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

Maintenance of cable tunnels

ITU-T Recommendation L.74

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Maintenance of cable tunnels

Summary

Concrete structures such as buildings, bridges, roads, dams and tunnels are deteriorating. Cable tunnels are also deteriorating. For example, cracks and water leakages occur and these phenomena degrade the safety and serviceability of a cable tunnel. If the deterioration is neglected, large-scale repair and reinforcement measures will probably be required, which will further increase the cost in the future. Therefore, it is highly recommended that periodic inspection and timely maintenance be performed.

Safety plans related to the maintenance of cable tunnels are discussed briefly in ITU-T Recommendation L.11. A model of a safety plan in the operational phase is presented in Tables A.1 and A.2 of ITU-T Recommendation L.11, with an indication of possible preventive measures. These tables, however, do not describe defects that may occur frequently in reinforced concrete structures such as cable tunnels, and the inspection procedures for maintenance. Therefore, recommendations concerning the maintenance of cable tunnels are needed.

Source

ITU-T Recommendation L.74 was approved on 6 April 2008 by ITU-T Study Group 6 (2005-2008) under the ITU-T Recommendation A.8 procedure.

Keywords

Crack, deterioration, inspection, non-destructive testing, water leakage.

FOREWORD

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Maintenance of cable tunnels

1 Scope

This Recommendation:

- describes the inspection and its frequency;
- describes the typical types of deterioration according to the cable tunnel type;
- describes the typical inspection methods and countermeasures.

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.11] ITU-T Recommendation L.11 (1988), *Joint use of tunnels by pipelines and telecommunication cables, and the standardization of underground duct plans*.

[ITU-T L.38] ITU-T Recommendation L.38 (1999), *Use of trenchless techniques for the construction of underground infrastructures for telecommunication cable installation*.

[ITU-T L.39] ITU-T Recommendation L.39 (2000), *Investigation of the soil before using trenchless techniques*.

[ITU-T L.40] ITU-T Recommendation L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

[ITU-T L.46] ITU-T Recommendation L.46 (2000), *Protection of telecommunication cables and plant from biological attack*.

[ITU-T L.48] ITU-T Recommendation L.48 (2003), *Mini-trench installation technique*.

[ITU-T L.63] ITU-T Recommendation L.63 (2004), *Safety procedures for outdoor installations*.

3 Definitions

This Recommendation defines the following terms:

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

- Carbonation: 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.
- Corrosion: Disintegration or deterioration of concrete or reinforcement by electrolysis or by chemical attack.

- Crack: An incomplete separation into one or more parts with or without space in-between. Cracks will be classified by direction, width and depth. The following adjectives can be used: longitudinal, transverse, vertical, diagonal and random.
- Disintegration: Deterioration into small fragments or particles due to any cause.
- Distortion: Any abnormal deformation of concrete from its original shape.
- Efflorescence: A deposit of salts, usually white, formed on a surface, the substance having emerged from below the surface.
- Erosion: Deterioration brought about by the abrasive action of fluids or solids in motion.
- Honeycomb: Voids left in concrete due to failure of the mortar to effectively fill the spaces among coarse aggregate particles.
- Peeling: A process in which thin flakes of mortar are broken away from a concrete surface; such as by deterioration or by adherence of surface mortar to forms as they are removed.
- Pitting: Development of relatively small cavities in a surface, due to phenomena such as corrosion or cavitation, or in concrete, localized disintegration.
- Popout: The breaking away of small portions of a concrete surface due to internal pressure which leaves a shallow, typically conical, depression.
- Scaling: Local flaking or peeling away of the near surface portion of concrete or mortar.
- 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.

3.2 inspection: Inspection means an examination of the soundness of a tunnel based on a comparison of the investigation, observation and measurement results according to the judgement standards. The tunnel inspection is conducted in order to grasp whether or not deformation has an influence on structural safety and durability, and then to take appropriate countermeasures to secure the function of the tunnels based on the evaluation results.

3.3 non-destructive testing (NDT): Non-destructive testing is also called non-destructive evaluation (NDE) and non-destructive inspection (NDI). This method does not destroy the test object. To detect different defects such as cracking and corrosion, there are different methods of testing available, such as the ultrasonic pulse velocity method and stress wave propagation method.

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 cable tunnels

Like other public infrastructures such as bridges, roads and buildings, cable tunnels also have trouble caused by cracks or water leakage as a result of deterioration of steel-reinforced concrete or reinforcing steel. It is found that typical deteriorations that may happen in cable tunnels are cracks, water leakage and the corrosion of reinforcing steel. If such deteriorations are left unrepaired, additional large-scale repair and reinforcement projects will probably be required, which will further increase cost in the future. The purpose of maintenance is to detect the defects in cable tunnels at an early stage and to take appropriate actions in order to enhance its durability and serviceability.

6.1 Inspection

Notwithstanding how well a cable tunnel is constructed, it will require preventive maintenance to preserve its integrity and to prolong its life. 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 cable tunnels is performed to detect damage or defects that are detrimental to the structural safety and durability. When crucial damage or defects are observed, they are evaluated by skilled experienced engineers, and then appropriate and prompt countermeasures, such as repair and reinforcement work, are taken. Inspections can be divided into regular and detailed inspections as follows.

6.1.1 Regular inspections

Regular inspections, also called routine inspections are usually performed visually to check the degradation status of the concrete surface such as cracks, water leaks, or exposed reinforced steel. At this stage, deformation is detected, and is evaluated to judge whether or not detailed inspections and/or temporary countermeasures are needed.

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

6.1.2 Detailed inspections

Detailed inspections are carried out when the defects and deformations are critical to the safety of the cable tunnel. These inspections 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 regular inspection are conducted by a specialist.

These inspections 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 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 the current state of cable tunnel concerned, and the changes in the operating environment.

6.2 Inspection technologies

6.2.1 Typical inspection items

Items used for inspection differ depending upon the type of cable tunnel. Cable tunnels are generally divided into two types as follows:

- Rectangular cross-section (box type);
- Circular cross-section.

A rectangular cross-section cable tunnel is constructed by a cut and cover method, and is made of reinforced steel concrete. On the other hand, a circular cross-section cable 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.

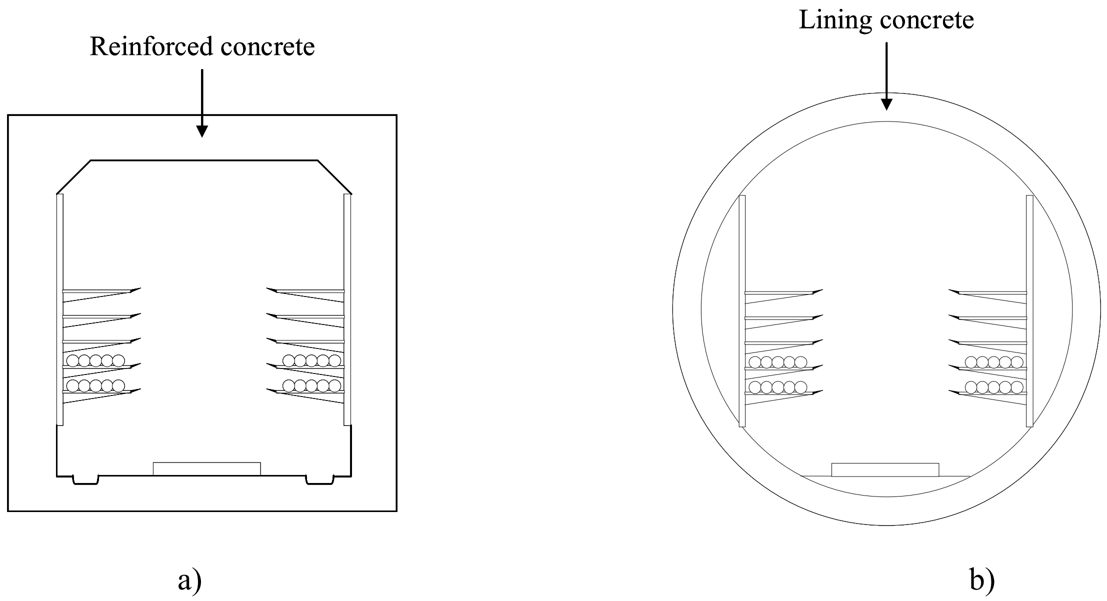


Figure 1 – Typical types of cable tunnel: a) rectangular or box type; and b) circular type

Since the designs and construction procedures of these cable tunnels are different from each other, the deteriorations occur differently. Typical inspection items are summarized in Table 1.

Table 1 – Typical inspection items

	Regular inspection	Detailed inspection
Rectangular cross-section cable tunnel	Cracks; Water leakage; Exposed steel.	Include regular inspection items; Compressive strength of concrete; Corrosion of reinforcing steel; Carbonation depth, etc.
Circular cross-section cable tunnel	Cracks in lining surface; Water leakage; Contamination of lining concrete; Spall of lining concrete.	Include regular inspection items; Deformation of lining; Heaving of tunnel bottom; Settlement of tunnel bottom; Cavities inside lining concrete; Voids behind lining.

6.2.2 Inspection technologies

Inspection methods mainly consist of visual inspection and non-destructive testing methods. When a defect is found during visual inspection, its cause is then established and its size and condition are investigated in detail. Since the crack is one of the most important inspection items, it is recommended to measure the crack width and depth using a crack gauge, and to check whether or not the crack propagates. Table 2 summarizes typical inspection technologies including non-destructive testing methods.

Table 2 – Typical inspection technologies

Typical inspection items	Technologies	Descriptions
Cracks, water leakage, and exposed steel	Visual inspection	Crack width can be measured by crack gauge with magnifier.
Carbonation depth	Phenolphthalein indicator	Core cut from hardened concrete is sprayed with phenolphthalein indicator, and then a purple-red coloration will be obtained where alkaline concrete has been unaffected by carbonation, but no coloration will appear in carbonationed zones.
Voids, water leakage	Infrared Thermography (Note)	This method measures the thermal radiation emitted by tunnel's walls, and can identify defects in the lining and voids. Infrared techniques allow visual presentation of the temperature distribution on the surface.
Compressive 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)	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)	This method injects ultrasonic wave into concrete to analyse the state within it by detecting the wave transmitted and reflected by substances with different elastic properties in the concrete wall. This method can identify the structural abnormalities such as cracks, thickness variations and degradation of the compressive strength.
Defects inside lining concrete	Stress wave propagation method (Note)	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)	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 antennae. 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. In cable tunnels, the wave frequencies are between 900 and 2000 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 – Non-destructive testing technologies.		

6.3 Countermeasures

Once the inspection of the cable tunnel is complete, the repair and reinforcement plans are established. Judgement of repair and reinforcement depends on the evaluation of the field inspection results. Cracks, water leakage and other deterioration is repaired considering the safety, durability and serviceability of the cable tunnel.

6.3.1 Countermeasures against cracks

Cracks are one of the most typical and important deteriorations to be considered. Cracks, however, have many causes and the types are various. In general, cracks that may happen in cable tunnels are categorized as follows:

- Crack with no water;
- Crack with some moisture;
- Crack with water leakage;
- Crack accompanying the corrosion of reinforced steel;
- 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 know its causes exactly. Whether the crack should be repaired or not is decided by a qualified engineer.

6.3.2 Countermeasures against water leakage

The corrosion of reinforced steel in concrete is accelerated by water leakage. The concrete surface and steel accessories in a cable tunnel are also deteriorated by toxic or polluted water. Various techniques have been developed as countermeasures against water leakage, but there are many cases in which water leakage takes place again after construction. It is necessary, therefore, to select countermeasures after carefully considering their effectiveness and workability, economic aspects and the durability of the countermeasures.

Appendix I

Korean experience with maintenance of cable tunnels

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

I.1 Typical deteriorations

Typical deteriorations that may happen in a cable tunnel are cracks, water leakage and the corrosion of reinforcing steel. 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 circular type cable tunnel; and Figure I.1-c shows exposed steel and the corrosion of reinforcing steel on the ceiling of a box type cable tunnel. These deteriorations degrade safety, durability and serviceability of the cable tunnel.

Figure I.1 – Typical deteriorations: a) cracks; b) water leakage; and c) the corrosion of reinforcing steel

I.2 Frequency of inspection

Inspections are 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) regular inspection; and 2) detailed inspection. Regular inspection includes periodic routine inspections that are performed at an interval of not more than once in every week, every month, or every 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, emergency inspection is carried out. Detailed inspection is also done at an interval of once in every five years. Table I.1 describes the frequency of inspection.

Table I.1 – Frequency of inspection

Inspection		Frequency	Inspector
Regular inspection	Periodic routine inspection	Every week 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
Detailed inspection		When a critical defect is detected, or a cable tunnel is in danger When ten 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 the routine monitoring sheet for box type and circular type cable tunnels are shown in Tables I.2 and I.3, respectively.

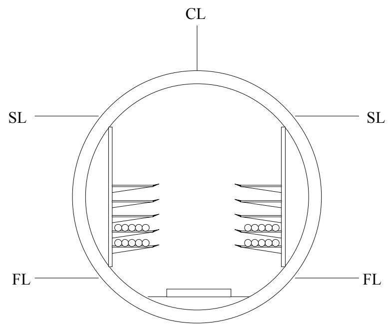
Table I.2 – Example of a routine monitoring sheet for box type cable tunnel

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 ( )			
Carbonation	Carbonation depth, if any: mm			

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

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

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



Cable tunnel name: Inspection site:	Date: Inspector name:
Inspection items	Descriptions
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 ( )

Table I.3 – Example of a routine monitoring sheet for circular 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 ( )

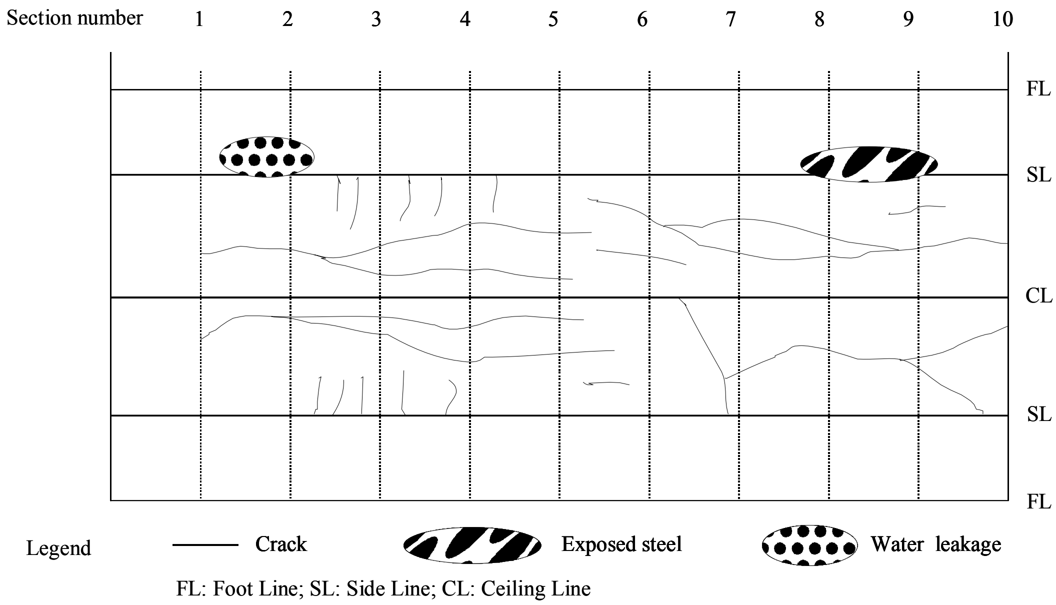


Figure I.2 – Unfolded map of cable tunnel

I.4 Tunnel inspection by GPR

It has been found that typical defects of cable tunnels are cracks, water leakage, voids, spall 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.

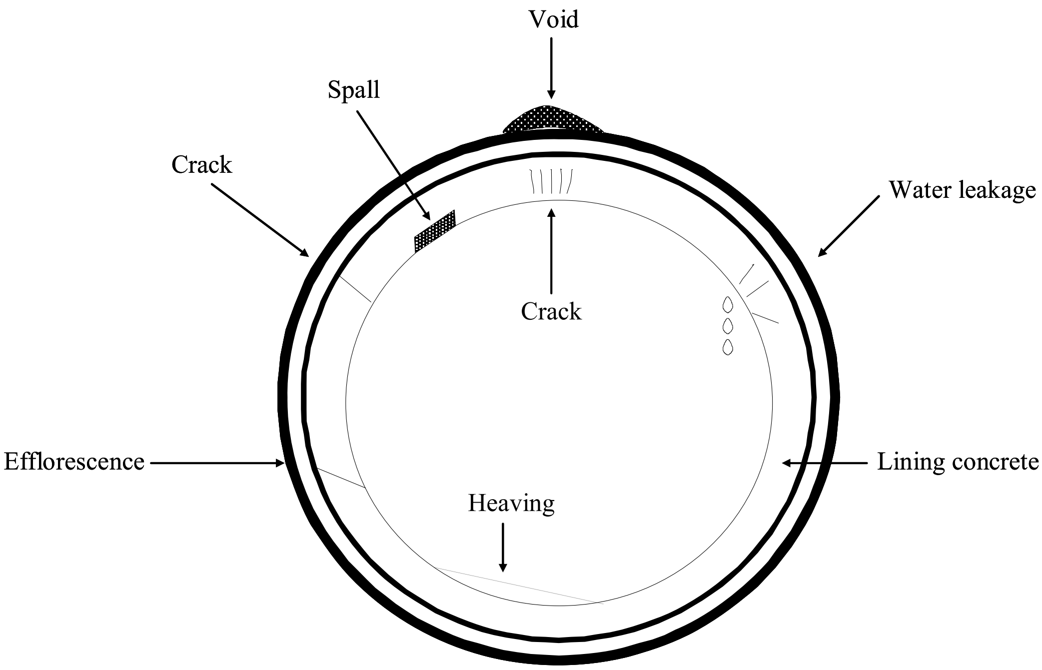


Figure I.3 – Defects that may happen in a cable tunnel

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 obtained.

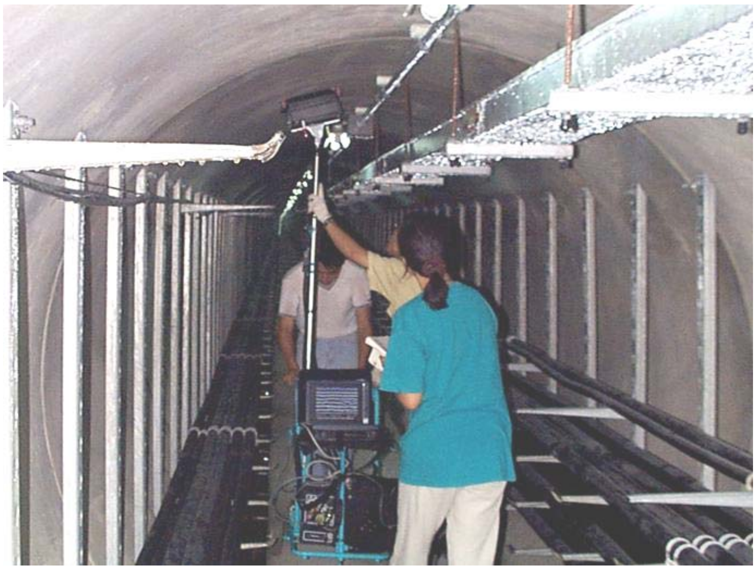


Figure I.4 – Tunnel lining inspection using GPR

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