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SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Installation of optical fibre cables inside sewer ducts

ITU-T Recommendation L.77

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Summary

ITU-T Recommendation L.77 describes methods to install optical cables inside sewer ducts, which applies to both the cable installation and the pre-installation of an infrastructure, if requested. This Recommendation covers both man- and non-man-accessible sewer ducts.

This Recommendation is not intended to address all of the safety concerns, if any, associated with its use. Therefore, it shall be the responsibility of the user of this Recommendation to establish appropriate health and safety practices and determine the applicability of regulatory limitations, if any, prior to its use.

Source

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Installation of optical fibre cables inside sewer ducts

1 Introduction

The installation of optical cables inside sewer ducts is basically a trenchless technique.

Optical cable installation in sewer ducts presents many advantages compared with traditional trench installation techniques, such as: less time for cable laying, not limited by weather conditions, increased protection of cable against damage, no traffic disruption, no noise pollution, no excavation, no damage to road surfaces and underground installations, no heavy equipment, no inconvenience to businesses or to citizens.

In general, there are two categories of sewers: man-accessible and non-man-accessible sewers.

The definition of whether a sewer is man-accessible or not depends not only on national regulations, but also on the individual regulations of different sewer network operators.

Usually, non-man-accessible sewers have diameters between 200 mm and 700 mm.

Installation in non-man-accessible sewers is carried out with the help of robots. In man-accessible sewers, both robot-assisted and manual installation of cables is feasible.

Basically, there are three different methods to install optical cables into sewer ducts:

a) Special armoured optical cables, designed to be directly installed at the bottom of the sewers;

b) Self-supporting optical cables, designed to be directly suspended at the top part of sewers;

c) Traditional optical cables or micro-cables, designed to be installed in protective ducts which have to be installed before the cable installation.

NOTE 1 – The most important optical cable structures and related performances suitable for these kinds of installation techniques are described in [ITU-T L.78].

NOTE 2 – The sewer optical cables and/or related infrastructure should be designed and manufactured for an expected operating lifetime of at least 15 years. It should be possible to install or remove the cable to/from the sewer throughout the operation lifetime. The materials in the sewer optical cable and/or the related infrastructure shall not present a health hazard within its intended use.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T L.1] ITU-T Recommendation L.1 (1988), *Construction, installation and protection of telecommunication cables in public networks*.

[ITU-T L.10] ITU-T Recommendation L.10 (2002), *Optical fibre cables for duct and tunnel application*.

[ITU-T L.12] ITU-T Recommendation L.12 (2000), *Optical fibre joints*.

[ITU-T L.35] ITU-T Recommendation L.35 (1998), *Installation of optical fibre cables in the access network*.

[ITU-T L.78] ITU-T Recommendation L.78 (2008), *Optical cable construction for sewer applications*.

3 Installation of infrastructure and/or optical fibre cables inside sewer ducts

3.1 Sewer assessment

Exact information about the structural condition of the sewer networks in which cable systems are to be installed is to be considered as a prerequisite. It must be clarified whether the pipes are suitable with respect to their structural/operating condition, capable of being used for the installation of an optical cable. Furthermore, in the case of non-man-accessible sections, it must be determined whether these are suitable for installation by a robot. Thus, for example, significant structural changes in the sewers (collapse) or promontory pipe junctions can hinder the use of robots or even make their use impossible if other remedial measures are unable to solve the problem.

The static bearing capacity of the sewers and their suitability for rehabilitation measures must be estimated using the results of the assessment. Equally important to the assessment of the static bearing capacity, the hydraulics must be checked with respect to the reduction of the section caused by installation of the cable. This will determine whether one or, if necessary, even several cables can be installed in a pipe or sewer. In planning the cable routes, the experience of the sewer network operator with respect to loading and strategic planning for the future, additional discharges into the sewer must be taken into account.

The operation of the sewer networks must not be affected by the installation of cables. The cables must adhere as much as possible to the pipe ceiling. The technology used must also ensure that the sewer ducts are not damaged during the installation or the operation of the cable network. In the area of the manholes, the cables must be laid so that solids cannot be caught on them and in such a way as to ensure safe accessibility to the manhole.

A suitable grounding system is documented to avoid the formation of high induced voltage and sparking, which is absolutely not acceptable in locations with explosion hazards, such as the sewer systems. At the entry and exit of sewer pipes, a connecting point for equipotential bonding between all the metallic parts of the infrastructure and the cables must be provided, measured and documented.

3.2 Installation in non-man-accessible sewers

Installation in non-man-accessible sewers is made by robots and shall be damage-free when using all types of pipe material (vitrified clay, plastics, concrete, etc.). Anchoring installation methods in non-man-accessible sewers are not recommended as the sewer pipe wall thickness is weakened by drilled holes and might break due to the heavy load or pipe sagging. Later alterations and extensions of manhole installations and/or of the telecommunications network shall be possible.

The optical cable infrastructure consists of protective conduits fixed, by using a robot, to the sewer duct by special clamps equipped with clips. All the materials used for the infrastructure in the sewer pipes must be of stainless steel type (V4A, CrNiMo-steel) to ensure the mechanical protection in the sewer environment and the protection against rodents for the optical cable.

The clamps are adjustable 360° ring straps. Depending on the requirements of the communication network, clamps for sewer pipes with a nominal diameter of 300 mm and above can be equipped with up to nine clips, so that up to nine protective conduits can be mounted. Sewer pipes with a nominal diameter of 200 mm or 250 mm can be equipped with a maximum of three clips.

Protective conduits shall be corrugated tubes. The corrugated steel tubes are available with an outer diameter of 11.5 mm or 15.5 mm in order to cause only a negligible reduction of cross section. Sewer rehabilitation work can still be carried out after the installation.

Flexible cable trays can be used to guide and protect the optical cables in sewer manholes if the protective conduits cannot pass the manhole or if an over-length storage box or a cable closure has to be installed in the manhole.

All the parts shall be designed to guarantee the minimum allowed cable bending radius on the entire network installed into the sewers.

For the application in sewer systems, the optical cables should have modified polyethylene sheaths.

3.2.1 Visual inspection

Visual inspection of the sewer by the installation robot is mandatory in order to exactly evaluate the status and geometry of sewer sections, and to confirm next-step installation possibility. When passing through the sewer, the exact location of pipe joints and laterals are recorded, allowing the determination and documentation of the optimum position of the clamps in the sewer pipe.

3.2.2 Installation of the clamps

First of all, the robot installs the clamps, which are mounted at a typical distance of 1.5-1.8 m inside the sewer ducts. In order to install a clamp, the spring box on the clamp is unlocked, so that the clip ring is expanded against the duct wall and tightly fixed to the inside sewer wall without drilling, cutting or screwing.

3.2.3 Laying and fixation of the protective conduits

In order to install the conduits, they are pulled into the sewer pipes, and then the robot presses them into the clips of the already installed clamps. They are laid straight like a bar directly onto the inside sewer duct wall.

3.2.4 Mounting of the manhole parts

The mounting of the manhole parts is done manually.

3.2.5 Installation of the optical cable

The optical cables are blown into the conduits. The necessary equipment and procedures are similar to the standard installation of optical cables into micro ducts.

It is recommended that the maximum diameter of the cable be 70-80% of the corrugated steel tube diameter. For example, for the installation in a 11.5-mm corrugated steel tube, the maximum diameter of the cable is 9.2 mm; for a 15.5-mm tube, the maximum cable diameter is 11.5 mm.

3.3 Installation in man-accessible sewers

The optical cable infrastructure consists of protective conduits fixed to the sewer wall by special clip holders equipped with clips, in which protective conduits can be fitted. All the materials used for the infrastructure in the sewer pipes must be of stainless steel type (V4A, CrNiMo-steel) to ensure mechanical protection in the sewer environment and protection against rodents for the optical cable.

The clip holders are straps fixed by the operators with expansion bolts. The wall thickness in sewers with a nominal diameter of 800 mm and above allows for the holes drilled to accommodate expansion bolts without causing any problems. The maximum number of protective conduits to be installed depends on the clip holder size.

In general, each clip holder allows the operator to install up to four clips and conduits.

3.3.1 Mounting of the clip holders and installation of the protective conduits

By means of an expansion bolt and a nut, these clip holders are bolted to the inside sewer wall at a typical distance of about 1.5 m. To fix the expansion bolt, a hole must be drilled into the sewer wall by operators. Protective conduits are pulled into the sewer pipes and then the robot presses them into the clips of the already installed clamps.

3.3.2 Mounting of the manhole parts

Same procedure as in non man-accessible sewers.

3.3.3 Installation of optical cables

Same procedure as in non man-accessible sewers.

3.4 Installation of special armoured optical cable into the sewer ducts

The installation of an optical cable pulled in and laid on the pipe invert is the easiest solution to deploying an optical cable. Fastening the cable into sewer pipes is not necessary because gravity keeps the cable on the floor. The condition of the pipe is not very important. Future development of the optical network and of the sewer system must be carefully taken into account, as their upgrade is quite difficult after installation. Access to the cable in every manhole is important in order to fix and survey the installation process, as well as for maintenance purposes.

As the cable lies on the invert of the sewer pipe, it is also recommended to plan maintenance operations and eventual pipe rehabilitation with liners, as in small pipes the cable might cause wrinkle formation in the invert area.

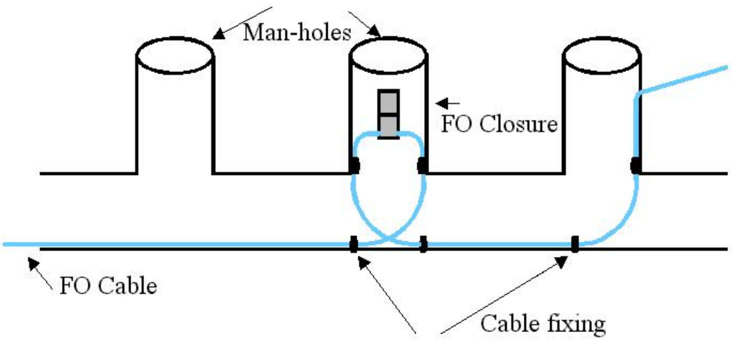

Figure 1 – Illustration of optical fibre cable deployment into sewer

Bonding methods (fixing cables or conduits to the sewer by means of plastic bonding) are not recommended since a lasting bonding of the adhesive cannot be guaranteed, costly surface treatment would be required to prepare the bonding; later damage-free removal or adding of the conduits would not be possible, and the sewer pipes concerned would need to be completely drained.

Tightening methods (cable wound under high tension from manhole to manhole at the sewer top, a high tensile load of several tons is created by means of tension fixtures) are not recommended for several reasons: the tension fixtures exert tremendous tensile loads on the manhole shafts, which are usually not capable of taking such loads; rehabilitation with liners is difficult; and it can happen that the cable runs in front of a tap which might cause a blockage of that tap.

3.4.1 General requirements for optical cables for direct installation inside sewer ducts

Optical fibre cables for direct installation inside sewer ducts shall guarantee maximum robustness and corrosion resistance since they are laid directly into bodies of water and of chemically corrosive elements. They might also have compact construction for easy transport and installation.

NOTE – It is very important to pay particular attention to the cable manufacturer's recommendations and stated physical limitations, not exceeding the given cable load rating for a particular cable design. Possible damage caused by overloading during installation in sewer ducts may not be immediately apparent, but can lead to later failure in its service life.

3.4.2 General guidelines for optical cable installation in sewers

For the installation of an optical cable in a sewer system without infrastructure, the following precautions are recommended:

a) carefully place the cable wheel near the sewer man-hole on a suitable let-off device;

b) put the suitable dragging rope device at the sewer entrance in order to ensure the correct rope positioning;

c) fix the dragging rope wire to the cable very well;

d) substitute pulling the cable by dragging the rope wire;

e) fix the cable in the manhole area only.

During all the installation operations, the cable shall be properly managed and conserved in order to avoid excessive temperature, tensile and bending radius conditions.

It is also recommended that the minimum cable's bending radius be strictly observed, and that it be between 20 and 30 times this diameter during the installation process and the operating life, respectively.

4 Application of over-length storage boxes and sewer splice closures

When traditional optical cables or micro-cables are used, over-length storage boxes can be installed in the sewer manhole to safely store over-length cable.

Each box shall be able to contain the standard over-length (at least 20 m of cable over-length is recommended) related to management procedures. The splice closures can also be installed in the manholes, so they shall have the same technical characteristics as the protective conduits. For operation and maintenance reasons, it has to be decided on a case-by-case basis whether it is better to install a special closure in a sewer manhole, or to install a standard splice closure in a telecommunication manhole and to make a duct connection between both manholes.

5 Connection between sewer manholes and telecommunication manholes

The connection between the optical network installed inside the sewer and the optical network inside the traditional polyethylene ducts is normally carried out with a polyethylene duct installed between a sewer manhole and a telecommunication manhole. These connections can either be performed with open trenches or be trenchless with a special bore rig and constantly monitored drilling. The special bore rig can be installed in sewer manholes with an appropriate minimum diameter.

5.1 Connections between sewer optical cables and traditional cables

For the connection of business or residential customers, the sewer ducts installed in a building (lateral) can be used for deploying the necessary infrastructure able to directly receive the optical cable coming from the sewer.

With a branching device on the corrugated steel tubes in the main sewer duct, and a flexible steel tube to the building, a duct route can be built into the building. For the fixation of the steel tube in the lateral, a so-called inline is used. The inline is a flexible hose made of felt, which is immersed in resin and installed together with the steel tube within the sewer duct. With steam or hot water, the hose is pressed against the inside of the sewer duct until it is hardened. Afterwards, an optical fibre cable can be blown from the nearest closure into the building.

6 Guidelines for the selection of the most appropriate installation method

The criteria reported in Table 1 shall be observed to select the appropriate method for the installation of optical cables in sewer ducts.

Table 1 – Comparison of installation methods

No.	Requirement	Special armoured optical cables	Infrastructure and conventional optical cables	Self-supporting optical cables
1	Applicable sewer pipe diameter	No limitations	From DN 200	From DN 300
2	Position in the sewer	Bottom	Top	Top
3	Sewer visual inspection before installation	Optional	Mandatory	Optional
4	Maintenance of the sewer	To be planned before installation	To be planned before installation	To be planned before installation
5	Risk of blockage	Depending on the water level and on the water flow	No	No
6	Upgrading of the optical network	Very difficult	Possible	Possible
7	Maximum number of cables and fibres	Maximum one cable (i.e., 144 optical fibres)	Up to nine cables (one in each corrugated steel tube)	Maximum two cables (i.e., 216 optical fibres each)
8	Flexibility of the optical network	Only for point-to-point connections	Very high	Medium
9	Access to optical network	No	Yes	Yes
10	Cable type	Special armoured	Standard	Self-supporting
11	Installation cost	Low	Medium	Low

7 Maintenance effects

Pressure washing, root saws, finishing brushes and tap cutters are used in the regular maintenance of a sewer system. It is recommended to carefully take the following effects into account when installing cables and infrastructure in the sewer. Cables and infrastructure shall satisfy the following requirements, and documentation must be provided by the installer.

7.1 Sewer integrity

The conduits are generally installed at or near the top of the pipe in non-man-accessible sewers. The cross-section of the conduit infrastructure and of the clamps shall be kept between 3% and 5% of the total cross-sectional area of the pipe. It must be demonstrated that the reduction to the cross section does not obstruct the flow of the normal sewer system and the clamps must not cause any interference or debris collection.

7.2 Pressure washing and finishing brush

In general, sewer ducts must be cleaned every two years. Pressure washing using a high-pressure water washer and vacuum cleaning system are adopted. Therefore, any cables or conduits placed into a sewer must withstand the rigors of the pressure washing as frequently as every two years.

A finishing brush attachment is also used for detailed cleaning work. Since the brush is a little smaller than the sewer pipe, it can be pulled along the sewer pipe, loosening any debris that remains after the high-pressure washing. Cables and infrastructure must withstand the action of the finishing brush without damage.

7.3 Root saws

Sometimes the root infiltration is such that a chemical foaming agent can be used to prevent possible infiltration. In sewer lines with significant root infiltration, saws are used to cut the roots. The blade of the root saw comes within 2.54 cm of the full diameter of the pipe, damaging anything that protrudes more than 2.54 cm. The chemical foaming agents used should not adversely affect the cables and the infrastructures.

7.4 Slip lining

Slip lining damaged sections of a sewer duct shall be allowed on lines carrying cables and conduits. As the curing temperature is a concern, it is recommended to verify that proper curing should occur below 70°C. Installed cables and infrastructures must not be damaged by exposure to 70°C.

8 General guidelines for the installation of self-supporting optical cable into the sewer ducts

The designed self-supporting cable must be suspended at the top part of the sewers, where proper hardware and fittings made of stainless steel or other materials after anti-corrosion, anti-rust and passivation treatment should be used to fix the cable. In this way, sufficient life expectancy of the cable can be guaranteed. In addition, the cable closure is also made of materials such as stainless steel, aluminium alloy or engineering plastics, and the closure should be airtight, waterproof and moisture-proof. Figure 2 illustrates the frequently used hardware made of several steel wires which can be stranded tightly around the cable sheath. The inner side of these steel wires is coated with a layer of emery to avoid slip between the cable and the hardware by increasing the friction.

Figure 2 – Frequently used hardware

Figure 3 is a sketch map illustrating the cable suspended in the sewer after installation.

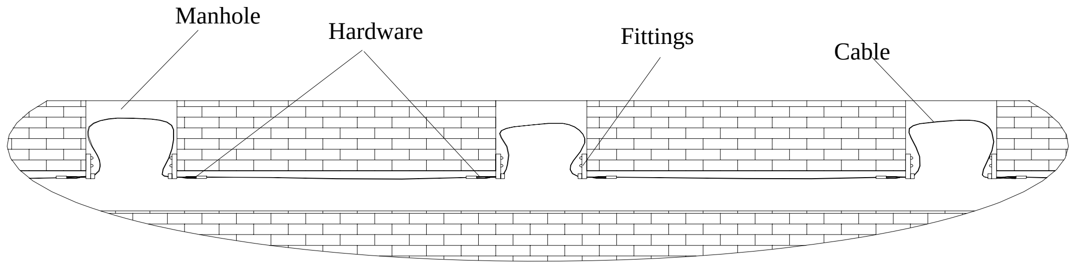

Figure 3 – Cable suspended in the sewers (sketch map)

The whole cable is divided into several segments according to the quantity of manholes. Each segment is suspended in the sewer between two adjacent manholes by hardware and fittings, so that the cable deployment will be finished segment by segment. The recommended installation method is as follows.

First, one end of the cable segment is fixed on the manhole wall by the above-mentioned hardware and fittings. Then the other end of the cable segment should be tightened by a tautening device at the adjacent manhole to make the sag of the cable not greater than the expected value. After that, this end of the segment should be also fixed on the corresponding manhole wall. Thus, one segment of the cable has been suspended in the sewer across two adjacent manholes. After all cable segments have been suspended from one end of the sewer to the other with the above method, the deployment of the whole cable is finished. It should be noted that in each manhole, a margin of 1.5 to 2.0 m of cable should be left in advance, in order to facilitate the subsequent operations. The surplus cable must be wound and fixed on the manhole wall with plastic clamps after cable installation.

During the cable installation, much attention should be paid to the following items:

1) First priority should be given to storm sewer pipes, confluent pipes and those pipes easy to enter for operation and maintenance during pipe selection process.

2) The selected pipes are required to be as straight as possible with a moderate span between two adjacent manholes. Generally, the span should be less than 50 m. If the span exceeds 50 m, an extra point should be added in the pipe between two manholes to fix the cable, and if the span is greater than 90 m, two points should be added.

3) The cable deployment should go along with the water flow in the pipes, and the radius of curvature for the deployed cable should meet the technical requirements.

4) The manholes should be solid and safe, conforming to the relevant construction standards.

5) The cable should be suspended close to the upper wall of the sewers and the sag of the cable should not exceed 3% of the span of two adjacent manholes.

6) The fibre splicing should be finished and the cable should be sealed hermetically as soon as possible after cable deployment.

7) The pulling force, the crush imposed on the cable during or after deployment, and the temperature range in which the cable is used should meet the technical requirements.

The location and the length of the surplus cable in the manhole should meet the needs of customers. The surplus cable should be wound and fixed on the manhole wall in good order so that it does not disturb the free passage of operators.

9 Safety

Safety practices should follow the guidelines of local regulations and/or the state laws. Guidelines shall be observed that address confined spaces, hazardous underground utilities, a competent person, trench safety, traffic safety, equipment safety and safety training. Personnel must be trained for those guidelines and regulations. There must always be a competent person trained to recognize dangerous conditions, to protect the personnel, and to manage the traffic with appropriate resources. All construction equipment and personal protective gear must meet guidelines and be kept in good condition. Prior to starting a project, a safety plan should be prepared and documented by the installer or the owner's designated representative. This plan should be implemented and followed by the personnel involved in the installation process.

Appendix I

Italian experience

(This appendix does not form an integral part of this Recommendation)

This appendix describes an optical cable designed to be installed in sewers. Such a cable is suitable to be directly laid on the ground of a non-man-accessible sewer.

I.1 General design of the optical cable

The cable is designed to ensure proper light-wave information transmission and to protect the optical fibres against water pressure, chemical corrosion/aggression, moisture/water penetration and the effect of hydrogen contamination throughout the cable's designed life.

Moreover, the fibres are protected from any external stress, either axial or radial, by being loosely contained in a structure which has been designed to guarantee a suitable degree of movement of fibres and also by means of an external aluminium tube.

I.2 Description of optical cable structure

– Dielectric central element: Fibreglass reinforced with a polyethylene (PE) sheath.

– Optical core: 6 loose tubes, stranded over the central element, containing up to 24 fibres each which are filled with a non-hygroscopic jelly compound.

– Protection of optical core: Water-blocking tape, plus an outside polyethylene sheath, plus an aluminium tube.

– Mechanical protection: A peripheral strength member, made by a single layer of Aluminium Clad Steel (ACS) wires, is stranded over the aluminium tube.

– Protection of ACS: A corrugated stainless steel tube, longitudinally welded, covers ACS wires.

– Other protective materials: Plastic tape may be inserted under the corrugated tube to lower the friction coefficient between ACS wires and steel tube and to make it easy to remove the outer tube from the inside part of the cable.

– External protection: An outer sheath completes cable construction. The material of the outer sheath is high density polyethylene (HDPE).

I.3 Main performance of the optical cable

Very high mechanical protection – High resistance to pulling loads and transversal stresses.

High chemical resistance to corrosive agents.

Cable may be installed by means of conventional techniques, e.g., by pulling, so there is no need for robotized installation.

The cable is directly laid on the ground of the sewer.

Optical core is sheathed so it can be used as a conventional all-dielectric cable (e.g., from the sewer and the splicing box which, for technical reasons, can be located far from the sewer itself).

Radial penetration of water or moisture is prevented by two metallic barriers (aluminium extruded tube and steel corrugated tube).

Longitudinal penetration of water is avoided by means of water blocking tape bedding and/or jelly compound filling or some other kind of water blocking materials.

I.4 Others characteristics of the optical cable

No need to fix the cable along the sewer because it is heavy enough to stay on the ground.

If necessary, cable can be removed directly by means of outside operations.

If needed, mechanical protection can be easily removed to use optical core alone.

Lengths of some tens of metres are easily allowable.

No need to clean or to dry the sewer conduit.

Fibre types

Fibres are in accordance with ITU-T Recommendations and with customer specification.

The cable can be equipped with G.652, G.655 or any other telecommunication fibre types, including mixed combinations such as single mode reduced (SMR) + non zero dispersion (NZD) fibres (G.652 + G.655 fibres).

Fibre count: From 12 to 144 fibres.

In low count cable, each tube has 12 fibres. In high count cable (e.g., 144-fibre cable) each tube contains 24 fibres.

Fibre identification

a) 12-fibre tube: Fibres are identified by 12 different colours according to the reference standard.

b) 24-fibre tube: Fibres are identified by coloured binding yarns or ring marking applied at a distance of 25 or 50 mm along the fibre.

Appendix II

Chinese experience

(This appendix does not form an integral part of this Recommendation)

This appendix describes two optical cable structures designed to be installed in sewers, which are suitable to be suspended at the top of a man-accessible sewer.

II.1 General design of the optical cable

The cable is designed to ensure proper light-wave information transmission and to protect the optical fibres against water pressure, chemical corrosion, moisture/water penetration and the effect of hydrogen contamination throughout the cable's designed life. Therefore, two cable structures are recommended here: 1) stranded plastic loose tube structure; 2) central metallic loose tube structure.

Moreover, the fibres are protected from any external stress, either axial or radial, by being loosely contained in a structure which has been designed to guarantee a suitable degree of free movement.

II.2 Description of optical cable structure

II.2.1 Stranded plastic loose tube structure

- Central strength member: PE-coated steel wire.
- Cable core: Up to 18 loose tubes, stranded around the central strength member, containing up to 12 fibres each which are filled with a non-hygroscopic jelly compound.
- Protection of cable core: Water-blocking compound plus an inner polyethylene sheath with an aluminium tape.
- Mechanical protection: Aramid yarns are stranded over the inner PE sheath as a peripheral strength member.
- External protection: An outer sheath. The material of the outer sheath is high density polyethylene (HDPE).

II.2.2 Central metallic loose tube structure

- Cable core: A metallic loose tube, filled with a non-hygroscopic jelly compound, containing up to 96 fibres.
- Protection of cable core: An inner polyethylene sheath (optional).
- Mechanical protection: A peripheral strength member, made by a single layer of small-diameter stainless steel wire, is stranded over the cable core.
- External protection: An outer sheath. The material of the outer sheath is high density polyethylene (HDPE).

II.3 Main performance of the optical cable

Very high mechanical protection – Good resistance to pulling force.

Good chemical resistance to corrosive agents.

Cable may be manually installed in the sewer, so there is no need for robots.

The cable is suspended at the top part of the sewer.

Cable core can be sheathed so it may be used as a conventional cable (e.g., the splicing box, for technical reasons, can be located far from the sewer itself).

Radial penetration of water or moisture is prevented by the metallic barrier (aluminium tape).

Longitudinal penetration of water is avoided by the adoption of water-blocking materials.

II.4 Other characteristics of the optical cable

Cables can be suspended along the top part of the sewer so that they present the minimum obstruction to liquid flow and to silt cleaning operations.

No need to use robot in cable installation.

The cable installation is cost-effective.

Fibre types

Fibres are in accordance with ITU-T Recommendations and with customer specification.

The cable can be equipped with G.652, G.655 or any other telecommunication fibre types, including mixed combinations such as single mode reduced (SMR) + non zero dispersion (NZD) fibres (G.652 + G.655 fibres).

Fibre count: From 12 to 216 fibres.

Fibre identification

a) 12-fibre tube: Fibres are identified by 12 different colours according to the reference standard.

b) Tube with more than 12 fibres: Fibres are identified by coloured binding yarns or ring marking applied at a distance of 25 or 50 mm along the fibre.

Bibliography

[b-ITU-T G.652] ITU-T Recommendation G.652 (2005), *Characteristics of a single-mode optical fibre and cable*.

[b-ITU-T G.655] ITU-T Recommendation G.655 (2006), *Characteristics of a non-zero dispersion-shifted single-mode optical fibre and cable*.

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