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Recommendation

ITU-T L.340 (06/2023)

SERIES L: Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

Maintenance and operation – Infrastructure maintenance

Maintenance of underground telecommunication facilities

ITU-T L-SERIES RECOMMENDATIONS

Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant

OPTICAL FIBRE CABLES	L.100-L.199
OPTICAL INFRASTRUCTURES	L.200-L.299
MAINTENANCE AND OPERATION	L.300-L.399
Optical fibre cable maintenance	L.300-L.329
Infrastructure maintenance	**L.330-L.349**
Operation support and infrastructure management	L.350-L.379
Disaster management	L.380-L.399
PASSIVE OPTICAL DEVICES	L.400-L.429
MARINIZED TERRESTRIAL CABLES	L.430-L.449
E-WASTE AND CIRCULAR ECONOMY	L.1000-L.1199
POWER FEEDING AND ENERGY STORAGE	L.1200-L.1299
ENERGY EFFICIENCY, SMART ENERGY AND GREEN DATA CENTRES	L.1300-L.1399
ASSESSMENT METHODOLOGIES OF ICTS AND CO2 TRAJECTORIES	L.1400-L.1499
ADAPTATION TO CLIMATE CHANGE	L.1500-L.1599
CIRCULAR AND SUSTAINABLE CITIES AND COMMUNITIES	L.1600-L.1699
LOW COST SUSTAINABLE INFRASTRUCTURE	L.1700-L.1799

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T L.340

Maintenance of underground telecommunication facilities

Summary

Underground facilities, such as tunnels, maintenance holes and handholes, deteriorating continuously with time. For example, cracks and water leakages occur and these phenomena degrade the safety and serviceability of the underground facilities. If the deterioration is neglected, large-scale repair and reinforcement measures may be required, which will increase future costs. Therefore, it is highly recommended that periodic inspection and timely maintenance are performed.

Safety management of telecommunication infrastructure facilities is described in general in ITU-T Recommendation L.330, but the detailed technologies and countermeasures for each facility are left for other Recommendations.

Recommendation ITU-T L.340 describes the inspection procedures, technologies and countermeasures for the maintenance of underground facilities as defined in Recommendation ITU-T L.330.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T L.340/L.74	2008-04-06	6	11.1002/1000/9328
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Keywords

Crack, deterioration, inspection, maintenance, underground facilities, water leakage.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

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Table of Contents

Recommendation ITU-T L.340

Maintenance of underground telecommunication facilities

1 Scope

This Recommendation describes detailed inspection technologies and countermeasures in case of deterioration of underground telecommunication facilities such as tunnels, maintenance holes and handholes. These inspection technologies and deterioration countermeasures are conducted when certain problems are identified during the regular inspection described in [ITU-T L.330]. This Recommendation covers:

– inspection technologies for tunnels, maintenance holes and handholes;

– countermeasures to prolong facility lifetime according to the inspection results;

– maintenance procedures to realize safe and effective facility management.

Appendix I provides the effective and quantitative maintenance technologies.

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.330] Recommendation ITU-T L.330 (2020), *Telecommunication infrastructure facility management*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 handhole [ITU-T L.330]

3.1.2 maintenance hole (manhole) [ITU-T L.330]

3.1.3 shield tunnel [ITU-T L.330]

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 concrete neutralization: Carbonation of concrete by attack from atmospheric carbon dioxide will result in a reduction in alkalinity of the concrete and increase the risk of reinforcement corrosion.

3.2.2 corrosion: Disintegration or deterioration of concrete or reinforcement by electrolysis or by chemical attack.

3.2.3 crack: An incomplete separation into one or more parts with or without space in between. Cracks are classified by direction, width and depth. The following adjectives can be used: longitudinal, transverse, vertical, diagonal and random.

3.2.4 deterioration: Deterioration is any adverse deviation from normal mechanical, physical and chemical properties either on the surface or in the whole body of concrete, generally through separation of its components.

3.2.5 disintegration: Deterioration into small fragments or particles due to any cause.

3.2.6 distortion: Any abnormal deformation of concrete from its original shape.

3.2.7 efflorescence: A deposit of salts, usually white, formed on a surface indicating that a substance has emerged from below the surface.

3.2.8 erosion: Deterioration brought about by the abrasive action of fluids or solids in motion.

3.2.9 honeycomb: Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.

3.2.10 inspection: An examination of the soundness of a telecommunication infrastructure facility based on a comparison of the investigation, observation and measurement results to the appropriate judgement standards.

NOTE – The inspection is conducted in order to grasp whether or not deformation is having an influence on the structural safety and durability, and then to take appropriate countermeasures to secure the infrastructure facility on the base of the evaluation results.

3.2.11 non-destructive testing (NDT): Method used to detect defects such as cracks and corrosion that does not destroy the object under test.

NOTE 1 – Non-destructive testing is also called non-destructive evaluation (NDE) or non-destructive inspection (NDI).

NOTE 2 – Different methods of testing are available, such as the ultrasonic pulse velocity method and stress wave propagation method.

3.2.12 peeling: A process in which thin flakes of mortar are broken away from an underlying concrete surface; such as by deterioration or by adherence of surface mortar to forms as they are removed.

3.2.13 pitting: Development of relatively small cavities in a surface, due to phenomena such as corrosion or cavitation, or in concrete, localized disintegration.

3.2.14 popout: The breaking away of small portions of a concrete surface due to internal pressure which leaves a shallow, typically conical, depression.

3.2.15 scaling: Local flaking or peeling away of the near surface portion of concrete or mortar.

3.2.16 spall: A fragment, usually in the shape of a flake, detached from a larger mass by a blow, by the action of weather, by pressure or by expansion within the large mass.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations:

GPR Ground Penetrating Radar

NDE Non-Destructive Evaluation

NDI Non-Destructive Inspection

NDT Non-Destructive Testing

5 Conventions

None.

6 Maintenance of underground telecommunication facilities

Like other public infrastructures such as bridges, roads and buildings, underground telecommunication facilities experience problems caused by cracks or water leakage as a result of deterioration of steel-reinforced concrete or the rebar itself. If such problems are left unrepaired, additional large-scale repair and reinforcement projects will probably be required, which will further increase the cost in the future. The purpose of maintenance is to detect the defects in underground facilities at an early stage and to take appropriate actions in order to enhance the facility durability and serviceability.

6.1 Inspection

Irrespective of how well an underground facility is constructed, it will require preventive maintenance to preserve its integrity and to prolong its lifetime. Maintenance will necessarily require inspection and testing to determine the condition of the structures and to establish appropriate repair and maintenance measures. The inspection of underground facilities is performed to detect damage or defects that are detrimental to structural safety and durability. When crucial damage or defects are observed, they are to be evaluated by skilled experienced engineers, and then appropriate and prompt countermeasures, such as repair and reinforcement work, are taken. Inspections can be divided into periodic and precise inspections as described in clauses 6.1.1 and 6.1.2.

6.1.1 Periodic inspections

Periodic inspections, also called regular inspections usually involve visual assessments to check the status of the concrete surface such as cracks, water leaks or exposed rebar. At this stage, deformation is detected, and is evaluated as to whether or not precise inspections and/or temporary countermeasures are needed.

It is recommended that procedures be established for the manager of the underground facilities to schedule/undertake periodic inspections. These inspections are mainly carried out by observing the surface of the underground facilities by visual inspection and measuring crack width with a crack gauge. The inspections are carried out using comprehensive identification sheets on which observations and measurements can be conveniently recorded.

6.1.2 Precise inspections

Precise inspections are carried out when the defects and/or deformations are deemed critical to the safety of the underground facilities. Quantitative measurements are also carried out when there is degradation that cannot be identified by visual inspection or when the cause of degradation must be clarified to judge whether countermeasures are needed and to select the optimum method. At this stage, a detailed investigation of the measurements and deformation detected in the periodic inspections is conducted by a specialist.

These inspections may use destructive testing of a concrete sample and chemical analysis of a core sample to determine the degree of degradation. In addition, non-destructive testing (NDT) methods can be used to determine abnormalities, defects and voids.

6.1.3 Frequency of inspection

It is recommended that the frequency of inspection be determined by the type and current state of the underground facilities concerned, and the changes in the operating environment.

6.2 Inspection items

6.2.1 Typical inspection items for tunnels

Inspection items depend on the type of cable tunnel. Cable tunnels are generally divided into two types as follows:

− Open-cut tunnel (rectangular cross-section or box type);
− Shield tunnel (circular cross-section).

An open-cut tunnel is constructed by a cut and cover method, and is made of steel-reinforced concrete. On the other hand, a shield tunnel is constructed by methods such as shield driving, boring, drilling and blasting, and jacked tunnelling. The cross-sections of these two types of cable tunnels are shown in Figure 1.

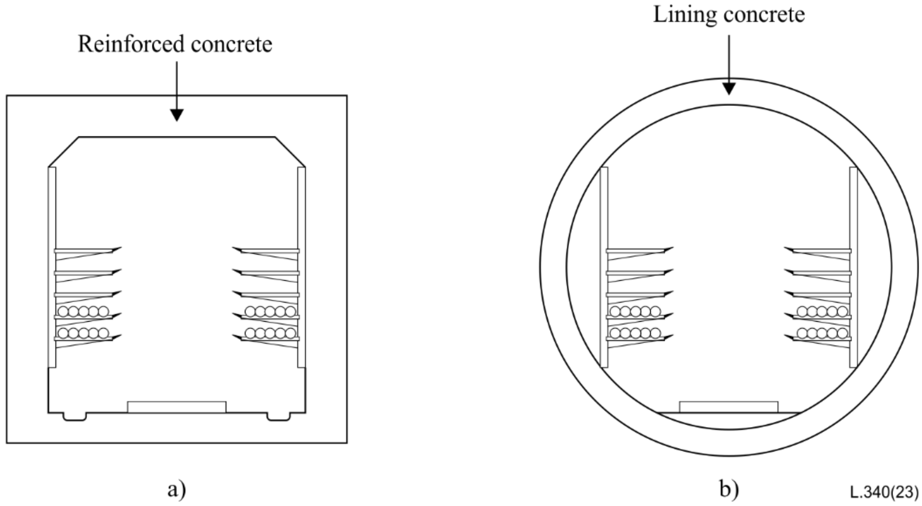


Figure 1 – Typical types of cable tunnels: a) open-cut tunnel; and b) shield tunnel

Since the designs and construction procedures of these cable tunnels are different, they may experience different types of deterioration. Typical inspection items for tunnels are summarized in Table 1.

Table 1 – Typical inspection items for tunnels

Facility type	Periodic inspection	Precise inspection
Open-cut tunnel	Cracks, water leakage; joint gap, offset; exposed rebar, length; surface damage; deformation.	Include periodic inspection items; buried depth of rebar; concrete neutralized depth; strength of concrete; concrete chloride content; corrosion of rebar, etc.
Shield tunnel	Cracks in lining surface; water leakage; joint gap, offset; exposed rebar, length; surface damage; deformation.	Include periodic inspection items; heaving of tunnel bottom; settlement of tunnel bottom; cavities inside lining concrete; voids behind lining, etc.

6.2.2 Typical inspection items for maintenance holes and handholes

Inspection items are generally divided into the two main facility parts of concrete frame and cover. Typical inspection items for maintenance holes and handholes are summarized in Table 2.

Table 2 – Typical inspection items for maintenance holes and handholes

Facility part	Periodic inspection	Precise inspection
Concrete frame	Cracks; water leakage; exposed rebar, length; surface damage.	Include periodic inspection items; covering depth of rebar; concrete neutralized depth; strength of concrete; concrete chloride content, etc.
Cover	Abrasion; crack; rattle; level difference.	None.

6.3 Inspection technologies

Inspection technologies commonly used for underground telecommunication facilities mainly consist of visual inspection and NDT methods. When a defect is found during visual inspection, its cause is then established and its size and condition are investigated in detail. Since cracks are among the critical inspection items, it is recommended to measure a crack's width and depth using a crack gauge, and to check whether or not the cracks are propagating. Table 3 summarizes typical inspection technologies including NDT methods.

Table 3 – Typical inspection technologies

Typical inspection items	Technologies	Descriptions
Cracks, water leakage, joint gap, exposed rebar, surface damage, abrasion and level difference	Visual inspection (Note 1)	Visual inspection results are recorded as a sketch or digital image. Crack width and joint gap can be measured by crack gauge with magnifier. Abrasion and level difference can be measured by caliper.
Concrete neutralized depth	Phenolphthalein indicator	Core cut from hardened concrete is sprayed with phenolphthalein indicator, and then a purple-red coloration will appear where alkaline concrete has been unaffected by carbonation; no coloration will appear in carbonation zones.
Voids, water leakage	Infrared thermography (Note 2)	This method measures the thermal radiation emitted by a tunnel's walls or concrete frame, and can identify defects in the lining and voids. Infrared techniques allow visual presentation of the temperature distribution on the surface.
Strength of concrete	Testing of cores	This is a well-established method. Cores are cut from hardened concrete by a core drill, and compressive testing is performed.
	Surface hardness method (Note 2)	This test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface. The results give a measure of the relative hardness of this zone, and there is a close correlation between rebound number and compressive strength of the concrete.
	Ultrasonic pulse velocity method (Note 2)	This method injects ultrasonic waves into concrete to analyse its internal state by detecting the wave transmitted and reflected by substances with different elastic properties in the concrete wall. This method can identify structural

Table 3 – Typical inspection technologies

Typical inspection items	Technologies	Descriptions
		abnormalities such as cracks, thickness variations and degradation in compressive strength.
Defects inside lining concrete	Stress wave propagation method (Note 2)	This method is based on the use of impact-generated stress waves that propagate through concrete and are reflected by internal flaws and external surfaces. This method can be used to determine the location and extent of flaws such as cracks and voids.
Voids inside lining concrete	Ground penetrating radar (GPR) (Note 2)	This is a geophysical method that uses radar pulses to image the subsurface. This method uses electromagnetic radiation, and detects the reflected signals from subsurface structures. GPR uses transmitting and receiving antennas. The transmitting antenna radiates short pulses of high-frequency (usually polarized) radio waves into the ground. When the wave hits a buried object or a boundary with different dielectric constants, the receiving antenna records variations in the reflected return signal. The depth range of GPR is limited by the electrical conductivity of the ground, and the transmitting frequency. Higher frequencies do not penetrate as far as lower frequencies, but give better resolution. The wave frequencies are between 900 and 2 000 MHz. This method can identify structural abnormalities such as voids, thickness variations and interface voids between the lining and the ground in a cable tunnel.
NOTE 1 – Visual inspection can be replaced by non-entry inspection using remote cameras. NOTE 2 – NDE technologies.		

6.4 Countermeasures

Once the inspection of the underground facility is complete, the repair and reinforcement plans are established. Judgement of repair and reinforcement depends on the evaluation of the field inspection results. The repair of crack, water leakage and other types of deterioration should consider the safety, durability and serviceability of the underground facility.

6.4.1 Countermeasures against cracks

Cracks are the most typical and important types of deterioration to be considered. Cracks, however, have many causes and so the types vary. In general, cracks that may happen in underground facilities are categorized as follows:

− Crack with no water;
− Crack with some moisture;
− Crack with water leakage;
− Crack accompanying the corrosion of rebar;
− Joint crack.

Three width ranges are typically suggested as follows:

− Fine: Generally less than 1 mm;
− Medium: Between 1 and 2 mm;
− Wide: Over 2 mm.

It is recommended that cracks be repaired for safety, durability and serviceability. When a crack is detected, it is important to precisely know its cause or causes. Whether the crack should be repaired or not is to be decided by a qualified engineer.

6.4.2 Countermeasures against water leakage

The corrosion of rebar in concrete is accelerated by water leakage. The concrete surface and steel accessories in an underground facility are also degraded by toxic or polluted water. Various techniques have been developed as countermeasures against water leakage, but there are many cases in which water leakage reoccurs after construction. Therefore, it is necessary to select countermeasures after carefully considering their effectiveness, workability, cost and durability.

6.5 Inspection work safety

For the tunnel inspection work, a sign that the work is being carried out should be displayed at the entrance of the tunnel. For the maintenance hole and handhole inspection work, a safety fence should be installed to prevent outsiders from entering the work area. In addition, toxic gases such as carbon monoxide may accumulate in underground facilities. Prior to commencing tunnel inspection, workers should confirm the normal operation of the ventilator before entering the tunnel. In maintenance hole inspection, adequate ventilation should be assured, and a toxic gas detector should be used before entering the maintenance hole.

Appendix I

Experience with maintenance of cable tunnels in the Republic of Korea

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

I.1 Typical deterioration

Typical types of deterioration that may happen in a cable tunnel are cracks, water leakage and the corrosion of rebar. Figure I.1(a) shows cracks with water leakage and efflorescence that occurred in a box type cable tunnel; Figure I.1(b) shows joint cracks with water leakage in a shield type cable tunnel; and Figure I.1(c) shows exposed steel and the corrosion of rebar on the ceiling of a box type cable tunnel. These defects degrade the safety, durability and serviceability of the cable tunnel.

Figure I.1 – Typical types of deterioration: (a) cracks; (b) water leakage; and (c) corrosion of rebar

I.2 Frequency of inspection

Inspections are to be performed by a specialist or a qualified engineer with experience in the design and construction of cable tunnels. The time, frequency and method of inspection are determined according to the type of cable tunnel. Inspections are performed at two different stages: 1) periodic inspection; and 2) precise inspection. Periodic inspection includes periodic routine inspections that are performed at an interval of not more than a month or year. Most defects are detected, recorded and evaluated at this stage. When a defect that is considered to affect the safety of a cable tunnel is detected, an emergency inspection is carried out. Precise inspection is also done at an interval of five years. Table I.1 describes the frequency of inspection.

Table I.1 – Frequency of inspection

Inspection		Frequency	Inspector
Periodic inspection	Periodic routine inspection	Every month Every year	Manager of cable tunnel
	Periodic inspection	Every two years	Specialist or a qualified engineer in the firm
	Emergency inspection	When a critical defect is detected, or a cable tunnel is in danger	Specialist or a qualified engineer in the firm
Precise inspection		When a critical defect is detected, or a cable tunnel is in danger When 10 years have passed after construction Every five years	Specialist in safety, durability and serviceability

I.3 Typical inspection items

The inspection is carried out using comprehensive identification sheets on which observations and measurements can be conveniently recorded. Two examples of routine monitoring sheet for box type and shield type cable tunnels are shown in Tables I.2 and I.3, respectively.

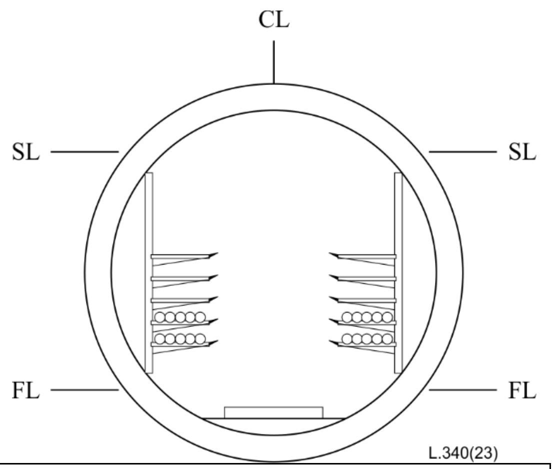
Table I.2 – Example of a routine monitoring sheet for box type cable tunnel

Cable tunnel name: Inspection site:		Date: Inspector name:		
Inspection items	Description	Location		
		Left wall	Upper slab	Right wall
Crack	Crack width: mm Crack length: cm Is crack progressive? YES ( ), NO ( )			
Water leakage	Crack width with water leakage: mm Severity of water leakage: wet ( ), dripping ( ), flowing ( ) Extent of water leakage: few ( ), intermittent ( ), frequent ( ), extensive ( ) Efflorescence:			
Exposed steel	Severity of steel corrosion: very slight ( ), slight ( ), moderate ( ), severe ( ), very severe ( ) Extent of steel exposure: few ( ), intermittent ( ), frequent ( ), extensive ( )			
Concrete neutralized	Concrete neutralized depth, if any: mm			
Facilities in cable tunnel	Condition of light: good ( ), moderate ( ), fix needed ( ) Condition of water pump: good ( ), moderate ( ), fix needed ( ) Condition of ventilation: good ( ), moderate ( ), fix needed ( )			

Table I.2 – Example of a routine monitoring sheet for box type cable tunnel

Remarks	(Describe what is needed)			
Photograph or sketch of site				

Table I.3 – Example of a routine monitoring sheet for shield type cable tunnel



Cable tunnel name: Inspection site:	Date: Inspector name:
Inspection items	Descriptions
Crack	Crack width: mm Crack length: cm Is crack progressing? YES ( ), NO ( )
Water leakage	Crack width with water leakage: mm Severity of water leakage: wet ( ), dripping ( ), flowing ( ) Extent of water leakage: few ( ), intermittent ( ), frequent ( ), extensive ( ) Efflorescence:
Exposed rebar	Severity of rebar corrosion: very slight ( ), slight ( ), moderate ( ), severe ( ), very severe ( ) Extent of steel exposure: few ( ), intermittent ( ), frequent ( ), extensive ( )

Table I.3 – Example of a routine monitoring sheet for shield type cable tunnel

Contamination of lining	Extent of contamination: few ( ), intermittent ( ), frequent ( ), extensive ( ), throughout ( )
Heaving of bottom	Severity of heaving: very slight ( ), slight ( ), moderate ( ), severe ( ), very severe ( )
Deformation of lining	Severity of deformation: very slight ( ), slight ( ), moderate ( ), severe ( ), very severe ( )

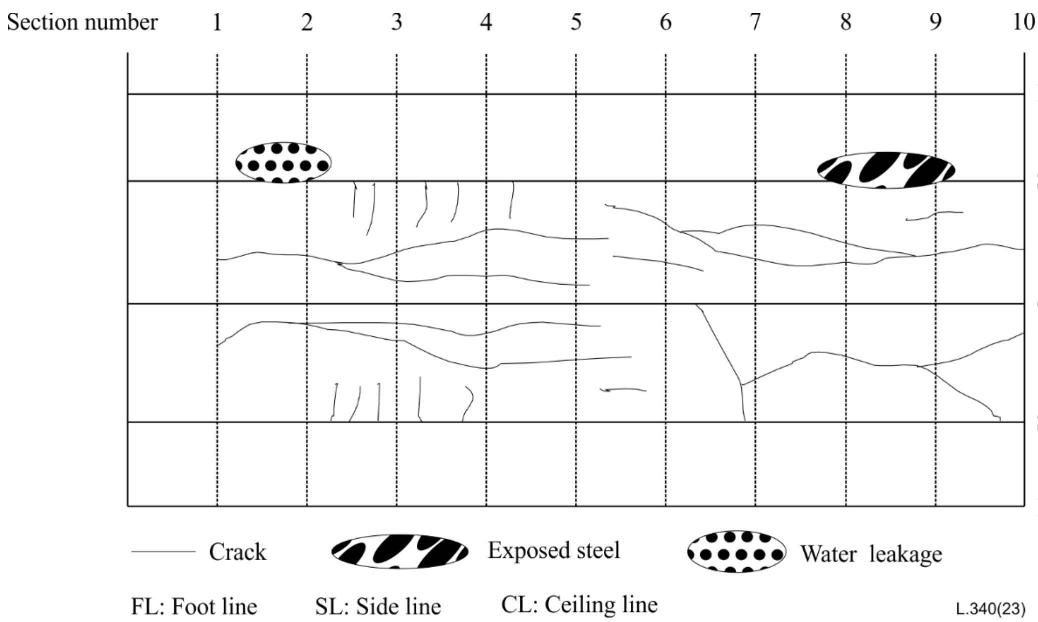


Figure I.2 – Unfolded map of cable tunnel

I.4 Tunnel inspection by GPR

It has been found that the typical defects of cable tunnels are cracks, water leakage, voids, spalling and heaving as shown in Figure I.3. Among them, it is known that voids behind lining concrete are most detrimental to the safety of tunnels.

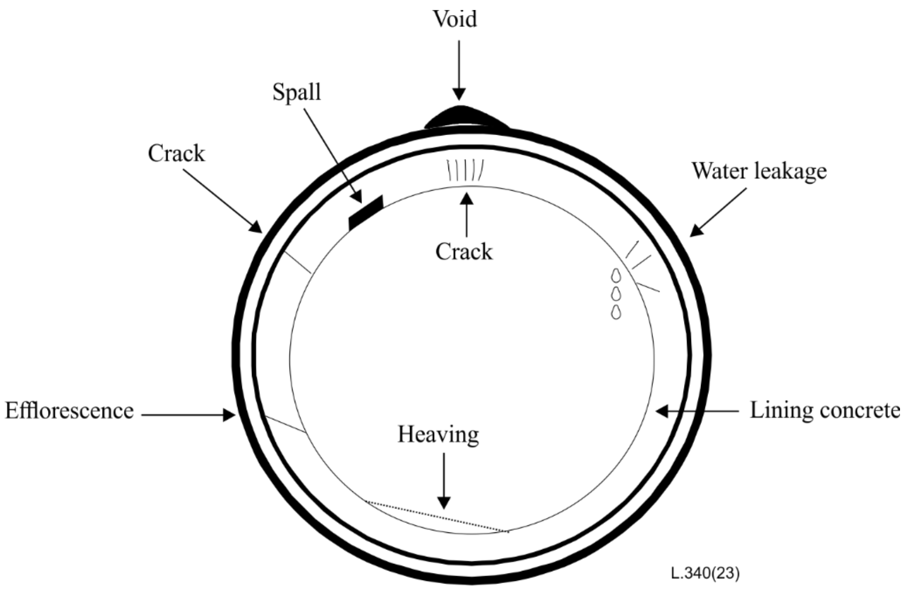


Figure I.3 – Defects that may happen in a cable tunnel

To detect voids, GPR is applied as shown in Figure I.4. The internal image can be acquired continuously as the antenna moves along the surface of the lining concrete. Structural abnormalities such as voids, thickness variations and interface voids between the lining and the ground can be detected.

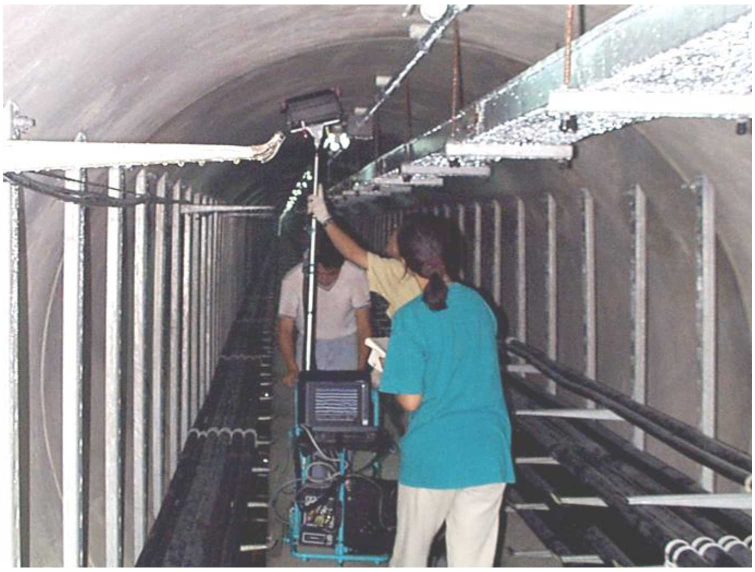


Figure I.4 – Tunnel lining inspection using GPR

Appendix II

Non-entry inspection of maintenance holes

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

II.1 Non-entry inspection of maintenance hole with capturing images

Convention inspection of the concrete frame of maintenance hole requires the worker to enter the maintenance hole, conduct a visual inspection and record a sketch. However, the conventional method has issues in terms of work efficiency, such as the necessity of safety measures before entering the maintenance hole and the time required for pumping out the condensation water and ventilating the hole. In addition, in order to improve the efficiency of future facility inspections, it is necessary to analyse the degree of deterioration of maintenance holes over time from the periodic inspection data, and to accumulate a large amount of digital data that is not dependent on worker skill. Therefore, focusing on the fact that cracks and exposed rebars, which are typical (and initial) surface defects in reinforced concrete structures, we can introduce a non-entry inspection method that captures high resolution images of the upper plate in periodic inspection. Thus, the pumping out time of the condensation water is shortened, ventilation is not required and efficient and constant quality inspection of the concrete frame can be performed.

II.2 Non-entry inspection methods

The non-entry inspection method focuses on grasping the state of the upper plate surface. There are two main types of camera for capturing the inspection images needed. One is the direct type in which the concrete frame surface is partially photographed in the vicinity of the plate, and a camera connected to a robot arm scans the plate. An inspection image of a plate is obtained by merging several images. The second type is an autonomous camera drone which flies inside the maintenance hole and captures images without distortion. In every case, the images taken inside the maintenance hole can be confirmed on a tablet device by communication links such as Wi-Fi. If it is required to check inside accessories placed on a concrete surface other than the upper plate, omni-directional cameras can be adopted as the third method. Omni-directional cameras using a fisheye lens can capture the whole inside surface. Although it takes time to pump up the condensation water, an image containing all plates and accessories is obtained after distortion correction in one pass. Figures and details of these three methods are given in Figure II.1 and Table II.1, respectively.

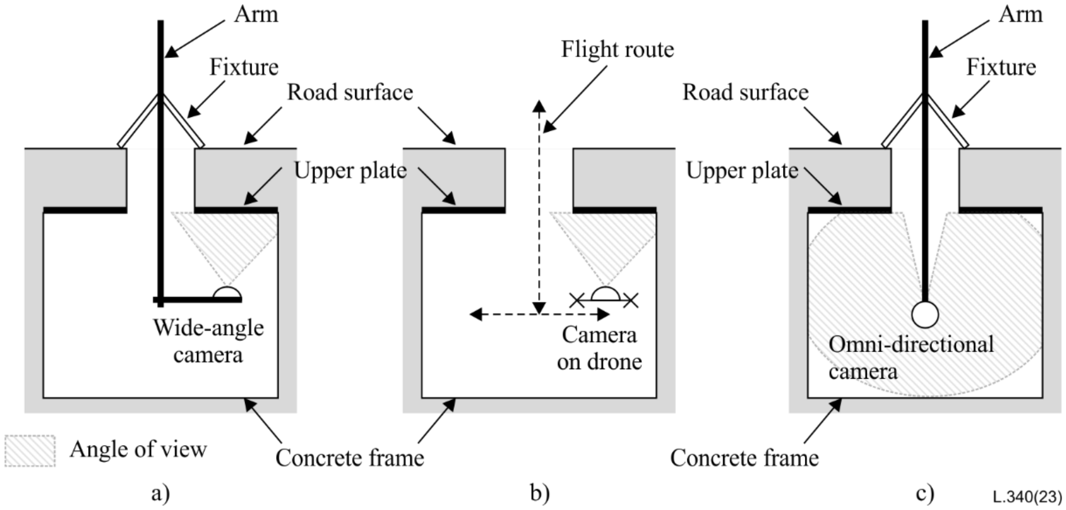


Figure II.1 – Non-entry inspection methods, a) direct type; b) camera drone; c) omni-directional type

Table II.1 –Features of cameras for capturing inspection image

Type	Advantages	Disadvantages
Direct type	– Capable of photographing details of defects such as cracks and exposed rebars	– Requires multiple camera images – Difficult to apply to deeper maintenance holes
Camera drone	– Capable of photographing details of defects such as cracks and exposed rebars – Applicable regardless of depth and width of maintenance hole	– Measures to meet flight regulations may need to be taken (e.g., dense urban area)
Omni-directional type	– Photographing the whole inside surface of the maintenance hole in one pass – Applicable regardless of depth of maintenance hole	– Distortion of the image makes it difficult to measure the absolute width of cracks – Images around large manholes are blurred – All condensation is pumped out to photograph all inside surfaces

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