over a public road or other area with passing traffic, the installation must be carried out in accordance with the Swedish Transport Administration's instructions for management work within the road area or other road maintenance instructions. Responsible road maintenance requirements always apply before Robust fiber's instructions if the requirement is higher

MINIMUM REQUIREMENTS REGARDING INSPECTION OF OVERHEAD CABLE

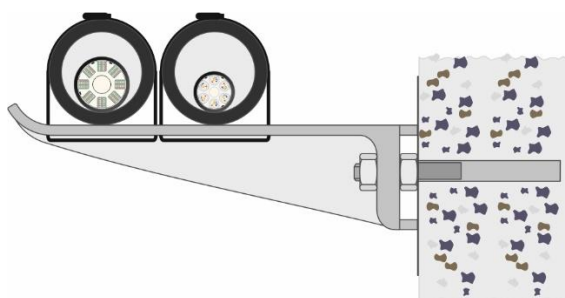
- Inspections are performed in accordance with the pole owner's and the supplier's instructions.

2.3.7 Installation at bridges

The location of ducts on bridges is determined by the road operator/bridge owner in consultation with the contractor.

MINIMUM REQUIREMENTS REGARDING INSTALLATION AT BRIDGES:

- The ducts must be securely attached and well protected.
- There must be a cable loop on at least one side of the bridge if the cable is a trunk fibre cable. Customer cables do not need to be looped.



Example of anchoring on a bridge

2.3.8 Routing in tunnels and culverts

When routing in a tunnel, ducting in the form of ducts is not needed. As an alternative, fibre optic cables and ducts can be installed with a catenary or wire span.

MINIMUM REQUIREMENTS FOR ROUTING IN A TUNNEL:

- Material that is used must be classified for indoor use.
- Fibre optic cables or ducts must be placed on a cable ladder or clamped to the tunnel wall. Fibre optic cables or ducts must be secured with e.g. cable ties, in which case at least every third cable tie must be made of metal to prevent the cable falling down in the event of a fire.
- If there is a risk of unauthorised entry, vandalism or pests, armoured fibre optic cables or ducts must be used.



Routing in tunnel

2.4 Fibre optic cables

2.4.1 Fibre optic cables, general

For cable designs and the choice of cable, you should generally refer to material suppliers. There are a few different fibre optic cable designs:

- Ribbon cable – the fibres are joined together in ribbon structures (4 or 8 fibres), making it possible to splice (weld) all the fibres at the same time. The ribbon is then placed in a plastic groove profile.
- Cables built up with tubes, where the fibres are protected in filled tubes located around a strain relief device.
- Cables with a central filled tube with fibres with or without external strain relief.
- Micro-cables are built up in a similar way to fibre optic cables, but with a more slender structure.
- Blow fibres are 1–12 fibres bundled with minimal external protection in the form of a sheath. If blow fibres are routed outdoors, only ducts intended for blow fibres may be used.

There are several standards for the colour coding of fibres in fibre optic cable. It is important to decide on a colour code and to use the same colour code throughout the fibre installation.

Colour code S12 is recommended for all fibre optic cables.

MINIMUM REQUIREMENTS REGARDING FIBRE OPTIC CABLES:

- Fibre optic cables must have single-mode fibres and must conform to the standard according to ITU-T G.652 or G.657.
- The fibre optic cable's strain relief must be adapted to the installation methods and the splicing units that are used in the fibre installation.

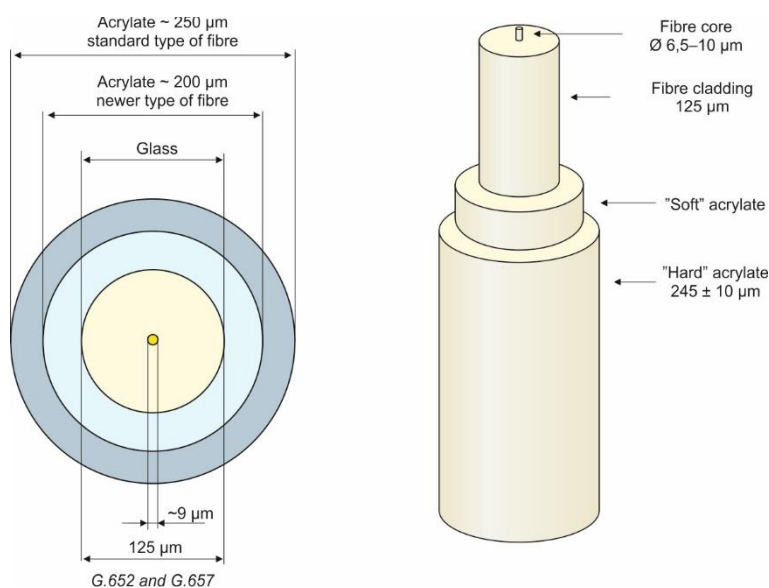
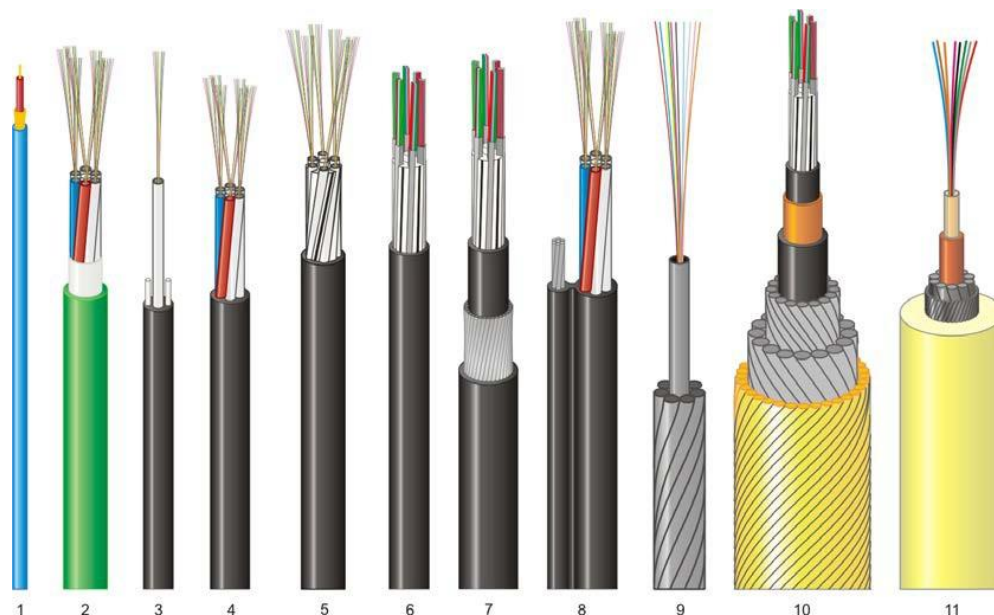


Image showing the structure of fibre optic cables G.652 and G.657.

Fibre optic cable with G.652 fibres is used in most standard cables. Fibre optic cables with fibres of type G.657 are less bend-sensitive and are used primarily in access networks to individual customers.

Below are examples of various types of fibre optic cables.



Examples of various fibre optic cables

1. Patch cables, fitted with connectors at either end and normally used to connect networks to networks or active equipment to networks, usually between ODFs in ODF racks.
2. Concentric cable with fibres in duct. The cable is used to build networks in ducts or in a protected environment, e.g. indoors, in tunnels, within industrial buildings, etc. The green colour indicates that the cable is flame-retardant. This is not a standard colour for this purpose, although it has become a de facto standard.
3. Thin cable for outdoor application. Loose fibres or fibre ribbons centrally located in a grease-filled duct or cavity. Two thin strain relief devices are located on either side of the cable.
4. A very common cable. It must be routed in standard ducts. Between 4 and 16 secondary ducts containing loose fibres (normally 24 fibres in each duct) are cabled around a central strain relief device. The cavity between duct and duct and outer sheath is filled with filler to make the cable longitudinally watertight. This applies to all cables 4–11.
5. Cable with slotted core profile, in whose slots tubes with fibres are placed. The cable is considerably more resistant to radial pressure than those that are only cabled concentrically.
6. The same type of cable as before, but instead of secondary tubes there are fibre ribbons in the slots. This type of cable is used primarily in sections with a considerable demand for fibre. Fibre ribbons can be spliced considerably faster than individual fibres.
7. Here, cable number 6 has been supplied with robust reinforcement for burying or ploughing directly. The reinforcement comprises steel or aluminium wires.
8. Cable with integrated catenary for suspending between poles (telecom poles), with the max. span restricted to 50 metres. This model is generally referred to as a “figure of 8 cable”.

9. The earth wire at the top of the lattice structure for high-voltage cables can be supplied with optical fibre. This type of cable is known as OPGW cable, as it is intended to connect the lattices to each other and to earth.
10. Underwater cables for coastal installations with a need for many non-reinforced fibres and with limited routing depth. Can be supplied with erbium-doped fibre amplifier, which is why the distance between transmitter and receiver can be in excess of 300 km. The heavy reinforcement with steel wire means that the cable is strong in relation to lighter anchors, as well as providing the weight to follow the contours of the sea-bed. Fibres of the type ITU-T G.655 may be appropriate.
11. Cable for ocean routing, where the routing depth can be up to 8–10 km. The extremely long routing distances mean that amplifiers are used. These are supplied with power through the inner copper duct. The fibre that is used is often ITU-T G.654 with extremely low attenuation.



Examples of micro-cables

1. An alternative to “blown fibre” is this 1.2 mm thick cable, which is used for blowing to individual end users.
2. Thin micro-cable with the fibres in a grease-filled tube surrounded by aramid yarn as strain relief. On the outside of the aramid yarn is a sheath made of flame-retardant polyethylene, FRPE.
3. This picture shows an unusual 48-fibre cable where the fibres are bundled in 12-fibre strands (bundles). The strands are identified through different coloured yarn that has been wound around each strand. All the strands are placed in a grease-filled plastic tube, which in turn is surrounded by aramid yarn as strain relief and an external flame-retardant sheath made of halogen-free PE.
4. Micro-cable with the same structure as a standard cable for routing in standard ducts. This picture shows a cable where each grease-filled tube has the same diameter as the centrally located strain relief device, resulting in six surrounding tube. The standard design is for each tube to contain 12 fibres, which is why the pictured cable contains 72 fibres. The number of fibres in each tube can be doubled.
5. In this cable, the central strain relief device has been made slightly thicker than the surrounding tube. In this case, it has been adapted for eight surrounding tube, producing a cable with 96 fibres. If the number of fibres in each tube is doubled, this produces a 192-fibre cable.

6. Same design as in the two previous cables, but has a few plastic strands placed between the secondary tube to make a more circular cable.

Fibres in a fibre optic cable that are connected at both ends are known as fibre links. A fibre link starts and ends in a node, a connection point (at a customer) or a distribution point (connecting point), normally an ODF (Optical Distribution Frame). Each end of the fibre link is connected to an outlet installed in an ODF unit. The ODF is mounted in a rack or in a small box at a customer.

A connection comprises a fibre link, or two or more fibre links that are connected together (cross-connected).

2.4.2 Fibre optic cables for underground routing

MINIMUM REQUIREMENTS REGARDING FIBRE OPTIC CABLES TO BE ROUTED IN THE GROUND

- Fibre optic cables must be routed in ducts.
- The fibre optic cable must be approved for routing in ducts outdoors.
- The fibre optic cable must be executed with an identification system for the identification of individual fibres, e.g. through colour marking.
- The fibre optic cable must be longitudinally watertight.
- The fibre optic cable must be halogen-free.

2.4.3 Fibre optic cables, cable gutters and cable ladders for indoor routing

MINIMUM REQUIREMENTS FOR FIBRE OPTIC CABLES FOR INDOOR ROUTING:

- Ducts and fibre optic cables intended solely for outdoor use may not extend by more than 20 m into a building and must remain within the same fire cell, according to Boverket's (National Board of Housing, Building and Planning) CPR class Dca-s2, d2, a2, valid from 2017. After this, ducts and fibre optic cables classified for indoor use must be used.
- Cable gutters and cable ladders can be designed according to SS-EN 61537. Cable rails can be designed according to SS-EN 61534 series. Suspension devices in escape routes must be designed in material class A2-sl, do. (BSF 2018: 4)

2.4.4 Minimum requirements for pole routing

From a robustness perspective, routing on poles should be avoided.

Fibre optic cables of the following types are available for pole routing:

- wrapping around power lines
- integrated in earth wire (OPGW)
- suspended from catenary (figure of 8)
- with integrated catenary, which is self-supporting (ADSS)
- in microducts for pole routing.

MINIMUM REQUIREMENTS REGARDING FIBRE OPTIC CABLES WHEN ROUTING ON POLES

- If fibre optic cables are being routed on poles, this must be carried out with cables and attachments that are adapted according to the routing method.
- The pole owner's rules and instruction will apply and may vary depending on local regulations, the use of the pole route (electricity, telecommunications), etc.

2.4.5 Fibre optic cables for routing in water

Important parameters when routing fibre optic cable in water are water depth, presence of maritime traffic, anchoring, fishing, etc. See more under "Routing in lakes or watercourses".

MINIMUM REQUIREMENTS REGARDING FIBRE OPTIC CABLES FOR ROUTING IN WATER:

- Routing must take place using fibre optic cables that are adapted for routing in water.
- The fibre optic cable must be longitudinally watertight.

2.4.6 Fibre optic cables for routing in tunnels and culverts

MINIMUM REQUIREMENTS REGARDING FIBRE OPTIC CABLES WHEN ROUTING IN TUNNELS AND CULVERTS

- In culverts, road, rail and pedestrian tunnels, the fibre optic cable must be halogen-free and self-extinguishing.
- If there is a risk of unauthorised entry, vandalism or pests, armoured fibre optic cables or ducts must be used.

2.5 Cable management

2.5.1 General requirements

In general, during all routing of fibre optic cable, pulling/blowing/floating must take place in a controlled manner with regard to tensile forces and bend radii, in accordance with the cable manufacturer's instructions and using equipment intended for the purpose.

MINIMUM REQUIREMENTS FOR HANDLING FIBRE OPTIC CABLE:

- Do not go below minimum permitted bend radius.
- Do not exceed maximum permitted tensile force.
- Do not exceed maximum permitted mechanical pressure.
- The ends of all non-connected cables must be sealed.
- The cable may not be handled at temperatures below that which has been specified. This means that, in certain cases, the drum has to remain in heated premises for some 24 hours before it can be transported. During transport, it should be covered so that the cable does not cool down.
- Loops must be placed at distribution points where future earthworks can be anticipated, for example by large ditches, roads and in the vicinity of urban areas where development can be expected to take place. Length and location of loops must be documented.
- Loop must always be routed in cable manhole, regardless of fibre optic cable type.
- Cable drums with fibre optic cable must be handled upright.
- The cable's flushing direction is marked on the cable drum and must be followed.

- When blowing micro-cable, a compressor with a moisture separator and the correct filter according to the compressor manufacturer must be used.

Cable dimensions: This table shows suitable matching for the dimension of fibre optic cable with suitable duct.

Cable outer diameter	Microduct with inner diameter						Standard duct with inner diameter							
	2.1	2.8	3.5	5.5	8	10	12	14	16	20	26	28	32	40
1.2	✓	✓	✓											
1.8		✓	✓											
2.4			✓	✓										
3.9				✓	✓	✓								
4.0					✓	✓	✓							
5.4					✓	✓	✓							
6.2					✓	✓	✓							
6.4					✓	✓	✓	✓						
6.8						✓	✓	✓	✓					
7.5						✓	✓	✓	✓	✓				
8.5							✓	✓	✓	✓	✓			
9								✓	✓	✓	✓			
10								✓	✓	✓	✓			
11								✓	✓	✓	✓	✓		
12									✓	✓	✓	✓		
13										✓	✓	✓		
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25														✓

2.5.2 Routing fibre optic cable in manholes and cabinets

In order to position the fibre optic cable correctly in the cable manhole or outdoor splice cabinet where a loop is to be created, careful preparation and handling are required. The cable’s properties are changed if the cable is twisted, and this can easily happen during looping if this is not done correctly. Comply with the cable manufacturers instructions regarding looping. For example, some cable types may need to be looped in the form of a figure of eight. Checking whether the fibre optic cable is twisted can be performed by inspecting that the cable’s longitudinal labelling is in the same direction. A cable length of approx. 20 metres is suitable as a loop length.

Micro-cable can be looped in the same way as standard cable. However, micro-cable is not as robust in the structure as standard cable, and extra care must therefore be taken when handling micro-cable.

MINIMUM REQUIREMENTS WHEN ROUTING FIBRE OPTIC CABLE IN CABLE MANHOLES AND OUTDOOR SPLICE CABINETS:

- Loop must be placed in manhole in order to facilitate future changes in the network, e.g. expanding, repairs, etc.
- The cable manufacturer's instructions regarding looping must be complied with.
- If individual fibres, fibre units, fibre ribbons or bundled fibres are used, these must never be looped freely in cable manholes as there is a risk of fibre breaks and moisture damage. They must be looped in a splicing box.
- All fibre-optic cables for outdoor use must be able to cope with lying in water.

2.5.3 Routing fibre optic cable indoors

Where fibre optic cables are routed in public areas such as cellars, garages, etc., and there is a risk of unauthorised entry, vandalism or sabotage, security must be improved by the cables being routed as well concealed as possible using mechanical protection.

MINIMUM REQUIREMENTS WHEN ROUTING FIBRE OPTIC CABLE INDOORS:

- When there is a risk of unauthorised entry, vandalism or sabotage, indoor fibre optic cables must be protected mechanically with ducts or equivalent.

2.5.4 Splicing cables

MINIMUM REQUIREMENTS WHEN SPLICING FIBRE OPTIC CABLE:

- The fibres in the cable must be spliced by means of welding.
- The fibre splice must be protected in a splicing sleeve. The spliced fibres must then be placed in one or more fibre cassettes, which in turn must be protected by a splicing cabinet or splicing box.
- Do not go below the fibres' minimum bend radius. See the cable manufacturer's specification.
- The strain on the fibre optic cables must be relieved in a splicing box or splicing cabinet using integral strain relief for the cable in question, e.g. glass fibre rod or aramid yarn.

As far as possible, avoid a network design where splicing takes place in connectors. Connectors always produce more attenuation and reflection, which can affect the signal.

2.5.5 Splicing units

The fibre optic cable's splice is protected in a splicing unit. Splicing units in the form of splice boxes or splice cabinets are selected according to the environment in which they are placed, the number of fibres to be spliced, as well as the cables and any microducts that are to be connected. Always following the manufacturer's instructions regarding temperature, pressure sealing, strain relief, cable twist, bend radii, splice holders, etc.

Splice boxes are normally intended for direct routing in the ground or cable manholes. Splice cabinets are available for installation outdoors in an outdoor splice cabinet and for installation in an indoor environment.

A wall box for outdoor use is a splice cabinet and outdoor splice cabinet in one unit.

A facade box is a box located on the facade of a building and used for splicing fibre optic cable for the building.

MINIMUM REQUIREMENTS FOR SPLICING BOXES AND WALL BOXES:

- Splice boxes and wall boxes for outdoor use must satisfy class IP68 as a minimum.
- Wall boxes for outdoor use must be able to be locked in the form of a seal.
- Wall boxes that are positioned so that they are accessible to the general public must be class IK 8.
- Splice boxes must be UV-resistant.
- Splice boxes must be pressure-tight in order to cope with a water pressure equivalent to a 5 m water column.
- Splice boxes must withstand the strains to which they are subjected in water-filled manholes, mounted outdoors or buried directly in the ground.

MINIMUM REQUIREMENTS FOR FACADE BOXES:

- Facade boxes for outdoor use must satisfy class IP54 as a minimum.
- Facade boxes that are positioned so that they are accessible to the general public must be class IK 7.
- Facade boxes must be UV-resistant.
- If penetration in the façade is done behind the façade box by drilling a hole in the façade box, it must be ensured that the occupied hole and through-hole penetration are sealed. Sealing takes place with the intended sealant to maintain the moisture barrier
- Splicing of fibre in the facade box can be done by welding or with a facade box mounted with a splice piece for mounting fibre



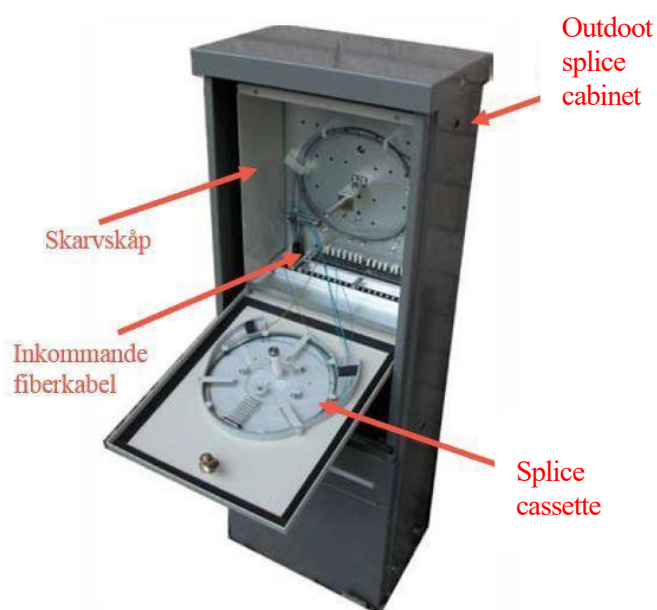
Example of facade boxes

MINIMUM REQUIREMENTS REGARDING SPLICING CABINETS:

- Splice cabinets for outdoor routing above ground must be surrounded with an external enclosure that satisfies at least classification IP34. Ensure that the sealing of the splice cabinet is enough, eg. in respect of pests and water penetration, for the environment where the splice cabinet is located.
- When outdoors, splice cabinets must be installed in an outdoor splice cabinet or equivalent enclosure.
- Splice cabinets must be UV-resistant.
- Splice cabinets that are positioned so that they are accessible to the general public must be class IK 8.



Example of outdoor splice cabinet for outdoor use with splicing unit



Example of outdoor splice cabinet with splicing cabinet and splice cassette

2.5.6 Termination of cable in node

Termination means that the fibres in a fibre optic cable are made accessible via connectors in a connection panel. The connection panel is part of an ODF (Optical Distribution Frame).

Fibre optic cable classified for outdoor use must be re-spliced (transition joint or station joint) to fibre optic cables for indoor use if the indoor section exceeds 5 m, see point 2.4.3.

Transition joints are normally located outdoors in an intake manhole or outdoor splice cabinet. Pre-connected indoor cable (known as stub cable) is often used from ODF to transition joint.

The indoor cable is terminated with optical connectors on the inside (line side) in an ODF unit. The fibres are thereby accessible for cross-connection or connection of active communication equipment on the front (connection panel) of the ODF unit.

2.5.6.1 ODF (Optical Distribution Frame)

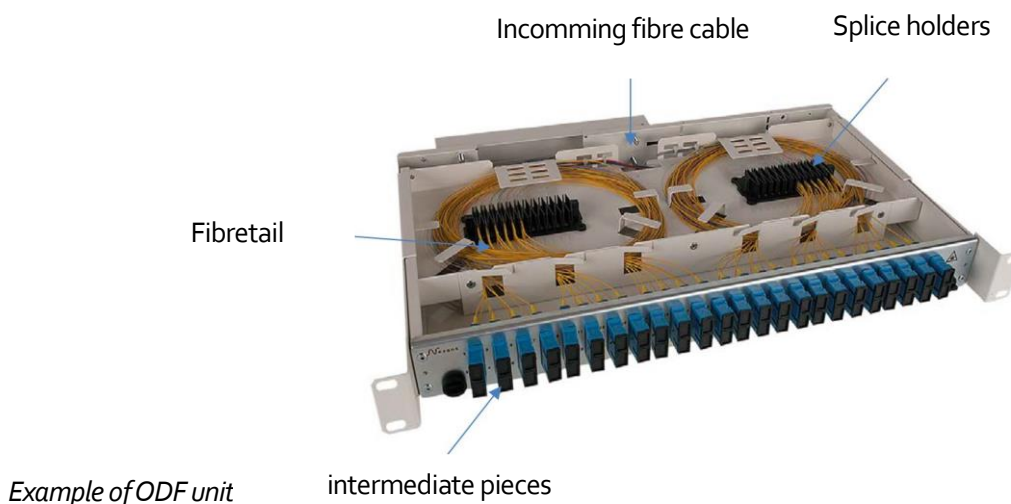
In an ODF unit, the fibre optic cable is welded to preconnected pigtailed or preconnected fan-outs. On the ODF unit's panel (front), intermediate pieces are installed where the connectors are connected. In this way, the fibres are made accessible for connection in connectors, for connecting equipment or cross-connection.

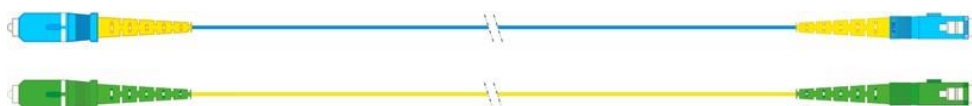
An ODF unit is often 19 inches wide and its height can range from 1U (height unit) up to 3U. An ODF can comprise everything from an individual ODF unit with a small number of connectors to covering many units in several racks where all fibre optic cables in the node are terminated.

When selecting equipment for an ODF, certain basic functions as shown below must be satisfied to achieve a robust network.

MINIMUM REQUIREMENTS REGARDING ODF UNIT:

- The ODF unit must have protection in front of the connector panel.
- It must be easy to access the inner connectors for cleaning or replacing intermediate pieces, e.g. via a removable or swivelling front panel.
- The empty intermediate pieces, where no connector is installed, must be supplied with dust protection both inside the ODF unit and on the panel.
- Having different solutions and models in the same rack must be avoided, as they can impede work in the unit above or below.
- Green intermediate pieces must never be used together with blue connectors or vice versa.





Examples of connecting cables

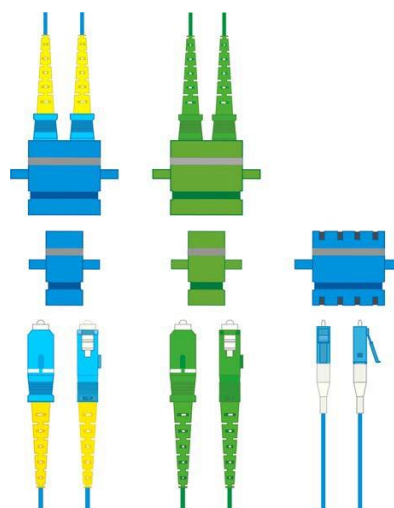
MINIMUM REQUIREMENTS REGARDING ODF RACK:

- ODF units with stub cable (prefabricated unit with connectors and fibre optic cable of various lengths) must be able to be installed in the rack. The stub cable is routed from the ODF rack, e.g. on cable ladders, up to a transition joint where it is welded to the incoming fibre optic cable.
- ODF racks must be placed so that incoming fibre optic cables that are routed indoors can be spliced directly inside the ODF unit.
- ODF racks must be designed so that future operational and maintenance work can easily be carried out, e.g. replacement, repair and supplementing in the ODF units.
- Cable routes must be present, and all connection cables must be located in cable holders. This requirement applies to the entire ODF, i.e. in panels within the same rack and between racks.
- ODF racks must be designed so that the handling of connection and connecting cables is rational in respect of radius restriction, order, excess length, quantity, switching, supplementing, etc.
- ODF racks must be designed so that cross-connection can take place within the same ODF rack or via designated transfer routes to another ODF rack or to racks with active equipment.

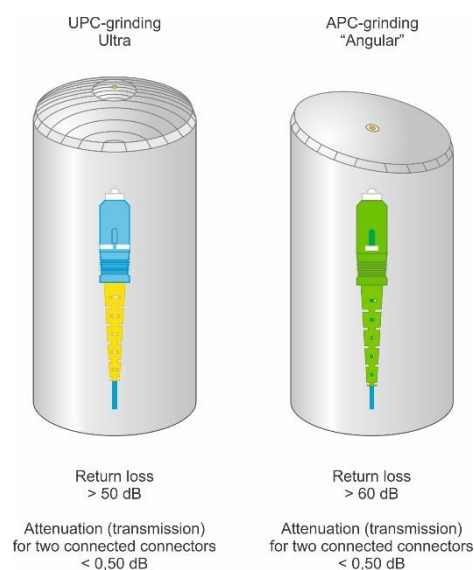
2.5.7 Optical connectors and cleaning

2.5.7.1 Optical connectors

There are several types of optical connectors. The most common connector types in broadband networks are LC (Lucent Connector) and SC (Subscriber or Standard Connector). In order to connect two connectors to each other, an intermediate piece is used. The colour of the connectors describes the type of polishing used on the connector's end surface. The most common are UPC (blue, spherical polishing) or APC (green, 8° angled polishing). UPC is most common in broadband networks. APC is mostly used in cable TV networks, where it is important for the reflection of light to be minimised (high reflection attenuation).



Examples of optical connectors and intermediate pieces. From the left: SC connector UPC, SC connector APC, LC connector UPC with intermediate pieces.



Different polishing of the connector ferrule. Specified attenuation values are quality parameters.

2.5.7.2 Cleaning

Optical connectors and intermediate pieces are normally only cleaned using dry methods (e.g. cleaning box/card and stylus/pen).

In exceptional cases, i.e. in the event of heavily soiled connectors, connectors can be cleaned using isopropanol. When cleaning with isopropanol, the connector must be dried immediately by cleaning using a dry method.



Cleaning fibre with cleaning cassette

2.5.8 Termination outdoors

ODF units or equipment open panels are not used outdoors in outdoor splice cabinets to create switch points, as this requires entirely sealed boxes.

If switch points with optical connectors are placed out in the network, these should be located indoors or in special outdoor cabinets (environmental cabinets).

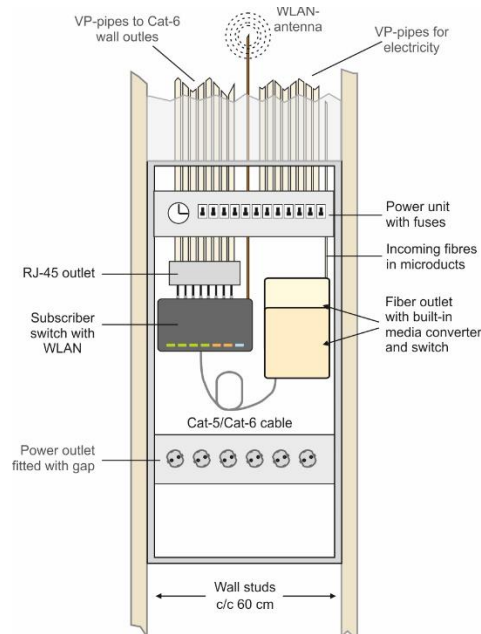
2.5.9 Termination in property

For termination in apartment buildings, see the recommendation "Robust property networks".

After a fibre optic cable has been routed into a property, a seal is installed between duct and fibre optic cable.

Incoming fibre optic cables into buildings are terminated in a fibre outlet that should be

located in the immediate vicinity of a cable intake in the wall or in a “broadband space” in order to create a flexible connection point. From the outlet, a connection cable that is robust and adapted for installation is routed into the household up to the active customer equipment.



Example of broadband space combined with distribution board in property

MINIMUM REQUIREMENTS FOR TERMINATION IN PROPERTY:

- An incoming cable entering a home must be terminated in a standalone fibre outlet. Standalone also means a unit/plate on which a switch is installed and there is a separate space for fibre on the unit/plate.

2.5.9.1 Fibre outlet

The fibre outlet in a home is the property of the network owner. The fibre outlet should be designed so that the connector on a connected connection cable is not too visible and easily accessible (otherwise it is easy for e.g. small children to pull out the connector).

A customer with the technical knowledge and a set of instructions should be able to disconnect and replace the **patch** cable without opening the fibre outlet. The **patch** cable should be in a robust version that is adapted for the purpose.

MINIMUM REQUIREMENTS FOR FIBRE OUTLETS IN DETACHED/TERRACED PROPERTIES:

- An outlet installed directly on a wall must be angled down, parallel with the wall.
- The intermediate piece must be physically protected against dust, even if the connector is removed.

2.5.10 Optical radiation

Optical radiation is principally a safety issue for those who handle optical connectors and cabling. Do not look into connectors if these are connected to a laser.

Laser radiation can damage vision. As the light is infrared and invisible,



warning labels must be present by fibre outlets to call attention to and warn about these risks. The infrared radiation does not trigger a blink reflect, which would protect the eye.

2.5.11 Delivery measurement of fibre connections

After installation, delivery measurement is conducted at the installation and a measurement report is prepared. Delivery measurement of fibre optic cables is performed to ensure that the physical installation and the documentation correspond, and to verify that minimum requirements in respect of e.g. attenuation are satisfied. An Excel calculation is available as an aid. See sub-appendix 2.1 Calculating attenuation.

2.5.11.1 Measurement methods

There are two common measurement methods for delivery measurement of newly installed fibre optic cables:

- Attenuation measurement, dB measurement
- OTDR measurement.

For Robust Fiber, OTDR measurement applies.

During OTDR measurement, an optical reflectometer is used (OTDR = Optical Time Domain Reflectometer). OTDR transmits a pulse of light, which is reflected in inhomogeneities, joints, connectors and end points.

OTDR is used to measure e.g. attenuation and connector reflections. OTDR is also used to find attenuation increases, e.g. in poor splices, pinching or defective cables. Always follow the instrument manufacturer's instructions in respect of executing measurement.

2.5.11.2 Choice of OTDR instrument

The instrument's performance is selected on the basis of the type of connection being measured.

An OTDR instrument that is used in national networks can measure long distances with a high degree of accuracy, while an OTDR instrument that is used in connection networks requires a good resolution over short distances.

2.5.11.3 If a defective fibre optic cable is suspected

If it is suspected that the fibre optic cable has been subjected to external influences in conjunction with installation, e.g. damaged cable drum, pinching, etc., the fibres must be checked using one of the listed measurement methods.

2.5.12 Delivery measurement of passive fibre

MINIMUM REQUIREMENTS IN RESPECT OF DELIVERY MEASUREMENT OF PASSIVE FIBRE:

- OTDR measurement must be performed on all connections at 1310 nm and 1550 nm.
- OTDR measurement must be done according to the instrument manufacturer's instructions.
- The measuring instruments must be calibrated in accordance with the manufacturer's procedures.
- The measurement report must specify the measuring instrument, OTDR settings (measurement area, pulse, time and index of refraction (IoR)), as well as who has carried out the measurement.
- The measurement results from attenuation measurements and OTDR measurements must be saved in a generally legible file format, e.g. Excel, .pdf or .sor for OTDR.
- The limit values according to table 2.5.12.1 must not be exceeded.

- Two-way OTDR measurement is to be performed for connection- and regional networks.

2.5.12.1 Measurement results and limit values for fibre in cables

Table: Minimum limit values for fibre in cables (summary table)

Limit value for attenuation in routed optical cable	
Limit values at 1310 nm	Max. 0.40 dB/km Mean 0.37 dB/km
Limit values at 1550 nm	Max. 0.25 dB/km Mean 0.22 dB/km
Limit values at 1625 nm ^{*1}	Max. 0.40 dB/km Mean 0.30 dB/km
Spot attenuation change at 1550 nm or 1625 nm. Spot attenuation change refers to "spikes" greater than 0.05 dB.	0.05 dB
Fibre attenuation may at most exceed the factory measurement of the fibre by 0.03 dB/km at 1310/(1550 or 1625) nm. Average value refers to the combined value of all the fibres in a section of cable.	
Limit value at individual splice	
Max. limit value, access network (<10 km)	0.25 dB
Max. limit value, connection network, regional network (>10 km)	0.20 dB
Limit value at connector	
Reflection attenuation, UPC (ultra-polished connector)	min. 50 dB
Reflection attenuation, APC (angular polished connector)	min. 60 dB

*1) When measuring active access connection with filtered wavelength 1625 nm to single dwelling unit (SDU) connections

The following requirements regarding fibre in cables constitute input data during delivery measurement of an installed system.

MINIMUM REQUIREMENTS, spot attenuation change

- Requirement regarding spot attenuation change at 1550 nm: Max. 0.05 dB
Spot attenuation change refers to "spikes" greater than 0.05 dB.

MINIMUM REQUIREMENTS, fibre attenuation at 1310 nm

- Max. attenuation 0.40 dB/km Average 0.37 dB/km
- Fibre attenuation may at most exceed the factory measurement of the fibre by 0.03 dB/km
- Average value refers to the combined value of all the fibres in a section of cable.

MINIMUM REQUIREMENTS, fibre attenuation at 1550 nm

- Max. attenuation 0.25 dB/km Average 0.22 dB/km
- Fibre attenuation may at most exceed the factory measurement of the fibre by 0.03 dB/km
- Average value refers to the combined value of all the fibres in a section of cable.

MINIMUM REQUIREMENTS at individual splice

- Max. attenuation 0.25 dB, access networks
- Average attenuation 0.20 dB, connection and regional networks

MINIMUM REQUIREMENTS in respect of measurement results:

MINIMUM REQUIREMENTS for distances less than 10 km have the character of access networks:

In the case of access networks (<10 km), max. attenuation is used during calculation.

The value obtained for attenuation must be below the following theoretical calculation:

At 1310 nm: length x 0.40 + splice x 0.25 + 1.0 + 0.5 dB

At 1550 nm: length x 0.25 + splice x 0.25 + 1.0 + 0.5 dB

MINIMUM REQUIREMENTS for distances greater than 10 km have the character of connection and regional networks:

In the case of connection and regional networks (>10 km), average attenuation is used during calculation.

The value obtained for attenuation must be below the following theoretical calculation:

At 1310 nm: $\text{length} \times 0.37 + \text{splice} \times 0.10 + 1.0 + 0.5 \text{ dB}$

At 1550 nm: $\text{length} \times 0.22 + \text{splice} \times 0.10 + 1.0 + 0.5 \text{ dB}$

Explanation of the above abbreviations:

length = optical length (km) **splice** = number of splices

1.0 dB relates to losses in event of connection to ODF, 2x if 0.5 dB (including first splice after ODF)

0.5 dB relates to the combined measurement uncertainty in instruments with connectors.

As support for calculating the connection attenuation, an Excel calculation has been produced that can be downloaded from robustfiber.se under Instructions.

2.5.13 Delivery measurement of active fibre

Active fibre refers to a connection that has an active CPE/Switch that signals at 1310 nm and 1550 nm on the fibre. Delivery measurement can then be conducted with a filtered wavelength of 1625 nm.

Active measurement assumes that measurement is from one direction only.

MINIMUM REQUIREMENTS IN RESPECT OF DELIVERY MEASUREMENT OF ACTIVE FIBRE:

- OTDR measurement must be performed at 1625 nm on active fibre connection. The measuring instruments must be calibrated in accordance with the manufacturer's procedures.
- OTDR measurement must be done according to the instrument manufacturer's instructions.
- The measurement report must specify the measuring instrument, OTDR settings (measurement area, pulse, time and index of refraction (IOR)), as well as who has carried out the measurement.
- The measurement results from attenuation measurements and OTDR measurements must be saved in a generally legible file format, e.g. Excel, .pdf or .sor for OTDR.
- The limit values according to table 2.5.12.1 must not be exceeded.
- Delivery measurement for an active fibre connection may only be used for single dwelling unit (SDU) connections.

2.5.13.1 Measurement results and limit values for fibre in cables

See Table 2.5.12.1 for minimum limit values for fibre in cables (summary table).

The following requirements regarding fibre in cables constitute input data during delivery measurement of an installed system.

MINIMUM REQUIREMENTS, spot attenuation change

- Requirement regarding spot attenuation change at 1625 nm: Max. 0.05 dB.
Spot attenuation change refers to "spikes" greater than 0.05 dB.

MINIMUM REQUIREMENTS, fibre attenuation at 1625 nm

- Max. attenuation 0.40 dB/km Average 0.30 dB/km.
- Fibre attenuation may at most exceed the factory measurement of the fibre by 0.03 dB/km.
- Average value refers to the combined value of all the fibres in a section of cable.

MINIMUM REQUIREMENTS at individual splice

- Max. attenuation 0.25 dB, access networks.
- Average attenuation 0.20 dB, connection and regional networks.

MINIMUM REQUIREMENTS in respect of measurement results:**MINIMUM REQUIREMENTS for distances less than 10 km have the character of access networks:**

In the case of access networks (<10 km), max. attenuation is used during calculation.

The value obtained for attenuation must be below the following theoretical calculation:

At 1625 nm: $\text{length} \times 0.40 + \text{splice} \times 0.25 + 1.0 + 0.5 \text{ dB}$

MINIMUM REQUIREMENTS for distances greater than 10 km have the character of connection and regional networks:

In the case of connection and regional networks (>10 km), average attenuation is used during calculation.

The value obtained for attenuation must be below the following theoretical calculation:

At 1625 nm: $\text{length} \times 0.30 + \text{splice} \times 0.10 + 1.0 + 0.5 \text{ dB}$

Explanation of the above abbreviations:

length = optical length (km) **splice** = number of splices

1.0 dB relates to losses in event of connection to ODF, 2x if 0.5 dB (including first splice after ODF)

0.5 dB relates to the combined measurement uncertainty in instruments with connectors

2.6 Labelling

The fibre installation must be labelled in a uniform manner.

MINIMUM REQUIREMENTS IN RESPECT OF LABELLING OF THE FIBRE INSTALLATION:

- All parts of the fibre installation must be labelled with unique designations and all labelling must be ageing and weather-resistant. This must be taken into consideration in particular when labelling outdoors.
- Labelling must correspond with the documentation's designation.
- Labelling must not be conducted using plain text for security reasons, e.g. "Arboga-Köping" or the customer's name.
- Labelling must be UV-resistant, cope with lying in water for long periods and cope with various types of liquids, such as oils, benzene, alcoholic solvents, etc.
- The labelling must be scratch-proof.

2.6.1 Labelling and designation of ducts

MINIMUM REQUIREMENTS IN RESPECT OF LABELLING AND DESIGNATION OF DUCTS:

- When routing several ducts in the same trench, the ducts must be supplemented with various longitudinal colour markings or other weather and ageing-resistant labelling systems, in order to facilitate identification and documentation so as to avoid confusion.
- Any sub-duct must be supplied with an identification system for identifying individual ducts, e.g. colour marking.
- Ducts must be labelled at both inputs and outputs in manholes and cabinets, at transitions from e.g. mast to cable ladder, as well as on either side of wall bushings.
- Ducts must be labelled at both inputs and outputs in wall bushings when connecting a building/property. Exceptions may be made if the duct is present for an individual customer connection, e.g. connection to a single dwelling unit.

Manholes and cabinets are ideally labelled inside the door/hatch in order to prevent unauthorised parties from seeing the labelling.



Example of labelling of ducts

2.6.2 Labelling cables

MINIMUM REQUIREMENTS IN RESPECT OF LABELLING OF CABLES:

- Fibre optic cables must be labelled at both inputs and outputs in manholes and cabinets, at transitions from e.g. mast to cable ladder, as well as on either side of wall bushings.
- Labels must not accompany e.g. covers or front panels when these are removed.



Example of labelling of fibre optic cable

2.6.3 Numbering and labelling of racks and panels

Rack numbering starts from the left-hand corner, viewed from the input (applies in smaller nodes). In large nodes, a site drawing must be created that shows the location and numbering of the racks.

A panel, e.g. an ODF unit, which is installed in a rack, will be designated according to where the upper left corner is positioned in relation to the layout of the rack.

Numbering of outlets in a panel must start from the upper left corner in each panel. Work on the basis of the manufacturer's label, if present. If there is no label, outlets must be numbered consecutively, e.g. 01, 02, 03, etc.

MINIMUM REQUIREMENTS REGARDING LABELLING OF RACKS AND PANELS:

- Each rack must be labelled with a unique designation.
- Each individual ODF unit must be labelled.
- The outlets' numbering must be labelled on the panel.

2.6.4 Splicing units

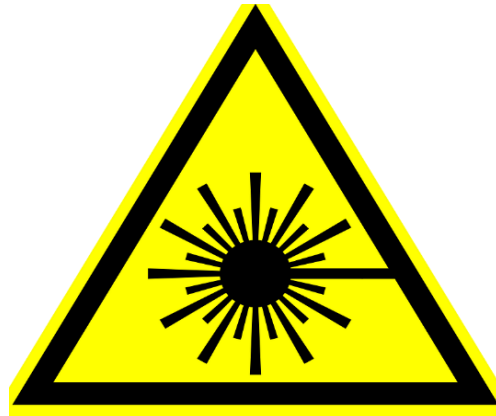
MINIMUM REQUIREMENTS REGARDING LABELLING OF SPLICING UNITS:

- On a splice cassette it must be clear which fibres / cables are in the cassette.
- The splicing unit must be labelled with "Warning: laser".

2.6.5 Fibre outlets

MINIMUM REQUIREMENTS FOR LABELLING FIBRE OUTLETS, DETACHED/TERRACED HOUSE:

- Fibre outlets in households must be labelled with the “Warning: laser” symbol.



2.7 Safety

2.7.1 Locks

A distribution point may be designed in many different ways. A common feature of all types of distribution points is that they are locked with a key, card or similar system, so that unauthorised parties cannot enter the area. This consequently applies to nodes, cable manholes, outdoor splice cabinets and splicing boxes, as well as other areas where there is access to end points or splices.

As regards cable manholes, there are a great many different types of locks, e.g. lockable inner hatches or specific “opening tools”. If a cable manhole is placed below ground level, i.e. with Selected Sandfill above the manhole cap, no locking device is required.

Locks such as “single-track”, which can be opened with a chisel, or “triangle” locks are not approved from a robustness perspective.

MINIMUM REQUIREMENTS IN RESPECT OF LOCKING:

- Distribution points must be locked with an approved key, card or in a similar manner.

Below are examples of locks that are approved:

- EBR lock or “Stockholm lock”.
- Padlock with key.
- Cylinder lock.
- Penta-head lock.



Examples of locks