

# JTG

Industry Standards of  
the People's Republic of China  
中华人民共和国行业标准

JTG H12—2015 (EN)

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Technical Specifications for Maintenance of Highway Tunnel

公路隧道养护技术规范

(英文版)

Issue date: January 16, 2015

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Issued by Ministry of Transport of the People's Republic of China

Industry Standards of the People's Republic of China  
中华人民共和国行业标准

**Technical Specifications for Maintenance of Highway Tunnel**

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Editing organization in charge: Chongqing Transport Commission

Issuing authority: Ministry of Transport of the People's Republic of China

Effective date: March 1, 2015

交通运输部  
公路隧道养护技术规范  
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# 中华人民共和国交通运输部

## 公告

第50号

### 交通运输部关于发布 《公路隧道设计规范 第一册 土建工程》 英、法文版等7项公路工程行业标准外文版的公告

为促进公路工程行业标准的国际合作与共享,现发布《公路隧道设计规范 第一册 土建工程》英文版[JTG 3370.1—2018(EN)][代替标准号JTG D70—2004(E)]及法文版[JTG 3370.1—2018(FR)]、《公路隧道设计规范 第二册 交通工程与附属设施》法文版[JTG/T D70/2—2014(FR)]、《公路隧道照明设计细则》英文版[JTG/T D70/2-01—2014(EN)]、《公路隧道通风设计细则》英文版[JTG/T D70/2-02—2014(EN)]、《公路隧道抗震设计规范》英文版[JTG 2232—2019(EN)]、《公路隧道养护技术规范》英文版[JTG H12—2015(EN)]。

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2023年9月20日

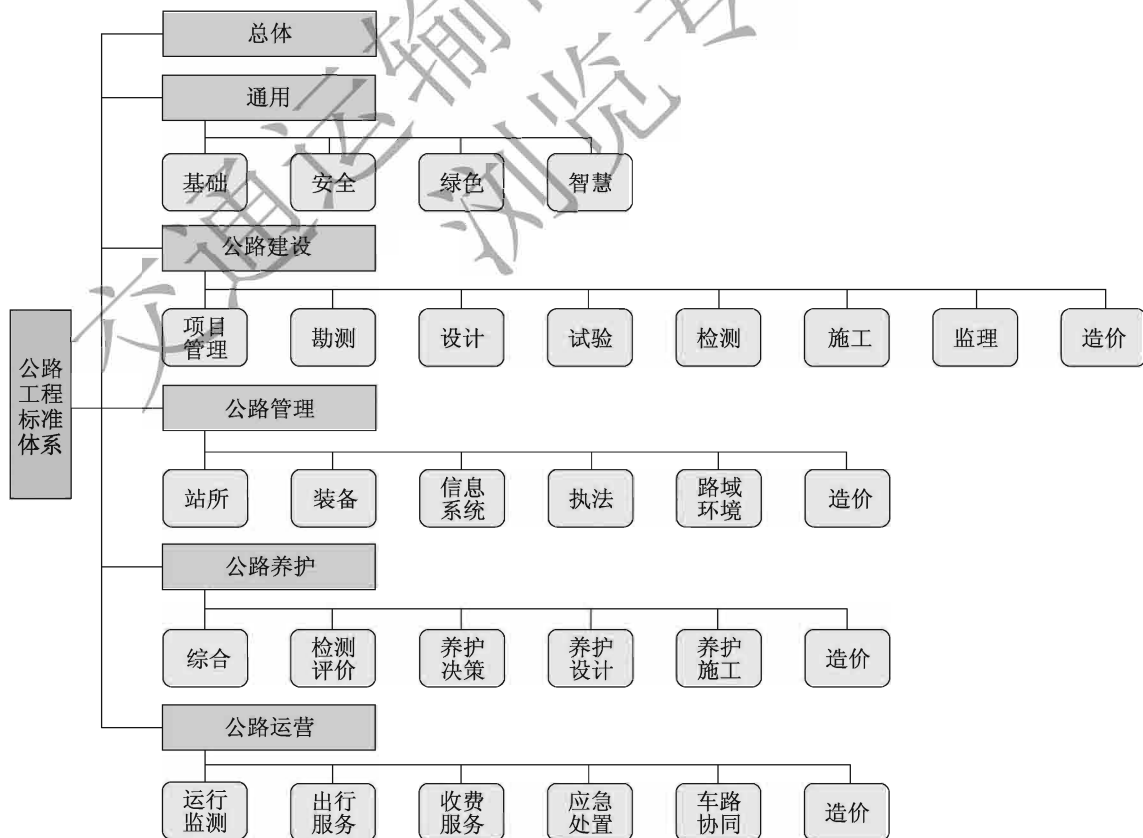
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标准是人类文明进步的成果,是世界通用的技术语言,促进世界的互联互通。近年来,中国政府大力开展标准化工作,通过标准驱动创新、协调、绿色、开放、共享的共同发展。在丝绸之路经济带与 21 世纪海上丝绸之路,即“一带一路”倡议的指引下,为适应日益增长的全球交通运输发展的需求,增进世界连接,促进知识传播与经验分享,中华人民共和国交通运输部组织编译并发布了一系列中国公路行业标准外文版。

中华人民共和国交通运输部发布的公路工程行业标准代号为 JTG,体系范围涵盖公路工程从规划建设到养护和运营管理全过程所需要的设施、技术、管理与服务标准,也包括相关的安全、环保和经济方面的评价等标准。



《公路隧道养护技术规范》(简称《规范》)是中国交通行业公路隧道运营养护的重要技术标准,主要用于各等级山岭公路隧道土建结构、机电设施、其他工程设施的技术状况评定、日常巡查、定期检查、保养维修、清洁维护、病害处治等,可供从事隧道运营相关的管理企业、设计院、检测机构、养护施工企业等使用。2003年由交通部首次发布实施《公路隧道养护技术规范》(JTG H12—2003),随着21世纪以来中国大量公路隧道投入运营,2022年中国运营公路隧道达24850处、2678.43万延米,并以年均超12%的速度快速增长。中国在公路隧道运营养护技术领域取得了长足进步,积累了较为丰富的养护管理经验。在充分总结近年来工程实践经验和科研成果的基础上,综合考虑了中国公路隧道运营现状和隧道养护技术发展趋势,积极采纳了新理论、新技术和新方法,并借鉴了国外公路隧道养护的成功经验和先进技术,2015年发布新版《公路隧道养护技术规范》(JTG H12—2015)。《规范》以科学合理、经济安全、利用高效为基本原则,强调公路隧道运营养护应坚持预防为主、防治结合的方针,分别针对正常交通工况和异常交通工况进行设计。《规范》对规范设计行为、保障中国公路隧道运营安全和推进公路隧道养护科技进步均起到了重要作用。

本英文版的编译发布便是希望将中国的工程经验和科技成果与各国同行进行交流分享,为其他国家山岭公路隧道运营养护提供参考借鉴。

《公路隧道养护技术规范》英文版的编译工作由中华人民共和国交通运输部委托招商局重庆交通科研设计院有限公司主持完成,并由中华人民共和国交通运输部公路局组织审定。本规范在编译过程中得到欧美多名专家的支持,特别感谢巴基斯坦专家 Asim Amin、澳大利亚专家 Bedi Anmol、马来西亚专家 Khoo Chee Min,以及巴基斯坦专家 Komal Khan 等在编译与审定期间给予的协助与支持。

本英文版标准的内容与现行中文版一致,如出现异议时,以中文版为准。

感谢中文版主要编写者蒋树屏、程崇国先生在本英文版编译与审定期间给予的指导与支持。

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## Ministry of Transport

### Public Notice

No.50

#### Public Notice on Issuing the English and French Versions of Seven Highway Engineering Industrial Standards including *Specifications for Design of Highway Tunnels Section 1 Civil Engineering*

The English and French versions of *Specifications for Design of Highway Tunnels Section 1 Civil Engineering* [ JTG 3370.1—2018 ( EN ), substituting JTG D70—2004 ( E ); and JTG 3370.1—2018 ( FR ) ], the French version of *Specifications for Design of Highway Tunnels Section 2 Traffic Engineering and Affiliated Facilities* [ JTG D70/2—2014 ( FR ) ], the English version of *Guidelines for Design of Lighting of Highway Tunnels* [ JTG/T D70/2-01—2014 ( EN ) ], the English version of *Guidelines for Design of Ventilation of Highway Tunnels* [ JTG/T D70/2-02—2014 ( EN ) ], the English version of *Specifications for Seismic Design of Highway Tunnels* [ JTG 2232—2019 ( EN ) ], and the English version of *Technical Specifications of Maintenance for Highway Tunnel* [ JTG H12—2015 ( EN ) ] are issued hereby for promoting international cooperation and sharing of standards in highway engineering industry.

The general administration and final interpretation of the foreign language versions of the above mentioned standards belong to Ministry of Transport, while particular interpretation for application and routine administration shall be provided by China Merchants Chongqing Communications Technology Research & Design Institute Co. , Ltd.

In event of any ambiguity or discrepancies between the foreign language versions and Chinese version, the Chinese version should be referred and accepted.

Comments, suggestions and inquiries are welcome and should be addressed to China Merchants Chongqing Communications Technology Research & Design Institute Co. , Ltd. ( Address: Institute of Tunnel and Underground Engineering, No. 33 Xuefu Avenue,

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**Ministry of Transport of the People's Republic of China**  
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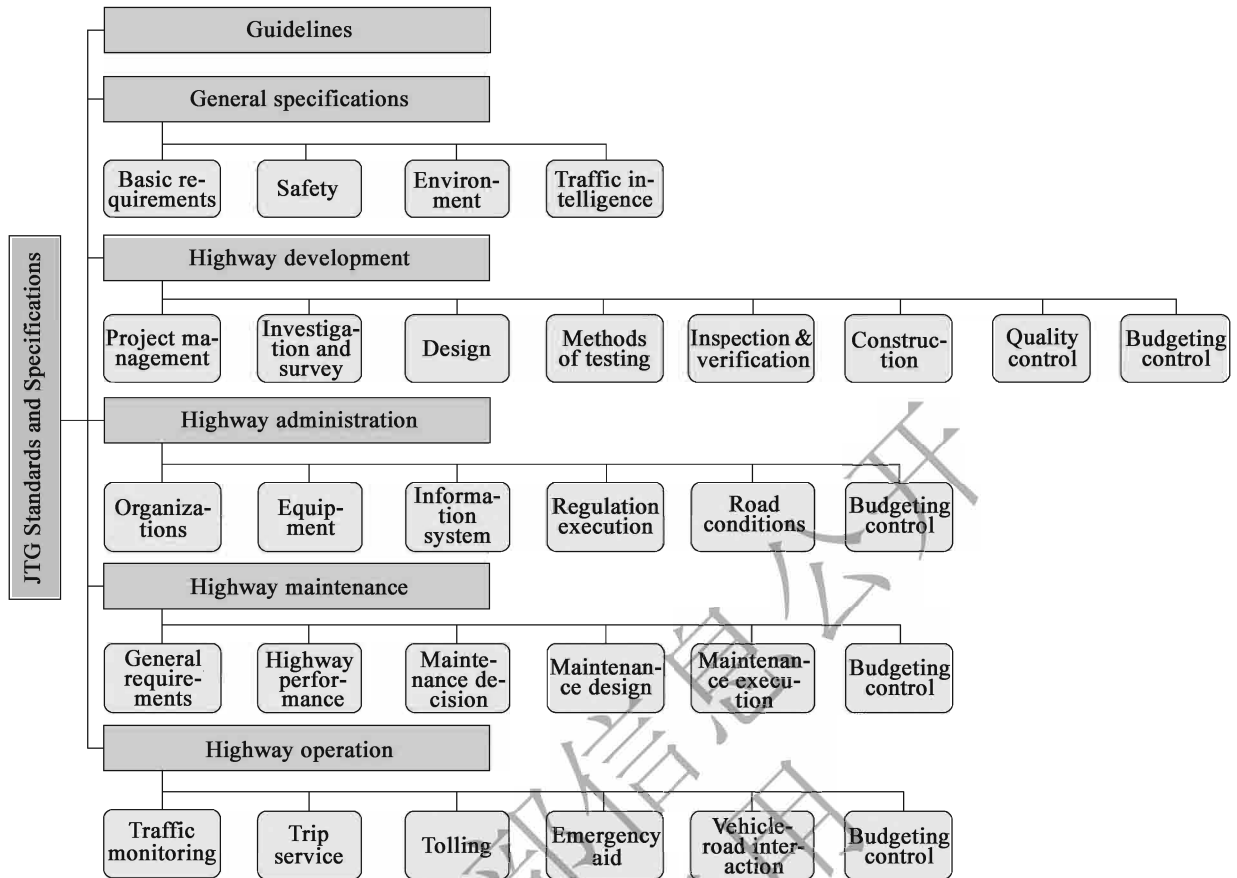


# Introduction to English Version

Standards reflect the achievement of civilization and progress, provide common languages for technical communications and improve global connectivity. In recent years, Chinese government has been proactively implementing the standardization to stimulate innovation, coordination, greening and opening up for shared development in China and worldwide. In light of mutual development along the Silk Road Economic Belt and the 21st-Century Maritime Silk Road (so called the "One Belt One Road" initiative), the Ministry of Transport of the People's Republic of China organized translation and published international version of Chinese highway industry standards and specifications to cope with the increasing demands for international cooperation in world transportation, achieve interconnected development and promote knowledge dispersion and experience sharing.

JTG is the designation referring to the standards and specifications of highway transportation industry, issued by the Ministry of Transport of the People's Republic of China. It covers the standards and specifications in terms of facilities, technology, administration and service for whole process from highway planning through to highway maintenance. The criteria for safety, environment and economy assessment are also included.

The *Technical Specifications of Maintenance for Highway Tunnel* (hereinafter referred to as the *Specifications*) are important technical standards for the operation and maintenance of highway tunnels in China transportation industry. It is mainly used by management enterprises engaged in tunnel operation, design institutes, testing institutions and maintenance construction enterprises for technical condition evaluation, routine inspection, regular inspection, maintenance, cleaning and defect treatment of civil structures, electromechanical facilities and other engineering facilities of mountain highway tunnels at all levels. The *Technical Specifications of Maintenance for Highway Tunnel* (JTG H12—2003) were first issued for implementation by the Ministry of Transport. As many highway tunnels have been put into operation in China since the 21st century, the total number of



highway tunnels in China reached 24,850 in 2022, amounting to 26,784,300 linear meters, and grew rapidly at an average annual rate of over 12%. China has made great progress in the technical field of highway tunnel operation and maintenance, and accumulated rich experience in maintenance management. Based on fully summarizing the engineering practice experience and scientific research achievements in recent years, the Specifications comprehensively consider the present situation of highway tunnel operation in China and the development trend of tunnel maintenance technology, actively adopt new theories, new technologies and new methods, and refer to foreign successful experience and advanced technology of highway tunnel maintenance. The new version of *Technical Specifications of Maintenance for Highway Tunnel* (JTG H12—2015) was released in 2015. Based on the basic principles of scientific rationality, economic safety and high utilization efficiency, the *Specifications* emphasize that the operation and maintenance of highway tunnels should adhere to the policy of prevention first and combination of prevention with control, and that highway tunnels should be designed for normal traffic conditions and abnormal traffic conditions respectively. The *Specifications* have played an important role in standardizing the design behaviors, ensuring the operation safety of Chinese highway tunnels and promoting

the scientific and technological progress of highway tunnel maintenance.

The purpose of compiling and publishing this English version is to exchange and share China's engineering experience and technical achievements with counterparts in other countries, and to provide reference for the operation and maintenance of mountain highway tunnels in other countries.

The Ministry of Transport of the People's Republic of China entrusted China Merchants Chongqing Communications Technology Research & Design Institute Co., Ltd. to preside over the compilation of the English version of *Technical Specifications of Maintenance for Highway Tunnel*, and the Highway Bureau of the Ministry of Transport of the People's Republic of China organized the review. These Specifications were supported by many experts in Europe and America during compilation. Special thanks are also given to Pakistani expert Asim Amin, Australian expert Bedi Anmol, Malaysia expert Khoo Chee Min, Pakistani expert Komal Raiz for their assistance and support during the editing and approval of these Specifications.

The English version of this standard is consistent with the current Chinese version. In the event of any ambiguity or discrepancies, the Chinese version shall be referred and accepted.

Gratitude is given here to Mr. Jiang Shuping and Mr. Cheng Chongguo, the editors in charge of Chinese version, for their guidance and support during the editing and approval of the English version.

Comments, suggestions and inquiries are welcome and should be addressed to the editing organization in charge of the English version (address: Tunnel and Underground Engineering Research Institute, Merchants Chongqing Communications Technology Research & Design Institute Co., Ltd., No. 33, Xuefu Avenue, Nan'an District, Chongqing, postal code: 400067, e-mail: chengliang@cmhk.com).

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# Foreword to Chinese Version

Under the request by the Ministry of Transport via GL Zi [2011] No. 115 *Notice of Revision Plan for Highway Engineering Standard in 2011*, Chongqing Transport Commission was authorized as the Editing organization in charge to undertake the preparation of the revision of *Technical Specifications for Maintenance of Highway Tunnel* (JTG H12—2003).

Over the last decade, China has gained extensive experience in maintenance management from the significant number of highway tunnels that came into service. The revision of these Specifications has been prepared based on the survey conducted by the editorial team. There was extensive consultation with the relevant authorities, constructors, working personnel, testing, and inspection organizations from the provinces with an extensive network of tunnels.

These Specifications consist 8 chapters and 4 appendixes, namely: 1 General Provisions, 2 Glossary and Symbols, 3 Maintenance Class and Technical Condition Assessment, 4 Tunnel Structure, 5 Mechanical and Electrical Systems, 6 Other Facilities, 7 Safety Management, 8 Technical Management, Appendix A Tunnel Structural Inspection Form, Appendix B Standard for Tunnel Structure Technical Condition Assessment, Appendix C Technical Condition Assessment and Inspection Form for Mechanical and Electrical Systems and Appendix D Technical Condition Assessment Form for Other Facilities.

This revision introduces the following key changes:

- (1) classification method proposed for tunnel maintenance class;
- (2) cleaning and inspection frequency adjusted according to the maintenance class;
- (3) assessment method of highway tunnel technical conditions, including tunnel structure, M&E equipment, other facilities, and overall assessment, proposed based on the principle of the existing judgment analysis;
- (4) maintenance and repair, and structural degradation treatment of tunnel structures supplemented and improved;

- (5) maintenance workscope of M&E equipment supplemented and improved;
- (6) emergency safety management specified; and
- (7) technical management chapter added.

All units related shall inform routine management team of the problems and suggestions found in implementation for reference in revision by writing to the contact person Lin Zhi at China Merchants Chongqing Communications Technology Research & Design Institute Co. , Ltd. , 33 Xuefu Avenue, Nan'an District, 400067, Chongqing Municipality via Tel. No. 023-62653050, Fax No. 023-62653128 and E-mail No. 106829864@qq. com.

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# 1 General Provisions

1.0.1 These *Specifications* are intended to serve as the technical standard for maintenance of highway tunnels.

1.0.2 These *Specifications* apply to the maintenance of mountain highway tunnels constructed with the drill-and-blast tunneling method.

1.0.3 The scope of maintenance of highway tunnels shall include the tunnel structure, mechanical and electrical (E&M) systems as well as other facilities.

1.0.4 Highway tunnel maintenance shall follow the guiding principle of “Prevention First, Integrated Approach to Prevention and Treatment” which emphasizes preventive maintenance to ensure highway tunnels remain in normal working conditions.

1.0.5 Highway tunnel maintenance shall be classified into different maintenance classes and maintenance work to be implemented according to the maintenance grading.

1.0.6 Periodic inspection shall be conducted for highway tunnels. The technical conditions of the tunnels shall be assessed based on the inspection results and the corresponding maintenance plan and program shall be proposed based on the traffic operating conditions, technical conditions of the tunnel structure and facilities as well as the extent of structural degradation, and geological conditions, etc.

1.0.7 Technical documentation of tunnel maintenance shall be provided throughout the highway tunnel maintenance period and should also be kept in the highway information-based maintenance management system.

1.0.8 Maintenance must be conducted so as to minimise the impact on traffic flow and ensure

safety for tunnel users and maintenance personnel.

1.0.9 New technologies, new materials, new equipment, and new processes shall be considered in assertiveness yet caution to ensure the maintenance and repair works meet the requirements of safety and practicability, quality and reliability, economic rationality, and technical advancement.

1.0.10 In addition to these *Specifications*, highway tunnel maintenance shall also comply with the provisions of the existing relevant National Standards and industry standards.

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# 2 Terms and Symbols

## 2.1 Terms

### 2.1.1 Highway tunnel maintenance

It includes daily patrol, cleaning, inspection, and assessment, maintenance, and repair work to best ensure the tunnel structure, mechanical & electrical systems, and other facilities are in working order.

### 2.1.2 Maintenance class

Highway tunnels are divided into several maintenance classes based on highway classification, traffic volume, tunnel size, technical conditions, geological and climate conditions, and other factors for implementing the maintenance standards and maintenance frequencies.

### 2.1.3 Tunnel structure

This includes the various civil engineering structures, the side and front slopes at the tunnel portals, tunnel frames, linings, pavements, waterproofing and drainage facilities, inclined (vertical) shafts, maintenance paths and ducts as well as other structural elements.

### 2.1.4 Mechanical & electrical (M&E) equipment

They are the functional systems for tunnel operations, including power supply and distribution facilities, lighting facilities, ventilation facilities, fire-fighting facilities, monitoring and communication facilities, etc.

### 2.1.5 Structural degradation treatment

The implementation of repairs or other enhancement measures such as ground improvement, structural strengthening, and partial structural replacement, to mitigate degradation of structural performance to restore or enhance structural performance and function.

## 2.2 Symbols

- $CI$ —overall technical condition score, with a range from 0 ~ 100;
- $JGCI$ —tunnel structure's technical condition score, with a range from 0 ~ 100;
- $JDCI$ —M&E equipment's technical condition score, with a range from 0 ~ 100;
- $QTCI$ —other facilities' technical condition score, with a range from 0 ~ 100;
- $W_{JG}$ —weightage for tunnel structure in overall assessment;
- $W_{JD}$ —weightage for M&E equipment in overall assessment;
- $W_{QT}$ —weightage for other facilities in overall assessment;
- $w_i$ —itemised weightage;
- $JGCI_i$ —tunnel structure individual condition value, with a range from 0 ~ 4;
- $JGCI_{ij}$ —condition value for each inspection zone of the tunnel structure, with a range from 0 ~ 4;  $j$  is the zone number and subject to the actual number of zones;
- $E_i$ —equipment readiness for individual component of M&E equipment, 0 ~ 100%.

# 3 Maintenance Class and Technical Condition

## 3.1 Maintenance class

3.1.1 Highway tunnel maintenance can be classified into the following three classes as per Table 3.1.1-1 and Table 3.1.1-2, in line with the highway classification system and its tunnel length and traffic volume.

**Table 3.1.1-1 Schedule of classification of tunnel maintenance classes for expressway, Class-1 highway**

Single lane annual average daily traffic (AADT) [pcu/(d · ln)]	Tunnel length“L” (m)			
	$L > 3,000$	$3,000 \geq L > 1,000$	$1,000 \geq L > 500$	$L \leq 500$
$\geq 10,001$	Class I	Class I	Class I	Class II
5,001-10,000	Class I	Class I	Class II	Class II
$\leq 5,000$	Class I	Class II	Class II	Class III

**Table 3.1.1-2 Schedule of classification of tunnel maintenance classes for Class-2 and below highway**

AADT (pcu/d)	Tunnel length “L” (m)			
	$L > 3,000$	$3,000 \geq L > 1,000$	$1,000 \geq L > 500$	$L \leq 500$
$\geq 10,001$	Class I	Class II	Class II	Class III
5,001-10,000	Class II	Class II	Class III	Class III
$\leq 5,000$	Class II	Class III	Class III	Class III

## 3.2 Technical condition assessment

3.2.1 Highway tunnel technical condition assessment is composed of individual technical condition

assessment for tunnel structure, M&E equipment, and other facilities as well as overall technical condition assessment, as shown in Figure 3.2.1. Highway tunnel technical condition assessment shall adopt the combination approach of staged assessment and tunnel's single control indicator. Firstly, it assesses each inspection item, and followed by a separate assessment for the tunnel structure, M&E equipment, and other facilities and finally the overall technical condition assessment of the tunnel.

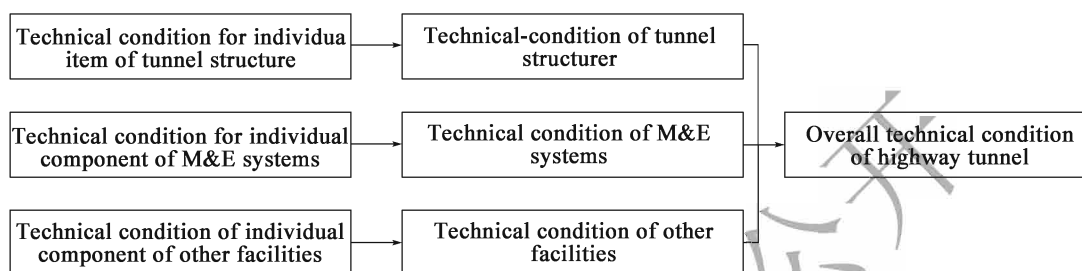


Figure 3.2.1 Highway tunnel technical condition assessment

3.2.2 The overall technical condition assessment of a highway tunnel shall be divided into Category 1, Category 2, Category 3, Category 4 and Category 5. Refer to Table 3.2.2 for the description and maintenance strategies of each category.

**Table 3.2.2 Category of overall technical condition assessment of highway tunnel**

Category of technical condition assessment	Description		Maintenance strategies
	Tunnel structure	M&E equipment	
Category 1	Intact condition. No abnormality, or with a negligible abnormality that does not affect traffic safety.	M&E equipment are in functional working order and operating properly.	Normal maintenance
Category 2	Slight damage. Slightly damaged, but in a stable condition and does not compromise traffic safety.	M&E equipment are basically in good working order and work properly; some vulnerable parts or damaged parts need to be replaced.	The parts with structural damage shall be inspected or monitored; maintenance and repair shall be carried out if necessary. Normal maintenance shall be carried out for M&E equipment and key equipment shall be repaired promptly.
Category 3	Medium damage. Damages with gradual deterioration and may affect pedestrian and traffic safety.	M&E equipment are still operating fairly, but some equipment, parts, and software need to be replaced or upgraded.	The parts with structural damage shall be monitored intensively; maintenance and partial repair shall be carried out. Specialist works should be carried out for M&E equipment.

continued

Category of technical condition assessment	Description		Maintenance strategies
	Tunnel structure	M&E equipment	
Category 4	Severe damage. Severe damages with faster deterioration and have affected pedestrian and traffic safety.	M&E equipment are generally in unsound working order and relevant equipment needs to be fully upgraded.	Structural degradation treatment measures shall be implemented as soon as possible. Specialist works shall be carried out for M&E equipment and traffic control shall be implemented immediately.
Category 5	Dangerous condition. More severe/ serious damages with rapid deterioration and endanger pedestrian and traffic safety.	—	The tunnel shall be closed in time for structural degradation treatment; partial reconstruction or upgrading should be required in special circumstances.

3.2.3 The category of overall technical condition assessment shall be assigned based on the individual technical condition of the tunnel structure or M&E equipment, whichever is worse.

3.2.4 The workflow for highway tunnel inspection and technical condition assessment is shown in Figure 3.2.4.

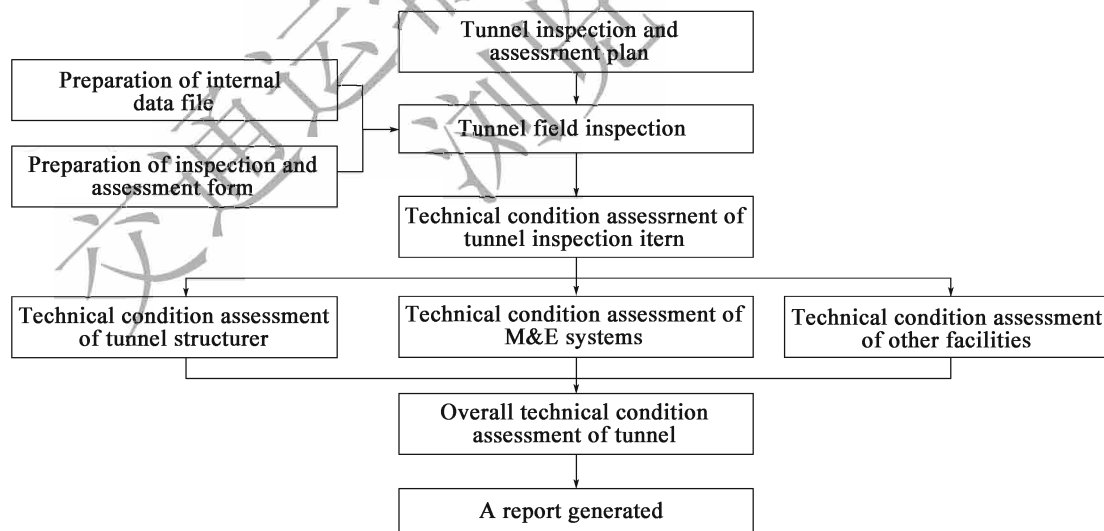


Figure 3.2.4 Workflow for highway tunnel technical condition assessment

# 4 Tunnel Structure

## 4.1 General provisions

4.1.1 Maintenance of tunnel structure includes daily patrol, cleaning, structural inspection, and technical condition assessment, maintenance and repair as well as structural degradation treatment.

4.1.2 The disposal of refuse, residual waste, and wastewater generated from tunnel maintenance shall comply with the relevant environmental protection regulations.

## 4.2 Daily patrols

4.2.1 Daily patrol shall be conducted to check if the tunnel portal, lining, and pavement are in normal working condition, or whether it impedes traffic safety, which includes:

- 1 Whether the side and front slopes at the tunnel portal have any symptoms of impending slope failure, landslide, or rock falling.
- 2 Whether the tunnel frame structure has a wide range of cracks, fractured lining, or concrete flaking.
- 3 Whether the tunnel lining has a wide range of cracks, apparent deformation, or chipped lining.
- 4 Whether there are large-scale groundwater flow and water inrush, gushing mud, or extensive stagnant water on the pavement that are potential threats to traffic safety.
- 5 Whether there are falling objects, severe heave, fault, and fracture on the tunnel



pavement.

- 6 Whether the built-in elements and hangers-on the tunnel roof have ruptured, become deformed, and/or fallen off.

4.2.2 Daily patrols should be conducted at least once a day; and the frequency shall be increased during the rainy season, freezing season, and extreme weather. Tunnel daily patrols may be carried out in conjunction with the daily patrol for road segments.

4.2.3 Daily patrols may adopt a combination of both manual and information-based methods.

4.2.4 During the daily patrols, if any obstacles or abnormalities are discovered on the pavement, they shall be removed in the appropriate situation or to be reported with a proper record. The documentation shall primarily be made in writing, assisted with the pertinent photo or video.

### 4.3 Cleaning

4.3.1 Cleaning strategies and frequency shall be determined with comprehensive consideration of the tunnel maintenance class, traffic composition, degree of fouling, the cleaning method, and its efficiency as well as the environmental conditions. Following the respective maintenance class, the tunnel cleaning and maintenance frequency should be not less than that specified in Table 4.3.1-1 and Table 4.3.1-2.

**Table 4.3.1-1 Frequency of cleaning for expressway and Class-1 highway tunnel**

Cleaning items	Maintenance class		
	Class I	Class II	Class III
Pavements	Once / day	Twice / week	Once / ten day
Interior decorations, maintenance paths, horizontal adits, signs, markings, and delineators	Once / month	Once / two-month	Once / quarter
Drainage facilities	Once / quarter	Once / half-year	Once / half-year
Roofs	Once / half-year	Once / year	Once / two-year
Inclined shafts	Once / half-year	Once / year	Once / two-year
Sidewalls and tunnel frame	Once / half-year	Once / quarter	Once / half-year

**Table 4.3.1-2 Frequency of cleaning for Class-2 and below highway tunnel**

Cleaning items	Maintenance class		
	Class I	Class II	Class III
Pavements	Once / week	Once / Bi-weekly	Once / month
Interior decorations, sidewalls, tunnel frames, maintenance paths, horizontal adits, signs, markings, and delineators	Once / quarter	Once / half-year	Once / year
Drainage facilities	Once / half-year	Once / year	Once / year
Roofs	Once / year	Once / two-year	Once / three-year
Inclined shafts	Once / year	Once / two-year	Once / three-year

4.3.2 Cleaning for the pavement inside the tunnel shall satisfy the following requirements:

- 1 It shall be kept clean and tidy, the side drains shall be free from residual waste.
- 2 Expressway and Class-1 highway should primarily be cleaned by the mechanical operation. Suspended dust shall be prevented during cleaning.
- 3 If the pavement is contaminated by oils or other chemicals, measures shall be taken to remove the pollutants.

4.3.3 Cleaning for tunnel roof, interior decoration, sidewall, and tunnel frame shall satisfy the following requirements:

- 1 They shall be kept clean and tidy, free from dirt, pollution, oil stain, and surface stains.
- 2 The roof, interior decoration, and sidewall should primarily be cleaned by mechanical operation and supplemented by manual operation.
- 3 If the wet cleaning process is adopted, water stagnation and freezing on the pavement shall be avoided. Due attention shall be paid to the M&E equipment in the tunnel to protect the safety and prevent water infiltration. Depending upon the actual cleaning procedure selected, a neutral cleaner should generally be used where appropriate. The cleaner shall be rinsed off the tunnel thoroughly.
- 4 If the dry cleaning process is adopted, the roof, interior decoration, and sidewalls, as well as the M&E equipment in the tunnel, shall be protected from damage. Dust suppression

measures shall be implemented as necessary during the cleaning process. A cleaner may be used for localized special treatment if there's any dirt that cannot be removed.

- 5 If there are no roof and interior decoration, the concrete wall shall be cleaned as needed.
- 6 The cleaning of tunnel frame shall be conducted as per the cleaning requirement of sidewalls.

4.3.4 The tunnel drainage facilities shall be cleaned and flushed in accordance with the following provisions:

- 1 It shall be kept free of silt and free-flowing.
- 2 The drainage facilities shall be inspected, cleaned, and flushed before, during, and after a flood and after extreme rainfall. During the freezing season, the frequency of drain cleaning shall be increased.
- 3 The cleaning and flushing frequency shall be increased for the tunnel with a gentle gradient or at the tunnel entrance; for manholes and sediment basins, the bottom sediments shall be removed.

4.3.5 The cleaning for tunnel signs, markings, and delineators shall satisfy the following requirements:

- 1 They shall be kept undamaged, clearly visible, and conspicuous.
- 2 The signs, markings, and delineators shall be cleaned immediately when they have impaired visibility caused by the specks of dirt. During the cleaning, their surface film or coating shall be protected from damage.

4.3.6 Debris and standing water in the horizontal adit of the tunnel shall be removed regularly.

4.3.7 Foreign objects that may damage the ventilation system or affect its performance in the inclined shafts, maintenance paths, and ventilation ducts shall be removed regularly.

## 4.4 Structural inspection

4.4.1 Tunnel structural inspection includes routine inspection, periodic inspection, emergency

inspection, and special inspection and shall satisfy the following requirements:

- 1 The routine inspection shall be a qualitative inspection of the general appearance of the tunnel structure.
- 2 The periodic inspection shall be a comprehensive inspection of the technical conditions of tunnel structure at a specified frequency.
- 3 The emergency inspection shall be a thorough inspection of the affected structure of the tunnel which suffers from a natural disaster, traffic accident, or other abnormalities.
- 4 The special inspection shall be the specialist inspection, testing, and analysis conducted for the tunnel which requires further investigation on the detailed conditions of defects or structural degradation according to the results of routine inspection, periodic inspection, and emergency inspection.

4.4.2 Following the respective highway tunnel maintenance class, the frequency of routine inspection for tunnel structure shall not be less than that specified in Table 4.4.2; and it shall be increased during the rainy and freezing season or extreme weather, or in the event of a severe abnormality.

**Table 4.4.2 Frequency of routine inspection for highway tunnel structure**

Type of inspection	Maintenance class		
	Class I	Class II	Class III
Routine inspection	Once / month	Once / two-month	Once / quarter

4.4.3 Through the routine inspection, the early stage of damages, noticeable structural degradation or other abnormalities may be detected in time and the countermeasures to be proposed. It shall comply with the following provisions:

- 1 Routine inspection should be carried out by a combination of both manual and information-based methods, and assisted by simple inspection tools. The “Highway tunnel routine inspection record form” (Appendix A.0.1) shall be filled up at the site with the detailed records on the type of damage of the inspection items, estimated extent and level of damage and the maintenance workload, evaluation and classification of the damages based on abnormality observed and subsequently propose the corresponding maintenance measures.
- 2 Routine inspection is mainly based on qualitative evaluation. Refer to Table 4.4.3 for the scope of inspection and evaluation standards. The damage conditions evaluated from the

routine inspection can be divided into three scenarios, namely normal condition, general abnormality, and severe abnormality.

**Table 4.4.3 Scope of routine inspection and evaluation standard**

Item	Scope of inspection	Description of evaluation	
		General abnormality	Severe abnormality
Tunnel portals	Hazardous rocks, standing water or snow on side (front) slope; icicles around the tunnel portal; silt in the side drains; crack, tilt, or settlement in the structure.	There are potential hazards of rockfall, waterstagnation, and snow; part of the tunnel portal is covered by icicles; crack, tilt, and settlement occurred in a part of the structure which may affect traffic.	Rocks are falling freely down the cliff, water stagnation or snow avalanche; icicles falling on the road; cracking, tilting, and settlement in the structure are threatening the structure's stability; and blocked side drains, which have affected traffic.
Tunnel frames	Structural crack, tilt, settlement, faulting, delamination, chipping; water leakage (icicles).	Delamination and chipping occurred in the sidewalls, and water leaking or getting iced but yet to affect traffic.	Chipping appears in and around the arch; the existence of water oozing or icicles, etc. which have affected traffic.
Linings	Structural crack, fault, delamination, and chipping.	Lining delamination and chipping occurred in the sidewalls, yet to affect traffic but maybe a risk in the future.	Lining delamination and chipping occurred in the arch, which has affected traffic.
	Water leakage	Water leaking but yet to affect traffic.	Massive water leaks which have affected traffic.
	Icicles and ice columns	Icing up, but yet to affect traffic.	Icicles and ice columns formed in the arch, which have affected traffic.
Pavements	Falling objects, oil stain; perched water or ice buildup; road heave, pothole, crack, and fault, etc.	Falling objects, the existence of perched water, ice buildup, and cracking, but yet to affect traffic.	Objects are falling from the arch, massive perched water, ice buildup, or cracking, which have affected traffic.
Maintenance paths	Structural defect; cover plate defect; handrail deformation and damage.	Handrail deformation and damage; cover plate defect; and structural damage, but yet to affect traffic.	The handrail is locally damaged or has encroached into the structural gauge; and defective road structure, which has affected traffic.
Drainage facilities	Defect, blockage, water stagnation and iced up	Defect, waterstagnation, or icing up, but yet to affect traffic.	Blocked drainage pipe, water stagnation, iced up, and drainage facilities is severely damaged, which have affected traffic.
Ceiling and built-in elements	Deformation, defect and water leakage (icicles)	Defect and water leakage, but yet to affect traffic.	Severe defect or ceiling leaks, which have affected traffic.

continued

Item	Scope of inspection	Description of evaluation	
		General abnormality	Severe abnormality
Interior decoration	Dirt, deformation, and defect	Defective, but yet to affect traffic.	Severe defect, which has affected traffic.
Signs, markings, and delineators	Intact or not.	Dirty and missing parts that may affect traffic safety.	Basic parts missing or badly incomplete and affect traffic safety.

3 If a tunnel is found with general abnormality during a routine inspection, it shall be monitored and observed or further inspection to be carried out. Appropriate treatment measures shall be taken if a tunnel is found with severe abnormality during a routine inspection. If the causes and details of the abnormality are unclear, periodic inspection or special inspection shall be carried out.

4.4.4 The frequency of periodic inspection shall be determined based on the technical conditions of the tunnel, preferably should be once per year or a period not exceeding three years. A periodic inspection shall be conducted when the technical condition assessment of important structures carried out during the routine inspection that reveals individual condition values of 3 or 4. Periodic inspection should generally be arranged in spring or autumn. The newly constructed tunnel shall have the first periodic inspection within the first year of service after delivery.

4.4.5 By conducting the periodic inspection, the technical and functional conditions of the structure shall be comprehended systematically; technical condition assessment of tunnel structure shall be carried out to provide a basis for the formulation of the maintenance plan, which shall comply with the following provisions:

- 1 Visual inspection or measurement inspection to be carried out with the necessary inspection tools or equipment during the periodic inspection. During the inspection, it is required to stay as close as possible to the structure to inspect each structural part, to observe if any new abnormalities and the development of pre-existing abnormalities; the structure with abnormality shall be marked and labeled at the appropriate position; besides, the inspection result should be quantifiable.
- 2 Refer to Table 4.4.5 for the scope of periodic inspection.

**Table 4.4.5 Scope of periodic inspection**

Item	Scope of inspection
Tunnel portals	Symptom and trend of development of landslide and rock toppling; opening, gully, undercurrent, gushing water, subsidence, and collapse of side slope, toe berm, and berm and their development trend.
	Location, extent, and degree of the crack, joint, tilting, bulging, sliding and subsidence of slope protection and earth retaining wall; surface weathering, weep hole blockage, water stagnation behind the wall, foundation problems and gap as well as their extent.
Tunnel frames	Location, width, length, extent, or degree of the crack in walls.
	Extent, displacement, and development trend of the structure tilting, settlement, and fracturing.
	Widening and outward trend of circumferential crack at the connection between tunnel and portal.
	Extent and depth of delaminated and chipped concrete; whether rebar has been exposed and corroded.
	Extent and degree of loss of backfill behind walls.
Linings	Location, width, length, extent or degree of the crack in linings; width and misalignment of the wall construction joint.
	Extent and depth of delaminated and chipped surface lining.
	Location, volume, turbidity, and degree of freezing of water leakage in linings.
Pavements	Extent and degree of road buckling, settlement, fault, cracking and slippage; extent and degree of water stagnation, and ice buildup on the road surface.
Maintenance paths	Location and condition of damage in the maintenance path and cover plate; location and condition of deformation, corrosion, and damage in the handrail.
Drainage facilities	Degree of structural damage, completeness of central manhole cover and side drain cover plate, condition of water leakage in the cracked pipeline; condition of siltation, sediment, perched water, and ice buildup in the drainage ditch (pipe) and sump.
Ceiling and built-in elements	Location and degree of deformation and damage in ceiling roof; whether the hangers and other built-in elements still intact, whether corroded or fall off as well as other phenomena that endangering the safety; extent and degree of water leakage (icicles).
Interior decorations	Extent and degree of dirt and damage in the surface; extent and degree of deformation and defect in the decorative sheet.
Signs, markings, and delineators	Condition of appearance defect and surface dirt, whether the condition of fixed fastener and luminosity satisfy the requirements.

- 3 The “Periodic inspection record form” ( Appendix A.0.2 ) shall be completed at the site with the inspection data and degradation details shown in the “Tunnel sketch” ( Appendix A.0.3 ). If the condition value exceeds 2, video recordings shall be made to record the defects or conditions of structural degradation in a detailed and accurate manner, to analyze the causes and assess the technical condition of structures.

- 4 The special inspection shall be carried out if any item with a condition value of 3 or 4 is found during the periodic inspection where its causes and details are unclear.
- 5 Tunnel structure periodic inspection report shall be prepared upon completion of the periodic inspection, which shall include:
  - 1) Inspection record, tunnel sketch, and relevant survey information, etc. ;
  - 2) Technical condition assessment of tunnel structure ;
  - 3) Evaluation and suggestions concerning the maintenance and repair condition of tunnel structure ;
  - 4) Recommendation for a special inspection, if necessary ;
  - 5) Recommendation for treatment measures, if necessary.

4.4.6 By conducting the emergency inspection, the conditions of structural damage shall be timely comprehended to provide a basis for the implementation of countermeasures, which shall comply with the following provisions:

- 1 The inspection methods, tools, and equipment shall be decided based on the structures affected by the abnormal event.
- 2 In principle, the scope and methods of emergency inspection shall be the same as those of the periodic inspection. However, a thorough inspection shall be carried out for the structure or structural part with an abnormality or affected by the abnormal event to comprehend the conditions of damages.
- 3 The standard for inspection evaluation shall be the same as that of periodic inspection. The special inspection shall be carried out if the causes and degree of defects are difficult to be determined.
- 4 The record of inspection results shall be the same as that of periodic inspection. Upon completion of the inspection, an emergency inspection report shall be prepared to summarize the scope of the inspection and its results, evaluate the impact of the abnormal event and determine the reasonable countermeasures.



4.4.7 By conducting the special inspection, the detailed information of defects or structural degradation shall be completely comprehended to provide a technical basis for the implementation of treatment and selection of treatment measures, which shall comply with the following provisions:

- 1 The targeted items, the scope of the inspection, and its requirements shall be objectively determined based on the results of routine inspection, periodic inspection, or emergency inspection and may be selectively implemented following Table 4.4.7.

**Table 4.4.7 Special inspection items**

Inspection items		Scope of inspection
Structural deformation inspection	Highway alignment and height inspection	Measurement of highway centerline location, pavement height, curb height and longitudinal and traverse gradients
	Tunnel cross-section inspection	Measurement of tunnel cross-section and wall displacement (comparison with adjacent or perfect cross-section)
	Convergence inspection	Measurement of tunnel convergence (comparison with its changes)
Crack inspection	Crack survey	Location, width, length, extent or degree of crack
	Crack monitoring	Development trend and rate, direction and depth of the crack
Leak inspection	Water leakage survey	Location, volume, turbidity, and freezing of water leakage and condition of existing waterproofing and drainage facilities
	Water leakage testing	Water temperature, pH value check, conductivity testing, and water chemistry analysis
	Waterproofing and drainage facilities	Condition of blockage and damage
Material inspection	Lining strength test	Simple strength determination test, core test, and various strength tests
	Lining surface structural degradation	Delamination, chipping, honeycomb, scaling, opening or hole, exposed rebar, etc.
	Measurement of carbonation depth in concrete	Measurement of the carbonation depth in concrete using phenolphthalein solution
	Measurement of rebar corrosion	Chisel test method, electrochemical method, and comprehensive analysis method

continued

Inspection items		Scope of inspection
Lining and surrounding rock mass condition inspection	Non-destructive test	Non-destructive tests for lining thickness, cavity, crack and water leakage, etc. ; and the location of rebar, steel arch and lining reinforcement and the thickness of the cover layer, condition of the surrounding rock mass, the degree of compactness of fill layer in the inverted arch and the development of karstic features
	Borehole inspection	Measurement of the lining thickness through drilling, observation of the internal condition of the lining and surrounding rock mass with borehole televiewer
Loading condition inspection	Lining stress and extrados pressure test	Stress and its changes on the different parts of lining, distribution, and changes of the extrados pressure
	Water pressure test	Magnitude, distribution and change rules of water pressure exerted on the lining for the tunnel in an aquifer

- 2 The inspector shall carry out a desk study on the relevant technical data and files and followed by site reconnaissance for the geological and topographical survey around the tunnel.
- 3 For severely adverse geological zone, major structural degradation, or potential hazards, long-term monitoring should be carried out during operating phrase to observe its long-term structural deformation, stresses, and groundwater conditions. Monitoring frequency should follow the routine inspection. When the development rate of the monitored parameter is found changing rapidly, the monitoring frequency shall be increased.
- 4 Upon completion of the inspection, a special inspection report shall be prepared, which shall include:
  - 1) Key information of the inspection, including implementing organization, time and main process of the inspection;
  - 2) Technical condition of the structure inspected, including inspection methods/tests, test items, and scope of testing, test data and analysis results as well as the assessment of the defect conditions;
  - 3) Analysis of the causes, extent, and degree as well as other conditions of the defects or structural degradation, and recommendations on maintenance and treatment strategies, technologies, workscope and costs as needed.

## 4.5 Technical condition assessment of tunnel structure

4.5.1 The technical condition assessment of tunnel structure shall be based on the information gathered from periodic inspection by considering comprehensively the impacts from tunnel frame, structure, pavement, and associated facilities to determine the score for the technical condition of the tunnel. During the special inspection, technical condition assessment should be carried out for the inspected items as specified in this *Specification*.

4.5.2 The technical condition assessment of tunnel structure shall be classified into Category 1, Category 2, Category 3, Category 4 and Category 5. Refer to Table 3.2.2 for the description of the assessment category and maintenance strategy. The determination of condition value for the technical condition of individual item of tunnel structure shall be based on the fundamental technical condition of the tunnel from zone to zone. The assessment results shall be recorded in the form “Technical condition assessment of tunnel structure” (Appendix B Table B-11).

4.5.3 Refer to Appendix B Table B-1 ~ Table B-10 for the standard of technical condition assessment of each item such as the tunnel portal, tunnel frame, lining structure, lining leakage, pavement, maintenance path, drainage facilities, ceiling, interior decoration, traffic signs, and markings.

4.5.4 The assessment method for the technical condition of a tunnel structure shall comply with the following provisions:

- 1 The score for the technical condition of tunnel structure can be calculated by Equation (4.5.4-1).

$$JGCI = 100 \cdot \left( 1 - \frac{1}{4} \sum_{i=1}^n (JGCI_i \times \frac{w_i}{\sum_{i=1}^n w_i}) \right) \quad (4.5.4-1)$$

Where:  $w_i$ — itemized weightage;

$JGCI_i$ — individual condition value, with a range from 0 ~ 4.

- 2 The individual condition value can be calculated by Equation (4.5.4-2).

$$JGCI_i = \max(JGCI_{ij}) \quad (4.5.4-2)$$

Where:  $JGCI_{ij}$ — condition value for each inspection zone,

$J$ — inspection zone number, subject to the actual number of zones.

3 Refer to Table 4.5.4-1 for the weightage of individual item of tunnel structure.

**Table 4.5.4-1 Weightage for individual item of tunnel structure**

Item	Itemized weightage $w_i$	Item	Itemized weightage $w_i$
Tunnel portal	15	Maintenance path	2
Tunnel frame	5	Drainage facilities	6
Lining	Structural damage	Ceiling and built-in elements	10
	Water leakage		2
Pavement	15	Traffic sign and marking	5

4 Refer to Table 4.5.4-2 for the classification threshold for technical condition assessment of tunnel structure.

**Table 4.5.4-2 Classification threshold for technical condition assessment of tunnel structure**

Technical condition score	Classification of technical condition assessment of tunnel structure				
	Category 1	Category 2	Category 3	Category 4	Category 5
$JGCI$	$\geq 85$	$\geq 70, < 85$	$\geq 55, < 70$	$\geq 40, < 55$	$< 40$

5 When the individual condition value for tunnel portal, tunnel frame, lining, pavement, ceiling, and built-in elements achieves 3 or 4 in the tunnel structure technical condition assessment, the corresponding tunnel structure technical condition shall be directly classified into Category 4 or 5.

4.5.5 In the technical condition assessment of highway tunnel, the technical condition assessment of tunnel structure shall be classified into Category 5 if it falls within any of the following conditions:

- 1 The side and front slopes at tunnel portal become unstable and severe landslide and rock falling happen.
- 2 The tunnel frame structure has extensive cracking, cracking in masonry and fall-off, which may endanger the safety of traffic.
- 3 The tunnel arch lining has extensive cracking and the structural cracking runs deep through the lining concrete.
- 4 Obvious permanent deformation occurs in the tunnel lining structure and tends to endanger the structure safety and traffic safety.

- 5 There are such problems as massive groundwater intrusions and injection, gushing mud onto pavement or extensive standing water that threatens traffic safety.
- 6 Severe upheaval occurs in tunnel pavement and the severe faulting and cracking of road slab seriously affect traffic safety.
- 7 Severe corrosion or cracking occurs in the built-in elements and suspensions on tunnel roof and the cable trays and widgets have severe deformation or fall-off.

4.5.6 Different maintenance measures shall be taken for different tunnel structures based on assessment classification:

- 1 Normal maintenance shall be conducted for the Category 1 tunnel.
- 2 Maintenance and repair shall be conducted as needed for Category 2 tunnel or a tunnel with an individual condition value of 1.
- 3 Structural degradation treatment shall be locally implemented for Category 3 tunnel or a tunnel with an individual condition value of 2.
- 4 Traffic control shall be conducted while structural degradation treatment to be implemented as soon as possible for the Category 4 tunnel.
- 5 Category-5 tunnel shall be closed immediately to implement structural degradation treatment.
- 6 When the individual condition value of other items other than key items is 3 or 4, structural degradation treatment shall be implemented as soon as possible.

## 4.6 Maintenance and repair

4.6.1 Maintenance and repair of tunnel structure shall include regular or preventative maintenance and maintenance for slightly defective parts, in order to restore and keep proper use of structures.

4.6.2 Maintenance and repair shall be conducted when any general abnormality is found during the routine inspection and periodic inspection of tunnel structure and the technical condition score is below 2.

4.6.3 Hazardous rocks and regolith on the side and front slopes at the tunnel portal shall be timely removed, the side/berm drains and interception drains shall be kept intact and free-flow conditions, cracks and deformation in the slightly damaged retaining wall, tunnel frame wall, slope protection, drainage facilities, and the luminance-reduction system shall be repaired, and the flowers and trees at the tunnel portal shall be maintained. The snow and icicles on the side and front slopes shall be removed during the winter.

4.6.4 When there's hazardous rock or possibility of collapse on the side slope of cut-and-cover tunnel, it shall be removed in time, and protective excavation and other measures may be taken. The fill depth and ground surface line on the top of cut-and-cover tunnel shall remain the original design condition. In case of local accumulations due to cave-in of side slope, or a massive loss of original filling due to rainstorm and flood, measures shall be taken to adjust it to the original state so as to avoid structural deformation and damage of cut-and-cover tunnel due to serious eccentric load. The waterproofing layer of cut-and-cover tunnel shall be restored without delay in case of any failure or damage.

4.6.5 Rain, snow and sundries in the mid-hill tunnel and the stones falling from tunnel roof shall be removed immediately and the side drain shall not be blocked. The defective guardrail and parapet shall be restored and repaired in a timely manner.

4.6.6 The fractured, loose and hazardous rocks in unlined tunnel shall be treated by the principle of "Removed if Slight, Reinforced if Extensive"; the drain hole shall be connected to a water conduit to drain water via side drain with regard to the water leakage of surrounding rock mass; in winter, the icicles on tunnel roof shall be removed immediately.

4.6.7 For lined tunnels, the delaminated and chipped lining shall be removed promptly; cracks in the lining shall be repaired in a timely manner and observation marks shall be made for follow up monitoring; water conduit shall be used to intercept the leaking water from lining and drain it to side drains; any icicles on tunnel roof shall be removed.

4.6.8 Falling objects (fallout) and debris inside or outside the tunnel shall be removed promptly. Manhole covers or cover plates of other facilities shall be repaired or replaced in a timely manner. In case of water leaking from the road surface, it shall be handled immediately by draining the water to side drains to avoid water stagnation or ice buildup on the pavement.

4.6.9 It is not allowed to put any non-relief supplies in horizontal adit and the sundries shall be removed immediately and slightly damaged structures shall be repaired; the gate of horizontal adit shall be maintained regularly and the horizontal adit shall be clean and smooth.

4.6.10 The foreign matters in inclined (vertical) shaft that may damage the ventilation facilities or affect ventilation effect shall be removed immediately; the drainage facilities in the shaft shall be intact and the trench (pipe) shall be unblocked; and the inspection passage or facility in the shaft shall be maintained to avoid corrosion or damage.

4.6.11 The mesh of intake (exhaust) vent shall be cleaned to remove sundries blocking the mesh; the duct board hanger shall be maintained regularly to avoid corrosion or damage; the defective exhaust vent or duct shall be repaired immediately and the damaged duct board shall be replaced.

4.6.12 The drainage facilities in and outside tunnel shall be intact and any defect or missing shall be repaired in time; if the drainage pipe is blocked, it may be dredged with high-pressure water or compressed air. The debris in drainage facilities such as side drains, central drains and sediment basins shall be removed immediately and the drain cover plates and drain walls shall be inspected irregularly to repair the defective and warping cover plate in time. In cold regions, the ice blocking drains shall be removed immediately. Anticorrosive treatment shall be carried out for metal drainage pipe.

4.6.13 The ceiling and interior decorations shall keep intact and tidy. In case of any defects and missing, they shall be repaired immediately. In the event of failure to repair, they shall be replaced appropriately. The built-in elements and cable bridges shall keep intact and firm without any corrosion. They shall be replaced or fastened in case of any defects.

4.6.14 The sidewalk or maintenance path shall be flat, intact and smooth and free from standing water. The board shall be repaired and supplemented in case of any defect, warping or missing; the sidewalk or maintenance path guardrail shall be maintained regularly and the guardrail shall keep intact, clean and firm without any corrosion; the column shall be upright and stable; and the cross bar shall be firmly connected, and it shall be restored in time if any defects.

4.6.15 The following special maintenance shall be carried out for tunnels in cold regions:

- 1 The anti-freezing insulation facilities of tunnels in cold regions shall be well maintained and repaired in case of any damage to ensure their proper function of use.
- 2 The tunnel with snow protection facility at the tunnel portal shall be well maintained and the facility shall be maintained and reinforced before heavy snow; in winter, the snow at the tunnel portal shall be removed in time.

4.6.16 The tunnel traffic signs shall be kept with intact appearance, clear and accurate

information at an appropriate location, height, and angle, to ensure that traffic information is correctly transmitted to drivers. The following provisions shall be complied with:

- 1 Any deformed and defective signboards shall be timely repaired, any curved and tilted supports shall be corrected, and loose connecting elements shall be fastened.
- 2 The corroded signs with ageing failure shall be replaced in time and the missing signs shall be supplemented immediately.
- 3 Damaged height restriction barriers and speed limiting devices shall be repaired in a timely fashion.

4.6.17 The tunnel traffic markings shall be kept intact, clean, and conspicuous. The following provisions shall be complied with:

- 1 Severely damaged, missing or loose markings shall be repaired or replaced immediately.
- 2 Loose road signboards shall be fastened promptly. They shall be repaired or replaced immediately if they are found damaged or missing.

4.6.18 The delineators of tunnel shall keep intact, clean and eye-catching and be repaired or replaced immediately in case of any damage or missing.

## 4.7 Structural degradation treatment

4.7.1 Structural degradation treatment includes restoration of the damaged structure, removal of structural degradation, resumption of the structural design standard requirements and maintaining good technical functionality; and shall comply with the following provisions:

- 1 Before the determination of degradation treatment plan, testing and analysis shall be conducted on the degraded tunnel to assess the causes, extent, degree, and development trend of damage or degradation.

- 2 Tunnel degradation condition, topography, geology, the ecosystem as well as the operation and construction requirements shall be considered comprehensively in the treatment design to produce a reasonable treatment plan. The treatment plan may consist of one or a combination of various treatment methods.



3 In treatment design and construction, the engineering risk assessment shall be conducted based on the degree of degradation, geological condition and treatment plan to work out corresponding emergency plans.

4 Construction organization plan shall be prepared for tunnel treatment implementation.

5 After the completion of degradation treatment works, the individual condition value of the treated zone shall be demonstrably 0 or 1.

4.7.2 The preparation of structural degradation treatment plan shall satisfy the following requirements:

- 1 In principle, the original technical standard of the tunnel shall not be compromised.
- 2 It shall be determined by comparing different options and technologies as well as the economic aspect of the principles of safety, economy, speed of construction, and rationality.
- 3 The treatment design shall demonstrate the concept of information-based design and dynamic construction, the instrumentation monitoring plan shall be proposed.
- 4 The construction impact on the tunnels normal operation shall be minimized as far as possible. The traffic management plan shall be proposed for minimising interruption to traffic flow.
- 5 Corresponding measures shall be taken to diminish the adverse impacts of treatment construction on existing structures, drainage facilities, M&E equipment and associated facilities.

# 5 M&E equipment

## 5.1 General provisions

5.1.1 Maintenance of M&E equipment includes daily patrol, cleaning, and maintenance, M&E inspection, repair and assessment, specialist works.

- 1 Daily patrols generally by way of visual inspection conducted by patrol car personnel or via foot patrol and other information-based approaches on the appearance and operating conditions of M&E equipment and documentation of the inspection results promptly.
- 2 Cleaning and maintenance refer to daily cleaning for the appearance of tunnel M&E equipment to ensure a clean and tidy appearance.
- 3 M&E inspection, repair, and assessment refer to the inspection carried out on the M&E equipment readiness, systematic comprehension, and assessment on the technical condition of M&E equipment, determination of the corresponding maintenance strategies, or measures. M&E inspection and repair mainly include regular inspection, periodic inspection, and emergency inspection.
  - 1) Regular inspection refers to the inspection of instrument reading, operating status, or damage condition of the equipment by walkover inspection or using simple tools, qualitative evaluation of the inspection results, and timely repair and replacement of the defective parts.
  - 2) Periodic inspection refers to the comprehensive inspection of the operating status and performance of M&E equipment through testing instruments as well as its calibration and repair.

- 3) Emergency inspection refers to the inspection and repair of highway tunnel or relevant M&E equipment as a result of abnormal events, major accidents, or natural disasters.
  - 4 Specialist work refers to the centralized and systematic repair of M&E equipment to fulfill their original technical standards. Specialist work may be activated according to the operating status of the equipment.
- 5.1.2 Maintenance personnel shall be trained to master the key usage and technical characteristics of the facilities. Special training shall be provided in line with the relevant national regulations and the personnel shall be certified before undertaking a special type of work.
  - 5.1.3 The maintenance of M&E equipment shall ensure that the technical conditions of all equipment meet the requirements of product specifications, design documents, and the relevant specifications.
  - 5.1.4 The technical condition assessment of highway tunnel M&E equipment shall be conducted not less than once per year. Technical Condition Assessment Form in Appendix C.0.1 shall be used.
  - 5.1.5 The maintenance of M&E equipment shall take into consideration the safety of vehicles and maintenance personnel and shall comply with the relevant provisions in Chapter 7 hereof.
  - 5.1.6 The maintenance of M&E equipment shall be equipped with special electrical tools, testing instruments, cleaning tools, and safety protection equipment. In an expressway, overhead working equipment shall also be provided. Such special tools and appliances shall be inspected regularly. For instance, the high voltage insulation test shall be performed at least once every six months, the calibration on testing instruments shall be performed at least once per year, and the inspection for safety protection equipment and overhead working equipment shall be performed at least once every six months.
  - 5.1.7 The maintenance of M&E equipment shall accurately record the inspection results of each piece of equipment and establish special technical files. Appendixes C.0.2 ~ C.0.3 can be used for the inspection records.
  - 5.1.8 Any breakdown of M&E equipment shall be accurately recorded and special technical files shall be established. Appendix C.0.4 can be used for the breakdown record.
  - 5.1.9 The M&E equipment breakdown record shall be reported and submitted monthly as per Appendix C.0.5.

5.1.10 Joint calibration and testing shall be conducted regularly for M&E equipment under the contingency plan.

## 5.2 Daily patrols

5.2.1 Daily patrols shall be conducted for the M&E equipment to check whether they are in normal working conditions or having potential troubles, and conforms to the following provisions:

- 1 For the daily patrol of power supply and distribution facilities, the inspector shall observe the appearance and operating conditions of the transformer, high-and-low voltage distribution cabinet, and relevant equipment in the distribution substation, and evaluate if there is any abnormality such as damage to the appearance, noise, heating, smell, and discharge.
- 2 For the daily patrol of the lighting facilities, the inspector shall observe their appearance and operating conditions, and evaluate if there is any abnormality.
- 3 For the daily patrol of the ventilation facilities, the inspector shall observe their appearance and operating conditions, and evaluate if there is any potential hazard.
- 4 For the daily patrol of the fire-fighting facilities, the inspector shall observe their appearance and evaluate if there is any abnormality.
- 5 For the daily patrol of monitoring and communication facilities, the inspector shall check the appearance and main functions of all monitoring equipment, information collection, and dissemination system inside the tunnel, monitoring equipment in the monitoring room, and evaluate if there is any abnormality.

5.2.2 The frequency of daily patrols for expressways shall not be less than once per day. For other classes of road, it can be once per day or once in three days. In case of extreme weather and large traffic volume, daily patrol shall be conducted more frequently.

5.2.3 Daily patrols can adopt a combination of both manual and information-based methods. When an abnormality is discovered, the inspector shall report and make a record including taking photos and videos when necessary.

## 5.3 Cleaning and maintenance

5.3.1 Cleaning and maintenance shall be conducted for M&E equipment according to its maintenance class, traffic composition, the impact of dirt on its functionality, cleaning methods, and environmental conditions. The frequency of cleaning and maintenance should be not less than that specified in Table 5.3.1.

**Table 5.3.1 Frequency of cleaning and maintenance for M&E equipment**

Cleaning item	Maintenance class		
	Class I	Class II	Class III
Power supply and distribution facilities	Once / month	Once / quarter	Once /half-year
Lighting facilities	Once / quarter	Once /half-year	Once / year
Ventilation facilities	Once / two-year	Once / three-year	Once / four-year
Fire-fighting facilities	Once / quarter	Once /half-year	Once / year
Monitoring and communication facilities	Once / quarter	Once /half-year	Once / year

5.3.2 If wet cleaning is adopted for the M&E equipment, attention shall be paid to the safety of personnel and electrical elements of the M&E equipment to prevent liquid from infiltrating the equipment. If dry cleaning is adopted, necessary measures shall be taken to reduce dust; if dust cannot be removed by such method, a cleanser may be used for local special treatment if it can be removed by wet cleaning after due consideration.

5.3.3 The cleaning and maintenance of M&E equipment shall ensure its appearance is clean, tidy, and free from dirt, and ensure that they are in good condition.

5.3.4 Cleaning of M&E equipment shall include the equipment specified in Table 5.3.4.

**Table 5.3.4 Equipment to be cleaned for highway tunnel M&E equipment**

System	Equipment
Power supply and distribution facilities	All power equipment, box-type substation, field distribution box, socket box and control box in a distribution substation
Lighting facilities	In-tunnel luminaries and off-tunnel road luminaries
Ventilation facilities	Axial fan & jet fan
Fire-fighting facilities	Hydrants and water pump adapters, fire extinguishers, fire alarm facilities, water spray control valves, and nozzles, gas fire-extinguishing facilities, electro-optic signboards, etc.
Monitoring and communication facilities	All kinds of detectors, closed-circuit televisions (CCTV), cable broadcasting, emergency telephones, the gate of horizontal adits, traffic control and guiding devices, controllers (control boxes), optical transceiver, switch, etc.

## 5.4 Inspection and repair for power supply and distribution facilities

5.4.1 Key elements and frequency of the regular and periodic inspection and repair for power supply and distribution facilities are listed in Table 5.4.1.

**Table 5.4.1 Key elements and frequency of the regular and periodic inspection and repair for power supply and distribution facilities**

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
High-voltage circuit breaker cabinet *	Circuit breaker contact & vacuum bubble	1 Whether the contact is burnt out, whether the contact is tight, whether the centers of the dynamic and static contacts align with each other.		✓
		2 Whether the contact or vacuum bubble is damaged.		✓
		3 Whether the operating mechanism works normally, and whether the switch-on/off time meets the requirements of the manufacturer.		✓
	“Five-prevention” function	1 Whether the handcart can be pulled out or added to when the circuit breaker is set at the switch-off position.		✓
		2 Whether the primary and secondary circuits work normally when the handcart is at different positions.		✓
		3 Whether the mechanical interlocks between circuit breaker and earthing switch work normally.		✓
		4 Whether the upper and lower gates behind the cabinet interlock normally.		✓
		5 Whether the control switch ( or anti-misoperation socket ) with the key on the instrument panel works normally.		✓
	Wall bushing	Whether the wall bushing is defective.		✓
	Exhaust duct	Whether the exhaust duct is blocked.		✓
	Secondary terminal	Whether the terminal is contaminated or loose.		✓
	Coil	Whether the coil insulation works normally.		✓
	Switch-on/off test	1 Whether it switches on or off normally.		✓
		2 Whether the electromagnetic spring operating mechanism is blocked or works normally.		✓
	Operation	1 Whether the electrical setting value meets the requirements of the power system.		✓
2 Whether the protection device can coordinate with the central signal system.			✓	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
High-voltage transformer and arrester cabinet *	High-voltage transformer	Whether it is contaminated or cracked, and whether its insulation works normally.		√
	Arrester	1 Whether the arrester's appearance is defective.		√
		2 Whether it has a sign of discharge.		√
		3 Whether the earthing device is corroded.		√
		4 Preventive test		√
High-voltage measuring cabinet	Current transformer	Whether it is contaminated or defective, and whether its insulation works normally.		√
	Meter	1 Whether the meter is contaminated and whether its readings are accurate.	√	
		2 Meter inspection shall be subject to "Meter" in "Power Capacitor Cabinet".		√
High voltage isolation switch and load switch *	Contact	1 Whether it is contaminated or defective.	√	
		2 Whether the contact is tight.	√	
		3 Whether the arc extinguishing device is burnt out.	√	
High voltage isolation switch and load switch *	Operating mechanism	1 Whether it is contaminated.	√	
		2 Whether it is blocked and works normally.	√	
	Load switch	1 Whether the contact is burnt out, whether the contact is tight, whether the centers of dynamic and static contacts align with each other.		√
		2 Whether the operating mechanism works normally, and whether the switch-on/off time meets the requirements of the manufacturer.		√
		3 As for the device consisted of SF <sub>6</sub> insulation and arc extinction, shall observe whether the air leakage rate of its shell conforms to the provisions of the manufacturer.	√	
	High-voltage fuses	1 Whether its appearance is contaminated or burnt out.	√	
2 Whether the fuse is broken.		√		

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
35kV power Transformer *	Assembly	1 Whether there is contamination or oil leakage, and whether there is sufficient oil.	√	
		2 Whether there is abnormal sound or overheating.	√	
		3 Whether the noise is satisfactory.	√	
		4 Whether the direct-current resistance of the internal coil meets the provisions of the manufacturer.		√
		5 Whether the inner phase-phase insulation, coil-coil insulation, and ground insulation are satisfactory.		√
		6 Whether the nameplate is contaminated.		√
		7 Whether the insulation sleeve is contaminated or cracked.		√
		8 Whether the wiring terminal is contaminated or loose.		√
		9 Transformer oil high-voltage insulation test		√
10kV power transformer *	Assembly	1 Whether there is abnormal sound or overheating.	√	
		2 Whether the noise is satisfactory.	√	
		3 Whether the direct-current resistance of the internal coil meets the provisions of the manufacturer.		√
		4 Whether the inner phase-phase insulation, coil-coil insulation, and ground insulation are satisfactory.		√
		5 Whether the nameplate is contaminated.		√
		6 Whether the insulation sleeve is contaminated or cracked.		√
		7 Whether the wiring terminal is contaminated or loose.		√
		8 Check the transformer ratio of all taps		√



continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Box-type substation *	Assembly	1 Whether the box shell is contaminated or defective or rusty.	√	
		2 Whether the room temperature and humidity are satisfactory.	√	
		3 Whether the noise is satisfactory.	√	
		4 Whether cable entry or exit is blocked tightly.	√	
		5 Whether the ground resistance around the box is satisfactory.		√
		6 Whether the electric appliances are connected reliably, and whether they are loose or heating.		√
		7 The inspection of indoor electrical elements shall be conducted as per the relevant contents herein.		
Power capacitor cabinet *	Power capacitor	1 Whether its appearance is contaminated and whether its contact is loose.	√	
		2 Whether there is oil leakage, overheating, or swelling.	√	
		3 Whether its insulation works normally and whether there is a punch-through.	√	
	Contactor	1 Whether there is a mechanical blockage, and whether the noise is satisfactory.	√	
		2 Whether the direct-current resistance of the coil meets the provisions of the manufacturer.	√	
		3 Whether its contact is burnt out, whether the contact is tight, whether the centers of the dynamic and static contacts align with each other.	√	
		4 Whether it can work normally.	√	
		5 Whether its lead connector is contaminated or loose.	√	
	Controller	Whether it works normally.	√	
	Fuse	1 Whether it is burnt out.	√	
		2 Whether its electric fuse is in good condition.	√	
	Meter	1 Whether its appearance is contaminated.	√	
		2 Whether it displays normally.	√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Low-voltage switch cabinet *	Circuit breaker	1 Whether its appearance is contaminated or cracked.	√	
		2 Whether its contactor is burnt out and whether the contact is tight.	√	
		3 Whether there is obvious sound.	√	
		4 Whether its trip unit works properly.	√	
		5 Whether its insulation works normally.	√	
		6 Whether its setting value meets the requirements of the system protection.	√	
		7 Whether its lead connector is contaminated or loose.	√	
	Contactor	It shall be subject to "Contactor" in "Power Capacitor Cabinet".		
	Transformer	1 Whether it is contaminated.	√	
		2 Whether its insulation works normally.	√	
		3 Whether its external wire is disconnected.	√	
	Fuse	Subject to "Fuse" in "Power Capacitor Cabinet".		
	Thermal relay	1. Appearance inspection 1) Whether its shell is clean, complete, and connected well. 2) Whether its shell is connected to base firmly, whether the dust-proof seal is in good condition and whether it is installed well.	√	
2 Internal and mechanical inspection 1) Whether its thermoelement is burnt out. 2) Whether its incoming and outgoing thread ends fall off. 3) Whether its wiring screw is tightened up. 4) Whether its contact is burnt out or whether the elasticity of the dynamic contact rod disappears			√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Low-voltage switch cabinet *	Thermal relay	5) Whether its bimetallic sheet is deformed. 6) Whether its actuating mechanism is jammed. 7) Whether its inside is clean. 8) Whether its setting handle can be fixed reliably in the setting position. 9) Whether its contact is firmly fixed.		√
		3 Validation 1) General validation 2) The error between the setting action value and the setting value should not exceed $\pm 3\%$ .		√
	Secondary circuit	Whether the terminal strip is contaminated or whether the wiring is loose.	√	
	Meter	It shall be subject to "Meter" in "Power Capacitor Cabinet".		
	Dual-power-supply changeover switch	1. Appearance inspection 1) Whether its shell is clean, complete, and connected well. 2) Whether its shell is connected to base firmly, whether the dust-proof seal is in good condition and whether it is installed well.	√	
2 Internal and mechanical inspection 1) Whether its terminal wiring is firm and reliable. 2) Whether its components are worn or damaged. 3) Whether its terminal is corroded. 4) After the handle turns, whether the static and dynamic contacts are closed or opened at the same time. 5) Whether its movable parts are flexible, and whether the rotating location is reliable and correct. 6) Whether it is short-circuiting between switch terminals. 7) Whether its control is satisfactory. 8) Whether its components are installed well, whether its screws are tightened, and whether its welding head is firm.			√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Distribution box, socket box, and control box *	Circuit breaker	Subject to "Circuit Breaker" in "Low-voltage Switch Cabinet".		
	Contactor	Subject to "Contactor" in "Power Capacitor Cabinet".		
	Fuse	Subject to "Fuse" in "Power Capacitor Cabinet".		
	Secondary circuit	Subject to "Secondary Circuit" in "Low-voltage Switch Cabinet".		
	Cabinet	Whether it is earthed properly.	√	
	Lighting control box	1 Whether its programmable control program is correct.	√	
		2 Whether the automatic centralized control manual operation is correct.	√ (once / week)	
	Fan start and control cabinet	1 Whether it is corroded or water-logged	√	
2 Whether the contract is good.		√		
Power cable *	Assembly	1 Whether its appearance is damaged.	√	
		2 Whether the wire-wire insulation, phase-phase insulation, and ground insulation work normally.		√
		3 Whether the joint is normal and whether it is burnt out.		√
		4 Whether the cable trench is clean, whether there is debris, standing water or oil, and whether the cover plate is complete.		√
		5 High-voltage overhead lines and cable lines and associated facilities inspection	√	
		6 High-voltage overhead lines and associated facilities lamppost-inspection		√
Cable bridge, cable tray, cable bracket, and cable support	Assembly	1 Whether its appearance is deformed or disconnected.		√
		2 Whether each component is connected firmly.		√
		3 Whether it is corroded.		√
		4 Whether it is earthed properly.		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Substation steel structure elements	Assembly	Whether it is corroded.		√
Integrated microcomputer protection device *	The hardware equipment of the master station	1 Check the running status of hardware equipment	√ (once / day)	
		2 Check system clock	√ (once / month)	
		3 Data saving, backup equipment defragment	√ (once / day)	
		4 Cable inspection and connector tightening	√	
		5 Check equipment lightning-protection performance and earth resistance		√
	The hardware equipment of sub-station	1 Check the running status of hardware equipment	√ (once / day)	
		2 Cable inspection and connector tightening	√	
		3 Dust removal and cleaning of communication management equipment		√
		4 Check equipment lightning-protection performance and earth resistance		√
	The software system of the master station	1 Data backup	√ (once / day)	
		2 Main station software test function	√ (once / month)	
		3 Log inspection	√ (once / month)	
		4 Database check	√ (once / month)	
		5 Record abnormalities, handling, system optimization, and adjustment	√ (timely)	
		6 System software upgrading and patching	√ (once / month)	
		7 Antivirus software updating	√ (once / month)	
	Communication network	Subject to “Communication Facilities” in “Monitoring and Communication Facilities”.		
	Computer equipment and software	Subject to “Monitoring Room Equipment and System” in “Monitoring and Communication Facilities”.		

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
DC power supply, uninterrupted power supply (UPS) and Emergency power supply (EPS) *	Cabinet	1 Clean appearance.	√	
		2 Check and fasten connectors.	√	
		3 Measure and record and input and output voltage.	√	
		4 Whether it is earthed properly.		√
	Battery pack	1 Whether its appearance is contaminated or damaged, whether its electrolyte is normal, and whether its temperature is normal.	√	
		2 Whether the battery voltage is normal.	√	
		3 Whether the battery insulation works normally.	√	
		4 Conduct a capacity recovery test.		√
	Charger and float charger	1 Whether the output DC voltage and current are normal.	√	
		2 Whether the rectifying device works properly.	√	
Self-generating equipment *	Operating with load for more than 30 minutes	1 Start and stop testing	√	
		2 Check oil pressure, abnormal sound, vibration and overheating	√	
		3 Determine rated revolution and voltage	√	
		4 Whether the pre-heating is normal.	√	
		5 Whether the temperature of each component is normal.	√	
		6 Whether the action state of each equipment is flexible.	√	
		7 Whether the automatically adjusting excitation is normal and whether the response time is normal.	√	
	Diesel engine	1 Whether its appearance is contaminated or defective.	√	
		2 Whether the gauge has abnormality, oil leakage, or water leakage.	√	
		3 "Three-cleaning" and replacing		√
4 Oil components		√		
5 Check whether each component is loose.		√		

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Self-generating equipment *	Generator	1 Whether its appearance is contaminated or defective.	√	
		2 Oil bearing	√	
		3 Brush ' s contact condition and wear condition	√	
	Wiring	1 Whether the wiring is reliable.		√
		2 Whether the insulation works normally.	√	
		3 Whether the temperature is normal.	√	
	Starter	1 Whether its appearance is contaminated or defective.	√	
		2 Lubricant capacity of air compressor	√	
		3 Whether the gauge is normal.	√	
		4 Whether there is abnormal sound or vibration	√	
Self-generating equipment *	Starter	5 Whether each component is contaminated or damaged, whether the oil capacity is normal and whether there is deformation or loose.	√	
		6 Whether it is to replace the lubricant.		√
		7 Whether the accessory device works normally.		√
		8 Whether the DC motor meets the starting requirements.		√
		9 Whether the DC motor works normally.		√
	Fuel unit	1 Whether its appearance is contaminated or defective.	√	
		2 Whether there is oil leakage or retention amount.	√	
		3 Whether the operating state of the pump is normal.	√	
		4 Whether the fuel filter is operated by hand reliably.	√	
		5 Action state of oil level gauge and oil leakage switch	√	
		6 Oil bearing component		√
		7 Whether the drainage pump of the oil storage tank is unblocked.		√
		8 Check whether each component is loose.		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Self-generating equipment *	Lubricant device	1 Whether its appearance is contaminated or defective.	√	
		2 Whether the fuel filter is operated by hand normally.	√	
		3 Whether the operating state of the pump is normal.		√
		4 Whether the viscosity of the oil is normal.	√	
		5 Whether the running state of the insulation device is normal.	√	
		6 Slag removal and water drainage		√
	Tower-type cooling device	1 Whether its appearance is contaminated or defective.	√	
		2 Whether the cooling water amount and water temperature are normal and whether there is leakage.	√	
		3 Operating state	√	
		4 Whether the operating state of the float valve is normal.		√
		5 Oil bearing component		√
	Radiator-type cooling device	1 Whether its appearance is contaminated or defective.	√	
		2 Whether the cooling water amount and water temperature are normal and whether there is leakage.	√	
		3 Whether the operating state of the fan is normal.		√
		4 Whether the operating state of pressure piston is normal.	√	
	Air purifier or ventilator	1 Whether its appearance is contaminated or defective.	√	
		2 Whether its running state is normal.	√	
		3 Whether exhaust color is abnormal.	√	
		4 Whether there is crack or corrosion in the exhaust pipe and support joint.		√
		5 Whether air purifier is contaminated.		√



continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Self-generating equipment *	Dampers	Whether the damping rubber or anchor bolt is deformed or damaged.	√	
	Console	1 Whether its appearance is contaminated or defective.	√	
		2 Whether the meter, display lamp, or fault indicator is abnormal.	√	
		3 Whether the operation switch, relay, electromagnetic switch, distribution circuit breaker, or other is normal.	√	
		4 Whether there is abnormal wiring inside the cabinet, contamination, damage, overheat, loose or broken wire.	√	
		5 Voltage, current and electricity measuring	√	
		6 Whether running time measurement is normal.	√	
		7 Periodic overhauling items of power supply and distribution cabinet		√
	Wire duct	Check whether each contact is loose.		√
Grounding wire	Whether there is a broken wire, and whether the state of the joint and the ground resistance are normal		√	
Lightning protection and earthing system *	Lightning protection device	1 Whether the surge protector of power supply and signal input terminal is in good condition.		√
		2 Strengthen the inspection of surge protectors during the thunderstorm season.		√
		3 Whether the external lightning protection device is installed firmly and whether the connection wire insulation is in good condition.		√
	Earthing device	1 Whether it is corroded.		√
		2 Whether its earthing insulation works normally.		√
		3 Tighten the earthing connection.		√
		4 Protect and treat the earthing connection zone.		√

Note: the equipment marked with “\*” are the key equipment of the system.

5.4.2 Maintenance of power supply and distribution facilities shall comply with the inspection and repair procedures of the relevant equipment and the relevant national provisions. Maintenance personnel shall obtain the qualification certificate for a special type of work and be equipped with dedicated electrician maintenance tools.

5.4.3 Maintenance of power supply lines shall be carried out following the relevant provisions of the power sector. When there is any abnormality in the power supply lines, measures shall be taken and report to relevant departments timely.

5.4.4 When live maintenance operation is required to be conducted for power supply and distribution facilities, it shall be implemented with close support and inter-coordination between the in-tunnel, distribution substation, and central control room and strictly comply with the relevant requirements in the electrical operating procedures.

## 5.5 Inspection and repair for lighting facilities

5.5.1 Key elements and frequency of the regular and periodic inspection and repair for the lighting facilities are listed in Table 5.5.1.

**Table 5.5.1 key elements and frequency of the regular and periodic inspection and repair for lighting facilities**

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
In-tunnel luminaries	Assembly	1 Whether the voltage is stable and whether their luminance is normal.	√	
		2 Damage and replacement of bulbs	√	
		3 Check the incoming wire and whether the electromagnetic contactor and distribution cabinet get logged.	√	
		4 Whether the timing of the switching device is accurate and whether its operation state is abnormal.	√	
		5 Painting make-up and lamp overhauling and replacement		√
		6 Whether the compensation capacitor, trigger, ballast, and contactor are damaged.		√
		7 Insulation inspection		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
In-tunnel luminaries	Installation parts	Whether they are loose or corroded.		√
	Tightness	Whether there is dust, standing water in lighting facilities, and whether the sealing is aging.		√
	Maintenance hole and hand hole	Whether there is standing water.		√
	Illumination test	The luminancetest shall be carried out after the lamp life cycle.	√ (once / six months)	
Off-tunnel road luminaries	Lamppost	1 Check whether there isa crack on its appearance, and its welding and joint condition.		√
		2 Whether thereare defects and coating damage.		√
		3 Whether the earthing terminal is loose.		√
	Foundation	1 Whether the setting condition is stable.		√
		2 Whether it is cracked or damaged.		√
		3 Whether the anchor and bolt are rusty or loose.		√
	Lamp body	1 Whether there is damage and visually check whether the luminance is normal.	√	
2 Protection level check		√		
Lighting lines *	Assembly	1 Whether the circuit works normally.	√	
		2 Whether there are corrosion and damage.		√
		3 Whether the bracket is loose or defective.		√
		4 Ground insulation check		√

Note: the equipmentmarked with “ \* ” are the key equipment of the system.

5.5.2 The tunnel pavement luminance shall meet the design requirements upon the inspection and repair of the lighting facilities.

5.5.3 For the inspection and repair for the lighting facilities, relevant equipment such as illuminance meter and luminance meter shall be provided apart from the electrical tools, aerial work platform truck, and cleaning tools.

## 5.6 Inspection and repair for ventilation facilities

5.6.1 Key items and frequency of the regular and periodic inspection and repair for ventilation facilities are listed in Table 5.6.1.

**Table 5.6.1 Key elements and frequency of the regular and periodic inspection and repair for ventilation facilities**

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Jet fan *	Assembly	1 Whether there is abnormal sound during fan operation.	√	
		2 Whether the current value is within the rated value range when the fan is running.	√	
		3 Whether the fan runs anticlockwise and normally.	√	
		4 Maintenance starting frequency	√ (once in 15 days)	
	Installation parts	1 Whether they are loose or corroded.	√	
		2 Check the degree of tightness of safety chain	√	
	Blade	Whether the blade is clean and whether there is abnormal sound.		√
	Motor	1 Whether the rotation shaft makes vibration, abnormal sound, or overheating.		√
		2 Inspection and replacement of lubricant and cleaning of bearing		√
		3 Disassembly and inspection of the motor, cleaning of bearing and replacement of lubricant		√
		4 Inspection of protection		√
		5 Insulation test		√
		6 Three-phase current balance test		√
		7 Whether the temperature rise of the motor in operation is normal.		√
Others	Wind speed and thrust test after disassembly and assembly		√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Axial fan *	Assembly	1 Whether there is abnormal sound or vibration in operation.	√	
		2 Whether the reading of each meter or gauge is correct.	√	
		3 Whether the state of foundation bolt and connection bolt is abnormal.		√
		4 Whether the bearing temperature, oil temperature, and oil pressure are abnormal.		√
		5 Whether the vibration test is abnormal.		√
		6 Whether there is abnormality when it counterclockwise rotates for 1 hour or more.		√
		7 Linkage test with monitoring test		√
		8 Balance state of manual rotation		√
		9 Test with a certain interval between counterclockwise rotation and anticlockwise rotation		√
		10 Check the blade installation state		√
		11 Maintenance starting frequency	√(once/15 days)	
Speed reducer		1 Whether the oil mass is normal.	√	
		2 Whether there is abnormal sound and whether the oil temperature is normal.		√
		3 Lubricant aging test		√
		4 Replacement of lubricant		√
Axial fan *	Lubricant cooling device	1 Piping, cooler, exchanger and circulating pump state	√	
		2 Whether there is vibration, abnormal sound, or overheating in operation.	√	
	Airflow regulator	1 Whether its running state is normal.	√	
		2 Whether the inner wing is defective or cracked.		√
		3 State of sealing materials		√
	Moving wing, stationary wing, and impeller		1 Whether the wing surface is damaged or stripped.	
2 Whether the welding parts are defective.				√
3 Check the hydraulic control device of the impeller.				√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Axial fan & centrifugal fan *	Guide blade and profiled tube	Whether they are rusty, whether their coating is stripped, and whether the nut is loose.		✓
	Driveshaft	1 Whether the lubricating state of joint and gear is normal.	✓	
		2 Whether there is an abnormality in driveshaft vibration and bearing temperature.	✓	
		3 Add lubricant		✓
	Motor	1 Whether there is abnormal sound or vibration or overheating in operation.	✓	
		2 Working condition of connecting parts	✓	
		3 Insulation test		✓
		4 Three-phase current balance test		✓
	Silencer	1 Clean the dust in silencer		✓
		2 Noise test		✓
		3 Sound-absorbing materials inspection and deteriorated materials replacement		✓
	Others	1 Meter inspection, calibration, and replacement		✓
		2 Oil feeder inspection		✓
		3 Metal defect detection if necessary		✓
		4 Trial operation after assembly and inspection, wind speed and pushing test		✓

Note: the equipment marked with “\*” are the key equipment of the system.

5.6.2 The inspection and repair for ventilation facilities shall be carried out following their operating procedures and maintenance requirements, the key performance indicators such as wind speed, thrust, power, noise, and protection level shall meet the requirements of product specifications.

5.6.3 The inspection and repair for the ventilation facilities shall be equipped with dedicated electrical tools and repair tools as well as wind pressure meter, anemometer, sound level meter, and other related equipment if necessary.

5.6.4 The efficiency of the tunnel ventilation facilities shall be comprehensively tested, and their ventilation capacity after inspection and repair shall meet design requirements upon periodic

inspection and specialist work.

## 5.7 Inspection and repair for fire-fighting facilities

5.7.1 Key elements and frequency of the regular and periodic inspection and repair for the fire-fighting facilities are listed in Table 5.7.1. The corresponding fire prevention measures shall be included during the inspection.

**Table 5.7.1 Key elements and frequency of the regular and periodic inspection and repair for fire-fighting facilities**

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Fire alarm facilities *	Point-type smoke detector and temperature detector	1 Clean their appearance.	√	
		2 Alarm random sampling test of each circuit		√
	Double-wavelength flame detector / three-wavelength flame detector	1 Clean their appearance.	√	
		2 Alarm random sampling test of each circuit		√
	Fiber optic temperature sensing linear fire detection system	1 Clean its appearance.	√	
		2 Alarm random sampling test of each circuit		√
	FiberBragg grating temperature sensing fire detection system	1 Clean its appearance.	√	
		2 Alarm random sampling test of each circuit		√
	Video-type fire alarm device	1 Clean its appearance.	√	
		2 Alarm random sampling test of each circuit		√
	Manual alarm button	1 Clean its appearance.	√	
		2 Check waterproofness	√	
		3 Alarm signal and transmission test		√
		4 Alarm random sampling test of each circuit		√
	Fire alarm control unit (FACU)	1 Clean its appearance.	√	
		2 Check waterproofness	√	
3 Whether the cable connection is normal.		√		
4 Alarm test			√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Liquid level detector	Assembly	1 Check electrode liquid level controller		✓
		2 Check magnetic float liquid level controller		✓
		3 Check ultrasonic liquidometer		✓
		4 Calibrate instrument accuracy		✓
Fire hydrant and fire extinguisher *	Assembly	1 Whether there is water leakage or corrosion, and whether the hose is defective.	✓	
		2 Drainage test and hydrostatic test of the outdoor fire hydrant	✓	
		3 Use and anti-clogging inspection of foam hydrant		✓
		4 Drainage test and hydrostatic test of the fire hydrant		✓
		5 Anti-freezing overhauling of fire-fighting pipes in cold regions		✓
		6 Confirm quantity and service life of fire extinguishers	✓	
		7 Corrosion of fire extinguishers	✓	
		8 Check equipment box and label	✓	
Valves	Assembly	1 Conduct an appearance check to confirm whether there is water leakage or corrosion.	✓	
		2 Whether the operation test is conducted normally.	✓	
		3 Conduction test	✓	
		4 State of attempurator		✓
Spray-type fire extinguisher *	Assembly	1 Check the running state of system components.	✓	
		2 Check the appearance of the equipment.	✓	
		3 Check the pipeline pressure.	✓	
		4 Check the alarm device.	✓	
		5 Check the system function.	✓	
		6 Wash the sealing ring of the deluge valve body.		✓
		7 Check the end socket and lock pin.		✓
		8 Wash control valve and diaphragm seal.		✓
		9 Pipeline pressure-tight test.		✓



continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Pump adapter *	Assembly	1 Clean its appearance and inside.	√	
		2 Check tightness.	√	
		3 Check whether the water supply and pressurization functions are normal.		√
Water pump *	Assembly	1 Check whether there is abnormal sound, vibration, and overheating in operation and whether the valve works normally in pressurization.	√	
		2 Whether its appearance is contaminated or defective.	√	
		3 Oil bearing component and conduct exhaust check.	√	
		4 Conduct a starting test and test on the automatic valve.	√	
		5 Tighten up the connecting bolts of pump components.	√	
		6 Remove the dirt in the centrifugal pump.	√	
Motor	Assembly	1 Whether there is abnormal sound or vibration or overheating in operation.	√	
		2 Whether its appearance is contaminated or defective.	√	
		3 Voltage and current test	√	
		4 Starting test	√	
		5 State of connecting parts		√
		6 Insulation test		√
Water supply pipe	Assembly	1 Check whether there is water leakage and whether the valves can be operated properly.	√	
		2 Check whether the pipe holder is corroded or loose.		√
		3 Anti-freezing or anti-corrosion by the salt spray of off-tunnel and in-tunnel pipes		√
		4 Clean pipes' filters.		√
Gas-type fire extinguisher	Assembly	1. Conduct a linkage test with FACU		√
		2 Check aerosol.		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Fire-fighting truck or motorbike	Assembly	1 Perform vehicle maintenance.	√	
		2 Check fire-fighting equipment.	√	
Fire cistern *	Assembly	1 Whether there is water leakage.	√	
		2 Whether the water level is normal and whether the liquid level detector is in good condition.	√	
		3 Whether the drain hole is blocked.	√	
		4 Clean the cistern.		√
		5 Thermal insulation and anti-freezing check in cold regions		√
Electro-optic sign *	Assembly	1 Check and regulate the luminance of the LED pixel pipe.	√	
		2 Check if the display function is normal.	√	
		3 Check whether there is contamination or damage or rust on its appearance and whether the writing is clear.	√	

Note: the equipment marked with “\*” are the key equipment of the system.

5.7.2 The signs of fire-fighting equipment shall be intact and conspicuous.

## 5.8 Inspection and repair for monitoring and communication facilities

5.8.1 Key elements and frequency of the regular and periodic inspection and repair for monitoring and communication facilities are listed in Table 5.8.1.

**Table 5.8.1 Key elements and frequency of the regular and periodic inspection and repair for monitoring and communication facilities**

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Luminance detector	Assembly	1 Whether there is an error.	√	
		2 Whether the installation is loose.	√	
		3 Calibrate instrument accuracy.		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Visibility detector	Photosensitive unit	1 Whether its appearance is contaminated or defective.	√	
		2 Comprehensively check to focus lens protective cover.	√	
	Monitoring unit	1 Whether its appearance is contaminated or defective.	√	
		2 Adjust operating state and transmittance	√	
		3 Whether the meter, display, or fault indicator is normal.		√
		4 Whether the operation switch, relay, electromagnetic switch, distribution circuit breaker, or other is normal.		√
		5 Whether there is abnormal wiring inside, contamination, damage, overheating, a loose or broken wire, or other.		√
Instrument calibration	Instrument's overall detection accuracy		√	
CO detector	Analysis meter and automatic corrector	1 Confirm whether the indicated value of the analysis meter is correct.	√	
		2 Whether the air filter is contaminated.	√	
		3 Confirm the function of the dehumidifier.		√
		4 Confirm the function of the automatic corrector.		√
		5 Confirm the function of the ventilation devices.		√
	Suction device	1 Whether there is abnormal sound or overheating or vibration in suction pump operation.	√	
		2 Whether its appearance is contaminated or defective.	√	
		3 Check whether detector readings are abnormal.	√	
	Gas inlet	Replace the filter of the gas inlet		√
	Monitoring unit	Subject to "Monitoring Unit" in "Visibility Detector".		√
	Instrument calibration	Instrument's overall detection accuracy		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Wind speed and direction detector	Analysis meter and automatic corrector	1 Confirm whether the indicated value of the analysis meter is correct.	√	
		2 Confirm the function of the automatic corrector.	√	
	Monitoring unit	Subject to "Monitoring Unit" in "Visibility Detector".		√
	Calibrate instrument.	Instrument's overall detection accuracy		√
Vehicle detector *	Detecting unit	1 Whether its appearance is contaminated or defective.		√
		2 Check its actuation and regulating sensitivity.		√
		3 Installation state		√
	Monitoring unit	1 Whether its appearance is contaminated or defective.	√	
		2 Operating state	√	
		3 Reliability of measured data	√	
		4 Whether there is an abnormality in meter, display, or fault indicator.		√
		5 Measure the transmission current.		√
		6 Installation state of the electronic circuit board and relay		√
		7 Whether there is defective, overheating, loose or broken wire in the cabinet.		√
		8 Check the insulation resistance and inductance value of the coil.		√
CCTV system *	Camera	1 Whether its appearance is contaminated or defective.	√	
		2 Confirm the operation.	√	
		3 Measure current and voltage.		√
		4 Regulate focus and focal length.		√
	Installation position	Whether it is loose or rusty.		√

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
CCTV system *	Control device	1 Whether its appearance is contaminated or defective.	√	
		2 Whether it is operated flexibly and normally.	√	
		3 Conduct a linkage test with an emergency phone.	√	
		4 Conduct a linkage test with FACU.	√ (once/15 days)	
		5 Measure voltage and current.	√	
		6 Perform inside maintenance.		√
	Coder and decoder	Whether the coder and decoder work normally.	√	
	Video matrix	Whether the video switch and control are normal.	√	
	Console	1 Whether its appearance is contaminated or defective.	√	
		2 Check if its function is normal.	√	
	Monitor	1 Whether its appearance is contaminated or defective.	√	
		2 Whether its imaging is clear and stable.	√	
	Digital video recorder	1 Check the BNC joint.	√	
		2 Test the index of the digital video recorder.	√ (once/week)	
Video traffic incident detector *	Assembly	1 Whether its appearance is contaminated or defective.	√	
		2 Reliability of measured data	√	
Large-screen projection system	Assembly	1 Display luminance conformity	√	
		2 Color and resolution	√	
		3 Video image via image splice-up controller	√	
		4 PC signal quality via RGB matrix	√	
		5 PC signal quality via network	√	
		6 Calling and switching of the video matrix	√	
		7 Turn on or off video and PC signal window	√	
		8 Power supply test		√
		9 Window scaling, moving, and multi-displaying	√	
		10 Image parameter adjustment	√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Map display	Assembly	1 Whether the date and weather display normally.	√	
		2 Whether other display functions are normal.	√	
		3 Road dynamic band display	√	
		4 Luminance, color balance, and image clarity	√	
		5 Power supply test	√	
		6 Emergency calls details display		√
Emergency call and broadcast *	Medium-wave broadcasting device	1 Test on answering in driving	√	
		2 Whether its appearance is contaminated or defective.	√	
		3 Measurement of voltage and output power		√
		4 Confirmation of modulation input		√
		5 Device cleaning		√
	Loud-speaking device	1 Whether its appearance is contaminated or defective.	√	
		2 Measure voltage and current.		√
		3 Confirm output power.		√
	Console	1 Whether its appearance is contaminated or defective.	√	
		2 Emergency broadcasting test		√
		3 Monitoring test		√
		4 Measure current and voltage.		√
	Microphone	1 Appearance inspection	√	
		2 Emergency broadcasting test		√
	Loudspeaker	1 Installation state inspection		√
		2 Test on answering		√
	Emergency call	1 Whether its appearance is contaminated or defective.	√	
		2 Test on communication effect	√	
		3 Internal check		√
		4 Measure the input and output current.		√
		5 Forced power-off test		√
6 Measure ground resistance			√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Local controller *	Assembly	1 Check surge protector.	√	
		2 Check the heater and radiator.	√	
		3 Power supply test		√
		4 Data acquisition cycle	√	
		5 Time delay in control command sending	√	
		6 Test on stand-alone operation function	√	
		7 Communication function	√	
		8 Transmission performance	√	
		9 Self-diagnostic function inspection	√	
Horizontal adit gate *	Assembly	1 Check whether it is damaged.	√	
		2 Whether the switch works normally.	√	
Control box of horizontal adit *	Assembly	1 Whether its programmable control program is correct.	√	
		2 Whether automatic and manual operation is correct.	√ (once / week)	
Traffic control and guiding devices	Real-time information sign	1 Appearance inspection	√	
		2 Find out the defective pixel pipe.	√	
		3 Clean the pixel pipe and circuit board.		√
		4 Overall performance check by running the detection procedure		√
		5 Whether the wiring terminals are loose.		√
		6 Replace the pixel pipe.		√
		7 Tighten up the connecting bolts.		√
	Real-time speed limit sign	1 Appearance inspection	√	
		2 Find out the defective pixel pipe.	√	
		3 Clean the pixel pipe and circuit board.		√
		4 Overall performance check by running the detection procedure		√
		5 Whether the wiring terminals are loose.		√
		6 Replace the pixel pipe.		√
	Lane indicator	1 Appearance inspection	√	
		2 Find out the defective pixel pipe.		√
		3 Clean the pixel pipe and circuit board.		√
4 Whether the wiring terminals are loose.			√	

continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Traffic control and guiding devices	Lane indicator	5 Replace the pixel pipe.		√
		6 Tighten up the connecting bolts.		√
	Traffic lights	1 Appearance inspection	√	
		2 Find out the defective pixel pipe.		√
		3 Clean the pixel pipe and circuit board.		√
		4 Whether the wiring terminals are loose.		√
		5 Replace the pixel pipe.		√
Communication facilities *	Optical fiber cable and cable	1 Walk-around inspection of optical fiber cable and cable	√	
		2 Appearance check of tail fiber (cable), terminal box, and distribution frame.	√	
		3 In-manhole inspection	√	
		4 Fiber channel backscattering signal curve test and inspection		√
		5 Cable insulation resistance test		√
		6 Optical fiber cable and cable lightning-protection and earthing device inspection		√
	Lightware terminal equipment	1 Transmitting optical power	√	
		2 Optical receiving sensitivity	√	
		3 Transmission error rate	√	
Communication facilities *	Router and switch *	1 Check the equipment running state and network operation data.	√	
		2 Check the alarm display.	√	
		3 Check the router's routing list and port flux.	√	
		4 Check the switch's VLAN list and port flux.	√	
		5. Check the radiator's fan.	√	
Monitoring room equipment and system *	Assembly	1. Check whether all parts are clean.	√	
		2 Check the voltage and current of all parts.		√
		3 Heating check.		√
		4 Virus control	√	
		5 Confirm system starting.		√
		6 Control software maintenance and system linkage.		√



continued

Facility	Inspection item	Main scope of inspection	Regular overhauling	Periodic overhauling
			Once / one to three-month	Once / year
Monitoring room equipment and system *	Assembly	7 Check the state of printing equipment		√
		8 Check system clock	√	
		9 Check the running status of hardware equipment	√	
		10 Equipment function and running state check	√	
		11 Data saving and backup equipment check	√	
Monitoring room	Assembly	1 Check humidity, temperature, and cleaning.	√ (once / week)	
		2 Floor anti-static check		√

Note: the equipment marked with “\*” are the key equipment of the system.

5.8.2 The maintenance frequency of tunnel monitoring software system for expressway shall be no less than once per year, and it should be no less than once per year for expressway Class-1 and below. During maintenance, the software system shall be fully updated to ensure the realization of linkage operation function and software reliability on the implementation of each technical measures. It shall be carried out following the instructions or user manuals.

## 5.9 Technical condition assessment of M&E equipment

5.9.1 The technical condition score of M&E equipment shall be determined based on the information collected from daily patrol, regular and periodic inspection and repair in combination with equipment readiness.

5.9.2 The technical condition assessment of M&E equipment should adopt and consider the assessment method with itemized weightage for each component of the M&E equipment.

5.9.3 The technical condition assessment of M&E equipment shall be conducted based on equipment readiness, and the calculation shall conform to the following provisions:

- 1 Equipment readiness shall be calculated by Equation (5.9.3), and the readiness assessment indicators of M&E equipment can be established for each M&E system component based on its importance to operational safety. 2 Refer to Table 5.9.3 for the unit used for “the number of equipment” in the equipment readiness calculation.

$$\text{Equipment readiness} = \left( 1 - \frac{\text{Number offaulty equipment} * \text{duration of breakdown in days}}{\text{Total number of equipment} * \text{number of calendar days}} \right) * 100\% \quad (5.9.3)$$

**Table 5.9.3 Unit used in M&E equipment readiness calculation**

Item	Equipment	Unit
Power supply and distribution facilities	High-voltage circuit breaker cabinet, high-voltage transformer and arrester cabinet, high-voltage measuring cabinet, high-voltage isolation switch and load switch cabinet, power transformer, box-type substation, power capacitor cabinet, low-voltage switch cabinet, distribution box, socket box, control box, comprehensive microcomputer protection device, DC power supply, UPS, EPS, self-generating equipment	Set
	Lightning-protection devices, earthing devices, and substation steel structure elements	Nos./location
	Power cable and cable bridge	Nos.
Lighting facilities	In-tunnel luminaries and off-tunnel road luminaries	Nos.
	Lighting lines	Nos.
Ventilation facilities	Axial fans, centrifugal fans, and jet fans	Set
Fire-fighting equipment	Double/three-wavelength flame detector, video-type fire alarm device, FACU, motor, gas-type fire extinguisher, fire-fighting truck or motorbike	Set
	Point-type smoke and temperature detector, fiber Bragg grating temperature sensing fire detection system, liquid level detector, fire hydrant and fire extinguisher, valve, manual alarm button, pump adapter, pump, fire cistern, and electro-optic signs	Nos. / location
	Fiber optic temperature sensing linear fire detection system, spray-type fire extinguisher and water supply pipe	Nos.
Monitoring and communication facilities	Video traffic incident detector, visibility detector, CO detector, wind speed and direction detector, vehicle detector, video camera, coder and decoder, video matrix, digital video recorder, Video traffic incident detector, local controller, horizontal adit control box, light ware terminal equipment, router, and switch	Set
	Large screen projection system, map display, wired broadcast, emergency call, horizontal adit gate, real-time information sign, real-time speed limit sign, lane indicator, traffic lights, and monitoring room equipment	Nos./location
	Optical fiber cable and cable	Nos.

5.9.4 The technical condition assessment of each item of M&E equipment shall conform to the following provisions:

- 1 The items' technical condition assessment values of M&E equipment are 0, 1, 2 & 3. The technical condition assessment of the items of M&E equipment shall be subject to Table 5.9.4.

**Table 5.9.4 Technical condition assessment for individual component of M&E equipment**

Item	Condition value			
	0	1	2	3
Power supply and distribution facilities	Equipment readiness $\geq 98\%$	$93\% \leq$ Equipment readiness $< 98\%$	$85\% \leq$ Equipment readiness $< 93\%$	Equipment readiness $< 85\%$
Lighting facilities	Equipment readiness $\geq 95\%$	$86\% \leq$ Equipment readiness $< 95\%$	$74\% \leq$ Equipment readiness $< 86\%$	Equipment readiness $< 74\%$
Ventilation facilities	Equipment readiness $\geq 98\%$	$91\% \leq$ Equipment readiness $< 98\%$	$82\% \leq$ Equipment readiness $< 91\%$	Equipment readiness $< 82\%$
Fire-fighting facilities	Equipment readiness 100%	$95\% \leq$ Equipment readiness $< 100\%$	$89\% \leq$ Equipment readiness $< 95\%$	Equipment readiness $< 89\%$
Monitoring and communication facilities	Equipment readiness $\geq 98\%$	$91\% \leq$ Equipment readiness $< 98\%$	$81\% \leq$ Equipment readiness $< 91\%$	Equipment readiness $< 81\%$

- When the equipment readiness of any key equipment in individual component of M&E equipment have the lowest value, the technical condition assessment of the component shall be determined based on the equipment readiness of this key equipment.

5.9.5 The assessment method on the technical condition of M&E equipment shall comply with the following provisions:

- The score for the technical condition of M&E equipment can be calculated by Equation (5.9.5).

$$JDCI = 100 \cdot \left( \frac{\sum_{i=1}^n E_i w_i}{\sum_{i=1}^n w_i} \right) \quad (5.9.5)$$

Where:  $E_i$ —equipment readiness of individual component determined in clause 5.9.4, with a range of 0 ~ 100% ;

$W_i$ —itemized weightage;

$\sum w_i$ —the sum of the weightage of all components;

$JDCI$ —technical condition score of M&E equipment, with a range of 0 ~ 100;

- Refer to Table 5.9.5-1 for the weightage of individual component of M&E equipment.

**Table 5.9.5-1 Weightage of individual component of M&E equipment**

Item	Itemized weightage $w_i$	Item	Itemized weightage $w_i$
Power supply and distribution facilities	23	Fire-fighting facilities	21
Lighting facilities	18	Monitoring and communication facilities	19
Ventilation facilities	19		

- 3 Refer to Table 5.9.5-2 for the classification threshold for technical condition assessment of M&E equipment.

**Table 5.9.5-2 Classification threshold for technical condition assessment of M&E equipment**

Technical condition score	Classification of technical condition assessment of tunnel M&E equipment			
	Category 1	Category 2	Category 3	Category 4
<i>JDCI</i>	$\geq 97$	$\geq 92, < 97$	$\geq 84, < 92$	$< 84$

5.9.6 Different maintenance measures should be taken for different category of M&E equipment:

- 1 Normal maintenance shall be conducted for Category 1 M&E equipment.
- 2 Normal maintenance and timely repair of damaged equipment shall be conducted for Category 2 M&E equipment or a component with an individual condition value of 1.
- 3 Specialist work should be implemented and daily patrol shall be enhanced for Category 3 M&E equipment or a component with an individual condition value of 2.
- 4 Specialist work shall be implemented and daily patrol shall be enhanced by undertaking traffic control measures for Category 4 M&E equipment or a component with an individual condition value of 3.
- 5 Repair shall be carried out immediately when there is fault to any key equipment of M&E equipment.

# 6 Other Facilities

## 6.1 General provisions

6.1.1 Maintenance of other facilities includes daily patrol, cleaning, and maintenance, inspection and assessment, maintenance and repair, etc.

- 1 The daily patrol shall include the findings, records, reports, or handling of remarkable abnormality during the patrol.
- 2 Cleaning and maintenance shall include the cleaning of the cable trench and equipment room, cleaning of debris in the cross-passage at the tunnel portal, removal of dirt in the height restriction barrier, and environmental landscape facilities at the tunnel portal, cleaning, and maintenance of ancillary buildings and facilities.
- 3 Inspection and assessment shall include the detection of abnormalities in other facilities, comprehension and assessment of their technical conditions, and determination of corresponding maintenance countermeasures or measures.
- 4 Maintenance and repair shall include the repair of the defective structures of other facilities, restoration of environmental landscape facilities, and maintenance of ancillary buildings and facilities.

6.1.2 Daily patrol, inspection, and assessment of other facilities should be conducted concurrently with tunnel structure.

6.1.3 Other facilities with special requirements shall be maintained as per stipulated provisions, and the professional maintenance of fan room, substation, monitoring room, and ancillary buildings' plumbing facilities and electricity shall be implemented according to the relevant provisions.

## 6.2 Daily patrol

6.2.1 Daily patrol is a routine inspection on the functionality of other facilities, which shall comply with the following provisions:

- 1 Inspect whether other facilities have remarkable structural deformation and damage, whether there is remarkable water gushing in the cable trenches or and equipment rooms, whether there are falling objects on the pavement of horizontal adits outside the tunnel, whether there are trees that are inclined towards the roadway and may collapse into the driving zone or obstruct visibility of signage and other warning devices upon signage especially near the tunnel portals, and whether there is remarkable siltation or obstruction of the sewage treatment facilities.
- 2 The daily patrol shall be conducted for the isolation facilities of horizontal adit outside the tunnel to ensure that they are in good condition and the horizontal adit shall be closed under normal conditions.

6.2.2 Any abnormality found during the daily patrol shall be recorded, reported, or handled.

## 6.3 Cleaning and maintenance

6.3.1 The frequency of cleaning and maintenance for other facilities shall not be less than that specified in Table 6.3.1.

**Table 6.3.1 Frequency of cleaning and maintenance for other facilities**

Item	Frequency of cleaning and maintenance
Cable trench and equipment room	Once / quarter
Horizontal adit at the tunnel portal	Once / month
Height restriction barrier at the tunnel portal	Once / year
Landscape at the tunnel portal	Once / year
Noise barrier	Once / quarter
Light-reduction facilities	Once / year
Sewage treatment plants	Once / year
Sculptures at the tunnel portal and tunnel nameplate	Once / three-year

Item	Frequency of cleaning and maintenance
Buildings and facilities	Once / week for floors and wall surfaces; once / month for ceiling, windows, and doors, and once / year for foundation and roof. The frequency of cleaning and maintenance for the fan room, substation, and monitoring room shall be decided based on the relevant provisions of M&E equipment.

6.3.2 Debris and dust in cable trench and equipment room shall be removed regularly, and the dewatering system shall be cleaned to ensure that the cable trench is tidy and there is no standing water in the equipment room.

6.3.3 The pavement of the horizontal adit outside tunnel shall be cleaned regularly, the dirt in isolation facilities shall be removed, and the drainage facilities shall be cleaned to ensure that the vehicles and passengers can pass through normally during an emergency.

6.3.4 The dirt on the height restriction barrier at the tunnel portal shall be removed regularly, the height restriction markings shall be clear and conspicuous, the crash-damaged height restriction barrier shall be removed and repaired, and the deformation of height restriction barrier shall be corrected to ensure that the high limit requirements are met.

6.3.5 The landscape and vegetation at the tunnel portal shall be harmonized with the surroundings, and the cleaning and maintenance shall satisfy the following requirements:

- 1 The trees within 30 ~ 50m on both sides of the tunnel entrance and exit shall be trimmed regularly to avoid encroachment into the driving zone or affecting the driving sight distance.
- 2 The trees shall be trimmed and nurtured appropriately to keep a moderate light transmission and good ventilation and reduce the occurrence of pests and diseases.
- 3 The turf shall be trimmed appropriately to remain beautiful.

6.3.6 The sculpture at the tunnel portal and tunnel nameplates should be cleaned regularly to keep tidy and nice.

6.3.7 The noise barriers shall be cleaned regularly, and the damaged parts and components shall be repaired or replaced.

6.3.8 The garbage and dirt on the roof of awning shall be cleaned regularly to maintain a good luminance-reduction effect and a clean and tidy appearance of luminance-reduction facilities.

6.3.9 The sediment and debris deposited in the sewage treatment tank and purification tank shall be removed regularly so that the sewage treatment tank and purification tank shall not overflow.

6.3.10 The ancillary buildings and facilities shall be cleaned and maintained regularly to keep a clean and beautiful building and the surrounding environment; and the surrounding site shall have a good drainage facilities, which shall comply with the following requirements:

- 1 The piles and weeds around the foundation shall be removed, and the drainage facilities shall be flushed, the plinth shall be kept intact to prevent the foundation from submerging and damage from freezing.
- 2 The dirt and dust on floors shall be removed to keep clean. Fan room, substation, monitoring room, and other main production buildings' floors shall be free of dust and oil; drainage pipes in water rooms shall be flushed, and floors shall effectively be waterproofed to avoid dampness and insect attack.
- 3 The dirt and dust on wall surfaces and ceilings shall be removed to keep clean.
- 4 The dirt and dust on doors and windows shall be removed, defective parts (components) shall be repaired or replaced to keep them in good condition.
- 5 The snow or dust accumulated on the roof shall be removed, the roof shall not leak.

## 6.4 Inspection and assessment

6.4.1 The inspection of other facilities can be divided into regular inspection and periodic inspection. The emergency or special inspections may be carried out as needed for abnormalities such as leakage in the equipment room, foundation deformation, and settlement.

6.4.2 The lightning-protection earthing device in ancillary buildings shall be inspected before and after the thunderstorm season every year.

6.4.3 Refer to Table 6.4.3 for the main scope of inspection of other facilities.



**Table 6.4.3 Mainscope of inspection of other facilities**

Item	Scope of regular inspection	Scope of periodic inspection
Cable trench	Whether it is intact and whether there is water gushing.	Whether it is intact and whether there is debris or dust accumulated or standing water.
Equipment room	Whether it is intact, whether there is water leakage and whether the sign is complete.	Whether it is intact, whether there is water leakage, debris or dust accumulated, and whether the sign is complete and clear.
Horizontal adit at the tunnel portal	Whether the isolation facilities are in good condition, whether the signage is complete and whether there are objects falling to the pavement.	Whether the isolation facilities are in good condition, whether the sign is complete and clear, whether the pavement is clean or heaved, or with standing water.
Height restriction barrier at the tunnel portal	Whether there is deformation to frame, whether the structure is in good condition, and whether the sign is complete.	Whether the structure is in good condition, whether the sign is complete and clear, and whether the clearance error meets the limit required.
Landscape at the tunnel portal	Whether trees interfere with the traffic, and whether there are dead trees.	Whether trees interfere with the traffic, whether there are dead trees or untrimmed turf, and whether the overall landscape looks good.
Noise barrier	Whether they are intact.	Whether they are intact and functional.
Light-reduction facilities	Whether their structure is in good condition.	Whether their structure is in good condition, whether the sign is complete and clear, and whether the light-reduction effect is normal.
Sewage treatment facilities	Whether there is leakage or deposit.	Whether there is leakage or debris or deposit.
Sculpture at the tunnel portal and in-tunnel nameplate	Whether there is damage.	Whether there is dirt on the surface or defect.
Buildings and facilities	Whether the load-bearing elements are deformed, whether the non-load bearing wall or the roof has leakage, and whether the floors, doors, and windows are intact.	Whether the load-bearing elements are deformed, cracked or loose; whether the non-load bearing wall is leaky or damaged; whether roof drainage is unblocked or leaky; whether floors, doors, and windows are in good condition; whether the ceiling is deformed; whether water, sanitation, electricity, heating, and other facilities are in good condition for normal use.

6.4.4 The condition value of each component shall be determined based on the inspection results such as the intactness, development trend of the damage and extent of the normal working condition of the facilities. Refer to Appendix D for the standard of technical condition assessment.

6.4.5 The score for the technical condition of other facilities can be calculated by Equation (6.4.5) according to the individual condition value of each component and its itemized weightage as per Table 6.4.5. The same component in multiple places shall be evaluated on a place-by-place basis, and the one with the highest score of  $QTCI_i$  shall be adopted in the equation of technical condition score.

**Table 6.4.5 Weightage for individual component of other facilities**

Item	Itemized weightage $W_i$	Item	Itemized weightage $W_i$
Cable trenches	10	Noise barrier	3
Equipment rooms	10	Light-reduction facilities	10
Horizontal adits at the tunnel portal	9	Sewage treatment facilities	4
Heightrestriction barriers at the tunnel portal	14	Sculptures at the tunnel portal and in-tunnel nameplates	2
Landscapes at the tunnel portal	3	Buildings and facilities	35

Note: Whenthere is an additional component of other facilities, the weightage and technical condition value of such additional components may be determined according to the importance of the facilities concerning the itemized weightage and the technical condition assessment standard of the component in Appendix D.

$$QTCI = 100 \cdot \left( 1 - \frac{1}{2} \sum_{i=1}^n \left( QTCI_i \times \frac{W_i}{\sum_{i=1}^n W_i} \right) \right) \quad (6.4.5)$$

Where:  $QTCI$ —technical condition score of other facilities;

$QTCI_i$ —individual condition value, with a range from 0 ~ 2 listed in Table D.0.1-D.0.10.

$W_i$ —itemized weightage.

6.4.6 The technical condition of other facilities can be divided into 3 categories. Refer to Table 6.4.6 for the standard and threshold value.

**Table 6.4.6 Classification standard and threshold valuefor other facilities**

Category of technical condition	Technical condition	$QTCI$ threshold value
Category 1	The facility is in good condition without any abnormality, or there is any slight abnormality or defect, but it can be used normally.	$\geq 70$
Category 2	The facilitydefects, some of its functions are affected but it can be used after maintenance, and the countermeasures shall be undertaken.	40-70
Category 3	The facility is severely defective, and mostly or completely loss of function, so it must be halted with emergency countermeasures undertaken.	$< 40$

6.4.7 Different maintenance measures shall be taken for different category of facilities;

1 Normal operation and maintenance shall be conducted fora facility with technical condition

category-1 and each component with an individual condition value of 0.

- 2 The observational operation, maintenance, and repair shall be conducted for a facility with technical condition category-2, and each component with individual condition value of 1.
- 3 Operations shall be suspended, repair and strengthening shall be conducted immediately for a facility with technical condition category-3, and each component with individual condition value of 2.

## 6.5 Maintenance and repair

6.5.1 Cable trench and equipment room shall be maintained, damaged trench and tunnel walls shall be repaired, the causes of water leakage in the equipment room shall be investigated and problems treated to keep the cable trench and equipment room intact and in working order. The maintenance and repair for the structural defects and leakage in the cable trench and equipment room may be carried out concurrently with that of tunnel structure or degradation treatment.

6.5.2 The structure of the height restriction barrier at the tunnel portal and light-reduction facilities shall be maintained. Damaged or deformed structure frame shall be repaired and reinstated to ensure it meets the functionality requirements. While any structural damage or malfunction shading devices of the light-reduction facilities shall be repaired and reinstated to ensure a normal light-reduction effect.

6.5.3 The damaged sculpture at the tunnel portal and tunnel nameplates shall be repaired or replaced. The causes of leakage in the sewage treatment tank and purification tank shall be investigated and treated to ensure it is free from leakage at the walls and bottom of the tanks.

6.5.4 The pavement of horizontal adit outside the tunnel portal shall be maintained and repaired as per the requirements of relevant specifications.

6.5.5 The maintenance and repair of ancillary buildings and facilities shall comply with the following provisions:

- 1 Leakage in the roof and wall of the buildings shall be maintained and repaired.
  - 1) Roof leakage repair shall be based on the category of building waterproofing, functionality requirements, phenomenon and location of leakage, the causes of leakage shall be investigated and leakage points identified to develop the corresponding maintenance

strategy ;

- 2) The materials selected shall be compatible with the original waterproofing layer and integrated firmly with the base ;
  - 3) After repair , the roof waterproofing layer shall be level without standing water or leakage ;
  - 4) Before wall leakage repair , site reconnaissance shall be conducted to inspect the areas of leakage , external painting joints , door and window frames , windowsills , pipelines crossing in-wall , connections between balcony , canopy and wall , deformation joints to find out the leakage areas and to investigate the causes and develop corresponding maintenance plans ;
  - 5) An inspection shall be conducted 3 days after completion of the repair work . No apparent leakage should occur after walls are repaired , and no leakage 2 hours after the walls are flushed or rained .
- 2 After the walls are painted , delamination , chipping , loose parts , or other damaged parts shall be removed and cleaned before repainting .
  - 3 The wooden doors and windows of buildings may be painted biennially and the damaged ones shall be repaired or replaced .
  - 4 The steel elements of buildings shall be maintained regularly to remove rust and coated with anti-rust paint and oil paint as required .
  - 5 The lightning-protection and earthing device shall be maintained and repaired if damaged or rusty .
- 1) Before repair and replacement of the lightning-protection and earthing system , a grounding resistance test shall be carried out on the earthing body . If the welding of earthing wire and body is cracked or broken , they shall be repaired or replaced ; and the complete ones shall be coated with anti-rust paint .
  - 2) When the earthing body is heavily corroded and unrepairable , it shall be replaced based on the design requirements .
  - 3) Before repair and replacement of the lightning-protection system , lightning rod , lightning strip , earth down-conductor , and others with broken weld and deformation shall be repaired , and the anti-corrosive coats shall be touched up ;

- 4) Galvanized products should be used for repair and replacement of earthing appliance and installation, and each connection point shall be firm and reliable.
- 6 Antifreezing insulation facilities shall be regularly maintained at a frequency of not less than once per year.

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# 7 Safety Management

## 7.1 General provisions

7.1.1 Tunnel safety management includes maintenance procedures and traffic management and safety protection during an emergency.

7.1.2 With the assistance of monitoring, specialist detection and watchkeeping approaches, any information on the abnormalities of highway tunnel shall be timely comprehended for decision making with the necessary traffic management and safety protection to be undertaken.

7.1.3 Alert and warning signs shall be set up at the tunnel entrance during tunnel maintenance and handling of the emergency.

7.1.4 Activities that threaten the safety of highway tunnel such as mining, quarrying, excavation, waste dumping, and blasting operation are prohibited within a range of 100m above the tunnel and outside the portal.

7.1.5 Storage of dangerous goods such as the flammable, explosive and poisonous and radioactive materials are prohibited for storage in the tunnel. Debris shall not be stock-piled in the emergency lay-by, traffic (pedestrian) passage in the tunnel .

## 7.2 Safety management of maintenance

7.2.1 Maintenance operation should be carried out during off-peak hours. It shall be confined to fewer lanes to reduce the impact on road traffic.

7.2.2 Tunnel facilities and equipment shall be protected from damage during a maintenance

operation.

7.2.3 Traffic management plan shall be proposed for tunnel maintenance operation. If the traffic is affected, a notice shall be made to the public as per the relevant regulations.

7.2.4 In-tunnel maintenance operation shall comply with relevant provisions in *Safety Work Rules for Highway Maintenance* (JTG H30)

7.2.5 If a road-occupied maintenance is performed in the tunnel with large traffic volume and difficulty in traffic organization, in addition to signs or real-time information signs for reminding, such safety precautions as fixed isolation facilities, forced deceleration and collision-prevention device should be used.

7.2.6 Maintenance operation shall ensure the safety of working personnel and machinery equipment.

7.2.7 The following works shall be done before maintenance operation:

- 1 Work out a thorough construction organization design, and determine a reasonable maintenance control area.
- 2 Working personnel shall accept specialized safety-related education and operating procedure training.
- 3 Working personnel shall detect the concentration of CO and particulate matter emissions and visibility in tunnel and judge the construction safety.
- 4 Working personnel shall observe if the tunnel structure will affect construction safety; if yes, take measures for treatment firstly.
- 5 Working personnel shall check if the construction signal indicator shows correctly and clearly, and if the construction signs are set as required.
- 6 Working personnel shall make a comprehensive safety inspection on the maintained machinery and platforms, and set up eye-catching reflective signs on the machinery and anti-dazzle light around the platforms to show the outline of the operation site.

7.2.8 When maintenance operation is implemented inside a tunnel, the following provisions shall be complied with:

- 1 The confirmed maintenance operation control area shall not be altered without permission .
- 2 Working personnel shall not move beyond the maintenance operation control area or park machinery or store materials outside the control area.
- 3 The lighting within the maintenance construction zone shall satisfy the operation requirements.
- 4 The air quality within the maintenance construction zone shall comply with the relevant provisions.
- 5 The electricity safety for maintenance operation shall comply with the relevant provisions.

7.2.9 Upon completion of maintenance, the construction site shall be cleaned in time, and the traffic control signs shall be removed along the direction opposite to the traffic flow to make the tunnel put into use normally.

7.2.10 For maintenance of power systems, overhead working equipment, and equipment with special requirements, they shall be implemented as per the safe operating procedures of the relevant authority.

### 7.3 Safety management of emergency

- 7.3.1 Tunnel emergency response should be implemented according to the following principles:
- 1 Report to the relevant authorities and make a public announcement according to the relevant provisions.
  - 2 Cooperate in the execution of traffic control, take measures to reduce the occurrence of secondary accidents.
  - 3 Perform rescue and evacuation, reduce casualties as much as possible.
  - 4 Cooperate with the local government and relevant institutions to carry out the treatment work properly.
  - 5 Remove the obstacles and let the traffic resumed as soon as possible.



7.3.2 Tunnel rescue equipment and facilities shall be regularly checked to ensure that they are in good technical condition.

7.3.3 The tunnel management and maintenance unit shall develop contingency plans and organize emergency drills. As for the long tunnel and extra-long tunnel, a dedicated contingency plan shall be developed; and as for other tunnels, a generic contingency plan can be developed. The contingency plan shall comprise the following contents:

- 1 Scope of application and type of emergency;
- 2 Objectives and principles of treatment;
- 3 Provisions on command system, dispatch, and dissemination of information;
- 4 Treatment schemes and stages, including traffic control, arrival of treatment team, evacuation and rescue personnel, on-site treatment, loss inspection and traffic condition assessment; and
- 5 Composition of the emergency team, including the source, size, and functionality of personnel and equipment and requirements for on-site safety protection.

7.3.4 The emergency drill of contingency shall be conducted using question paper, sand table training, or field drill as well as other methods. For the independent long tunnel or extra-long tunnel of the expressway and the independent extra-long tunnel of other categories of highways, the field drill shall be performed at least once a year. Besides, the management and maintenance unit of multiple long and extra-long tunnels shall choose not less than one tunnel to perform the field drill. For the management and maintenance unit which does not perform field drill, they shall observe or attend the field drill organized by other units.

7.3.5 After emergency treatment, the causes of the incident shall be analyzed, experience, and lessons learned shall be summarised to improve the capacity in emergency response.

# 8 Technical Management

8.0.1 A maintenance technical file containing the tunnel handover and completion data, daily patrol, inspection and assessment data, maintenance and repair data, and other data shall be created on a per tunnel basis.

8.0.2 Tunnel maintenance management database should also be developed, which includes written information, digital information, and image information. Where any severe abnormality or defect is found during the tunnel inspection, the image data shall be recorded in the tunnel maintenance management database with the relevant information updated timely.

8.0.3 The highway tunnel management and maintenance unit shall classify and determine the technical requirements of tunnel maintenance based on the maintenance class and requirements as well as the allocation of specialized technical personnel.

8.0.4 Tunnel maintenance technical personnel shall be organized to undergo maintenance technical training regularly.

8.0.5 The results of inspection and assessment shall be used in combination with the tunnel maintenance management database to correctly assess and comprehend the technical condition of highway tunnels, analyze the causes of structural degradations dynamically and predict the development trend of degradation to provide a scientific basis for the decision making of maintenance work.

8.0.6 When a fire, traffic accident, earthquake, collapse, and other emergencies has occurred in the highway tunnel, the tunnel operating condition shall be comprehended with the relevant information be reported following the regulations.





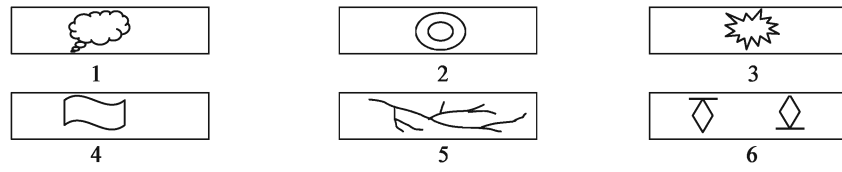


Figure A.0.3-2 Legend of the structural degradation

1-Seepage and mud rush; 2-Lining warping; 3-Fracture and fallout of surrounding rock mass; 4-Wall deformation; 5-Cracks in lining or surrounding rock mass; 6-Water leakage, icicles or ice heaping

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# Appendix B

## Technical Condition Assessment Standard for Tunnel Structure

**Table B-1 Technical condition assessment standard for tunnel portal**

Value	Description of technical condition
0	Intact, without any damage
1	Slight fracture in the mountains and rock masses, retaining walls, protection slopes, etc. ; slight damage in the drainage facilities
2	Fracture developing in the mountains and rock masses; early signs of landslides and collapses; slight tilting of trees on slopes or poles; cracks and deformation of retaining walls, protection slopes, etc. ; sporadic falling of earth and rocks; a certain degree of fracture and clogging of the drainage facilities
3	Severe fracture in the mountains and rock masses; observable tilting of trees on slopes or poles; severe fracture and noticeable permanent deformation of retaining walls, protection slopes, etc. ; earth and rocks piling up at the corners or on slopes; drainage failure due to complete blockage or damaged drainage facilities
4	Noticeable scenario of severe slide and collapse in the mountains and rock masses; fractures, tilting and partial collapse of retaining walls and protection slopes; collapse of trees on slopes or poles, etc.

**Table B-2 Technical condition assessment standard for tunnel frame**

Value	Description of technical condition
0	Intact, without any damage
1	Slight cracking, delamination, and chipping of walls
2	Local cracking of wall structures; slight tilting, subsidence or fault of walls; slight water seepage on wall surfaces, not hindering the traffic yet
3	Severe cracking or fault of wall structures; delamination and chipping of sidewalls, potential or fell out of concrete blocks; exposure and corrosion of rebars; an observable trend of tilting, subsidence or fault of walls; severe water seepage ( icicles ) on wall surfaces that will hinder the traffic
4	Large-scale cracking of portal structures, fractures of masonry structures, potential or fell out of concrete blocks; partial tilting and collapse of walls, water spray or large-scale icicles, which has already hindered the traffic

**Table B-3 Technical condition assessment standard for lining damage**

Value	Description of technical condition	
	Due to external load effect	Due to material deterioration
0	No cracking, deformation of or cavity behind structures	No material deterioration
1	Occurrence of deformation, displacement, settlement, and fracture, but with no development trend or ceased	With material deterioration, local corrosion on rebar surfaces, no delamination or chipping of lining, almost no impact on the section strength
2	Occurrence of deformation, displacement, settlement, and fracture, with slow development; existence of void behind side wall lining with potential for expansion	Remarkable material deterioration, rusting and corrosion of all rebar surfaces; slight reduction in section strength; possible impairment in functions of structures
3	Frequent occurrence of deformation, displacement, settlement and fracture, occurrence of shear crack with a rapid development; fracture of the lining of sidewalls, resulting in deformation, chipping and potential falling of sidewall concrete; existence of large void behind the arch, with the possibility of rock falling on the extrados; and encroachment of lining structure into the boundary line	Severe material deterioration, a remarkable reduction in rebar section due to corrosion, a considerable reduction in section strength, impairment in functions of structures; deformation, chipping and potential falling of sidewalls, potential or fell out of concrete blocks
4	Observable permanent deformation of lining structures, occurrence of dense cracks, shear cracks, with the depth of cracking through the lining concrete and rapid development; deformation, chipping and potential falling of concrete blocks due to dense cracks on extrados and cracking of lining	Significant material deterioration, a remarkable reduction in section strength; remarkable impairment in functions of structures; concrete delamination and chipping due to deterioration of the arch materials, potential or fell out of concrete blocks

**Table B-4 Technical condition assessment standard for water leakage in the lining**

Value	Description of technical condition
0	No water leakage
1	Water seepage on lining surfaces, no impact on the traffic
2	Water dripping off the lining arch; some water gushing from side walls; water seepage on the pavement but no water stagnation; a small number of icicles on the arch and side walls; ice accretion at the foot of sidewall, which may soon affect traffic safety
3	Water bursting from the arch and water spray from side walls with water stagnation on the pavement; outflow of sand and soil, large icicles formed on and swelling of the arch lining due to water seepage; or gushing water and ice accretion to the pavement edge, which affects traffic safety
4	Water spray from the arch; water gushing from side walls with significant impact on the traffic safety; groundwater gushing from inspection wells, causing a large amount of water stagnation on the pavement, accompanied by a significant outflow of sand and soil and icicles on the lining, which significantly affects traffic safety

**Table B-5 Technical condition assessment standard for tunnel pavement**

Value	Description of technical condition
0	Intact pavement
1	Wetting, slight crack or debris on the pavement, causing slight discomfort to users
2	Local pavement subsidence, bump, pit, surface flaking, rebar exposure, damage, crack and a slight amount of standing water, which causes noticeable discomfort to users and may affect traffic safety
3	Relative large-area pavement subsidence, bump, pit, surface flaking, rebar exposure, damage, crack and a large amount of standing water, affecting the traffic safety; skidding of vehicles caused by too low skid-proof coefficient
4	Large-area subsidence, bump and pit on the pavement; severe fault, fracture, surface flaking, rebar exposure, damage, crack of road slabs; occurrence of flooding, ice covering or heaping, which significantly affects traffic safety and may cause traffic accidents

**Table B-6 Technical condition assessment standard for maintenance path**

Value	Description of technical condition	
	Qualitative description	Quantitative description
0	Intact guardrail, curb, and maintenance path slab	—
1	Deformation of guardrail; a small number of broken corners and damages of curb or maintenance path slab; and local rusting of metal, which does not affect the functionality	Length of damaged guardrail, slab or curb $\leq 10\%$ , length of missing part $\leq 3\%$
2	Deformation and damage of guardrail, loosening, and distortion of bolts, rusting of the metal surface, missing or cracking of partial curb or maintenance path slabs, and partial loss of functionality, which may affect the safety of traffic and pedestrians	Length of damaged guardrail, slab or curb $> 10\%$ and $\leq 20\%$ , length of missing part $> 3\%$ and $\leq 10\%$
3	Collapse and severe damage of guardrail, encroachment into the boundary line; damaged, cracking or significant missing of curb or maintenance path slab, and loss of original functionality, which affect the safety of traffic and pedestrians	Missing rate of guardrail, slab or curb $> 20\%$ , length of missing part $> 10\%$

**Table B-7 Technical condition assessment standard for in-tunnel drainage facilities**

Value	Description of technical condition
0	Intact, in normal working condition
1	Slight defect of structures, but in normal working condition
2	Slight siltation, defect of structures and overflowing in the rainy season, which may affect traffic safety
3	Severe siltation, relatively severe damage of structures, local standing water and ice on pavement due to overflowing, which affects traffic safety
4	Complete blockage, significant damage of structures, sheet flood and large-area ice on pavement due to overflowing, which significantly affects traffic safety



**Table B-8 Technical condition assessment standard for ceiling and built-in elements**

Value	Description of technical condition
0	Intact ceiling
1	Slight deformation, defect and water seepage, not hindering the traffic yet
2	Defect, cracking and dripping of ceiling, corrosion of suspenders and other built-in elements, which does not affect traffic safety yet
3	Severe deformation and damage of ceiling, with gushing water and icicles; serious corrosion of hangers and other built-in elements, which may affect traffic safety
4	Severe damage, cracking and even falling off the ceiling with spewing water and severe icicles; severe corrosion or fracture of various built-in elements and hangers; severe deformation or falling of various cable trays and suspension parts, which significantly affects traffic safety

Note: This item includes the assessment of the suspended structures of various lighting facilities, fans, and other vault equipment.

**Table B-9 Technical condition assessment standard for interior decoration**

Value	Description of technical condition	
	Qualitative description	Quantitative description
0	Intact interior decoration	—
1	Deformation and damage of several interior decoration panels, which does not affect traffic safety	Damage rate $\leq 10\%$
2	Deformation, damage, and falling of partial interior decoration panels or tiles, which affects traffic safety	Damage rate $> 10\%$ , and $\leq 20\%$
3	Deformation damage and falling of large-area several interior decoration panels or tiles, which significantly affects traffic safety	Damage rate $> 20\%$

**Table B-10 Technical condition assessment standard for traffic sign and markings**

Value	Description of technical condition	
	Qualitative description	Quantitative description
0	Intact	—
1	Dirt and incompleteness, which has not hindered traffic	Damage rate $\leq 10\%$
2	Dirt, partial falling and missing, which may affect traffic safety	Damage rate $> 10\%$ , and $\leq 20\%$
3	Dirt, falling and missing of most of them, which significantly affects traffic safety	Damage rate $> 20\%$

**Table B-11 Technical condition assessment of tunnel structure**

Tunnel information		Tunnel name	Route name			Tunnel length			Completion time	
Assessment information		Management and maintenance authority	Class of last assessment			Date of last assessment			Date of current assessment	
		Item name	Location	Value	Weightage $w_i$	Inspection item	Location	Value	Weightage $w_i$	
Technical condition assessment of tunnel frame and tunnel portal		Tunnel portal	Entrance			Tunnel frame	Entrance			
			Exit				Exit			
No.	Chainage	Value								
		Lining defect	Water leakage	Pavement	Maintenance path	Drainage facilities	Ceiling		Interior decoration	Sign and markings
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
max( $JGCI_i$ )										
Weight $w_i$										
$JGCI = 100 \cdot \left[ 1 - \frac{1}{4} \sum_{i=1}^n \left( JGCI_i \times \frac{w_i}{\sum_{i=1}^n w_i} \right) \right]$				Assessment class of tunnel structure						
Suggestion on maintenance measures										
Assessed by					Person in charge					

# Appendix C

## Technical Condition Assessment and Inspection Record of M& E Systems

C.0.1 The technical condition assessment of M&E equipment may be recorded in accordance with Table C.0.1.

**Table C.0.1 Technical condition assessment of M&E equipment**

Tunnel information	Tunnel name		Route name	Tunnel length		Completion time	
Assessment information	Management and maintenance authority		Class of last assessment	Date of last assessment		Date of current assessment	
Equipment name	Power supply & distribution system		Lighting facilities	Ventilation facilities	Fire-fighting facilities	Monitoring and communication facilities	
Equipment readiness $E_i$							
Assessment indicator (0 ~ 3)							
Weightage $w_i$							
$JDCI = 100 \cdot \left( \frac{\sum_{i=1}^n E_i w_i}{\sum_{i=1}^n w_i} \right)$				Assessment class of M&E equipment			
Suggestion on maintenance measure							
Assessed by				Person in charge			

C.0.2 The daily patrol record may be made in accordance with Table C.0.2.

**Table C.0.2 Daily patrol record form**

Tunnel name: \_\_\_\_\_ (upline / downline) Route name: \_\_\_\_\_  
 Tunnel code: \_\_\_\_\_ Route code: \_\_\_\_\_  
 Maintenance authority: \_\_\_\_\_ Date of inspection: \_\_ (D) \_\_ (M) \_\_ (Y) Weather: \_\_

Equipment name					
Inspection location					
Inspection scope					
Inspection result	Normal		Abnormal		Abnormal and severe
Information about patrol/operating vehicle use	Vehicle No.				
	Quantity of vehicles				
Attentions					

Inspected by: \_\_\_\_\_

Recorded by: \_\_\_\_\_

C.0.3 The regular and periodic inspection and repair records shown in Table C.0.3 may be adopted. Where photos or other materials may form a separate volume, their numbers shall be recorded in the corresponding columns of the Table.

**Table C.0.3 Regular (periodic) inspection and repair record form**

Tunnel name: \_\_\_\_\_ (upline / downline) Route name: \_\_\_\_\_  
 Tunnel code: \_\_\_\_\_ Route code: \_\_\_\_\_  
 Maintenance authority: \_\_\_\_\_ Date of overhauling: \_\_ (D) \_\_ (M) \_\_ (Y) Weather: \_\_

Equipment name	Inspection location	Inspection scope	Inspection result		Abnormality description (characteristic, extent, degree, etc.)	Maintenance measures	Photo or picture (No./ Time)
			Normal	Abnormal & severe			
			Normal				
			Abnormal				
			Abnormal & severe				
⋮							

Inspected by: \_\_\_\_\_

Recorded by: \_\_\_\_\_

C.0.4 The M&E equipment failure may be recorded in accordance with Table C.0.4

**Table C.0.4 Mechanical and electrical failure record form**

Tunnel name: \_\_\_\_\_ (upline / downline) Route name: \_\_\_\_\_  
 Tunnel code: \_\_\_\_\_ Route code: \_\_\_\_\_  
 Maintenance authority: \_\_\_\_\_ Date of failure: \_\_ (D) \_\_ (M) \_\_ (Y) Weather: \_\_

1	Equipment name	
2	Equipment location	
3	Failure position	
4	Causes and details of failure	
5	Emergency measures	

Inspected by: \_\_\_\_\_

Recorded by: \_\_\_\_\_

C.0.5 The monthly report on mechanical and electrical failures may be recorded in accordance with Table C.0.5.

**Table C.0.5 Monthly report on mechanical and electrical failures**

Tunnel name: \_\_\_\_\_ (upline / downline) Route name: \_\_\_\_\_  
 Tunnel code: \_\_\_\_\_ Route code: \_\_\_\_\_  
 Maintenance authority: \_\_\_\_\_ Date: \_\_ (D) \_\_ (M) \_\_ (Y)

No.	Date of failure	Place of failure	Equipment name	Summary of failure or accident	Reason and disposal	Repair time	Remark

Prepared by: \_\_\_\_\_

Verified by: \_\_\_\_\_

Approved by: \_\_\_\_\_

# Appendix D

## Technical Condition Assessment of Other Facilities

D.0.1 The technical condition assessment of cable trench may refer to Table D.0.1.

**Table D.0.1 Technical condition assessment standard for cable trench**

Value	Description of technical condition
0	Intact ~ basic intact cable trench structure, no debris, no or slight accumulation of dust or water in the trench, which ensures the normal ~ basic use of cable
1	Defect of cable trench structure, with dust and water accumulation in the trench, which affects the normal use of cable but not traffic and pedestrian safety
2	Severe defect of cable trench structure, with the severe accumulation of dust and water in the trench, which significantly affects the normal use of cable and may affect the traffic and pedestrian safety

D.0.2 The technical condition assessment of equipment room may refer to Table D.0.2.

**Table D.0.2 Technical condition assessment standard for equipment room**

Value	Description of technical condition
0	Intact or basic intact equipment room structure, no or slight water seepage; complete or clear signs or missing of part signs, which ensures the normal use of equipment
1	Damage of equipment room structure, with water seepage in the chamber, which affects the normal use of equipment but not traffic and pedestrian safety
2	Severe damage of equipment room structure, with severe water seepage in the chamber, missing of signs, which significantly affects the normal use of the equipment and may affect the traffic and pedestrian safety

D.0.3 The technical condition assessment of cross-passage at the tunnel portal may refer to Table D.0.3.

**Table C.0.3 Technical condition assessment of cross-passage at tunnel portal**

Value	Description of technical condition
0	Clean, intact or basic intact isolation facilities, with slight dirt; complete signs or missing of part signs; intact or slightly cracked the passage pavement; and unblocked drainage, which ensures the closed state of the horizontal adit under normal conditions, and the normal ~ basic use of the horizontal adit under emergency conditions
1	Missing and severe dirt of part isolation facilities; missing of signs; slight subsidence, bump of and standing water on the passage pavement, which ensures that no vehicle enters by mistake under normal conditions and can pass through under emergency conditions
2	Missing of isolation facilities; obvious surface distortion or bump, severe standing water; and missing of signs, which can't ensure the closed state of the horizontal adit under normal conditions or the passing of vehicles under emergency conditions

D.0.4 The technical condition assessment of height restriction barrier at the tunnel portal may refer to Table D.0.4.

**Table D.0.4 Technical condition assessment of height restriction barrier at the tunnel portal**

Value	Description of technical condition
0	Intact or slightly damaged frame structures, neat appearance, and complete signs, which meets the height restriction requirements
1	Less severe damage and deformation of frame structures, missing of part signs, with large clearance error but meets the height restriction basic requirements, which does not affect traffic safety
2	Damage or overall deformation of frame structures, missing of signs, with a very large error that can't meet the height restriction requirements and may affect traffic safety

D.0.5 The technical condition assessment of landscape at the tunnel portal may refer to Table D.0.5.

**Table D.0.5 Technical condition assessment of landscape at the tunnel portal**

Value	Description of technical condition
0	Moderate light transmission and good ventilation of trees without withering, timely pruning of turf, beautiful overall landscape
1	With no weed or withering, timely removal of dead trees and timely replanting, relatively beautiful overall landscape
2	Withered and toppled trees, and turf lacking maintenance, which significantly affects the landscape at the tunnel portal

D.0.6 The technical condition assessment of noise barrier may refer to Table D.0.6.

**Table D.0.6 Technical condition assessment of noise barrier**

Value	Description of technical condition
0	Intact, neat, function normally
1	Dirty, missing, basically functional
2	Severely dirty and missing, loss of function

D.0.7 The technical condition assessment of tunnel portal light-reduction facilities may refer to Table D.0.7.

**Table D.0.7 Technical condition assessment of tunnel portal light-reduction facilities**

Value	Description of technical condition
0	Intact, neat or slightly damaged or dirty structures, basically complete and clear signs, with basically normal light-reduction functions
1	Deformation and damage of local structures, and loss of part of light-reduction functions, which does not affect traffic and pedestrian safety
2	Severe deformation and damage of structures, and loss of light-reduction functions, which may affect traffic and pedestrian safety

D.0.8 The technical condition assessment of sewage treatment facilities may refer to Table D.0.8.

**Table D.0.8 Technical condition assessment of sewage treatment facilities**

Value	Description of technical condition
0	Sewage treatment tank and purification tank with no leakage, or no deposited silt and sundries, which supports the normal usage
1	Sewage treatment tank and purification tank with local leakage, deposited silt and sundries, which affects the normal usage
2	Sewage treatment tank and purification tank with severe leakage, deposited silt and sundries, which causes loss of functionality.

D.0.9 The technical condition assessment of Sculpture at the tunnel portal may refer to Table D.0.9.

**Table D.0.9 Technical condition assessment of sculpture at the tunnel portal**

Value	Description of technical condition
0	Intact, neat and beautiful
1	Moderate damage, and very severe surface dirt, which affects the landscape at the tunnel portal
2	Severe damage, a replacement needed

D.0.10 The technical condition assessment of ancillary buildings may refer to Table D.0.10.



**Table D.0.10 Technical condition assessment of ancillary buildings**

Value	Description of technical condition
0	Intact or basic intact load-bearing members, intact or slightly damaged non-load bearing walls; no seepage or local seepage of roofs and walls; flat and intact or slightly cracked floors; intact doors and windows; no remarkable deformation of the ceiling; intact water, sanitation, electricity, heating and other facilities that can support normal usage or basic usage
1	Slightly damaged load-bearing members, relatively seriously damaged non-load bearing walls; relatively severe seepage of roofs and walls; severe flaking of floors; less severe deformation of doors and windows or missing of part doors and windows; remarkable deformation of the ceiling; severely damaged water, sanitation, electricity, heating and other facilities that can't support normal usage
2	Remarkably damaged load-bearing members, severely damaged non-load bearing walls; severe leakage of roofs; severe flaking and cracking of floors; severe deformation of doors and windows or missing of most doors and windows; severe deformation of the ceiling; severely damaged water, sanitation, electricity, heating and other facilities that can't support normal usage

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## Wording Explanation for the *Specifications*

1 The strictness in execution of the *Specifications* is expressed by using the wording as follows:

- 1) MUST—A very restrict requirement in any circumstances.
- 2) SHALL—A mandatory requirement in normal circumstances.
- 3) SHOULD—An advisory requirement.
- 4) MAY—A permissive condition. No requirement is intended.

2 Expressions used for reference to standards are explained as follows:

The standards for which a year is added to the standard number shall be the specific versions to be used. Otherwise they shall be the latest available versions.

## Background to Provisions

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# 1 General Provisions

1.0.3 The tunnel structure mentioned herein shall include tunnel frames, tunnel trunks, pavements, horizontal adits for pedestrians (and vehicles), inclined (vertical) shafts, ducts, waterproofing and drainage facilities. The M&E equipment shall include relevant necessary facilities for power supply and distribution, ventilation, lighting, disaster prevention and monitoring to guarantee the traffic safety and good environment in tunnel. Other facilities shall include the tunnel facilities other than tunnel structure and M&E equipment.

1.0.4 The guideline of “Prevention First, Prevention and Treatment Integrated” is aimed at enhancing the highway tunnel technical condition survey to timely discover and eliminate potential hazards and guarantee safe, smooth and comfortable traffic conditions.

1.0.5 Due to the greatly different scales, traffic volumes, highway classifications, geological and technical conditions of different highway tunnels, the maintenance requirements (for contents, items and frequencies) are also different. In order to adapt to such different maintenance demands, the tunnel maintenance shall be carried out in accordance with different classes.

1.0.6 Due to the impact of different natural environment, the structural damage and facility condition of each tunnel are different, so the corresponding maintenance planning and scheme shall be worked out in accordance with the specific conditions.

1.0.7 The design documents and completion data of tunnel during the construction period are important bases for the preparation of maintenance planning, so they shall be collected completely. In order to improve the scientific level and efficiency of the maintenance management and decision-making work, it is necessary to establish technical files for tunnel maintenance. If conditions permit, the information-based means shall be encouraged to be used to establish a highway tunnel management database, so as to realize efficient and scientific maintenance management.

1.0.8 The safety measures adopted during in-tunnel maintenance are aimed to prevent the mutual interference between maintenance and traffic and guarantee the safety of maintenance workers, drivers and passengers.

1.0.9 In general, China's highway tunnel work still faces the problems of low maintenance technology level, backward methods, low information levels and lagged management. In order to improve the tunnel maintenance quality and technology level, it is necessary to actively adopt new technology, new material, new equipment and new process for tunnel maintenance, so as to make China's tunnel maintenance technology reach a relatively advanced level as soon as possible.

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# 3 Maintenance Class and Technical Condition

## 3.1 Maintenance class

3.1.1 The maintenance demands and resources for tunnels of the same-class highways are different due to the difference of traffic volume, technical conditions and natural conditions. In reality, the maintenance requirements for different tunnels of the same-class highways shall be detailed to meet such different maintenance demands, which is also the original intention of the “maintenance classification” proposed herein. The research on China’s relevant maintenance specifications shows that: there is a clear maintenance class classification in current maintenance specifications for urban roads, bridges and tunnels. Now there is no concept of “maintenance class” in the current highway maintenance technical standard system, but the idea of classed maintenance has been reflected in the maintenance specifications that different maintenance frequencies and maintenance technical standards have been implemented for different categories of highways.

Relevant researches and analyses show that the highway maintenance class are mainly determined by: highway classification, traffic volume, technical conditions, climate conditions, etc. The highway classification, traffic volume and tunnel scale are the main factors to be considered when the highway tunnel maintenance class is classified. In practical application, the maintenance class may be appropriately adjusted according to other indicators due to different local conditions.

The so-called *AADT* refers to the average value obtained by dividing the total traffic volume observed in a year by the total number of days in a year (365) (unit: veh/d). The calculation formula is:

$$AADT = \frac{1}{365} \sum_{i=1}^n Q_i$$

In the analysis and calculation of traffic capacity and level of service, the traffic volumes of various types of vehicles in the actual or estimated traffic compositions shall be converted into traffic volumes of

standard passenger cars (traffic volume unit after conversion: pcu/d). In accordance with *Notice on Adjusting Vehicle Type Classification & Conversion Coefficient for Highway Traffic Survey* (TGH Zi [2010] No. 25) of the Ministry of Transport, the reference conversion coefficients for motor vehicle types are as shown in Table 3-1. The conversion coefficient for traffic volume conversion is the equivalent value of the influence of all non-standard vehicles on traffic flow equivalent to standard vehicles (small passenger car) under specific conditions of highway and traffic compositions.

**Table 3-1 Reference values for conversion coefficients of motor vehicles**

Vehicle type	Automotive							Motorcycle	Tractor
Category	Small vehicle		Medium vehicle		Large vehicle	Super-large vehicle			
Sub-category	Medium bus	Minibus	Big-bus	Medium trunk	Large truck	Super-large truck	Container car		
Reference conversion coefficient	1	1	1.5	1.5	3	4	4	1	4

After the highway is put into service, the data obtained by the management and maintenance authority with the traffic volume survey test equipment is usually the traffic volume of various vehicles (veh/d), which can be converted into the AADT of passenger car (pcu/d) according to Table 3-1.

By the classification of maintenance class, the maintenance resources can be allocated reasonably. The Class-I maintenance needs the strongest maintenance resources and technical force, followed by Class-II maintenance and the Class-III maintenance needs the least maintenance resources and technical force. In practical application, the maintenance classes of different tunnels in the same road segment may also be different due to the differences in traffic volume, tunnel length, geological conditions, hydrological conditions and technical conditions.

### 3.2 Technical condition assessment

3.2.1 Tunnels cover three parts herein, including tunnel structure, M&E equipment and other facilities. The tunnel technical condition assessment includes: tunnel structure, M&E equipment, other facilities and overall assessment of the tunnel, with the parts-to-overall assessment adopted.

Firstly, each item shall be assessed in accordance with the technical condition assessment methods for the tunnel structure, M&E equipment and other facilities as specified in Chapters 4 ~6 to determine the value of each item, which is the key to and basis of the overall technical condition assessment work. After that, the technical condition scores of tunnel structure, M&E equipment and other facilities shall be

calculated by the specified methods and then the overall technical condition of the whole tunnel shall be determined finally.

In practice, the tunnel structure, M&E equipment and other facilities of some tunnels are not complete. Therefore, during the assessment, attention shall be paid to the impact of corresponding missing items on the assessment results.

3.2.2 In the *Highway Performance Assessment Standards* (JTG H20-2007), the highway technical condition is divided into 5 classes: excellent, good, medium, inferior, poor. In the *Technical Specification of Maintenance for Highway* (JTG H10-2009), it is also stipulated that “the assessment of highway maintenance quality shall be in strict accordance with the provisions as stipulated in the *Highway Performance Assessment Standards* (JTG H20)”. Such established practice has been adopted in relevant specifications on pavement, subclass and bridge maintenance, while it is not adopted in the original *Technical Specification for Maintenance of Highway Tunnel*. Therefore, in this revision, it is proposed to divide the overall technical condition assessment of highway tunnel into 5 categories and give the respective qualitative descriptions on the basis of overall consideration of the tunnel technical condition assessment methods and established practice.

3.2.3 For determination of the overall technical condition of highway engineering or highway bridge, the method is adopted by which the weighted sum of technical condition scores of various items is obtained first, and then the technical condition class is determined based on the indicator range. For this revision, special topic researches on the method for overall technical condition assessment of highway tunnel have been carried out and two methods are proposed. The first method is to take the worst technical condition category of those of tunnel structure and M&E equipment as the overall technical condition category. The second method is to classify the overall technical conditions by quantitative calculation according to the weighted sum of indicators. The specific scheme is as follows:

The overall technical condition score of tunnel is calculated by formula (3-1).

$$CI = (JGCI \times W_{JG} + JDCI \times W_{JD} + QTCI \times W_{QT}) / \sum \cdot W \quad (3-1)$$

Where:  $CI$ —overall technical condition score, with a range from 0 ~ 100;

$JGCI$ —technical condition score of tunnel structure, with a range from 0 ~ 100;

$JDCI$ —technical condition score of M&E equipment, with a range from 0 ~ 100;

$QTCI$ —technical condition score of other facilities, with a range from 0 ~ 100;

$W_{JG}$ —weight of tunnel structure in overall assessment, with the value according to Table 3-2;

$W_{JD}$ —weight of M&E equipment in overall assessment, with the value according to Table 3-2;

$W_{QT}$ —weight of other facilities in overall assessment, with the value according to Table 3-2;

$\sum W$ —sum of weights of all items in the overall technical condition assessment.



**Table 3-2 Values of weights in overall technical condition assessment of tunnel**

Item	Weight	
	Expressway, Class-1 highway	Class-2 and below highways
Tunnel structure	60	70
M&E equipment	35	25
Other facilities	5	5

The overall technical condition score of tunnel is calculated by multiplying the value of items by the corresponding weights, avoiding the adjustment of weight values in the case of possible missing item. Considering that the proportions of M&E equipment and other facilities vary for highways of different classes, namely the importance and proportion of M&E equipment in expressway tunnels are greater than those in Class-2 and below highway tunnels, and the lower the highway classification, the lower the proportion of M&E equipment. Therefore, the weight values for high-class highways and Class-2 and below highways are respectively given in Table 3-2. The weight values for various items as listed in Table 3-2 is determined after statistical analysis on weight schemes solicited nationwide.

The threshold values for overall technical condition category of tunnel are as shown in Table 3-3.

**Table 3-3 Threshold values for overall technical condition category of tunnel**

Technical condition score	Overall technical condition category of tunnel				
	Category 1	Category 2	Category 3	Category 4	Category 5
<i>CI</i>	$\geq 90$	$\geq 80, < 90$	$\geq 70, < 80$	$\geq 60, < 70$	$< 60$

However, considering that the interrelation among tunnel structure, M&E equipment and other facilities is weak, especially the tunnel structure and M&E equipment belong to civil works structure and traffic operating condition facilities respectively, if the technical condition category is divided in accordance with the weighted sum, it is difficult to achieve satisfactory results in determining the weights and boundaries of items. Therefore, after solicitation of opinions in the industry, the method that takes the worst technical condition category as the overall technical condition category is adopted herein.

3.2.4 This clause describes the work flow of technical condition assessment of highway tunnel. The tunnel field inspection is carried out in accordance with the tunnel inspection plan; the technical condition assessment for each inspection item is performed, based on the results of which, the technical conditions of tunnel structure, M&E equipment and other facilities are calculated in accordance with relevant assessment models; and finally, the overall technical condition assessment of the whole tunnel is performed. Relevant materials shall be filed as prescribed after the completion of assessment.

# 4 Tunnel Structure

## 4.1 General provisions

4.1.1 The tunnel structure mainly refers to various civil works structures constituting the highway tunnel, such as tunnel portal, lining, pavement, waterproofing and drainage facilities, inclined (vertical) shaft, maintenance path and duct, as well as surrounding rock mass and portal side and front slopes that are closely related with the tunnel safety.

One item is added and one item is revised for the maintenance of tunnel structure herein. “Daily patrol” is added. The daily patrol is specified in the *Technical Specification of Maintenance for Highway* (JTG H10-2009). Different from the regular inspection in “structural inspection”, it mainly refers to the walk-around visual inspection on abnormalities affecting the tunnel traffic and structure safety in daily maintenance, both the depth and breadth of which are less than those of regular inspection, but the frequency of which is higher than that of regular inspection.

The “structural inspection” in the original *Specification* is revised as “structural inspection and technical condition assessment”. The technical condition assessment of structure is a key and difficult work in highway tunnel maintenance, which is carried out immediately after structural inspection. The revision is intended to emphasize the importance of assessment.

The daily patrol refers to the daily walk-around inspection on the normal use and safe passage of highway tunnels.

The cleaning work mainly includes sweeping garbage in tunnel, removal of dirt from structures, and cleaning (dredge) the drainage facilities, so as to maintain clean and neat appearance of structures.

The contents of structural inspection and technical condition assessment are focused on identifying abnormalities of structures, systematically identifying and assessing the technical conditions of structures

and determining corresponding maintenance countermeasures or measures.

The focus of the maintenance and repair section is upon preventative maintenance of structures and repair slight damages of structure, so as to maintain structures in good condition.

The contents of structural degradation treatment include repairing damaged structures, removing structural diseases and restoring structures to meet design standards, so as to maintain normal technical functions of structures.

### 4.3 Cleaning

4.3.1 Generally, the larger the traffic volume of a tunnel, the more serious the pollution, the more quickly the structure gets dirty, the shorter the cleaning cycle; vice versa. Compared with other highway structures, tunnels are long tubes in which particulate matter emissions are less likely to be diluted and dispersed, so the cleaning cycle is relatively short. The cleaning and maintenance of structures are usually carried out when the traffic volume is small, such as holidays and nights, so as to minimize the traffic interference and reduce the risk of accidents.

The cleaning and maintenance frequencies for various structures are summarized in Table 4.3.1-1 and Table 4.3.1-2 according to different maintenance classes. Generally, the maintenance frequency for expressway in the original *Specification* is defined as the “Class-I maintenance” frequency for expressway, which is the upper limit; the frequencies of “Class-II and Class-III maintenance” are reduced appropriately on the basis of the “Class-I maintenance” frequency, so as to adapt to the actual maintenance experience. The maintenance frequency for other highways in the original *Specification* is defined as the “Class-III maintenance” frequency for other highways, which is the lower limit; the frequencies of “Class-I and Class-II maintenance” are increased appropriately on the basis of the “Class-III maintenance” frequency, so as to meet the actual maintenance quality requirements. On the basis of the above principles, the final recommended frequencies are given after statistical analysis of opinions from all provinces (regions and municipalities) throughout China on specific frequencies.

4.3.2 The pavement shall be cleaned frequently in order to keep the pavement clean and provide a safe and comfortable traffic environment. The pavement in tunnel is more likely to get dirty because there is no rain to wash them, while the cleanliness of pavement is closely related to the service quality of tunnel. The debris on pavement is a great threat to traffic safety. Therefore, it is recommended to specify a relatively short cleaning cycle and the combination of sweeping with picking may be adopted.

The pavement dirty parts refer to both sides of lanes, lay-bys, etc. Dust tends to accumulate on both sides of lanes, which will cover the lane signs and markings, delineators, etc., making it hardly

recognizable; while dust and debris often accumulate on lay-bys, so special attention shall be paid during cleaning. Due to the limited spacing, tunnels shall be cleaned rapidly and effectively, so road sweepers should typically be used. The road sweepers mainly include brush type and vacuum type. The brush-type is applicable to the pavement with relatively more sand and soil, while the vacuum-type one is applicable to the environment with requirements for rapid cleaning. According to the national conditions of China, hand sweeping is still very common for the cleaning of highway tunnel pavement, by which the pavement is swept by hand and then the garbage is transported by vehicles.

The cleaning of roadside drains shall be enhanced to avoid the tunnel drainage facilities being blocked by garbage, causing water overflowing on pavement and affecting the traffic safety. Large garbage scattered on the pavement shall be frequently removed. It is emphasized that in case of large traffic volume, the safety inspection on tunnels should be enhanced to ensure the tunnel safety.

It is difficult to remove oil substances and other chemicals, so effective measures must be taken for removal.

4.3.3 In order to keep clean and tidy appearance of roof and interior decoration, maintain a comfortable traffic environment and improve the efficiency of lighting system, the roof and interior decoration must be cleaned and maintained regularly.

There are two cleaning methods for tunnels; wet cleaning and dry cleaning. Currently, wet cleaning is adopted widely, but it needs to set up a cleaning water sedimentation tank to treat waste water before discharging; while dry cleaning does not need the treatment of waste water, but it will produce a large amount of dust that worsens the tunnel environment, so it may need the use of dust collectors simultaneously or need to guide the passing vehicles. The characteristics of such two cleaning methods are as listed in Table 4-1.

**Table 4-1 Characteristics of wet cleaning and dry cleaning**

Cleaning method	Wet cleaning	Dry cleaning
Equipment	Waste water sedimentation tank	Relatively simple equipment
Working scale	Relatively large	Relatively small
Impact on interior decoration panel	The pressure of brushing is smaller than that of dry cleaning	The pressure of sweeping is relatively large, which may damage the interior decoration panel
Impact on passing vehicles	Waste water spreads, but it can be controlled, with small impact on traffic	A large amount of dust will be produced, affecting traffic
Cleaning effect	Relatively good	Relatively poor, the floating dust may re-attach

If the wet cleaning method is adopted, some dirt may be removed by washing with water, while the deposited smoke ash and oily (combustion) residues, especially the soot from diesel engine, may need cleaning agents and tools for removal. Neutral cleaning agents shall be adopted to reduce the hazard to in-tunnel maintenance workers, structures and facilities.

High-pressure water guns may be used to clean the roof and interior decorations of tunnels instead of brushes. The method is to spray the cleaning agent solution first and after the reaction of cleaning agent with dirt, spray clear water under 500 ~ 600 Pa by small nozzles for high pressure washing.

4.3.4 1 Tunnel drainage facilities shall be cleaned and dredged regularly to maintain their good drainage functions, ensure unimpeded water drainage and timely discharge of the groundwater behind tunnel lining and in-tunnel water leakage, sewage, water carried in by vehicles and other standing water, so as to avoid the water to affect traffic or damage tunnel structure or facilities.

2 In rainy season and freezing season, the tunnel drainage facilities are easy to be blocked, which poses a threat to traffic safety and will induce damage to the lining structure in severe case, so it is necessary to enhance the inspection and dredging of drainage facilities.

3 The *Specification for Design of Highway Tunnels* (JTG D70-2004) stipulates that: the tunnel longitudinal slope shall not be less than 0.3%. When the slope is 0.3% ~ 0.5%, the water flows slowly and the debris is easy to deposit, resulting in easy blocking of ditches, so special attention is required; the tunnel portal zone is prone to the accumulation of garbage and various debris, resulting in side drain siltation and affecting the drainage.

4.3.5 The cleaning of markings and delineators is included in the scope of tunnel structure cleaning; the cleaning of electro-optic signs is included in the scope of M&E equipment cleaning; and the cleaning of other signs is included in the scope of tunnel structure cleaning. Over recent years, tunnel alignment guiding signs and delineators are more and more widely adopted. In order to maintain their clear and eye-catching appearances, and to ensure the clear and correct delivery of traffic information and improve the safety and energy conservation of tunnels, the signs, markings and delineators inside and outside tunnels must be cleaned.

4.3.6 ~ 4.3.7 The cleaning and maintenance of auxiliary passages such as tunnel horizontal adit, inclined (vertical) shafts, maintenance paths and ducts are not stipulated in the original *Specification*. With the increasing number of long tunnels, the corresponding cleaning for these auxiliary passages shall be stipulated in order to ensure the normal and emergency use of the passages. The cleaning frequency is determined according to the frequency of use and degree of importance.

## 4.4 Structural inspection

4.4.1 The structural inspection is divided into four categories based on factors like the inspection purpose, content and method.

1 The appearance condition refers to the appearance of a structure by visual observation. “Regular inspection” and the usual “daily patrol” in maintenance have similarities and differences. The “daily patrol” in practical work is a means of maintenance management, which is a visual inspection on the safety of the whole route by car or on foot by maintenance personnel. As for tunnels, the inspection shall focus on abnormalities that may hinder from traffic safety and structural safety, such as the instability of tunnel portal side and front slopes, lining damage, leakage of water and obstacles on pavement. Compared with “daily patrol”, the “regular inspection” is more detailed with a lower frequency.

3 The natural disasters refer to earthquake, landslide or collapse, mudslide, rainstorm, mountain torrent, snowstorm and avalanche, etc. ; the traffic accidents refer to scratch, crash against vehicle (wall), rollover, fire, etc. ; other abnormalities refer to abnormalities that endanger the safety of traffic and structural facilities, such as sudden damage of structure, passing of over-limit vehicles, tunnel portal rockfall, surrounding rock mass collapse, lining deformation or collapse, road subsidence, large amount of water leakage, large amount of icicles, severe freeze damage or explosion, etc.

4 “By other ways” means to obtain potential problems of structures by other tunnels with similar conditions; the detailed defect or structural degradation information refers to the causes, range, development degree and condition, impacts on using functions of structures, etc. ; further special investigation refers to special field test detection, trial, analysis and identification, investigation and analysis of relevant materials, etc.

4.4.2 This clause specifies the frequency of regular inspection according to different maintenance classes. Where there is high risk of structure instability that endangers the safety of pedestrians and vehicles, the frequency of regular inspection shall be increased. Severe weather conditions may also increase the risk of surrounding rock mass and structural instability. For example, extremely heavy rainstorm may cause the surge of water pressure behind linings, leading to lining cracking and collapse; extreme low temperature may cause accumulation of snow at tunnel portal, icicles on the structural surface, road ice-up and frost heaving behind lining, etc. , all of which will endanger traffic and structural safety, so the frequency of regular inspection shall also be increased.

4.4.3 1 Simple inspection tools refer to tape, steel tape, hammer, flashlight, and chalk that are commonly used and easy to be carried. The results of regular inspection shall be classified in accordance

with Table 4.4.3.

2 The judgment follows the methods as stipulated in the original *Specification*. The three-level defect judgment is a pre-established strategy so that quick response can be made in case of abnormality, which is mainly carried out by the personnel responsible for tunnel regular inspection, and the defect condition is also judged by the personnel. The work flow is as shown in Figure 4-1. The tunnel portal in Table 4.4.3 includes the tunnel portal protection facilities, surface drainage facilities, light-reduction facilities, etc.; the ceiling includes the suspension structures of M&E equipment; and the interior decoration includes the trim panel, veneer (surface treatment), etc.

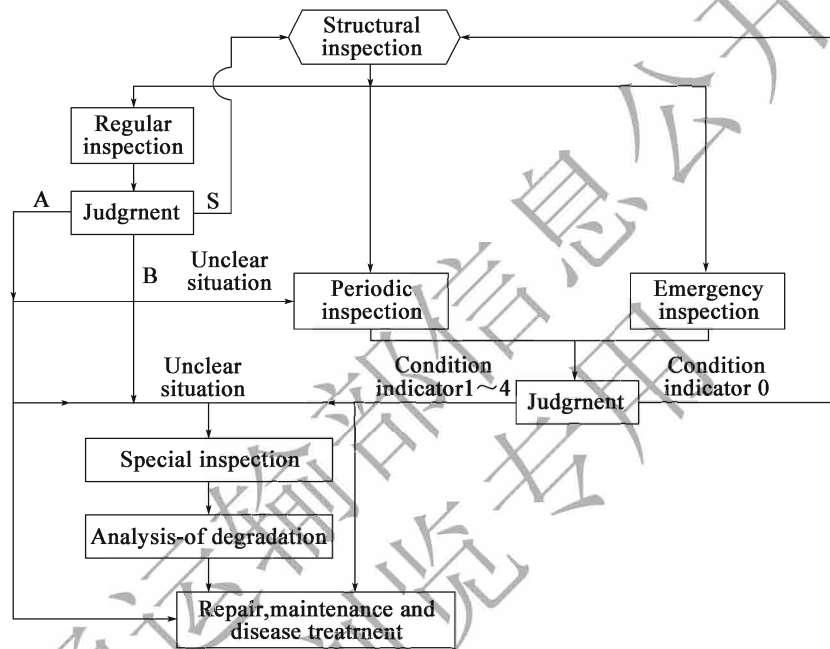


Figure 4.1 Work flow of tunnel structural inspection

Note: The English letters “S, B and A” may be used to represent the judgment results of “normal, general abnormality and severe abnormality” respectively. S-normal; B-general abnormality, requiring further inspection or observation / unclear abnormal situation; A-severe abnormality, requiring treatment measures

4.4.4 The maximum cycle of periodic inspection is determined by considering factors like China’s highway tunnel technical level, engineering quality, tunnel importance and technical condition. The important structural items refer to the tunnel portal, tunnel frame, lining structure, pavement, various roof built-in elements, etc. The inspection time is usually after the spring thawing period or around the flood season. The requirements for newly built tunnels are aimed to discover the structural defects as early as possible to provide basic technical data for future maintenance and repair.

4.4.5 In order to master the functional condition of tunnel structure, assess the technical condition of structures and update the technical data and files, comprehensive inspection must be carried out on the tunnel structure regularly. The technical condition assessment refers to the assessment on the intactness,

defect or degradation and function of tunnel structure in accordance with the methods as specified in Section 4.5 hereof.

1 In order to meet the qualitative and quantitative requirements for technical condition assessment, the technical level of periodic inspection shall be improved. The necessary tools and equipment mainly refer to equipment such as:

Dimension measurement—tape, vernier scale, level gauge, laser profiler, etc. ;

Crack inspection—graduated magnifier, width measuring ruler, point gauge, graticule, crack width and depth meter, etc. ;

Lining structural inspection—hammer, resiliometer, ultrasonoscope, geological radar, etc. ;

Water leakage inspection—pH test paper, thermometer, etc. ;

Pavement inspection—friction-meter, profilometer, etc. ;

Lighting appliances—halogen lamp or visual inspection lamp, flashlight;

Recording tools—tunnel sketch, record book, camera or camcorder;

Lifting equipment—movable platform, lifting trolley.

In addition, cleaning tools and traffic control sign boards are also needed. If possible, the maintenance authority may use vehicle-mounted tunnel rapid scanning or shooting equipment, which can improve the inspection accuracy and speed and also beneficial to the electronic storage and use of inspection results.

3 Seen from the tunnel general section, the structures near the skewback are very weak. Under the effect of external pressure, the structural deformations usually occur here first, such as footing expansion, frost heaving, up-warping and subsidence of subgrade lower part, etc. , leading to cracking of pavement, faulting and cracking of construction joint, etc. During the inspection, cracks inside side drains, bump and inclination of side drain cover plates, pavement cracks, faulting and cracks of joints and other conditions shall be observed and recorded on the sketch.

Generally, it is required to draw cracks on the tunnel sketch, indicating the width and length, so as to provide basic data for the crack assessment, changes in time and maintenance and repair.

The “Tunnel Sketch” contains drawings (coordinate paper) on the front face and text records on the



back, which are recorded year by year for the convenience of discovering the law of the structural degradation development to assess the safety degree of tunnel. Comparatively speaking, photographs, videos and scanning results can record the actual conditions of structures more objectively and accurately, which are helpful to correctly judge the technical condition of structures and shall be actively adopted. Over recent years, vehicle-mounted continuous photographing technology and laser scanning technology have been developed, and professional equipment has been successfully applied at home and abroad.

4 ~ 5 In periodic inspection reports, the inspection results of all structures are integrated, the technical conditions and using functions of tunnel structure are assessed and suggestions or measures for improvement of maintenance are proposed based on the problems found in the inspection; where the causes of the abnormality are unclear, the suggestions on special inspection shall be proposed, with the contents including the special inspection causes, items, purposes and requirements; for identified structural degradation, the suggestions for treatment measures shall be proposed, with the contents including the causes for implementation of treatment measures, items, treatment measures, engineering costs and implementation time required, etc.

4.4.6 The method of emergency inspection is basically the same as that of periodic inspection, with necessary instruments and equipment; the contents of emergency inspection are more focused than those of periodic inspection, mainly specific to the impacts of abnormalities; the purpose of emergency inspection is to know about the impacts of abnormalities on structures and master the damage information of structures to ensure the safety of personnel, vehicles, structures and facilities. It is an inspection under special circumstances and must be carried out as soon as possible. Where abnormalities are discovered during the inspection, special inspection shall be carried out.

4.4.7 1 Where some tests require professional testing means and equipment, so they are usually entrusted to professional testing institutions. Besides, where a single inspection is insufficient to provide detailed information, a continuous or long-term inspection regime is required.

The items of special inspection are usually proposed in the report of regular inspection, periodic inspection or emergency inspection, in which the contents and requirements of special inspection are also determined. Generally, the contents in Table 4.4.7 may be implemented selectively.

2 The data research and geological and surface environment survey around a tunnel are key contents of special inspection, so as to fully grasp relevant technical information, find out the reasons for the development and change of tunnel structure, explore the rules and ensure the accuracy of special inspection results.

## (1) Data research

Generally, the following data must be collected for the data research:

- ① Design documents ( including the tunnel length, type of portal, shape of section, thickness of lining, material, buried depth, support, lining, etc. ) and geological survey memoir;
- ② Construction methods ( including main excavation methods, special construction methods, surrounding rock mass change records, various test reports, measurement reports, etc. ) and relevant construction records;
- ③ Handover and completion materials, quality inspection data during construction;
- ④ Inspection records ( including the section clearance inspection report, etc. );
- ⑤ Lining and reinforcement records, leakage treatment construction records, pavement deformation records ( including repair records ), temperature and rainfall records, records of natural disasters suffered by entrance open-cut zone, etc. ;
- ⑥ Field inspection records for defects or degradation like cracking, chipping, faulting, water leakage, etc.

## (2) Geological and surface environment survey of tunnel

① Surface environment survey: the mountains nearby may have the problems like poor drainage of slope, puddle with standing water, mountain cracks, karst cave development, mountain instability and slide, the reasons for which may be that the tunnel is within or near a landslide area; the tunnel is within or near a fault; there is development of rock joint development and the rock is fragmented; there are problems like the mountain vegetation destruction, soil erosion and karst cave development. The understanding of the surface conditions outside tunnel is helpful to analyze abnormalities inside tunnel. During inspection, the attention may be paid to the topography, landform, surface crack, subsidence, trees, etc. around the tunnel, as shown in Figure 4-2.

② Investigation on surrounding rock mass abnormality: it mainly focuses on the detection of the changes inside surrounding rock mass, aimed to monitor the deformation of surrounding rock mass, find out the causes of structural changes, monitor the impact of adjacent projects or the change of surrounding rock mass or lining during the treatment. Usually, a displacement meter or inclinometer is set in the surrounding rock mass to measure the axial deformation or vertical axial deformation. The ground surface deformation may be measured by a ground displacement meter.

a. Surrounding rock mass deformation investigation; a surrounding rock mass deformer is inserted into the borehole to measure the changes between arbitrary points of surrounding rock mass. The surrounding rock mass deformation investigation is used to confirm the existence of eccentric compression and the range of loosened rock mass, to monitor the impact of adjacent projects, and to monitor the implementation of treatment measures and judge effects.

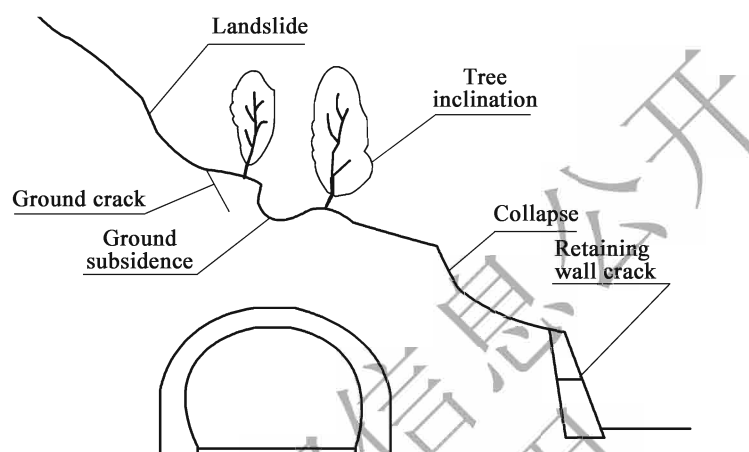


Figure 4-2 Abnormalities of surface environment outside tunnel (conceptual)

b. Surrounding rock mass inclination investigation; an inclinometer is inserted into the borehole to measure the horizontal deformation of surrounding rock mass.

c. Ground displacement investigation; the mobile pile and fixed pile are respectively set inside and outside the abnormal ground displacement area, with a ground displacement meter installed on the fixed pile, which is connected with the mobile pile by a invar steel wire to reflect the ground displacement by the length of steel wire.

3 In recent years, highway tunnel structural degradation has become increasingly prominent, especially some areas with seriously unfavorable geology, major structural degradation or potential hazards, are prone to the structural instability, mud and water gushing and other accidents, causing heavy economic and life losses and great social impacts. Therefore, in order to enhance the monitoring and management of these special areas, a long-term observation system should be established to observe the deformation, stress and groundwater state.

4 The form of special inspection report is not specified, which can be written on the basis of actual inspection contents, but it shall meet relevant requirements for the management of engineering technical files.

## 4.5 Technical condition assessment of tunnel structure

4.5.1 The highway tunnel belongs to underground work and the reasons for the occurrence and development of its structural degradation are varied, so it requires rich knowledge and experience to assess the technical conditions of structure in the presence of degradation. For the assessment, comprehensive analysis shall be carried out based on the structure type, degradation form, location, state, development trend and other factors to make judgment by comparison.

More comprehensive and professional inspection equipment is adopted for the periodic inspection and emergency inspection of tunnel structure to carry out more detailed and comprehensive inspections, the results of which shall be subject to the technical condition assessment. The assessment shall be included into the contents of periodic inspection, which may be completed by the person responsible for periodic inspection.

Usually, special inspection is, on the basis of regular, periodic and emergency inspections, a more in-depth special inspection carried out when there is a need to further investigate the details and causes of defect or degradation, aimed to provide basic data for the preparation of degradation treatment scheme, focused on the local areas of defect or degradation. Therefore, the above noted normal technical condition assessment is not applicable to special inspections, but the value of the item inspected can be assessed.

4.5.2 On the basis of following the judgment method specified in the original *Specification*, the technical condition assessment method for tunnel structure is established also by reference to *Highway Performance Assessment Standards* (JTG/T H20-2007), *Code for Maintenance of Highway Bridges and Culverts* (JTG/T H11-2004), *Standards for Technical Condition Assessment of Highway Bridges* (JTG/T H21-2011) and the tunnel technical condition assessment methods of Japan and Taiwan Province of China. Specifically, a quantitative assessment method is adopted, which takes relevant factors into account, such as the weight of each item, degree of defect, development trend of defect, impact on traffic and structural safety.

4.5.3 The value of each item obtained by the technical condition assessment is established on the basis of following the judgment basis for special inspection of the original *Specification* and by embracing the achievements of relevant specifications at home and abroad, and also considering the impact degree of defect on traffic safety and structural functions and the development and change trend of defect from the quantitative and qualitative perspectives. Table 4-2 is the technical condition assessment standard for tunnel structure given in the notes to provisions of the original *Specification*.

**Table 4-2 Technical condition assessment of tunnel structure**

Value	Assessment factor			
	Damage degree	Development trend	Impact on the safety of pedestrians and vehicles	Impact on the safety of tunnel structure
0	None or very slight	None	No impact	No impact
1	Slight	Tending to be stable	No impact yet	No impact yet
2	Medium	Slow	It will affect the safety of pedestrians and vehicles	It will affect the safety of tunnel structure
3	Less severe	Less rapid	It has already affected the safety of pedestrians and vehicles	It has already affected the safety of tunnel structure
4	Severe	Rapid	It has severely affected the safety of pedestrians and vehicles	It has severely affected the safety of tunnel structure

Lining is the most important tunnel structure of highway tunnel, which is related to the safety of structures, pedestrians and traffic. The qualitative standards for assessment of lining damage and leakage are given in appendix Table B-3 and Table B-4.

(1) Due to external load effect

① Usually, the deformation, movement and settlement of lining are gradual changes and may become obvious after earthquake, landslide and rainstorm. In cold regions in north China, the structure deforms due to frost heaving and occurs repeatedly with the seasonal cycle.

The covering layer around the tunnel portal is relatively thin. Even if the structure deforms, the movement and settlement are typically not large however they may also lead to the instability of slope, cavity of extrados and increase of water leakage. This should be the focus of inspections in these regions. In case of the section deformation, the pavement and side drain usually change first, so special attention shall be paid to these places during inspections. In the technical condition assessment at home and abroad, there are also quantitative assessment standards for deformation caused by external load, as shown in Table 4-3.

**Table 4-3 Assessment standards based on deformation speed**

Structure	Deformation speed $v$ (mm/year)				Assessment value
	$v \geq 10$	$10 > v \geq 3$	$3 > v \geq 1$	$1 > v$	
Lining	√				4
		√			3
			√		2
				√	1

Note: “√” represents the judgment classification that should be adopted under corresponding circumstances, similarly hereinafter.

② Factors such as the development of cracks shall be considered for the assessment of defects like lining cracking. There are also quantitative assessment standards for lining cracking at home and abroad, as shown in Table 4-4 and Table 4-5. The cracks in the table are mainly horizontal or shear cracks. For transverse cracks, the assessment value can be reduced by 1 class accordingly. When the crack breadth is more than 0.3 ~ 0.5mm and the distribution density is more than 200cm/m<sup>2</sup>, the judgment may be increased by one class or the higher one in the judgment classification may be adopted.

Besides, where there are many cracks, the crack with the largest breadth should be the main inspection object.

**Table 4-4 Assessment standards in the presence of crack development**

Structure	Crack breadth $b$ (mm)		Crack length $l$ (m)		Assessment value
	$b > 3$	$b \leq 3$	$l > 5$	$l \leq 5$	
Lining	√		√		3/4
	√			√	2/3
		√	√		2
		√		√	2

**Table 4-5 Assessment standards in case of unclear crack development**

Structure	Crack breadth $b$ (mm)			Crack length $l$ (m)			Assessment value
	$b > 5$	$5 \geq b > 3$	$3 \geq b$	$l > 10$	$10 \geq l > 5$	$5 \geq l$	
Lining	√			√			3/4
	√				√		2/3
	√					√	2/3
		√		√			3
		√			√		2/3
		√				√	2
			√	√	√	√	1/2

③ For the assessment of lining delamination, chipping and other damages, there are also qualitative assessment standards at home and abroad, as shown in Table 4-6.

**Table 4-6 Assessment standards for lining delamination and chipping**

Structure	Position	Probability of falling		Judgment
		Yes	No	
Lining	Arch	√		4
			√	1
	Side wall	√		3
			√	1

As for the concrete lining delamination and chipping, if there is probability of falling, the value shall be 4 for arch and 3 for side wall; as for the falling of waterproofing mortar and other materials, the value may be reduced by 1 because the chipping layer is relatively thin.

④ As for sudden collapse, according to foreign data, where there is a cavity more than 30cm high behind extrados and the effective lining thickness is less than 30cm, the lining structure may be broken by the cavity rockfall, and there have been similar cases at home and abroad. Therefore, where similar situation is found, the value may be 3/4. In particular, adequate attention shall be paid to the areas with a history of landslides or joints development and severe water leakage.

(2) The inspection in the lining material deterioration and other defects shall be mainly conducted from the perspectives of structural function and traffic safety. Therefore, the strength requirement for lining concrete and chipping of concrete are taken as the assessment factors. As for reinforced concrete structures, additional assessment shall be performed from the perspective of steel corrosion. As for the lining concrete delamination and chipping, from the perspective of ensuring traffic safety, the assessment standard shall be consistent with that for defect due to external load effect. Except for abnormalities such as fire, the speed of material deterioration is generally slow compared with the change caused by external load. It is possible to prevent or inhibit the development of deterioration by taking appropriate measures. There are also qualitative and quantitative assessment standards at home and abroad, as shown in Table 4-7 and Table 4-8.

**Table 4-7 Assessment standards for lining section strength reduction, delamination and chipping**

Structure	Main causes	Probability of delamination and chipping		Degree of deterioration			Assessment value
				Effective thickness / design thickness			
				< 1/2	1/2 ~ 2/3	> 2/3	
Arch	Deterioration, freeze damage, improper design or construction, etc.	Yes	No				4
		√					1
			√				3
				√			2
					√		1
Side wall	Deterioration, freeze damage, improper design or construction, etc.	Yes	No				3
		√					1
			√				3
				√			2
					√		1

**Table 4-8 Assessment standards for steel corrosion**

Structure	Main causes	Degree of corrosion	Assessment value
Lining	Salt damage, seepage, acidification (alkalization), etc.	Corrosion of surface or a small area	1
		Shallow hole corrosion or rusting around rebar	2
		Obvious reduction in steel material section, impairment of steel structure function	3

The strength change of the lining sections is expressed by the ratio of effective lining thickness to design lining thickness. The said effective thickness refers to the lining thickness where the concrete strength is not less than the design standard strength. Where the design standard strength is unclear, 15 MPa (150kgf/cm<sup>2</sup>) may be taken as the standard. For example, the design lining thickness is 50 cm and the actual lining thickness is 60 cm, among which the thickness of the part with a strength lower than the design standard strength is 20 cm, then the effective thickness is 40 cm, so the deterioration degree of lining is 40/50, and more than 2/3 parts are in line with the design requirements. The actual effective lining thickness must be 30cm atleast, otherwise the assessment value may be 2/3, which will be comprehensively judged with consideration to other relevant factors.

3) As for water leakage of cracks or construction joints, generally they usually do not require emergency measures. However, where the water leakage is combined with freeze damage or salt damage and other degradation, it may promote the deterioration of lining material, concrete corrosion, etc., which must be addressed. There are also relevant qualitative assessment standards at home and abroad, as shown in Table 4-9.

The expansion of leakage scope and increase of water leakage may be related to the loosening of extrados rock mass and the increase of precipitation. Due to the loosening of rock mass, the former may result in new water flow paths and expand the scope of leakages due to increased precipitation infiltrating into the ground and potential elevation of the ground water table.

**Table 4-9 Assessment standards for water leakage**

Structure	Main abnormalities	Degree of water leakage				Affecting passing vehicles or not		Assessment value
		Jetting	Gushing	Dripping	Infiltration	Yes	No	
Arch	Water leakage	✓				✓		4
			✓			✓		3
				✓		✓		2
					✓		✓	1
	Icicles					✓		3
						✓	1	



continued

Structure	Main abnormalities	Degree of water leakage				Affecting passing vehicles or not		Assessment value
		Jetting	Gushing	Dripping	Infiltration	Yes	No	
Side wall	Water leakage	✓				✓		3
			✓			✓		2
				✓		✓		2
					✓		✓	1
	Ice column					✓		3
							✓	1
Pavement	Outflow of sand and soil					✓		3/4
							✓	1
	Standing water					✓		3/4
							✓	1
	Ice-up					✓		3/4
							✓	1

The occurrence of standing water on pavement will affect traffic safety and will likely infiltrate into the subgrade. This has the potential to reduce subgrade strength and damage pavement. In cold regions, the standing water will freeze, affecting traffic safety. Therefore, the drainage facilities shall always be maintained unobstructed.

4.5.4 2 The inspection results of the segment with the most serious tunnel structural degradation shall be selected as the itemized inspection result of the tunnel. The segmentation method for items shall be determined according to the characteristics of each item, for example: the tunnel portal item is segmented according to the number of portals and is assessed separately for the entrance and exit; the lining item is segmented by length and generally, the unit length can be the formwork length or a value between 10m and 100 m; the horizontal adit for pedestrians (vehicles) can be included in the lining assessment as an assessment unit of the main tunnel lining.

3 In the technical condition assessment, different items are given different weights according to their importance. The proposal for weight values herein is put forward after statistical analysis of opinions solicited throughout China. Due to different conditions in different places, the expert assessment method may be adopted to adjust local highway tunnel maintenance standards according to actual conditions. The built-in elements in the “ceiling and built-in elements” refer to the built-in elements for hanging equipment like fans, lighting facilities and cables, and their damage may cause the falling of equipment from the roof and directly endanger the safety of traffic or structure.

4 The highway tunnel structural degradation classification are divided into S/B/A/2A/3A by current assessment method, with the same number of classes as the classification of bridges and culverts,. The assessment method herein classifies the results of the technical condition assessment of tunnel structure into 5 categories by reference to the *Technical Specification of Maintenance for Highway* (JTG H10-2009) and *Code for Maintenance of Highway Bridges and Culverts* (JTG H11-2004). The current threshold values of technical condition assessment classification of tunnel structure (Table 4.5.4-2) are comprehensively determined by the statistical analysis of empirical assessment classification by experts and *JGCI* calculation classification based on a large number of periodic inspection and special inspection reports of tunnels.

5 The additional requirements for technical conditions of category 4 and category 5 tunnels are established out of the protection of the safety of structure and traffic. Where the value of an important item reaches 3, the whole tunnel is category 4; where the value of an important item reaches 4, the whole tunnel is category 5.

## 4.7 Structural degradation treatment

4.7.1 The main technical working procedures for degradation treatment include: inspection, assessment, design, construction and acceptance.

1 The inspection and assessment mainly focus on the segmented inspection of each structure item and analysis of degradation causes to provide basis for treatment design.

2 The key to the selection of degradation treatment method is to correctly understand the causes of structural degradation. In order to find out the causes of structural degradation, it is necessary to comprehensively analyze and research relevant tunnel design and construction technical data, geological data and the process of degradation since its occurrence. The causes of structural degradations are generally classified as follows:

- (1) Relaxation earth pressure (including sudden collapse);
- (2) Eccentric compression;
- (3) Stratum landslide;
- (4) Expansive earth pressure;
- (5) Inadequate bearing capacity;

- (6) Hydrostatic pressure;
- (7) Frost-heaving force;
- (8) Material deterioration;
- (9) Water leakage;
- (10) Void behind lining;
- (11) Insufficient lining thickness;
- (12) No invert.

The above degradation causes rarely appear alone and on the contrary, several causes occur repeatedly in most cases. The degradations are usually caused by design defects, material properties and improper construction.

For the selection of degradation treatment methods, the treatment methods as shown in Table 4-10 must be comprehensively researched, with full consideration to single or combined treatment methods, and also the traffic management and safety during construction and the construction period.

3 The tunnel with structural degradation always has the risk of structural instability, which is a threat to the safety of construction personnel, pedestrians and traffic. Therefore, it is necessary to introduce the risk management into the degradation treatment work and establish special emergency plan.

4.7.2 3 The structural degradation treatment work is still a tunnel work. In consideration of the complexity and unpredictability of tunnel work, the treatment shall still follow the ideas and principles of information-based design and dynamic construction.

4 The degradation treatment construction of in-service tunnel will inevitably interfere with pedestrians and traffic. Therefore, the treatment schemes and measures shall be established on the premise of guaranteeing operation and traffic safety and reducing the mutual impact between construction and traffic as much as possible, and reliable safety measures and deliberate traffic organization design shall be established to guarantee the safety of traffic and construction personnel.

Table 4-10 Structural degradation treatment method selection

Treatment method	Causes of structural degradation										Degradation phenomenon characteristics	Expected effects		
	Changes caused by external forces							Others						
	Relaxation pressure	Eccentric compression	Stratum landslide	Expansive earth pressure	Inadequate bearing capacity	Hydrostatic pressure	Frost-heaving force	Material deterioration	Water leakage	Void behind lining			Insufficient lining thickness	No invert
Grouting behind lining	★	★	★	★	★	★	★	○	★	★	★	★	① Crack, chipping and peeling of lining ② Cavity of supporting structure	The primary lining and rock mass, secondary lining and primary lining are closely combined, with uniform load distribution and stable lining and surrounding rock mass
Protection mesh					★		★						① Crack, chipping and peeling of lining ② Deterioration of lining material	Prevent local deterioration of lining
Shotcrete		★		★	★	○	★	○	○	★	★		① Crack, chipping and peeling of lining ② Deterioration of lining material	Prevent local deterioration of lining
Steel strip construction					★		★		○	★	★		① Crack, chipping and peeling of lining ② Deterioration of lining material	Prevent local deterioration of lining
Bolt reinforcement	★	★	★	★	★	○	○	○	○	★	★		① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Crack of pavement, expansion of subgrade	① The rock mass stability increases after the rock mass improvement to avoid the increase of relaxation pressure; ② Improve the strength to withstand expansive earth pressure and eccentric compression by applying pre-stress
Drainage and water stopping	○	○	★	○	○	★	○	★					① Increase of water leakage from lining crack or construction joint; ② A large amount of sand or soil flow out with water leakage from lining crack	① Prevent lining deterioration and maintain beautiful appearance ② Recover the function of drainage facilities to reduce water pressure
Grooving for arch embedding or adding steel arch	★	★	★	★	★	★	○						① Crack, chipping and peeling of lining ② Deterioration of lining material	Increase the stiffness of lining to improve the shear and compressive strength of lining
Cover arch	○	★	★	★	★	○	★	○	○	★	★		① Crack, chipping and peeling of lining ② Deterioration of lining material	The shear strength of lining is improved due to the increase of lining thickness

Table 4-10 (Cont'd)

Treatment method	Causes of degradation										Degradation phenomenon characteristics	Expected effects
	Changes caused by external forces					Others						
Thermal Insulation	Relaxation pressure										① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Change with seasons	① Prevent the deterioration of lining by prevention of freezing ② Prevent the formation of frost heaving pressure
	Frost-heaving force	★										
Landslide treatment	Relaxation pressure										① Crack of lining, reduction of clearance width; ② Crack of pavement, expansion of subgrade	Prevent the landslide of rock stratum
	Stratum landslide		★									
Surrounding rock mass grouting	Relaxation pressure										① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Crack of pavement, expansion of subgrade	Improve the surrounding rock mass to improve the shear strength and cohesive force
	Stratum landslide			★								
Anchor grouting	Relaxation pressure										① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Crack of pavement, expansion of subgrade	Improve the strength of expansive rock stratum and eccentrically compressed rock stratum by applying pre-stress
	Stratum landslide			★								
Tunnel bottom reinforcement	Relaxation pressure										① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Crack of pavement, expansion of subgrade	Improve the resistance against the pressure of expansive and eccentrically compressed surrounding rock mass
	Stratum landslide			★								
Lining replacement	Relaxation pressure										① Crack of arch and side wall concrete, extrusion of side wall concrete; ② Crack of pavement, expansion of subgrade	Replace the lining to improve durability
	Stratum landslide			★								

Note: 1. Symbol description: ★ - very effective method for degradation treatment; ☆ - relatively effective method for degradation treatment; ○ - slightly effective method for degradation treatment.

2. The relaxation earth pressure includes the sudden collapse.

5 The highway tunnel is a combination of civil structure and M&E equipment. Therefore, the treatment schemes and measures shall be established in a way to minimize the impact on M&E equipment; and M&E equipment, drainage facilities and associated facilities shall be restored after the completion of construction.

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# 5 M&E Equipment

## 5.1 General provisions

5.1.1 M&E equipment refers to the equipment for tunnel operation, including power supply and distribution facilities, lighting facilities, ventilation facilities, fire-fighting equipment and monitoring and communication facilities.

In the *Specification*, maintenance of M&E equipment includes four parts: daily patrol, cleaning and maintenance, overhauling and assessment, and special work. “Emergency overhauling”, “regular overhauling” and “periodic overhauling” in previous specifications are included in “M&E equipment overhauling and assessment”, that is, M&E equipment overhauling and assessment include regular overhauling, periodic overhauling and emergency overhauling. According to maintenance practice, “special work” is newly added. Since “disassembled overhauling” is hard to carry out in practice, the related requirements are abrogated in the *Specification* and the related contents are included in “special work”.

The maintenance periods of various equipment or positions of one equipment are different. The *Specification* is compiled on the basis of suggestions proposed by tunnel maintenance authority of Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities.

Special work refers to repairing of M&E equipment to make them meet the original technical standards.

5.1.3 Product manuals of M&E equipment specify the detailed requirements on product application and maintenance. It is essential for equipment maintenance. Apart from the general standards, the related specifications include the bid invitation documents and technical standards of M&E equipment. The documents normally specify requirements on main technical indicators.

5.1.6 The requirement that the aerial tunnel work of expressway tunnel structure requires to be done with aerial work platform truck so as to ensure maintenance safety and improve maintenance efficiency. In consideration of unbalanced economy development and different maintenance measures, there is no mandatory requirement for other classes of highway tunnels.

## 5.2 Daily patrol

5.2.1 3 Daily patrol of ventilation facilities mainly aims to recognize and solve faults via visible and sensible phenomena.

## 5.3 Cleaning and maintenance

5.3.1 Generally, the larger the traffic volume of a tunnel, the more serious the pollution, the more easily the M&E equipment getting dirty, the shorter the cleaning cycle; vice versa. Compared with other highway structures, tunnels are long tubes in which particulate matter emissions is less likely to escape, so the cleaning cycle is relatively short.

The cleaning and maintenance frequencies for M&E equipment are summarized in this Article according to the maintenance classes. Class-III and Class-IV cleaning cycles are decided by reference to the upper and lower limits of original frequencies and the suggestions proposed by tunnel maintenance authority of Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities. Class-II cleaning cycle is given a range here, which is between those of Class-III and Class-IV cleaning cycles.

Cleaning and maintenance of M&E equipment shall be carried out when the traffic volume is small, such as holidays and nights, so as to minimize traffic interference and reduce the risk of accidents.

5.3.2 There are two cleaning methods: wet cleaning and dry cleaning. The wet cleaning mainly adopts water while dry cleaning requires no water. However, dry cleaning will produce a large amount of dust that worsens the tunnel environment, so it may need the use of dust collectors simultaneously or need to guide the passing vehicles.

By wet cleaning, some dirt may be removed only by washing with water, while the deposited smoke ash and oily (combustion) residues, especially the lampblack from diesel engine, may need cleaning agents and tools for removal.



5.3.4 Power equipment of distribution substation includes HV switch cabinet, LV switch cabinet, power transformer, power capacitor cabinet, self-generating equipment and so on.

Electro-optic signs include emergency call sign, fire-fighting equipment sign, pedestrian horizontal adit sign, vehicle horizontal adit sign, evacuation indicator sign, lay-by sign, electronic information board and others.

## 5.4 Overhauling of power supply and distribution facilities

5.4.1 Power supply and distribution facilities include HV/LV switch cabinet set, box-type substation, distribution box, power cable, integrated microcomputer protection device, power supply device, hardware and other accessories for tunnel power supply.

Maintenance specifications are normally provided for large power supply and distribution facilities, which are essential for maintenance operation and can be saved as important technical files. Maintenance worker shall obtain qualification certificate for special work, and be provided with professional tools since the maintenance of HV/LV electric appliance is professional, casualty accident may occur and the facilities may be damaged in case of negligence.

The contents and cycles for regular overhauling and periodic overhauling of power supply and distribution facilities in Table 5.4.1 are confirmed by consideration of China's actual status, maintenance practice in Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities, and the suggestions of maintenance authority.

5.4.3 Since the power supply circuits are mainly maintained by the Power Supply Department and they have detailed requirements on maintenance, thus, the maintenance contents are not detailed here.

5.4.4 This Article aims to guarantee the safety of working personnel and equipment.

## 5.5 Overhauling of lighting facilities

5.5.1 Lighting facilities include luminaries, off-tunnel road luminaries, lighting circuits and associated facilities for tunnel lighting. The distribution box and control box are included in power supply and distribution facilities rather than lighting facilities of tunnel.

The contents and cycles for regular overhauling and periodic overhauling of lighting facilities in

Table 5.5.1 are confirmed by consideration of China's actual status, maintenance practice in Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities, and the suggestions of maintenance authority.

## 5.6 Overhauling of ventilation facilities

5.6.1 Ventilation facilities include jet fan, axial fan, centrifugal fan and associated facilities for tunnel ventilation.

By now, jet fan, axial fan and associated facilities are widely used. The centrifugal fan is not used at present but may be used in future works. The ventilation starting and control boxes are included in the power supply and distribution facilities.

The contents and cycles for regular overhauling and periodic overhauling of ventilation facilities in Table 5.6.1 are confirmed by consideration of China's actual status, maintenance practice in Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities, and the suggestions of maintenance authority and technicians.

5.6.4 Test devices, such as wind pressure meter, anemometer and sound level meter, shall be equipped for the tunnel with large ventilation facilities. The overhauling of the tunnel with small ventilation facilities can be entrusted to competent test organizations.

## 5.7 Overhauling of fire-fighting equipment

5.7.1 Fire-fighting equipment refers to that preventing fire and performing rescue, including fire alarm devices, fire-fighting equipment, electro-optic signs and so on.

The contents and cycles for regular overhauling and periodic overhauling of fire-fighting equipment in Table 5.7.1 are confirmed by consideration of China's actual status, maintenance practice in Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities, and the suggestions of maintenance authority. During fire-fighting equipment overhauling, disaster prevention measures shall be established, because the disaster prevention performance during equipment overhauling is lowered. Traffic control is a common method.

## 5.8 Overhauling of monitoring and communication facilities

5.8.1 Monitoring and communication facilities include luminance detector, visibility detector, CO detector, wind speed and direction detector, vehicle detector, CCTV system, emergency call and broadcasting, lane guide sign, information handling device, monitoring software and others for monitoring tunnel operation, equipment operation and control. There are lots of monitoring and communication facilities, only the main and auxiliary facilities for tunnel monitoring and communication are listed herein.

The contents and cycles for regular overhauling and periodic overhauling of monitoring and communication facilities in Table 5.8.1 are confirmed by consideration of China's actual status, maintenance practice in Chongqing, Yunnan, Shaanxi, Fujian, Sichuan, Zhejiang, Guangdong, Shanxi, Beijing, Liaoning and other cities, and the suggestions of maintenance authority.

5.8.2 Maintenance of monitoring software refers to the comprehensive test of control software so as to ensure a safe and economical operation.

## 5.9 Technical condition assessment of M&E equipment

5.9.1 Technical condition assessment of M&E equipment aims to confirm the operation of M&E equipment and provide references and measures for targeted maintenance and overhauling.

5.9.2 Since there are many kinds and items of M&E equipment for highway tunnel and they are relatively independent, it is necessary to assess the overall technical condition according to the item weights.

5.9.3 Equipment availability is an important indicator for judgment of technical condition and assessment of equipment management. As a key indicator for enterprise's equipment management, it has been utilized in China for many years and plays an important role in the guarantee of equipment operation and normal production. After years of operation and practice, the management and maintenance authorities of transport industry can expertly assess the technical condition of M&E equipment with equipment availability, which can be summarized in time via the tunnel or road segment monitoring center. Therefore, equipment availability shall be used for the technical condition assessment of M&E equipment.

Failure rate and other indicators are used for the assessment of equipment management. However,



# 6 Other Facilities

## 6.1 General provisions

6.1.1 Other facilities shall cover the cable trench, equipment room, cross passage at the tunnel portal, height restriction barrier at the tunnel portal, environmental landscape facilities at the tunnel portal and ancillary buildings and facilities. The maintenance of other facilities is similar to that of tunnel structure, so it is subject to the classification and maintenance of tunnel structure.

The daily patrol is intended to find out whether there is any traffic obstruction by other facilities and whether there is any obvious abnormality in the facilities.

In order to relieve visual fatigue, due to the small number of samples of artificial greening landscape set in extra-long and super-long tunnels, this part is not included in the revision of the *Specification*; landscape main structure is maintained with reference to the environmental landscape facilities at the tunnel portal; and lighting landscape is maintained with reference to the lighting in tunnel.

6.1.2 Daily patrol, inspections and assessment of other facilities shall be conducted together with tunnel structure so as to improve efficiency, reduce the impact on traffic operating condition and facilitate the technical condition assessment of a tunnel.

6.1.3 Other facilities with special requirements shall be maintained in accordance with relevant provisions which mainly refer to the national provisions about the maintenance and repair of environmental landscape facilities and the construction procedures of civil housing repairs; and the maintenance of the equipment and facilities in the fan room, substation, monitoring room, and the water, heating and power facilities in ancillary buildings shall be carried out in accordance with professional requirements.

## 6.3 Cleaning and maintenance

6.3.1 The frequency of cleaning and maintenance shall be determined according to the importance of facilities and the maintenance frequency of civil structure. If there are special requirements for the M&E equipment in fan room, substation and monitoring room, the cleaning and maintenance frequency shall be determined according to the relevant provisions which mainly refer to the relevant provisions in Chapter 5 herein.

6.3.2 The cable trench cover plate shall be included into the “maintenance path” of tunnel structure for cleaning and maintenance.

6.3.3 As for the long and extra-long double-tube separated tunnels, the cross passage at the tunnel portal shall be set up for special use, repairing, maintenance and rescue as well as cleaning to ensure that they can be used in emergency.

6.3.4 Height restriction barrier at the tunnel portal is one of height restriction facilities, and it shall be cleaned and maintained regularly to keep its sign clear, and correct the frame deformation to ensure its height restriction function.

6.3.5 Tall trees shall be planted within 30 ~ 50m on both sides of the entrance and exit of a tunnel to form a transition zone of light inside and outside the tunnel as much as possible so as to facilitate safe driving of vehicles. Side and front slopes at the tunnel portal shall be fully covered by wild flowers and plants, and planted with trees so as to integrate the tunnel portal into the surrounding natural landscape. When the side and front slopes of the tunnel are of soil, the grid landscape shall be generally adopted; and for the stone side and front slopes, the landscape shall be planted with net. Trees and vegetation shall be managed and controlled frequently, and done timely inspection, replanting, watering, weeding, ripping, fertilization, pruning and pests and diseases prevention.

6.3.6 Sculpture and nameplate can beautify the tunnel portal and they are the image characteristics of a tunnel, so they should be cleaned and maintained regularly.

6.3.7 The noise in tunnel increases with the increase of traffic volume, so the sound-absorbing materials can be covered on the surface of a tunnel to reduce noise.

(1) Sound-absorbing materials refer to glass wool, mineral wool, inorganic fiber materials and their plates.

(2) Sound-absorbing structures includes membrane resonance sound-absorbing, plate resonance sound-absorbing and cavity resonance sound-absorbing structure.

(3) Maintenance and repairing mainly cover wiping dirt, and repairing damaged parts (components). The damaged parts (components) should be repaired with the original materials.

6.3.8 Light-reduction facilities refer to the sunshade set up to improve the environmental brightness and landscape at the tunnel portal, mainly in the form of arch and scaffolding, and their materials include reinforced concrete, steel members and other light materials.

6.3.9 The cleaning and maintenance of sewage treatment facilities are mainly to ensure that the capacity of sewage treatment tank and purification tank will not be insufficient due to sediment and debris deposition.

6.3.10 The cleaning and maintenance of buildings and facilities shall be based on the provisions for use and maintenance in *Residential Building Code*, including foundation, floor and ground work, wall and ceiling work, doors and windows work, and roofing work.

Plinth is the foot of outer wall of a building, namely the thickened part of the wall between the outer wall and the outdoor ground (to disperse water). It is to prevent the erosion by surface water and protect walls. If the plinth is in good condition, it may effectively prevent the foundation and walls from being damaged, ensure indoor drying, and improve the durability of the building.

## 6.4 Inspection and assessment

6.4.1 Other facilities may not be performed the regular inspection and periodic inspection. It is necessary to check if the equipment room leaks water when the special inspection is conducted, and the emergency or special inspections can be carried out as needed for abnormalities such as foundation settlement and deformation.

6.4.4 Technical condition assessment on the pavement of cross passage at the tunnel portal shall be made as per that of in-tunnel pavement, and that of buildings and facilities is subject to the *Standard for Assessing Damage Condition of Buildings*.

6.4.5 For example, when assessing the technical condition of ancillary buildings and facilities, the fan room, substation room, monitoring room, water pump room and auxiliary production and living room shall be assessed one by one, and the highest condition value shall be taken as the

condition value of ancillary buildings to calculate the comprehensive score formula of technical condition of other facilities.

## 6.5 Maintenance and repair

6.5.2 The maintenance and repair of height restriction barrier at the tunnel portal and light-reduction facilities mainly refer to the restoration of the defects of main structures to ensure their using functions.

6.5.3 The sewage from the tunnel cleaning and fire-fighting activities contains a large amount of toxic and harmful substances, so it shall not be discharged until meeting the discharge criteria after being treated by sewage treatment facilities to avoid polluting the environment around tunnel. Therefore, the sewage treatment facilities shall be in good working condition. In case of any damage or leakage, the causes shall be found out and the leakage position shall be found out and repaired.

6.5.4 Relevant specifications mainly refer to the *Technical Specification of Maintenance for Highway* (JTG H10) and the technical specifications for maintenance of subgrade and pavement.

6.5.5 1 According to different classes of waterproofing and use requirements, as well as the leakage phenomenon and location, the leakage position shall be found out before repair. Visual inspection is the primary method for roof waterproofing layer inspection and if necessary, sampling method may be adopted. However, it is usually only adopted under special circumstances. In order to avoid more serious leakage caused by the destruction of waterproofing layer, the sampling method is not usually adopted.

As for the waterproofing materials for repair, in addition to the original materials, other materials may also be utilized and their service life shall be based on the remaining service life of waterproofing layer.

As for the leakage inspection after roof repair, in addition to observation on rainy days, water spray or storing may also be adopted and the waterproofing layer shall be reconstructed for leakage positions.

As for the site survey for wall leakage repair work, the wall structure, material performance and using condition shall be taken into consideration to find out the causes of leakage and effective repair scheme shall be established. After the wall leakage repair, in addition to flushing test, one-year observation shall also be carried out, during which it will go through the season changing and



rainy season tests, and then it will be assessed.

5 Before the replacement of lightning-protection and earthing device, necessary tests shall be conducted for the grounding electrode to check if the grounding resistance complies with relevant specifications. After that, the inspection and replacement can be carried out. In case of nonconforming grounding resistance or grounding resistance with partial but not serious corrosion, the method of adding grounding electrode will be adopted; in case of welding joint breakage, after replacement, the one passing the test after being de-rusted and coated with anti-rust paint can be continued to be used.

The welding joint breakage or deformation of lightning protection net (bar) or down lead shall be restored. In order to prevent corrosion of earthing device, all materials should be galvanized.

6 The antifreezing insulation facilities of buildings include: heating pipeline, and heating equipment (radiator, valve).

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# 7 Safety Management

## 7.1 General provisions

7.1.4 In accordance with the *Regulations on Highway Safety Protection*, behaviors prohibited within 100m above and outside a tunnel are stipulated herein.

## 7.2 Safety management of maintenance

7.2.1 The maintenance site shall occupy as little spacing as possible, mainly to prevent scratches caused by operating vehicles, while if the spacing is too small, it will also affect the safety of operation.

7.2.3 The traffic organization modes for tunnel maintenance include road-occupying construction, single-tube closure construction, single-tube passage (single-lane bi-directional traffic), detour, etc.

7.2.7 3 The smoke referred to in this paragraph also includes CO<sub>2</sub>, methane gas and other gases harmful to human body or flammable gases.

7.2.8 3 The lighting requirements as referred to in this paragraph mean that the luminance must meet the construction requirements and make the construction section more conspicuous without causing glare to passing vehicles that may result in safety risks.

4 The “air quality” as referred to in this paragraph means that the pollution of particulate matter emissions, waste gas, etc. produced during construction to the air in tunnel shall not affect the construction requirements.

## 7.3 Safety management of emergency

7.3.1 The emergencies in tunnel include traffic accident, tunnel collapse, water gushing, debris flow in-burst, earthquake and other natural disasters, as well as hazardous chemical leakage or explosion, fire and other incidents obstructing traffic.

7.3.2 The rescue facilities mainly refer to mobile rescue facilities and equipment such as fire-fighting truck or motorbike and rescue vehicles.

7.3.3 The contingency plans for emergencies include the duties of tunnel management institutions and relevant departments under different circumstances, such as the one for unified command, the one for organizing rescue, emergency action and personnel rescue, the one for controlling and organizing traffic, the one for contacting relevant departments, the one for publishing information and the one for recording the losses and analyzing the causes after emergency. After the contingency plan drills, the personnel at each position can calmly and effectively deal with complex situations in case of an emergency, so as to try to prevent the accident expansion and occurrence of secondary accident and reduce the loss caused by the accident. The contingency plan can be improved after the drill.

7.3.4 The field drill is aimed for the quickest and most appropriate response in case of any traffic accident or fire in tunnel, so as to reduce the losses to tunnel caused by the accident and test the effectiveness and applicability of the contingency plan, and then make necessary and more applicable modifications to the contingency plan. However, due to the large difficulty and impact of the field drill, sand-table drill, question-answering drill and other modes can also be adopted. Tunnels refer to 2 or more (including 2) tunnels. The field drill may be organized by region or line according to the management scope of the management and maintenance authority and the drill personnel may include the management personnel and local road administration, traffic police, fire control and medical personnel. For tunnels with special requirements, such as Qinling-Zhongnanshan tunnel, special rescue teams may be established, and fire-fighting trucks or motorbikes, cranes, command vehicles and adequate fire extinguishers and other equipment may be equipped with too.